



RELIABILITY-BASED DESIGN PROCEDURE OF AXIALLY LOADED PILES

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ABSTRACT:

Geotechnical engineering involves many different and complex materials and many different mechanisms of behaviour. The direct use of experience as a guide to the prediction and design is effective, provided these are understood. Geotechnical engineering is a relatively new science. Its successful application to prediction requires realistic assumptions to be made, and predictions must be tested against reality. Methods of prediction need then to be refined. An example of the importance of making realistic assumptions is examined in this paper. It includes the effects of soil properties on the ultimate capacity of axially loaded piles.

Better analysis offers better prediction and better understanding. Both are only possible when reality is modelled. There are occasions when mechanisms are too complex for predictive analysis. Prediction must then be based directly on experience, applied with an understanding of the mechanisms involved. Moreover, methods of analysis may become too sophisticated for everyday use. However, pseudo-analysis, involving standardized methods based on oversimplified and unrealistic mechanisms of behaviour and material properties, is dangerous. The use of engineering experience as a guide to prediction and design may offer a more effective alternative, provided it is based on a realistic understanding of mechanisms and materials.

In this paper, a procedure is recommended to estimate the bearing capacity of axially loaded piles based on reliability calculations. The procedure is an extension of the point estimate method in which the expected values of the standard deviation of the capacity and demand functions are calculated. The probability of failure, the reliability, central factor of safety and reliability index are calculated as appropriate. The procedure is then applied to two cases where the pile in the first case is driven in sand while in the second, it is driven in clay.

طريقة تصميم للركائز المحملة محوريا مبنية على أساس مبدأ الاعتماد

الخلاصة:

تتطلب الهندسة الجيوتقنية العديد من المواد المعقدة و العديد من آليات السلوك. يعتبر الاستعمال المباشر للخبرة كدليل في التخمين و التصميم فعالا عند إدراك هذه المتطلبات. تعتبر الهندسة الجيوتقنية علما حديثا نسبيا و يتطلب تطبيقها بنجاح في التخمين و صنع فرضيات مقبولة, و هذه التخمينات يجب أن تختبر من

ناحية قبولها و اعتمادها. و عليه فان طرق التخمين في حاجة إلى تهذيب. في هذا البحث أختبر مثال على أهمية وضع فرضيات معقولة. و هذا يتضمن تأثير خواص التربة على قابلية التحمل القصوى للركائز المحملة محوريا.

إن التحليل الجيد يوفر تخمينا جيدا و فهما جيدا, و كلاهما يصبحان ممكنين عند التمثيل بشكل معقول. هناك حالات تصبح عندها الآليات معقدة لوضع تحليل تخميني, و عندها يجب أن يستند التخمين مباشرة على الخبرة مقترنا مع فهم الآليات المطلوبة, فضلا عن ذلك قد تصبح طرق التحليل معقدة بالشكل الذي يجعلها صعبة الاستعمال بشكل يومي. و على كل حال, إن التحليل الساكن الذي يتطلب طرقا قياسية مبنية على آليات غير معقولة و مبسطة بشكل مفرط لتصرف المواد و خواصها يعتبر خطرا. ان استعمال الخبرة الهندسية كدليل للتخمين و التصميم قد يوفر بديلا فعالا عندما يكون مستندا إلى فهم معقول للآليات و للمواد.

في هذا البحث أقترح أسلوب لتخمين قابلية تحمل الركائز المحملة محوريا بناء على حسابات مبدأ الاعتماد و المعقول. إن هذا الأسلوب يعتبر امتدادا لطريقة تخمين النقطة التي من خلالها تحسب القيم المتوقعة للانحراف المعياري لقابلية التحمل و دوال الحاجة. و تحسب احتمالية الفشل و الاعتماد و معامل الأمان المركزي و مؤشر الاعتماد و المعقول حسب الحاجة. ثم طبق الأسلوب على حالتين حيث في الأولى الركيزة مساقة في رمل و في الثانية الركيزة مساقة في طين.

INTRODUCTION

The trend in civil engineering today, more than ever before, is toward providing economical designs at specified levels of safety. Often these objectives necessitate a prediction of the performance of a system for which there exists little or no previous experience. Current design procedures, which are generally learned only after many trial-and-error iterations, lacking precedence, often fall short of expectations in new or non conventional situations. In addition, there is an increasing awareness that the raw data, on which problem solutions are based, themselves exhibit significant variability. It is the aim of reliability methods of design to demonstrate how concepts of probability analysis may be used to supplement the geotechnical engineer's judgment in such matters.

Quite often, deterministic approaches are employed in the analysis and design of engineering structures. These approaches are characterized by the use of specified minimum factors of safety or specified minimum material properties. Deterministic approaches do not rigorously account for uncertainties in engineering analysis and design. In order to address uncertainty, probability theory has been widely accepted and used in engineering design in which some statistical knowledge of random variables such as their mean values and standard deviations is used to introduce them into applications (Kaymaz et al., 1998). Probabilistic methods, especially, reliability analysis, have frequently been used in structural engineering (e.g. Grigoriu, 1983; Afolayan, 1998) as well as in geotechnical and geoenvironmental engineering (e.g. Christian et al., 1994; Rowe and Fraser, 1995; Gui et al., 2000). Reliability calculations provide a means of evaluating the combined effects of uncertainties, and a means of distinguishing between conditions where uncertainties are particularly high or low (Duncan, 2000). Moreover, reliability analysis provides a framework for establishing appropriate factors of safety and other design targets and leads to a better appreciation of the relative importance of uncertainties in different parameters (Christian and Baecher, 2001).



The interaction between theory and practice is complex. To predict real behaviour, realistic assumptions for material properties must be made, based on the geological origins of materials, on their intrinsic nature and on their behaviour observed in the laboratory and in the field. Realistic assumptions for boundary conditions must also be made. Theory must be examined regularly to see whether or not it meets these requirements, and it must be refined when it does not. Terzaghi, Peck and Mesri (1996) recognized the need to link theory and practice, and to test one against the other, nearly 60 years ago. Theory is much more coherent now. Perhaps old habits should be recovered. Often, if problems are understood, simple methods of analysis will provide adequate solutions.

The primary value of realistic analysis is to aid understanding of problems. If they are understood they can usually be solved. Understanding provides a framework within which uncertainties which cannot be avoided can be defined and managed. The ability to make exact deterministic theoretical predictions, even by the most advanced methods, is uncertain. There are many areas where analysis may help to explain a problem, but not solve it in a predictive way. Then the direct use of field experience is necessary, and this is proper and safe provided the mechanisms governing behaviour are understood. Recognition of when this approach is appropriate needs to be improved. A theoretical framework provides the language with which experience can be digested, learned from and made generally available, but reality must be incorporated if success is to be achieved. Such an approach often makes things more complicated than they need be, and so introduces the risk of unnecessary errors. Doubtless these can be eliminated by quality assurance, but quality assurance applied to unrealistic and therefore irrelevant calculations merely eliminates the possibility of being right by accident.

There is an alternative: practical guidance carefully linked to both geology and type of construction, with warnings as to where uncertainties lie. This offers a much more effective approach to everyday problems. Probably the most important question facing the profession, and the one of greatest economic significance, is in what form should effective guidance in geotechnical engineering be given to non-specialist engineers? It controls how effectively the considerable expertise of geotechnical engineers is used, (Vaughan, 1994).

Phoon (2004) presented an overview of the evolution in structural and geotechnical design practice over the past half a decade or so in relation to how uncertainties are dealt with. The key elements of reliability-based design (RBD) were briefly discussed and the availability of statistics to provide empirical support for the development of simplified RBD equations is highlighted. Several important implementation issues were presented with reference to an EPRI study for reliability-based design of transmission line structure foundations (Phoon et al., 1995).

PROBABILISTIC PRELIMINARIES

The **probability** of the success of a structure is called its **reliability**, R , Symbolizing the probability of failure as $p(f)$, we have the important expression:

$$R + p(f) = 1 \quad (1)$$

Moments

Consider a system of discrete parallel (vertical) forces, $P(1), P(2), \dots, P(N)$, acting on a rigid beam at the respective distances $x(1), x(2), \dots, x(N)$, as in Fig. 1(a). From statics, we have that the magnitude of the *equilibrant*, M , is:

$$M = \sum_{i=1}^N P(i) \quad (2)$$

and its point of application, $\bar{x}$, is

$$\bar{x} = \frac{\sum_{i=1}^N x(i) \cdot P(i)}{\sum_{i=1}^N P(i)} \quad (3a)$$

Suppose now that the discrete forces $P(i)$ in Fig. (1a) represent the frequencies of the occurrence of the N outcomes $x(1), x(2), \dots, x(N)$. As the distribution is exhaustive, the magnitude of the equilibrant must be unity, $M = 1$. Hence, Eq. (3b) becomes:

$$E[x] = \bar{x} = \sum_{i=1}^N x(i) P(i) \quad (3b)$$

The expected value (mean) provides the locus of the central tendency of the distribution of a random variable. To characterize other attributes of the distribution, recourse is had to higher moments. Again, returning to statics, a measure of the dispersion of the distribution of the force system about the centroidal axis, at $x = E[x]$ in Fig.1(b), is given by the *moment of inertia* (the *second central moment*),

$$I(y) = \int_{x(a)}^{x(b)} (x - \bar{x})^2 p(x) dx \quad (4)$$

The equivalent measure of the scatter (variability) of the distribution of a random variable is called its **variance**, denoted as $v[x]$ and defined as:

$$\langle \text{Discrete} \rangle v[x] = \sum_{\text{all } x(i)} [x(i) - \bar{x}]^2 \cdot p(i) \quad (5a)$$

$$\langle \text{Continuous} \rangle v[x] = \int_{x(a)}^{x(b)} (x - \bar{x})^2 p(x) dx \quad (5b)$$

In terms of the expectation, these can be written as:

$$v[x] = E[(x - \bar{x})^2] \quad (6)$$

which, after expansion, leads to a form more amenable to computations:

$$v[x] = E[x^2] - (E[x])^2 \quad (7)$$

This expression is the equivalent of the parallel-axis theorem for the moment of inertia.

As an example, let us find the expected value and the variance of the exponential distribution:

$p(x) = a \cdot \exp(-a x)$, $x > 0$ a is a constant.

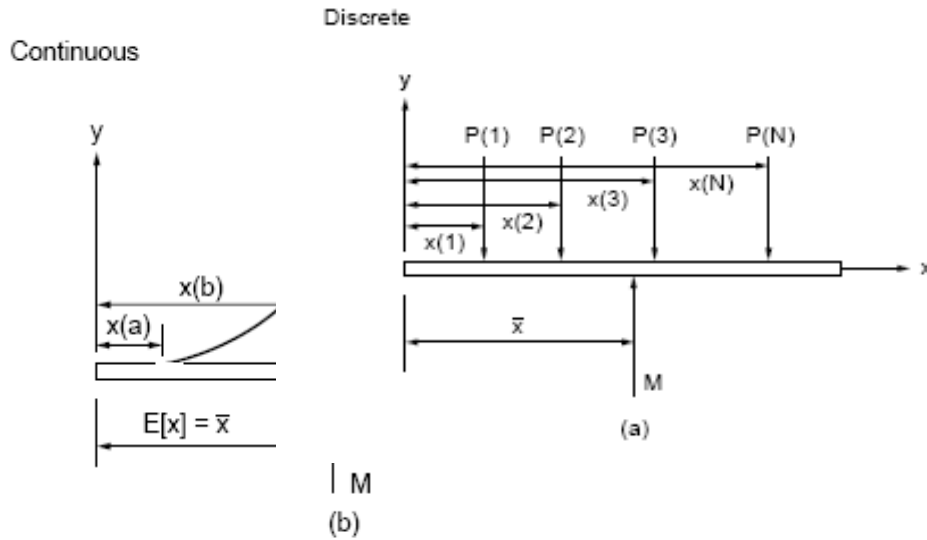


Figure (1): Equilibrant for discrete and continuous distributions, (Harr, 2002).

It is first required to show that $p(x)$ is a valid probability distribution:

$$\int_0^{\infty} p(x) dx = a \int_0^{\infty} e^{-ax} dx = 1 \quad ,$$

The expected value is:

$$E[x] = a \int_0^{\infty} x e^{-ax} dx = \frac{1}{a}$$

Continuing,

$$E[x^2] = a \int_0^{\infty} x^2 e^{-ax} dx = \frac{2}{a^2}$$

whence, using Eq. (7),

$$v[x] = \frac{2}{a^2} - \left(\frac{1}{a}\right)^2 = \frac{1}{a^2}$$

It is seen that the variance has the units of the square of those of the random variable. A more meaningful measure of dispersion of a random variable (x) is the positive square root of its variance (compare with radius of gyration of mechanics) called the standard deviation, $\sigma[x]$,

$$\sigma[x] = \sqrt{v[x]} \quad (8)$$

From the results of the previous example, it is seen that the standard deviation of the exponential distribution is $\sigma[x] = 1/a$.

An extremely useful relative measure of the scatter of a random variable (x) is its coefficient of variation $V(x)$, usually expressed as a percentage:

$$V[x] = \frac{\sigma[x]}{E[x]} \times 100(\%) \quad (9)$$

It should be emphasized that a straight line fit can be assumed. The reasonableness of this assumption is provided by the correlation coefficient, ρ defined as:

$$\rho = \frac{\text{cov}[x, y]}{\sigma[x] \cdot \sigma[y]} \quad (10)$$

where $\sigma[x]$, and $\sigma[y]$ are the respective standard deviations and $\text{cov}[x, y]$ is their covariance which is defined as:

$$\text{cov}[x, y] = \frac{1}{N} \sum_{i=1}^N [x(i) - \bar{x}] [y(i) - \bar{y}] \quad (11)$$

With analogy to statics, the covariance corresponds to the product of inertia, (Harr, 2002).

Point Estimate Method — Several Random Variables

Rosenblueth (1975) generalized the methodology for any number of correlated variables. For example, for a function of three random variables say, $y = y[x(1), x(2), x(3)]$, where $\rho(i, j)$ is the correlation coefficient between variables $x(i)$ and $x(j)$,

$$E[y^N] = p(+++)y^N(+++) + p(++-)y^N(++-) + \dots + p(---)y^N(---) \quad (12a)$$

where:

$$y(\pm\pm\pm) = y[\bar{x}(1) \pm \sigma[x1], \bar{x}(2) \pm \sigma[x2], \bar{x}(3) \pm \sigma[x3]] \quad (12b)$$

$$p(+++) = p(---) = \frac{1}{2^3} [1 + \rho(1,2) + \rho(2,3) + \rho(3,1)]$$

$$p(++-) = p(--+) = \frac{1}{2^3} [1 + \rho(1,2) - \rho(2,3) - \rho(3,1)]$$

$$p(+ - +) = p(- + -) = \frac{1}{2^3} [1 - \rho(1,2) - \rho(2,3) + \rho(3,1)]$$

$$p(+ - -) = p(- + +) = \frac{1}{2^3} [1 - \rho(1,2) + \rho(2,3) - \rho(3,1)] \quad (12c)$$

where $\sigma[x_i]$ is the standard deviation of $x(i)$.

The sign of $\rho(i, j)$ is determined by the multiplication rule of i and j ; that is, if the sign of $i = (-)$, and of $j = (+)$, then $(i)(j) = (-)(+) = (-)$.

Equation (12a) has $2^3 = 8$ terms, all permutations of the three $+$ s and $-$ s. In general, for M variables there are 2^M terms and $M(M - 1)/2$ correlation coefficients, the number of combinations of M objects taken two at a time. The coefficient on the right-hand side of Eqs. (12c), in general, is $(1/2)^M$, (Harr, 2002).

RELIABILITY ANALYSIS

Capacity–Demand

The adequacy of a proposed design in geotechnical engineering is generally determined by comparing the estimated resistance of the system to that of the imposed loading. The resistance is the **capacity** C (or strength) and the loading is the induced **demand** D imposed on the structure. In the present procedure, because of its greater generality, we shall use a *capacity– demand* concept. Some common examples are the bearing capacity of a soil and the column loads, allowable and computed maximum stresses, traffic capacity and anticipated traffic flow on a highway, culvert sizes and the quantity of water to be accommodated, and structural capacity and earthquake loads.

Conventionally, the designer forms the well-known factor of safety as the ratio of the single-valued nominal values of capacity C and demand D (Ellingwood et al., 1980), depicted in Fig. 2(a),

$$FS = \frac{\bar{C}}{\bar{D}} \quad (13)$$

For example, if the allowable load is 400 tons per square meter and the maximum calculated load is 250 tons per square meter, the conventional factor of safety would be 1.6. The design is considered satisfactory if the calculated factor of safety is greater than a prescribed minimum value learned from experience with such designs. Thus, in concept, in the above example, if a factor of safety of 1.6 was considered intolerable, the system would be redesigned to decrease the maximum induced load.

In general, the demand function will be the resultant of the many uncertain components of the system under consideration (vehicle loadings, wind loadings, earthquake accelerations, location of the water table, temperatures, quantities of flow, runoff, and stress history, to name only a few). Similarly, the capacity function will depend on the variability of material parameters, testing errors, construction procedures and inspection supervision, ambient conditions, and so on.

A schematic representation of the capacity and demand functions as probability distributions is shown in Fig. 2(b). If the maximum demand ($D_{\max}$) exceeds the minimum capacity ($C_{\min}$), the distributions overlap (shown shaded), and there is a nonzero probability of failure.

The difference between the capacity and demand functions is called the safety margin (S); that is,

$$S = C - D \quad (14)$$

Obviously, the safety margin is itself a random variable, as shown in Fig. 2(c). Failure is associated with that portion of its probability distribution wherein it becomes negative (shown shaded); that is, that portion wherein $S = C - D \leq 0$. As the shaded area is the probability of failure $p(f)$, we have:

$$p(f) = P[(C - D) \leq 0] = P[S \leq 0] \quad (15)$$

Reliability Index

The number of standard deviations that the mean value of the safety margin is beyond $S = 0$, Fig. 2(c), is called the *reliability index*, β ; that is,

$$\beta = \frac{\bar{S}}{\sigma[S]} \quad (16a)$$

The reliability index is seen to be the reciprocal of the coefficient of variation of the safety margin, or

$$\beta = \frac{1}{v(S)} \quad (16b)$$

Application to their definitions, produces the following identities (a, b, and c are constants), (Ditlevesen, 1981):

$$E[a + bx + cy] = a + bE[x] + cE[y] \quad (17a)$$

$$v[a + bx + cy] = b^2 v[x] + c^2 v[y] + 2bc \cdot \text{cov}[x, y] \quad (17b)$$

$$\text{cov}[x, y] \leq \sigma[x] \cdot \sigma[y] \quad (17c)$$

$$v[a + bx + cy] = b^2 v[x] + c^2 v[y] + 2b \cdot c \cdot \sigma[x] \cdot \sigma[y] \cdot \rho \quad (17d)$$

From Eq. (17a), we have:

$$E[S] = E[C] - E[D] = \bar{C} - \bar{D} \quad (18)$$

Equation (17c) produces:

$$\sigma^2[S] = \sigma^2[C] + \sigma^2[D] - 2\rho \cdot \sigma[C] \cdot \sigma[D]$$

Hence,

$$\beta = \frac{\bar{C} - \bar{D}}{\sqrt{\sigma^2[C] + \sigma^2[D] - 2\rho \cdot \sigma[C] \cdot \sigma[D]}} \quad (19)$$

It is seen that β is a maximum for a perfect positive correlation and a minimum for a perfect negative correlation. It can be shown that the sum of difference of two normal variates is also a normal variate (Haugen, 1968). Hence, if it is assumed that the capacity and demand functions are normal variates, it follows that:

$$p(f) = \frac{1}{2} - \psi[\beta] \quad (20)$$

where $\psi[\beta]$ is standard normal probability as given in standard normal probability tables.

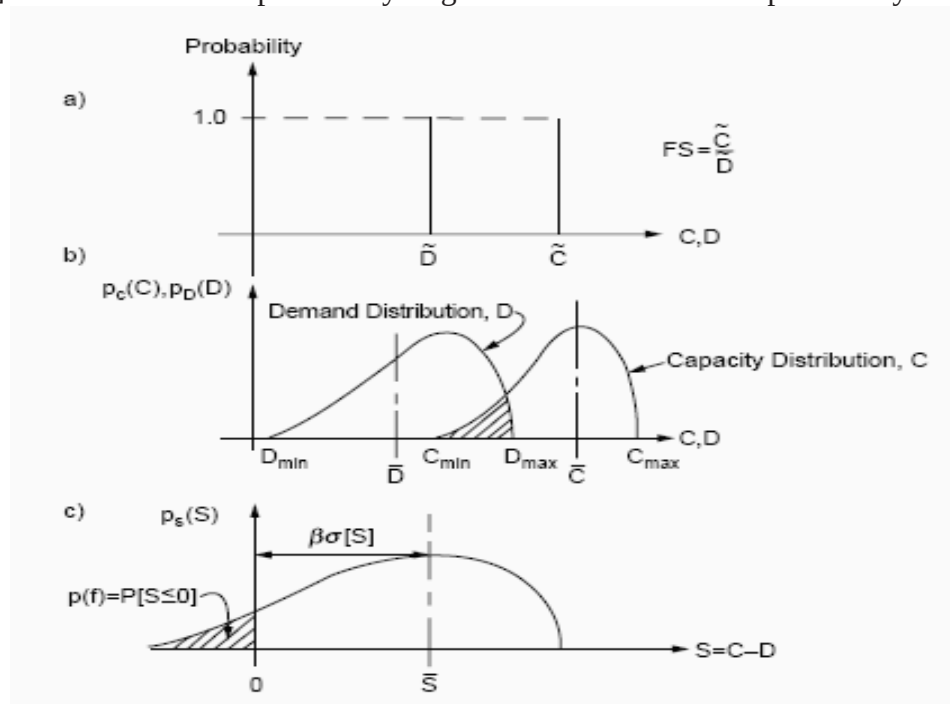


Figure (2): (a) Conventional factor of safety, (b) capacity–demand model, (c) safety margin, (Harr, 2002).

RECOMMENDED PROCEDURE

The following points represent the desirable attributes of a reliability-based design procedure (Harr, 2002):

- It should account for the pertinent capacity and demand factors, their components, and their interactions.
- It should produce outputs that can be related to the expected performance during the design life
- of the system under consideration.

- It should employ as input into formulations quantities, parameters, or material characterizations that can be ascertained within the present state of the art.
- It should not disregard indices currently considered to be pertinent, such as factor of safety or reliability index. It should serve to supplement this knowledge and reduce uncertainty.
- Ideally, mathematical computations should be reduced to a minimum.

All of the above can be accommodated by an extension of the point estimate method. The recommended procedure is as follows, where it is here applicable to the problem of bearing capacity of axially loaded piles:

- Using the point estimate method, or an equally valid probabilistic formulation, the expected values and standard deviations of the capacity and demand functions: $E[C]$, $E[D]$, $\sigma[C]$, $\sigma[D]$ are obtained.
- Calculating the expected value and standard deviation of the safety margin, $E[S]$, $\sigma[S]$.
- Fitting a beta distribution (and normal distribution, as a check) to the safety margin, using appropriate upper and lower bounds. If unknown, take them as $E[S] \pm 3\sigma[S]$.
- Obtaining the probability of failure, $p(f) = P[S \leq 0]$, the reliability, central factor of safety, and reliability index, as appropriate.

Application to Axially Loaded Piles

I. Piles in Sand

The ultimate bearing capacity Q of a pile in a dry sand (cohesion, $c = 0$) is given by the following equation (Tomlinson, 1993):

$$Q = Q_b + Q_s$$

where: Q_b = base resistance.

Q_s = shaft resistance

$$Q_b = A_b \cdot \sigma'_{vb} \cdot N_q$$

$$Q_s = Ks \cdot \tan(\delta) \cdot A_s \cdot \sigma'_v$$

where: A_b = area of the pile base,

A_s = the surface area of the pile,

σ'_v = effective overburden pressure along the pile,

σ'_{vb} = effective overburden pressure at the pile base,

Ks = a factor depending on the pile type and the relative density of the soil,

δ = the coefficient of friction between the pile and the soil ($= 3/4 \phi$ for concrete piles),

N_q = bearing capacity factor.



Example: If a 12 m length concrete pile having a square cross-section (0.285 x 0.285 m) is to be driven in a sandy soil with the following parameters:

Parameter, x	Expected Value	Standard Deviation	x (+)	x (-)
Unit weight, γ (kN/m ³)	18	2	20	16
Angle of friction, ϕ (°)	35	5	40	30
Cohesion, c (kN/m ²)	0	-	-	-

The correlation coefficient $\rho(\phi, c) = -0.5$:

- Estimate the expected value and the standard deviation of the bearing capacity.
- If a central factor of safety (CFS) of 4 is required, and it is assumed that the coefficient of variation $V(D) = 50\%$, estimate the probability of failure.

Solution:

(a) Forming the required values of N_q as the bearing capacity factors are functions of ϕ only (Terzaghi, Peck and Mesri, 1996):.

Bearing capacity factors

ϕ	N_γ	N_q	N_c
0	0.00	1.00	5.14
5	0.45	1.57	6.49
10	1.22	2.47	8.34
15	2.65	3.94	10.98
20	5.39	6.40	14.83
25	10.88	10.66	20.72
30	22.40	18.40	30.14
35	48.83	33.30	46.12
40	109.41	64.20	75.31
42.5	170.25	91.90	99.20
45	271.75	133.87	134.87
50	762.86	319.06	266.88

$N_q (+) = 64.20$ and $N_q (-) = 18.40$

Since $c = 0$, the bearing capacity Q becomes $Q(\phi, \gamma)$.

The respective values of $Q(\phi, c, \gamma)$ are calculated in (kN):

$Q(i, j)$ (kN)	$Q^2(i, j)$
$Q(++) = 2087.94$	4359493.44
$Q(+-) = 964.30$	929874.49
$Q(-+) = 1670.36$	2790102.53
$Q(--) = 771.44$	595119.67

and

$$p(+ +) = p(- -) = \frac{1}{2^2}(1 + \rho) = \frac{1}{8}$$

$$p(+ -) = p(- +) = \frac{1}{2^2}(1 - \rho) = \frac{3}{8}$$

From equation (3b):

$$E[Q] = \bar{Q} = \sum Q(ij)p(ij) = 1345.42 \text{ kN}$$

$$E[Q]^2 = \sum Q^2(ij)p(ij) = 2014318.02$$

and from equation (7), we have:

$$V[Q] = E[Q^2] - (E[Q])^2 = 204163.04$$

and equation (8) gives:

$$\sigma[Q] = \sqrt{V(x)} = \sqrt{204163.04} = 451.84$$

Equation (9) requires:

$$V[Q] = \frac{\sigma[x]}{E[x]} \times 100 = \frac{451.84}{1345.42} \times 100 = 33.6\%$$

(b) For a CFS = 4:

$$\bar{D} = \frac{\bar{Q}}{4} = \frac{1345.42}{4} = 30.57$$

As V (D) = 50%

$$\sigma[D] = E(D) * V(D) = 30.5 * 0.5 = 15.28$$

Forming the characteristics of the safety margin with $\rho(Q, D) = +\frac{3}{4}$, we have:

$$E[S] = \bar{Q} - \bar{D} = 1345.42 - 30.57 = 1314.85 \text{ kN}$$

From equation (19), we have:

$$\beta = \frac{1314.85}{\sqrt{(451.84)^2 + (15.28)^2 - 2(0.75)(451.84)(15.28)}} = \frac{1314.85}{40.49} = 2.98$$

If S is to be taken as normal:

From equation (20):

$$p(f) = \frac{1}{2} - \psi(\beta)$$

since $\beta > 2.2$:



then: $\psi(\beta) = \frac{1}{2} - \frac{1}{\beta} (2\pi)^{-\frac{1}{2}} \cdot \exp\left[-\frac{\beta^2}{2}\right] = 0.49$

The probability of failure $p(f) = 0.01$

II. Piles in Clay

The ultimate bearing capacity Q of a pile in a saturated clay ($\phi = 0$) is given by the following equation (Tomlinson, 1993):

$$Q = Q_b + Q_s$$

where: Q_b = base resistance.

Q_s = shaft resistance

Since $\phi = 0$, the bearing capacity factors, $N_q = 1$ and $N_\gamma = 0$

$$Q_b = C_u \cdot N_c \cdot A_b$$

$$Q_s = \alpha \cdot P \cdot L \cdot C_u$$

where: P = perimeter of the pile,

L = length of the pile,

C_u = undrained cohesion,

N_c = bearing capacity factor,

α = a factor depending on the undrained shear strength of the pile.

Example: If the same concrete pile of the previous example is to be driven in saturated clay having the following parameters:

Parameter, x	Expected Value	Standard Deviation	x (+)	x (-)
Unit weight, γ (kN/m ³)	20	2	22	18
Angle of friction, ϕ (°)	0	-	-	-
Cohesion, c (kN/m ²)	60	20	80	40

The correlation coefficient $\rho(\phi, c) = -0.5$:

- Estimate the expected value and the standard deviation of the bearing capacity.
- If a central factor of safety (CFS) of 4 is required, and it is assumed that the coefficient of variation (VD) = 50%, estimate the probability of failure.

Solution:

(a) The required values of the bearing capacity factor N_c are constant since ($\phi = 0$).

α is calculated following Tomlinson method.

Since $\phi = 0$, the bearing capacity Q becomes $Q(c, \gamma)$.

The respective values of $Q(\phi, c, \gamma)$ are calculated in (kN):

$Q(i, j) \text{ (kN)}$	$Q^2(i, j)$
$Q(+ +) = 631.43$	376296.36
$Q(+ -) = 454.76$	206806.65
$Q(- +) = 613.43$	376296.36
$Q(- -) = 454.76$	206806.65

and

$$p(+ +) = p(- -) = \frac{1}{2^2} (1 + \rho) = \frac{1}{8}$$

$$p(+ -) = p(- +) = \frac{1}{2^2} (1 - \rho) = \frac{3}{8}$$

From equation (3b):

$$E[Q] = \bar{Q} = \sum Q(ij)P(ij) = 379.06 \text{ kN}$$

$$E[Q]^2 = \sum Q^2(ij)P(ij) = 291551.50$$

and from equation (7), we have:

$$V[Q] = E[Q^2] - (E[Q])^2 = 147865.0$$

and equation (8) gives:

$$\sigma[Q] = \sqrt{V(x)} = \sqrt{147865.0} = 384.53$$

Equation (9) requires:

$$V[Q] = \frac{\sigma[x]}{E[x]} \times 100 = \frac{384.53}{379.06} \times 100 = 101.44\%$$

(b) For a CFS = 4:

$$\bar{D} = \frac{\bar{Q}}{4} = \frac{379.06}{4} = 94.76$$

As $V(D) = 50\%$

$$\sigma[D] = E(D) * V(D) = 94.76 * 0.5 = 47.38$$



Forming the characteristics of the safety margin with $\rho(Q, D) = +\frac{3}{4}$, we have:

$$E[S] = \bar{Q} - \bar{D} = 1379.06 - 94.76 = 284.3 \text{ kN}$$

From equation (19), we have:

$$\beta = \frac{284.3}{\sqrt{(384.53)^2 + (47.38)^2 - 2(0.75)(384.53)(47.38)}} = \frac{284.3}{250.39} = 1.13$$

If S is to be taken as normal:

From probability tables, $\psi(\beta) = 0.370762$

From equation (20):

$$p(f) = \frac{1}{2} - \psi(\beta)$$

The probability of failure $p(f) = 0.129$

CONCLUSIONS

A procedure is recommended to estimate the bearing capacity of axially loaded piles based on reliability calculations. The procedure is an extension of the point estimate method in which the expected values of the standard deviation of the capacity and demand functions are calculated. The probability of failure, the reliability, central factor of safety and reliability index are calculated as appropriate. The procedure is then applied to two cases where the pile in the first case is driven in sand while in the second, it is driven in clay.

It was found that the proposed procedure is simple and can be extended to other applications in geotechnical engineering.

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STUDY THE PERFORMANCE OF SULFAMIC ACID AND CITRIC ACID IN REMOVAL THE SCALE DEPOSITED ON THE DURA REFINERY HEAT EXCHANGE PIPING SYSTEM

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ABSTRACT

This paper describes an experimental study on the performance of sulfamic acid and citric acid in scale removal of Dura refinery heat exchange piping systems.

Experiments were carried out using sulfamic acid and citric acid inhibited by hexamine as cleaning solutions at different time, temperature and concentrations. A dynamic flow system was designed for this state. A scaled copper alloy pipes from the main hot water lines (heat exchanger) was used. Hexamine was used as corrosion inhibitor. The research involved a study of effect of the time, temperature and acid concentration of each acid on the scale removal, and a comparison of the performance of the two used acids were investigated.

دراسة ادائية حامضي السلفامك والستريك في ازالة التكلسات المترسبة على انابيب اجهزة المبادلات
الحرارية في مصفى الدورة

الخلاصة

يهدف البحث الى دراسة عملية لادائية حامضي السلفامك و الستريك في ازالة التكلسات المترسبة على انابيب المبادلات الحرارية المستخدمة في مصفى الدورة .اجريت تجارب عملية استخدم فيها حامضي السلفامك والستريك المثبطة بمادة الهكسامين كمواد كيميائية مزيله للتكلسات عند ازمان مختلفة ودرجات حرارة مختلفة وتركيز متعددة.

صممت منظومة جريانية لهذا الغرض استخدمت فيها قطع من انابيب مأخوذة من اجهزة المبادلات الحرارية المستخدمة في مصفى الدورة. لقد تضمن البحث دراسة تأثير زمن المعالجة ودرجة الحرارة وتركيز الحوامض المستخدمة واجراء مقارنة لادائية كل من الحامضين المستخدمين لازالة تكلسات الانابيب المستخدمة في المبادلات الحرارية في مصفى الدورة.

INTRODUCTION

Problems involved with use of water are caused by the dissolved constituents namely solids. Chemical reaction sometimes occur between some constituents dissolved in water produce insoluble compounds. These insoluble compounds deposited by the water are called scale.

Scale deposition in the heat exchanger tubes is the most undesirable yet unavoidable problem.[1]

Formation of scale on the interior surfaces of pipes, tubes, tanks, heat exchangers, and other vessels has been a source of trouble where such pipes come in contact with aqueous liquid. The formation or deposition of scale markedly reduces the heat transfer through walls of such pipes and furthermore, the capacity of the pipes and the passage of fluids therethrough is restricted by the formation of such scale. Because of the scale formation on the inner surfaces of the pipes, particularly in the heat transfer appliances, pipes are subjected to excessive heat due to the loss in the heat transfer capacity. Furthermore, greater pressures are required to overcome the restricting effect of the deposited scale. These disadvantages often lead to leaks and rupture which necessitate undesirable down time and maintenance cost. Still further, the reduced cross-section of pipes caused by the deposition of scale can cause increased pressure drop.[2]

Cleaning can be done either mechanically or with the use of chemicals. Mechanical cleaning obviously takes a great deal of downtime and does not always get all the scale out. Chemical cleaning can get at scale buildup not always reachable in mechanical cleaning. Scale removal by acid cleaning is commonly employed in many types of plants.[3]

For removal of Calcium Carbonate and/or Magnesium hydroxide scales, Circulation of an inhibited acid solution (HCl, H_2SO_4 , $C_6H_8O_7$ (citric acid) or HSO_3NH_2) through the scaled system was found to be appropriate. Adding an inhibitor to the acids is essentially to diminish its corrosive effect on metals. [4]

Explanation of the scale inhibitor action is that the inhibiting compounds serve to blanket the entire metal surface with a protective layer of compound used. This occurs as simple adsorption of the inhibitor ion on the metal surface.[5]

The modes of adsorption of an inhibitor are dependent on chemical structure of the molecule, chemical composition of the solution, nature of the metal surface and the electrochemical potential at the metal solution interface.[6]

Hexamine as corrosion inhibitor has been effectively used with the solutions for acid cleaning.[5]

The present investigation of the problem of scale removal is being studied mainly on tubes of heat exchanger obtained from Dura Refinery using sulfamic acid and citric acid as cleaning solutions.

A special flow system has been designed where parts of these piping were being fixed in exposed to the treating solution.

Percentage of scale removal was studied as a function of time and acid concentration. Furthermore, a comparison between sulfamic acid and citric acid performance in the scale removal process has been investigated in this study.

EXPERIMENTAL WORK :

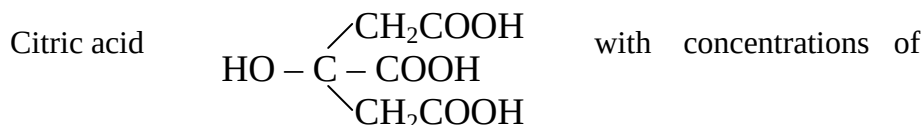
Materials

All chemical cleaning bench-scale tests, metals (copper alloy) heat exchanger tubes from Dura refinery.

The scaled tube specimens were prepared by cutting sections from the exchanger tubes. The tubing was of (20mm) outside diameter, 100mm long and (2mm) thickness having the chemical composition listed in table(1).

The large thickness (2.5-5mm) scale used has a mixed type composition as shown in table (2).

SOLUTIONS AND TEST APPARATUS:



(3%, 6%, 9%) and sulfamic acid (HSO_3NH_2) at concentrations of (3%, 6%, 9%) were used. Hexamine with concentration of 0.1% was used as corrosion inhibitor. The dynamic system for descaling investigation was all made of Q.V.F. glass(Quick fitting). It consisted of 5 liter round bottom container with three necks, the container was connected from the bottom with tubing through which hot solution circulated. A controlled heating tapes were rapped around the insulated Q.V.F glass tubing for heating the circulating solution.

The circulation of the chemical solution was effected using Q.V.F pump (0.25kw) and total flow rate was measured by a rotameter ranged from (0-1000) liter/hr.The flowing liquid passed the scaled metal specimen, and returned to the round bottom container, as shown in figure (1).

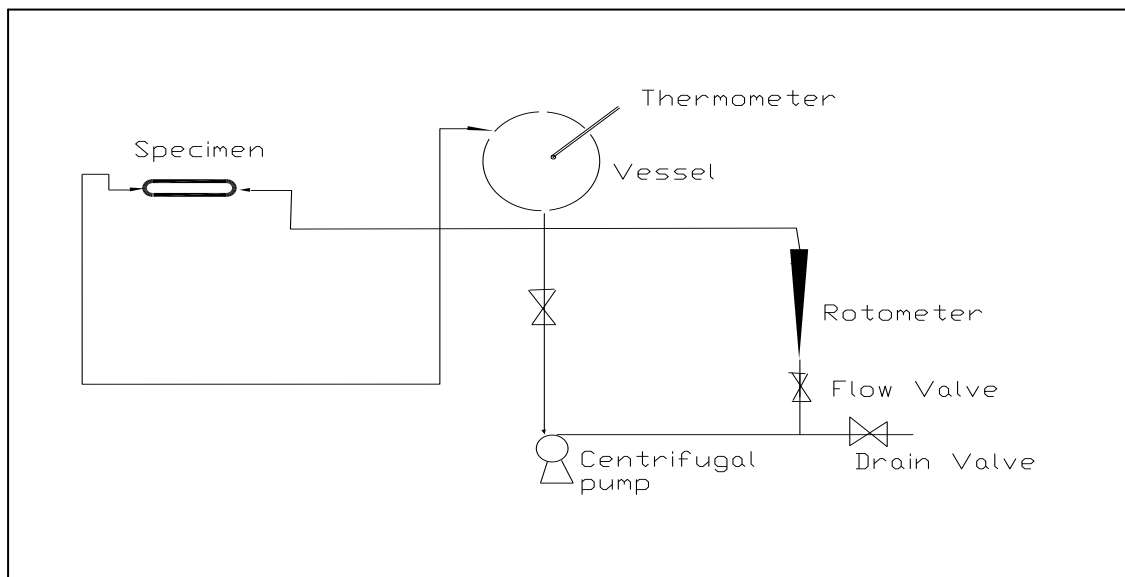
The temperature of the test solution ranged from 0-100°C and it was measured by means of thermometer.

The amount of the scale deposits which has been removed at each run was calculated by weight difference of the scaled tube before and after the tests.

PROCEDURE

The scaled tube was inserted into Teflon section and the Teflon section was tightened carefully to prevent leakage of test fluid.

The flow system contained (5) liter of circulating fluid. To obtain scale removal rate data, the pre-weighed test specimens were removed and weighted after the experiment. The tests were conducted at constant flow rate of 300l/hr.



Fig(1) Schematic diagram of the experimental system

RESULTS AND DISCUSSION:

The present work including the effects of temperature, time and concentration, on scale removal for a given turbulent flow rate.

-EFFECT OF TEMPERATURE

Rising temperature imparts kinetic energy to molecules causing them to move faster and collide more frequency and causing the rate of reaction in general to increase.

Such an increase in temperature on a cleaning job should speed up chemical reaction, There by decreasing the cleaning time [7].

Temperature ranged from (25°C – 65°C) have been used for the process of scale removed.

Figures (2), (3), and table(3) show the effect of temperature on the scale removal process for sulfamic acid and citric acid respectively it was clear that the higher the temperature the higher the percentage of scale removal when other conditions of the process (time, concentration) remained constant. This may be due to the effective penetration of above compounds at high temperature to internal structure of the scale. Also the reaction rate constant increases as the temperature increases, and has its maximum value at the highest temperature.

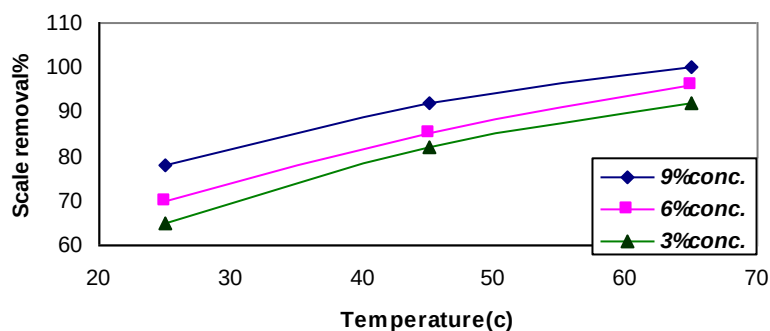
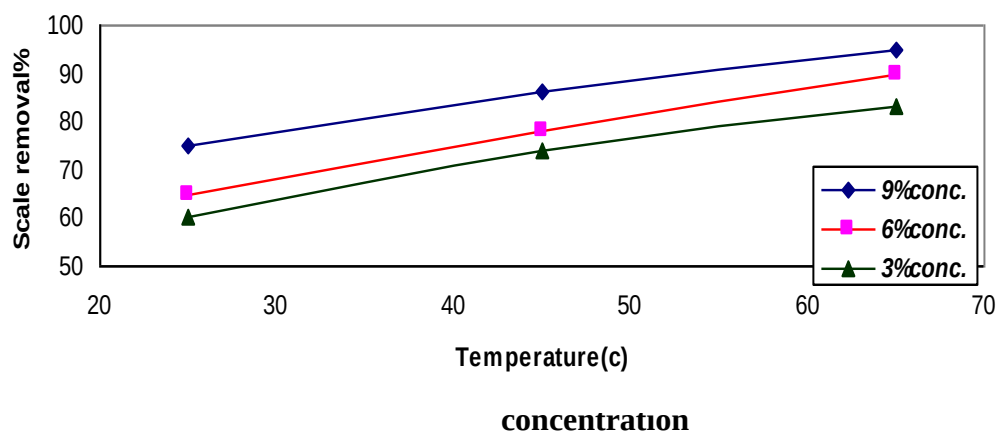


Fig.(2)-Sulfamic acid scale removal versus temperature at different concentration



- EFFECT OF TIME :

The effect of time on scale removal is observed in figures (4), (5) for citric acid and sulfamic acid respectively at different concentrations and (temperature 45°C).

It can be seen that the percentage of scale removal increases with reactions time at a constant concentration and temperature.

The pattern of the curves is similar to those of Moor [8]. Above 4 hours of reaction time with all concentrations of sulfamic acid greater than 85% scale removal could be accomplished while at all concentrations of citric acid above 75% scale removal could be obtained after 4 hours at 45°C temperature and different concentrations.

Increasing the time cause the scale removal to increase, that is due to increasing the action of the fluid to break the bound between the scale particles as increasing the time of passing over it.

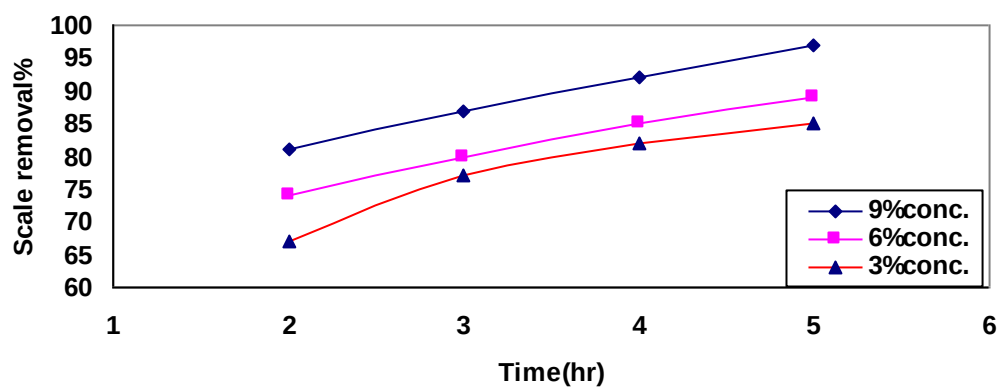


Fig.(4)-Sulfamic acid scale removal% versus time at different concentration

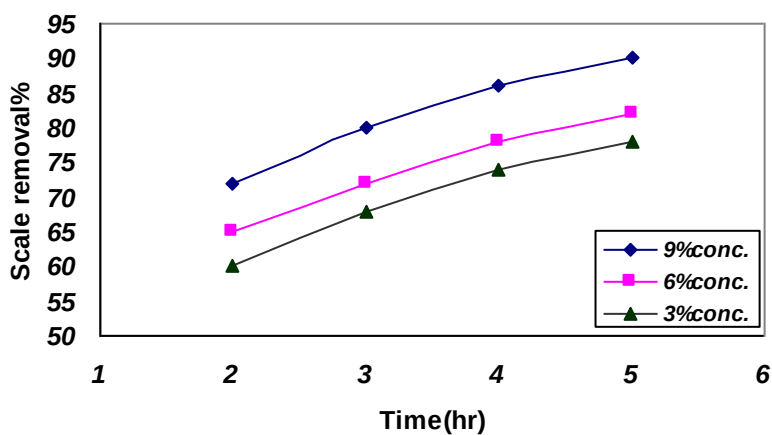


Fig.(5)-Citric acid scale removal% versus time at different concentration

-EFFECT OF CONCENTRATION :

Sulfamic acid and citric acid were tested in three concentrations of 3%, 6%, 9%. Figures (6), (7) shows the effect of increasing the concentration of each acid with scale removal percentage. It was clear that increasing the acid concentration cause to increase the scale removal percentage at any time.

It can be observed that more than 75 wt% of scale can be removal at concentration of 4 wt% of sulfamic acid and more than 70 wt% of scale can be removed with citric acid of concentration above 4 wt% at constant time and temperature.

Increasing the scale removal with increasing acid concentration due to the increase in concentration gradient between the bulk and the solid solution interface consequently, the reaction rate of the scale with the acid will be increased.[9]

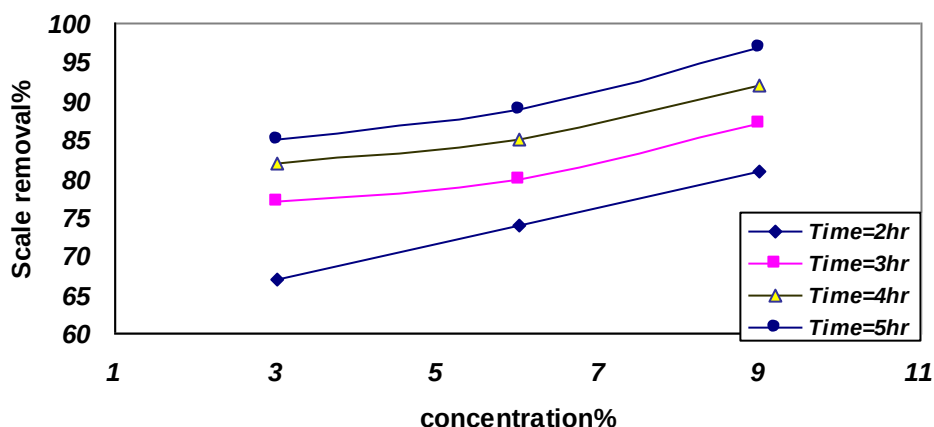


Fig.(6)-Sulfamic acid scale removal % versus concentration at different time

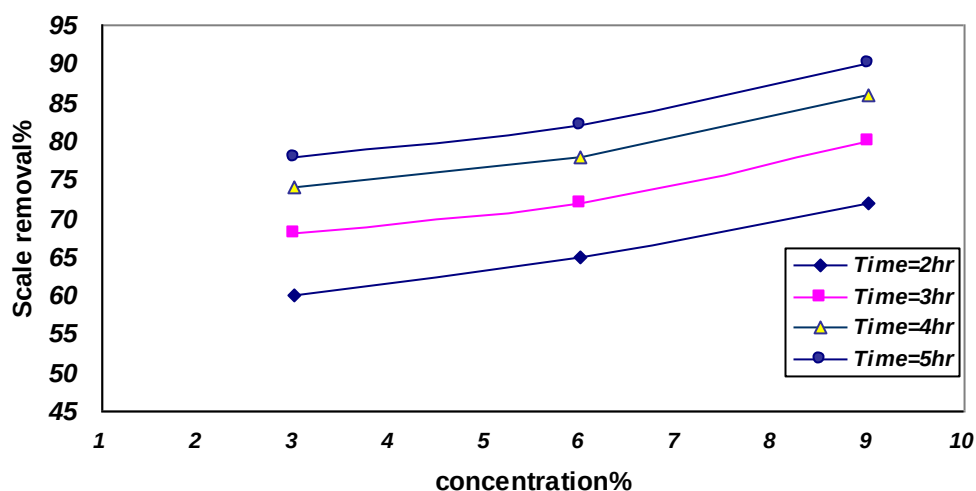


Fig.(7)-Citric acid scale removal % versus concentration at different time

-COMPARISON OF THE TWO ACIDS USED :

Figure (8) shows the performance of sulfamic acid and citric acid in the scale removal, it was clear that sulfamic acid appears to be the better scale removal than citric acid.

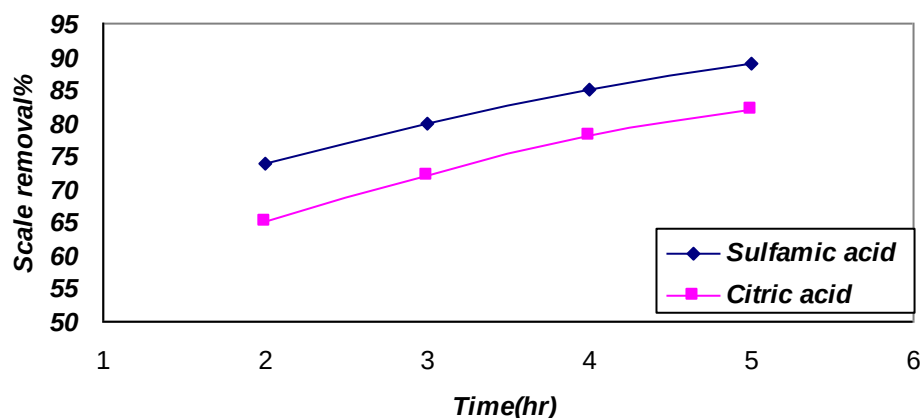


Fig.(8)-Comparison of scale removal % of sulfamic acid and citric acid versus time at 6% concentration

CONCLUSION

- The following conclusions could be obtained from the present study :
- Scale removal by means of inhibited sulfamic acid and citric acid increases as the temperature of the process increase and it was observed that above 80 wt% of the scale was removed when the temperature of the process was 45°C at time 4 hr and different concentration.
- The amount of scale removal increases with increasing the reaction time, and above 75% of the scale removed at a time greater than 4 hours using any of the two acid solutions.
- The amount of scale removal increases with increasing the acid concentration for each of the two acids used and it was found that above 70wt% of the scale was removed with acid concentration more than 4wt% of each acid.
- Sulfamic acid was found to be the better solution than citric acid for Dura refinery heat exchanger piping scale removal.

Table (1) Chemical Composition Of The Tube Used From Dura Refinery Heat Exchangers

Comp.	Copper	Tin	Lead Max.	Iron Max.	Zinc	Arsenic
Wt%	70-73	0.9-1.2	0.07	0.06	Balance	0.02-0.1

Table (2) Complete analysis of scale Al-Dura refinery water deposit from heat exchanger tubes

Element Analysis	Wt%
Iron (Fe_2O_3)	20.6
Aluminum (Al_2O_3)	2.04
Calcium Carbonate (CaCO_3)	32.71
Calcium (CaO)	14.1
Magnesium (MgO)	3.25
Sulfur (SO_3)	2.2
Potassium (K_2O)	0.04
Copper (CuO)	1.12
Zinc (ZnO)	3.6
I.R (Insoluble Residue)	9.11
L.O.Z (Loss on Ignition)	11.23

Table(3) Effect of temperature on scale removal% using sulfamic and citric acids at different concentrations

Temperature (C°)	Scale removal%		Concentration
	Sulfamic acid	Citric acid	
25	65	60	3%
	70	65	6%
	78	75	9%
45	82	74	3%
	85	78	6%
	92	86	9%
65	91	83	3%
	95	90	6%
	100	95	9%

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APPLYING ADAPTIVE FUZZY NEURAL ALGORITHM FOR INTRUSION DETECTION

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الخلاصة

معظم التطبيقات التي يتم الدخول عليها من خلال شبكة الانترنت لها طرق خاصة لتمييز المستخدمين المخولين بالدخول لها عن المتطفلين. هذه الطرق أغلبها تقليدية تتم عن طريق المقارنة بين المعلومات المدخلة من قبل المستخدم وتلك المخزونة بالنظام. النظام المقترح يقوم بعملية اكتشاف المتطفلين باستعمال طريقته الجديدة يطلق عليها طريقته الشبكة الضبابية التكيفية والتي لها قدره على اكتشاف المتطفلين بنفس الفترة الزمنية حتى عند ازدياد عدد مستخدمي النظام. النظام المقترح يتكون من مرحلتين، المرحلة الاولى تتضمن مراقبة جميع الحوادث والفعاليات التي تحدث بالنظام وتحليلها، اما المرحلة الثانية فتتضمن تحديد الاختراق والذي يكون بنوعين الاستعمال الطبيعي والاستعمال الخاطئ باستعمال الشبكة الضبابية التكيفية وهي الطريقه المقترحه في هذا البحث لتمييز المرور الطبيعي والمرور غير الطبيعي في النظام.

ABSTRACT

Many Network applications used as remote login have some ways for detecting the intruders which are classical ways applied by comparison of operations between login user interface and system stored information. The proposed system tried to detect the intrusions happened by the network intruders using new technique called Adaptive Fuzzy Neural Network which have the ability to detect the intrusions at the same time even if the number of users is large. The proposed system consists of two stages, the first stage is for monitoring all events that happen and analyzing them, and the second stage is to detect intrusions. The detection operation combines anomaly intrusion detection and misuse intrusion detection using the Adaptive Fuzzy Neural Network system, which is a suggested method in our paper used to learn the normal network traffic and detect the abnormal traffic.

INTRODUCTION

Intrusion detection is the process of monitoring the events occurring in a computer system or network and analyzing them for signs of intrusions, defined as attempts to compromise the confidentiality, integrity, availability. Intrusions are caused by attackers accessing the systems from the Internet, authorized users of the systems who attempt to gain additional privileges for which they are not authorized, and authorized users who misuse the privileges given to them. Intrusion Detection Systems (IDS) are software or hardware products that automate this monitoring and analysis process [1].

Intrusion detection is classified into two types: misuse intrusion detection and anomaly intrusion detection. Misuse intrusion detection uses well-defined patterns of the attack that exploit weaknesses in the system and application software to identify the intrusions. These patterns are encoded to match against the user behavior to detect intrusion. Anomaly intrusion detection uses the normal usage behavior patterns to identify the intrusion. The normal usage patterns are constructed from the statistical measures of the system features. The behavior of the user is observed and any deviation from the constructed normal behavior is detected as intrusion [2].

Since the system is concerned with the development of an effective, simple Fuzzy logic system for modeling of ill-define dynamical system used. The system represented as a feed forward neural network. Supervised linear back propagation learning algorithm has been applied to model a system through identifying the Fuzzy parameters. The Fuzzy learning system with the training algorithm is called the Adaptive Fuzzy Neural Network (AFNN). [3].

It is in this context that we present an overview of Intrusion Detection system that uses the content of Fuzzy Neural Network (FNN) for adopting the proposed IDs system. In the next section an overview of Fuzzy Neural Network is explained. After that the proposed system is described. Then the results from different experiments are presented. Finally conclusions are expressed.

FUZZY NEURAL NETWORK: AN OVERVIEW

Unlike classical logical systems, Fuzzy logic aims at modeling the imprecise modes of reasoning that play an essential role in the remarkable human ability to make rational decisions in an environment of uncertainty.

Fuzzy logic allows variables to be partial members of a particular set and uses generalization of the conventional Boolean logical operators to manipulate this information. By allowing partial membership of a set, it is possible to represent the smooth transition from one rule to another as the input is varied smoothly, which is a very desirable property in modeling and control application [4].

Our approach deploy in a different manner that uses the Fuzzy Neural Network. There are several reasons for using such method, which are:

- Most papers used the classical Neural Network such as back propagation for IDS, so we want to adopt a new technique.
- The normal approach will slow down as the number of users increases because we need to compare all the data base in order to reach the specified user. Our approach need no time as an average, so that all the information related to each user is propagated through the Fuzzy Network learning, i.e. we need to supply the input to this net in order to discover the confidentiality of the user.
- The FNN has a significant property that is the ability to confident users even the input data is not complete, i.e. if we use part of the information as the input for Fuzzy Network. This net will still be able to recognize the confident user like supplying the data entering without operations and vice versa.

- Fuzzy Set Basic Operations [5, 6, 7]

A Fuzzy set **F** in a universe of discourse **U** is characterized by a membership function μ_F which takes values in the interval [0,1], namely:

$$\mu_F: U \rightarrow [0,1]$$

A Fuzzy set may be viewed as a generalization of the concept of an ordinary set whose membership function takes only two values $\{0,1\}$.

Let A and B be two Fuzzy sets in U with membership functions μ_A and μ_B respectively. The set theoretic operations of union, intersection and complement for Fuzzy sets are defined via their membership functions as follows :

- The membership function $\mu_{A \cup B}$ of the union $A \cup B$ is pointwise defined for all $u \in U$ by :

$$\mu_{A \cup B}(u) = \text{Max} \{ \mu_A(u), \mu_B(u) \}$$

- The membership function $\mu_{A \cap B}$ of intersection $A \cap B$ is pointwise defined for all $u \in U$ by:

$$\mu_{A \cap B}(u) = \text{Min} \{ \mu_A(u), \mu_B(u) \}$$

- The membership function μ_A of the complement of a Fuzzy set is pointwise defined for all $u \in U$ by :

$$\mu_A(u) = 1 - \mu_A(u)$$

Membership Function (MF) is the function which corresponds to a real number between 0 and 1 to any generic element of the Universe of Discourse. There are different shapes of membership functions like, Triangular, Trapezoidal, Gaussian, and Singleton.

Adaptive Fuzzy Systems Architecture

The fundamental configuration of a Fuzzy logic system consists of four basic blocks; the Fuzzy role base, the Fuzzy interface engine, the fuzzifier, and the defuzzifier, as shown in Figure (1).

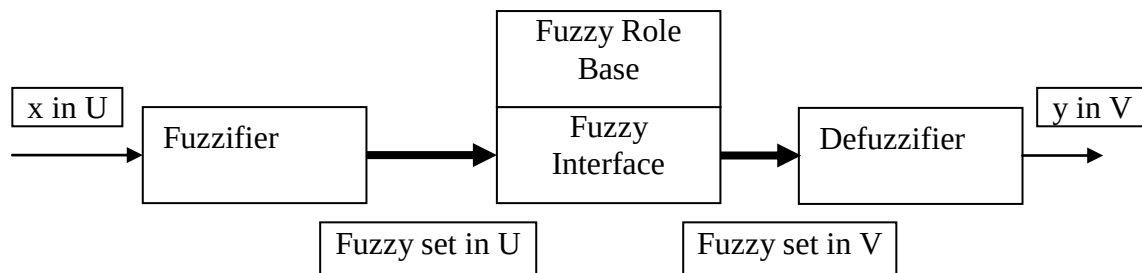


Figure (1) Basic Configuration of Fuzzy Logic Systems

There are different types of fuzzifiers and defuzzifiers. Several combinations of the Fuzzy interface engine, fuzzifier, and defuzzifier may constitute useful Fuzzy logic system. If the Fuzzy logic system can be represented as a feed forward network, then the idea of back propagation training algorithm can be used to train them.

Adaptive Fuzzy System Structure

The most useful class of fuzzifier is the center average [8, 4], of the form:

$$f(\underline{x}) = \frac{\sum_{j=1}^M y_j (\mu_{F_j}(y_j))}{\sum_{j=1}^M (\mu_{F_j}(y_j))} \quad (1)$$

Where M is the number of Fuzzy rules, y_j is the center of Fuzzy set F_j , which is, a point in the universe of discourse V when $\mu_{F_j}(y)$ achieves its maximum value, and $\mu_{F_j}(y)$ is given by a product interface engine. Hence using product operator becomes:

$$f(\underline{x}) = \frac{\sum_{j=1}^M y_j \left(\prod_{i=1}^n \mu_{F_j}(x_i) \right)}{\sum_{j=1}^M \left(\prod_{i=1}^n \mu_{F_j}(x_i) \right)} \quad (2)$$

Where n is the number of input variables.

In order to develop training algorithms for this Fuzzy logic system, the functional form of $\mu_{F_i}(x_i)$ must be specified. The bell shaped membership function, based on the normal distribution of the grades of the membership [9, 10], was proposed, i.e. the membership function will be given by:

$$\mu_{F_i}(x_i) = \exp \left[- \left(\frac{x_i - m_i}{\sigma_i} \right)^2 \right] \quad (3)$$

Where m_i and σ_i are, respectively, the center and width of the bell-shaped function of the i^{th} input variable. By combining Equations (2, 3), the overall function of the Fuzzy logic system is:

$$f(\underline{x}) = \frac{\sum_{j=1}^M y_j \left[\prod_{i=1}^n \exp \left[- \left(\frac{x_i - m_{ij}}{\sigma_{ij}} \right)^2 \right] \right]}{\sum_{j=1}^M \left[\prod_{i=1}^n \exp \left[- \left(\frac{x_i - m_{ij}}{\sigma_{ij}} \right)^2 \right] \right]} \quad (4)$$

This equation represents a Fuzzy logic system with center average defuzzifier, product interface rule, non-singleton fuzzifier, and bell-shaped membership function. Equation(4) can be implemented on a Forward Neural Network. This connectionist model combines the approximate reasoning of Fuzzy logic into a five layer neural network structure [11], as in Figure (2).

Associated with each node in a typical neural network is an integration function, which serves to combine information or activation from the other nodes. This function

X_i^L provides the net input of the i^{th} node in layer L . A second action taken by each node is to output an activation value as a function of its net input:

$$O_i^L(k) = g(X_i^L(k)) \quad (5)$$

Where $g(.)$ denotes the activation function.

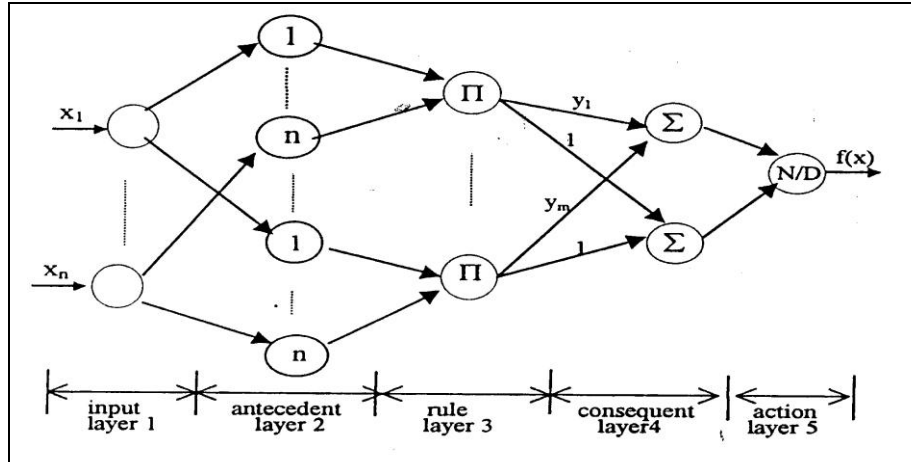


Figure (2) Adaptive Fuzzy System as a FNN

The basic function of the nodes in each layer would be defined as follows:

a) Input layer

The nodes in this layer just transmit their inputs to layer 2:

$$X_1^1 = x_1, X_2^1 = x_2, \dots, X_n^1 = x_n \quad (6)$$

$$O_i^1 = X_i^1 \quad (7)$$

Where $i = 1, 2, \dots, n$ and n is the number of the input linguistic variables.

b) Antecedent Layer

The output from this layer is:

$$O_i^2 = \mu_{F_i}(X_i^2) \quad (8)$$

Where X_i^2 is the input to node i in layer 2 and F_i is the linguistic label assigned to Fuzzy set (small, large, etc.). Using Equation(3), Equation(8) can be rewritten to have:

$$O_i^2 = \exp \left[- \left(\frac{x_i^2 - m_{ij}}{\sigma_{ij}} \right)^2 \right] \quad (9)$$

Where m_{ij} and σ_{ij} are, respectively, the center and width of the bell-shape function of the i^{th} input of the j^{th} rule.

c) Rule Layer

The output from each node in this layer is dictated by the firing strength of the corresponding rule. With the proposed scheme (i.e. Equation(4)), the rule node perform the Fuzzy product operation; Therefore:

$$z_j = O_j^3 = \prod_{i=1}^n X_{ij}^3 \quad (10)$$

Where X_{ij}^3 denotes the i^{th} . Input to node j in layer 3.

d) Consequent Layer

The upper node of these layer sums all outputs from the rule layer with action strengths (y_i) and the lower node those with unity strength:

$$N = O_1^4 = \sum_{j=1}^M y_j X_j^4 \quad (11)$$

$$D = O_2^4 = \sum_{j=1}^M X_j^4 \quad (12)$$

Where N and D are the numerator and denominator of Equation(4)

e) Action Layer

The network output would be pumped out the single node layer.

$$f(\underline{x}) = O^5 = \frac{X_1^5}{X_2^5} = \frac{N}{D} \quad (13)$$

PROPOSED SYSTEM

Adaptive Fuzzy System Training Algorithm

Fuzzy-neural network will be used here in an intrusion detection system. The data sets from the monitoring system data base are used for the training and the testing of the fuzzy-neural networks.

Based on the error back propagation algorithm, the goal is to determine a Fuzzy logic system $f(\underline{x})$ in the form of Equation(4), which minimizes the error function:

$$E(k) = \frac{1}{2} \sum_{j=1}^P [f_j(\underline{x}(k)) - d_j(k)]^2 \quad (14)$$

Where P is the number of outputs and $d_j(k)$ is the j^{th} desired output at time k . Without loss of generality, Multi-input single-output (MISO) Fuzzy logic system was considered in this paper. A multi-output system can always be decomposed into a group of single-output systems [12,13], therefore for $P=1$, Equation(14) is reduced to:

$$E(k) = \frac{1}{2} (f(\underline{x}(k)) - d(k))^2 \quad (15)$$

According to Equation(4), if the number of rules is M , then the problem becomes training the parameters y_j , m_{ij} , and σ_{ij} such that $E(k)$ is minimized.

Based on the back propagation training algorithm the iterative equations for training the parameters y_j , m_{ij} , and σ_{ij} are:

$$y_j(k+1) = y_j(k) - \eta (f(\underline{x}(k)) - d(k)) \frac{1}{D} z_j \quad (16)$$

$$m_{ij}(k+1) = m_{ij}(k) - 2\eta \frac{z_j}{D} (f(\underline{x}(k)) - d(k)) \cdot (y_j(k) - f(\underline{x}(k))) \cdot \left(\frac{x_i^2(k) - m_{ij}}{(\sigma_{ij})^2} \right) \quad (17)$$

$$\sigma_{ij}(k+1) = \sigma_{ij}(k) - 2\eta \frac{z_j}{D} (f(\underline{x}(k)) - d(k)) \cdot (y_j(k) - f(\underline{x}(k))) \cdot \left(\frac{(x_i^2(k) - m_{ij})^2}{(\sigma_{ij})^2} \right) \quad (18)$$

Where η is the learning rate, Equation (16), (17), and (18) perform an error back propagation procedure.

Our system combines the two distinct intrusion detection approaches, (anomaly and misuse). Combining these two approaches enables bypassing drawbacks that appear in each approach.

The proposed system has six main components to be maintained along the project implementation:

- i. **Subject:** The users and their identification information, for the machine that they are working with, represent the subjects here.
- ii. **Object:** This term refers to the resources managed by the system.
- iii. **Audit records:** This is the basic element of IDS because it is generated by the server machine (where the IDS is residing) in response to actions performed or attempted by subjects on objects such as user login, command execution, file access, and time of accesses. These records are arranged into database to be referenced along the execution of IDS. Each record field will be stored in the string type to increase the analysis and detection speed.
- iv. **Profiles:** are structures that characterize the behavior of subjects. The more important profiles fields are: the IP address, PC name, type of event (delete, create, rename, open), the time of accessing (starting and ending) per day (in hour).
- v. **Anomaly records:** are generated when abnormal behavior is detected.
- vi. **Activity rules:** actions taken when some condition is satisfied, which update profiles, detect abnormal behavior, relate anomalies to suspected intrusions, and produce reports.

The block diagram for the proposed system is shown in Figure (3). Each part of the proposed system will be discussed in detail in the following subsections.

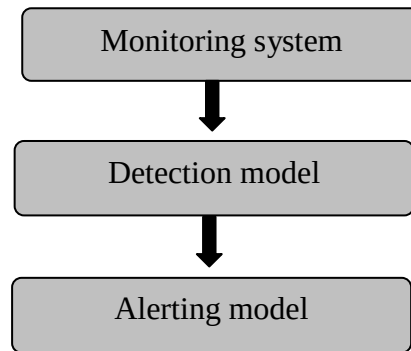


Figure (3) Proposed IDS block diagram

The Proposed IDS Architecture

The architecture of the proposed IDS is shown in Figure (4) and is stated in the following points:

- i.** An audit record is created. This occurs when an action happens, such as open file.
- ii.** The detection engine searches for anomaly behavior comparing the current data with the historical data.
- iii.** Anomaly record is generated when abnormal behavior is observed. The anomaly record is forwarded to a number of different sub-systems for security officer, response, and storage.
- iv.** The security officer is notified through visual method such as showing the message as alarm.
- v.** A response is generated. Responses include actions such as shutdown the target, restart the target or notify the security officer.
- vi.** Store the anomaly record to use it in expecting new type of intrusion.
- vii.** Reports can be generated and forwarded to the security officer.

The Proposed Monitoring System

Host based monitor activities are normally executed only by an administrator. Operating systems log any event user accounts are added, deleted, and renamed. Host-based IDS can detect an improper change as soon as it is executed. Host-based IDS can also audit policy changes that affect what systems track in their log.

The proposed system does not contain any special features for dealing with complex actions that exploit a known or suspected security flaw in the target system; indeed, it has no knowledge of the target system's security mechanisms or its deficiencies. By detecting the intrusion, however, the security officer may be better able to locate vulnerabilities.

The proposed system was built as an administrator for a LAN network with a two personal computer connected to server. These two computers will operate under windows, the first step is start up the server, no network services without server. Each client registers himself as an employee. The employee has to fill registration form

which asks him about many personal aspects. This personal information is decided previously. After that, employee returns to his office to get himself ready for the next step through which the system learns more about him, as shown in Figure (5). Monitoring Algorithm can be characterized as seen in algorithm (1)

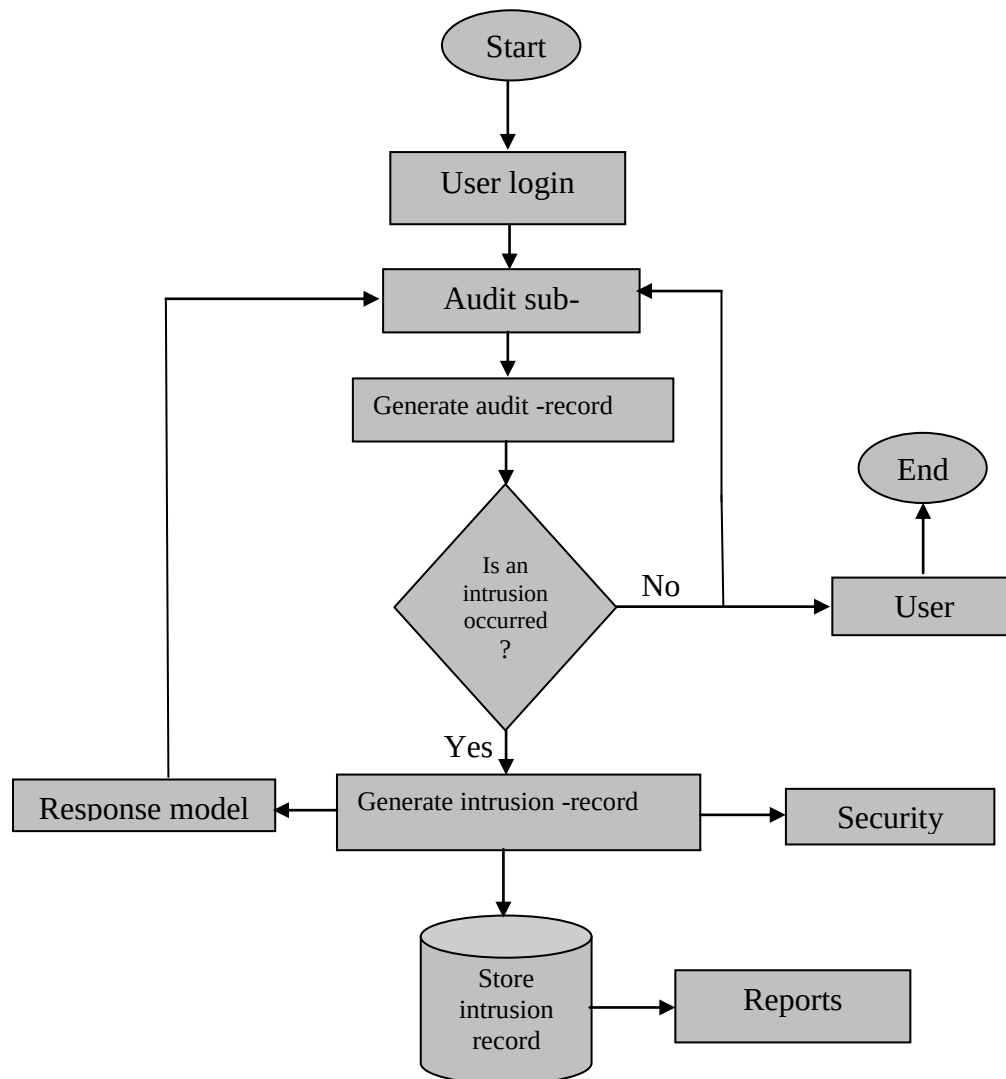


Figure (4) The architecture of the proposed system

Algorithm (1):

- Start when the computer is turned-on.
- Specify the target system that wants to monitor it.
- Monitoring the specified target system.
- Check if any operation of (delete, create, rename, and open) on the file or folder has occurred then add a record in database, go to step 3.
- End.

Detection Model

There are two categories of intrusion detection system. They are called network-based IDS and host-based IDS. Networks have made computer systems easily

accessible from remote location. This allows legitimate users to access computer systems and information on those computer systems and this may lead to a large number of intrusions.

A single intrusion of a computer network can result in the loss or unauthorized utilization or modification of a large amount of data and cause users to question the reliability of all the information on the network. An important shortcoming of IDS is that can detect when an event is unusual, which may or may not indicate an attack.

This model acts the heart of the proposed system, it consists of two phases: Encoding phase and Detection phase.

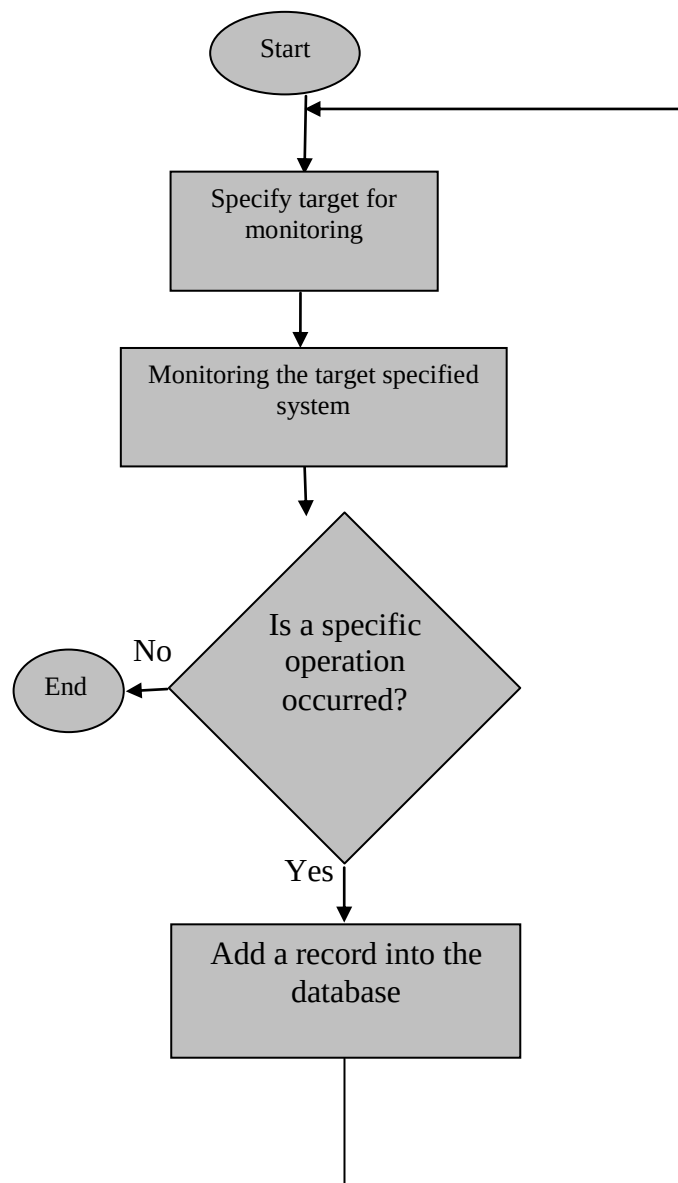


Figure (5) The proposed monitoring system

Encoding Phase

The main function of this phase is reading the records from monitoring system database and encoding it. The input files to the Fuzzy Neural Network must be encoded. These files must be in decimal format, therefore, all log files must be converted to decimal format, as shown in the figure (6). Encoding phase explained in the following algorithm.

Algorithm (2):

- Start while DB contain operation record.
- If rec. no from MSDB larger than zero, then go to step 3.
- Else go to step 11.
- Read record from MSDB.
- Set coding = 0 , x =0.
- $x = x + 1$.
- If $x < \text{field no.}$ then go to step 7.
- Else go to step 2.
- 7. Execute Query
- Query = "select target field, code, ser, max (ser). As m ser from code table where target field = record, field (x)"
- Check if rec. no. Of Query larger than zero then go to step 9
 - Else go to step 10
- Coding (x + ser) = Query (code).
- $x = x + \text{Query (m ser)}$ and go to step 5
- End.

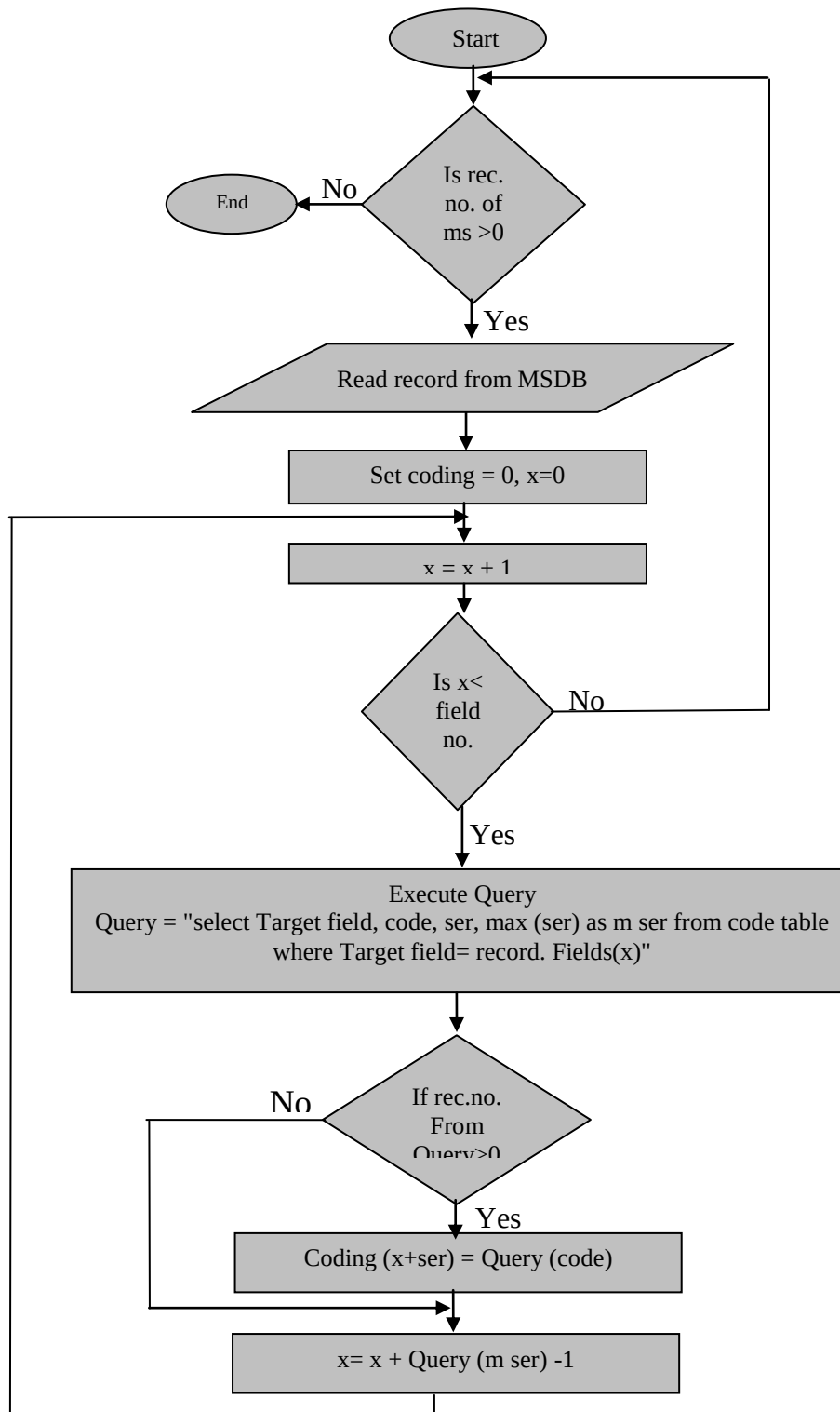


Figure (6) Flow chart of Encoding phase

Detection Phase

The purpose of this phase is to detect intrusions by using Fuzzy Neural Network. In this phase, two kinds of intrusions will be detected, anomaly and misuse intrusion.

a. Anomaly Detection

This is the first detection mechanism in the proposed system. The structure of the anomaly detection is shown in Figure (7).

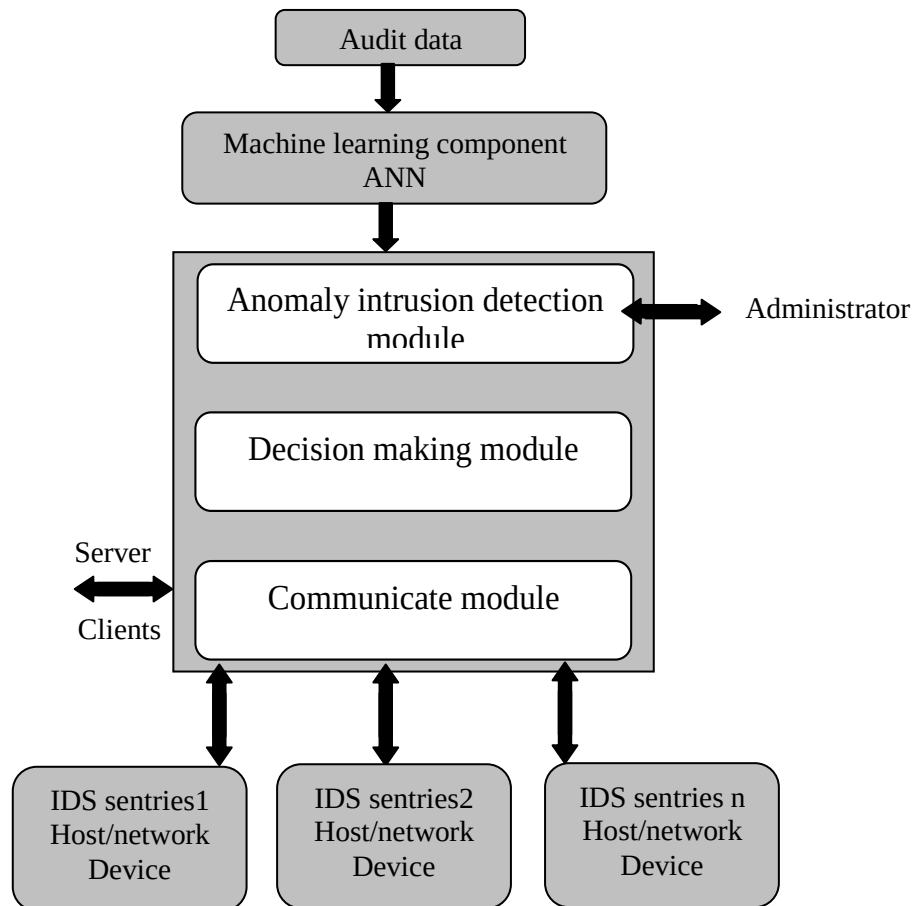


Figure (7) Structure of the anomaly detector

- **Machine Learning Component:** This part uses fuzzy-neural (back propagation) to learn normal patterns of system behavior. This normal behavior is stored in profiles. This allows the system to adapt to new environment.
- **Anomaly Intrusion Detection Module:** This module extracts patterns of an observed audit trail and compares these new patterns with the normal patterns. If the similarity of the sets of patterns is below a specified threshold, the system alarms of an intrusion.
- **Decision- Making Module:** This will decide whether or not to activate anomaly intrusion detection and integrates evaluation results provided by the anomaly intrusion detection.
- **Communication Module:** It is the bridge between the intrusion detection and decision- making module.
- **Intrusion Detection Sentries:** Pre-process audit data and send results to the communication module.

Algorithm (3) shows the steps of anomaly detector. Figure (8) shows Neural Network for anomaly detector.

Algorithm (3):

1. Begin
2. Monitoring system turn on.
3. Select specific fields from monitoring system data base and arrange them in vectors
4. While .T. DO
 Begin
 Read vector from monitoring system data base.
 Apply encoding algorithm.
 Input vector to the designed FN
 If the output of FN is (1) then
 Mark the specified Vector as normal
 Else mark the specified vector as abnormal
5. If no more vector found then
 Exit
6. End (while)
7. End.

The input values to the FN are coded as $x_1, x_2 \dots x_9$.

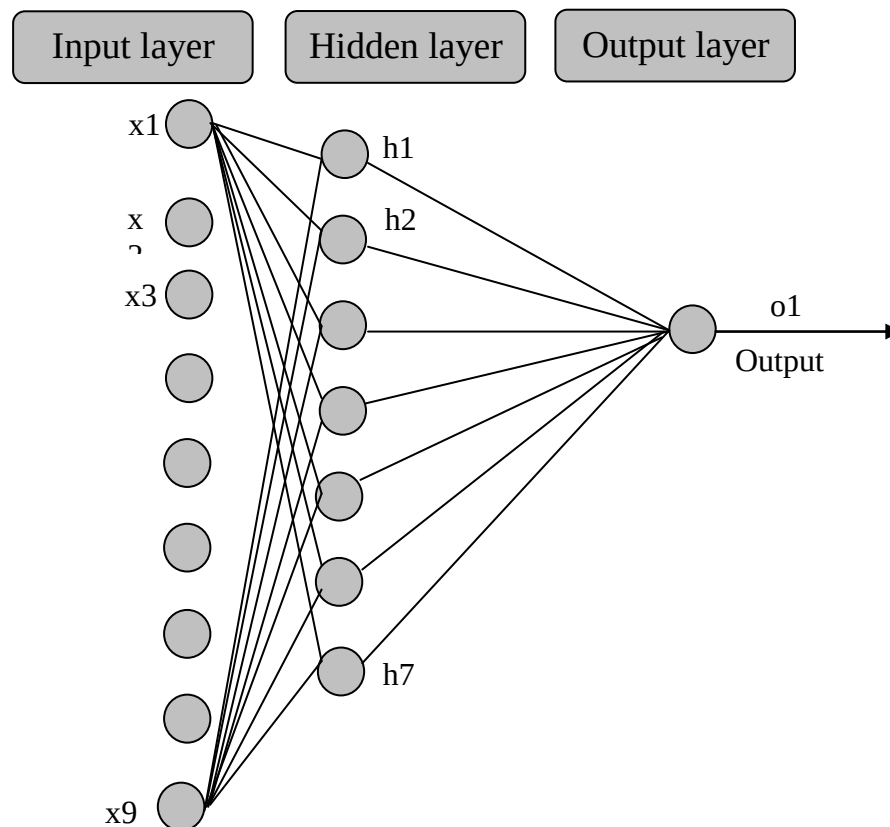


Figure (8) Neural network architecture used for anomaly detector

Where:

x_1 : the destination name.

x_2 : create event.

x_3 : delete event.

x_4 : rename event.

x_6 : the attribute of folder (hidden or not).

x_7 : the file

x_8 : the folder.

x_9 : the event in time.

x5: open event.

The main task of this phase is to identify intrusion patterns by considering the threshold that was computed in the fuzzy-neural network with back propagation training algorithm. The detector was designed using Fuzzy Neural Network, which utilizes back propagation architecture that consists of (9) input nodes, the hidden layer consist of (7) nodes and one output node.

The FN is designed to provide an output value (0) to indicate a misuse attack, and if output value is larger than error then anomaly intrusion has occurred. If output value is smaller than error then behavior is normal.

The number of hidden layers and the number of nodes in hidden layer is determined based on the process of trial and error.

The hidden layer consists of seven nodes, because this number of nodes gives good rate of accuracy in learning operation. If the number of nodes in hidden layer is increased then the accuracy will be increased but this number of nodes in hidden layer needs more time because of the computations between the nodes.

The output layer consists of one node, because we need either yes or no. It means intrusion or not- intrusion.

b. Misuse Detector

This type of detection involves a comparison of user's activities with the known behaviors of attackers. This detection mechanism matches the current behavior with a signature of known attacks. A signature is a pattern that we want to look at in event records. The structure of the misuse detector is shown in Figure (9).

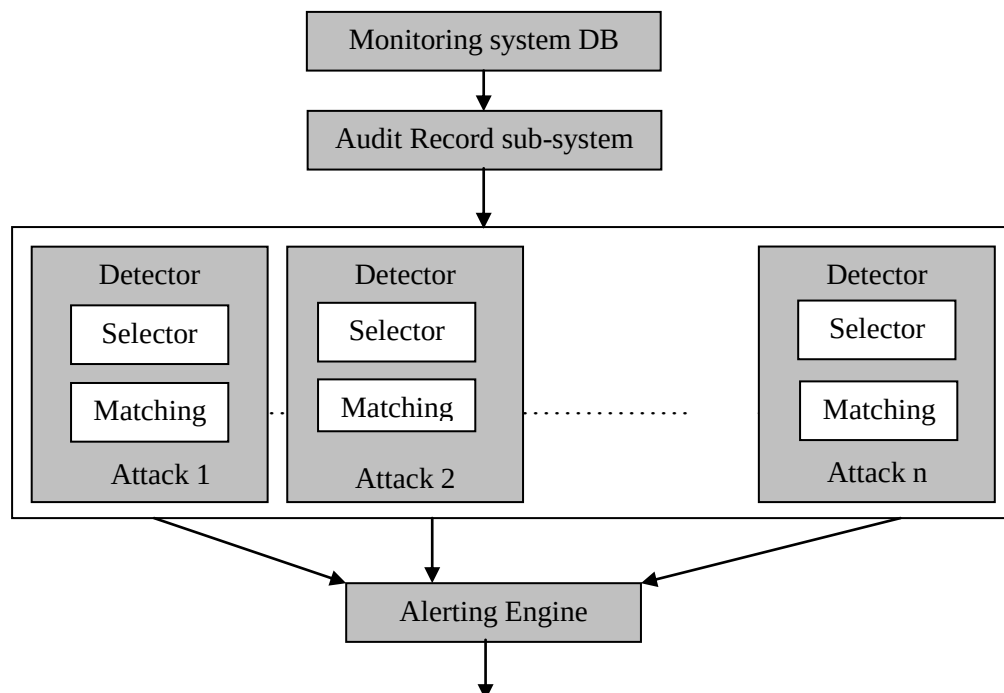


Figure (9) The structure of the misuse detector

The algorithm of the misuse detector is illustrated in algorithm (4).

Algorithm (4):

1. Begin
2. Monitoring system turn on.
3. Select specific fields from monitoring system data base and arrange them in vectors
4. While .T. DO
 - a. Begin
 - b. Select specific features from records in MSDB depending on the Signature of the attack
 - c. Match the selected features with the features of the attack
 - d. signature
 - e. If the two sets of features match then
Misuse attack is found
Else
Mark the event as normal
 - f. If no more attacks found then
Exit
Else
Check another attack type
End
5. End

Alerting Model

This is the last stage in the proposed system. This stage is concerned with deciding if an event or a set of events is an intrusion or not. It receives the output of anomaly detection or misuse detection part and then gives the result in a report. This report shows if the event is an intrusion and normal. The report also specifies the source that causes the abnormal behavior and the data and time of it. This model is important, since it is used to stop an intruder. Alerting model has many levels of reactions against the intruder, using any one of them depends on the nature of attack. Figure (10) shows this mechanism.

This model may be enough in showing the warning messages or locking some bottoms in the keyboard or freezing the IP that causes that attack.

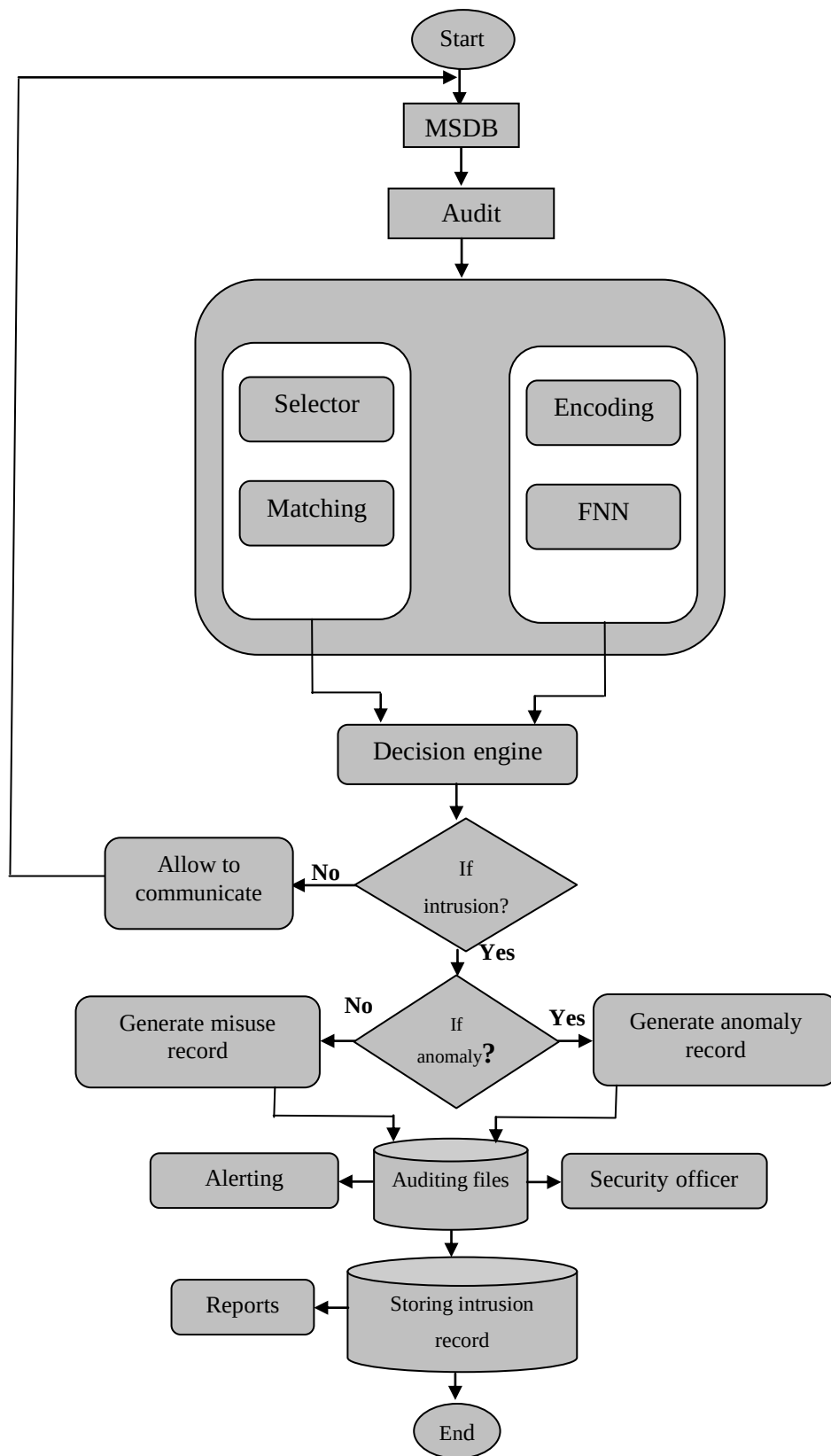


Figure (10) General block diagram of the proposed system

SYSTEM IMPLEMENTATION

The system is divided in two parts: the first one for the user and the second part for Administrator only. The final experiments were conducted to see what percent of the normal patterns and the attacks that are classified correctly.

The first part of the proposed system represents the user behavior by applying the four operation (open, rename, delete, and create) on folder or file and select the file categories. By executing that we obtain the total path and its history in exact time and date. This will record the required information for the user who authorized to work on this IP address by registering correct username and password. The second part of the proposed system that represents the administrator will record the required information to register users like (user name, password, etc).

Since our work is in LAN environment, therefore, all clients in the LAN must be monitored and all events that occurred should be notified and registered in the database. The events that monitoring system monitors are open, rename, create and delete file or folder. Our system monitors the files that have the following extensions (*.sys, *.txt, *.avi, and custom).

The experiments were conducted in two parts, the preliminary experiment and final experiment.

- i. **The Preliminary Experiment:** In this test we used both known and unknown attacks in the same file. When we used just three hidden units, no attacks were detected at all. With 5 hidden units, we got a detection rate of 86%. The results from this experiment gave the background for choosing the number of hidden units and iterations used for the training of the fuzzy-neural network in the final experiment. This means that number of hidden units must be over 5; number of iterations must be over 100. There is a huge drop in the error between 3 and 5 hidden units. Table 1 shows Preliminary experiment results, figure (11) shows the error for the preliminary experiment.

Table 1: Preliminary experiment results

Hidden number	Iterations number	Error
2	100	0.3544
3	100	0.3541
4	100	0.0219
5	100	0.0195
6	100	0.0183
7	100	0.0031

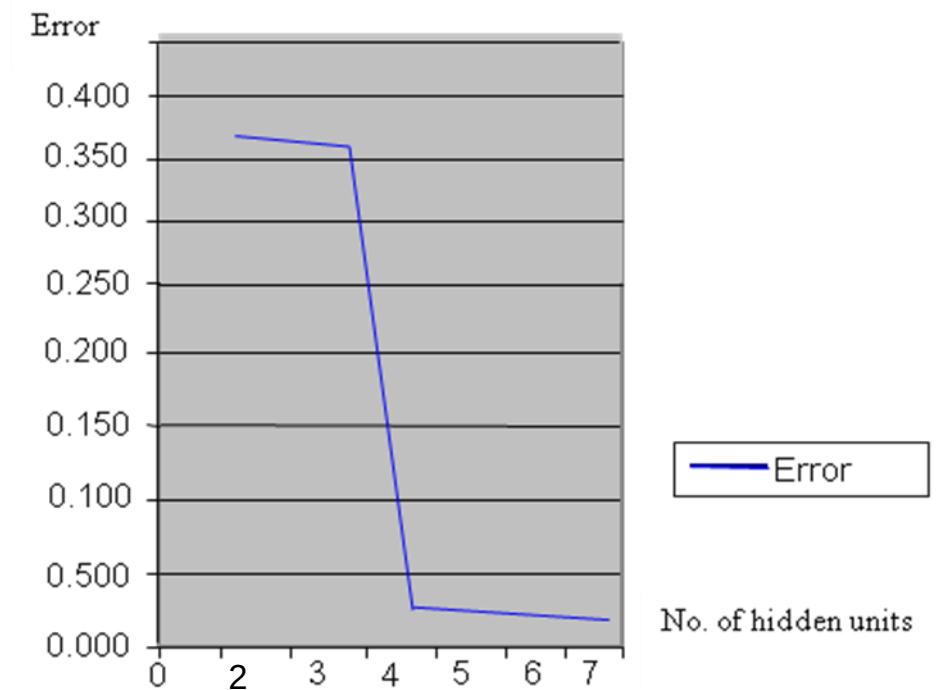


Figure (11): Error for the preliminary experiment

- ii. **The Final Experiment:** The testing was divided into normal traffic, known attacks, and unknown attacks. The classification rate of normal is 82%, but for the known attacks is 82% and the classification rate of unknown attacks is 80%, as shown in table 2:

Table 2: Final experiment results for normal traffic

Hidden number	Iterations number	Error
4	100	0.021995822141
7	100	0.018322100972
12	100	0.018230336374
24	100	0.018132969630
4	1000	0.006137723648
7	1000	0.004811317503
12	1000	0.004608365849
24	1000	0.004337760720
7	5000	0.002035273630
12	5000	0.001919316337
24	5000	0.001778245927
7	20000	0.000985901225
12	20000	0.000917864210
24	20000	0.000841241861

As explained before, the lower error rate is, the better rate normally is, in Figure (12) the differences in the errors when we used 100,1000,5000 and 20000 iterations for the training of the neural network are shown,

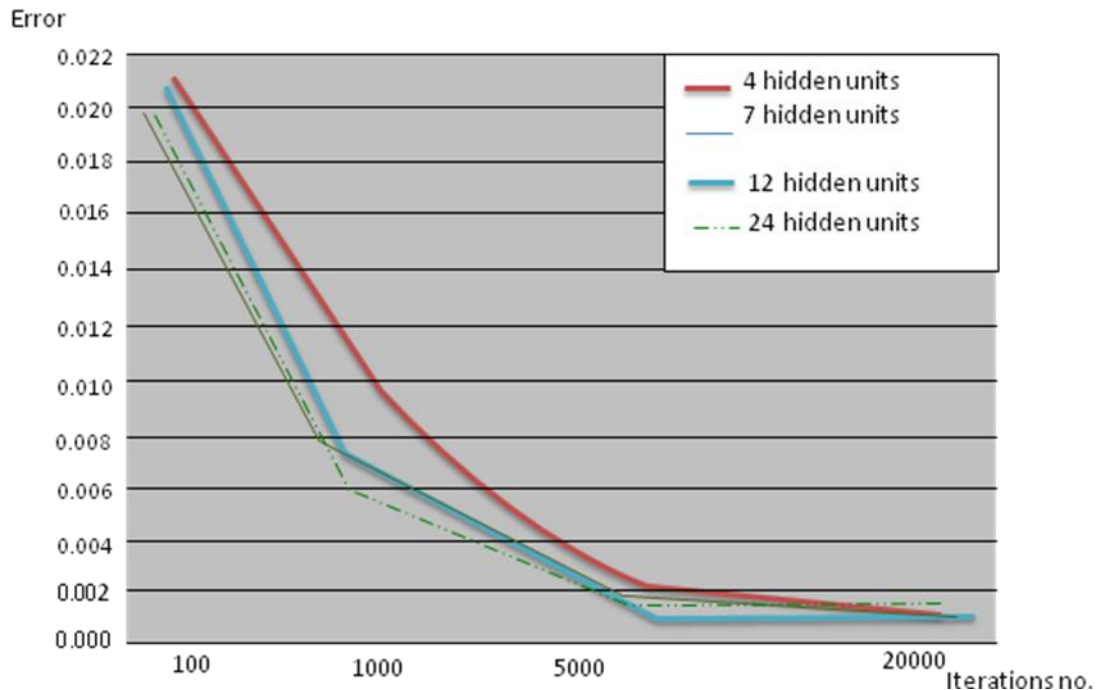


Figure (12): Error comparison

CONCLUSIONS

The proposed system is dedicated to design a network-based intrusion detection system on a network. Using the machine learning component of IDS architecture allows the system to adopt new environments. This makes the proposed system able to detect both of attacks anomaly and misuse attacks. Both anomaly detection and misuse detection are supported by the system. This gives the ability to respond to anomaly and not only to signatures of known attacks. Using Fuzzy Neural Network in anomaly detection shows that it can learn the characteristics of normal behavior and identify instances that are unlike normal behaviors that are anomalies. The training of the neural network requires a very large amount of data to ensure that the results are accurate.

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ECG CLASSIFICATION USING SLANTLET TRANSFORM AND ARTIFICIAL NEURAL NETWORK

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ABSTRACT

Automatic detection and classification of cardiac arrhythmias is important for diagnosis of cardiac abnormality. This paper shows a method to accurately classify ECG arrhythmias through a combination of slantlet transform and artificial neural network (ANN). The ability of the slantlet transform to decompose signal at various resolutions allows accurate extraction of features from non-stationary signals like ECG. The low frequency coefficients, which contain the maximum information about the arrhythmia, were selected from the slantlet decomposition. These coefficients are fed to a Multi-Layer Perceptron (MLP) artificial neural network which classifies the arrhythmias. In the present work the ECG data is taken from standard MIT-BIH database. The proposed system is capable of distinguishing the normal sinus rhythm and nine different arrhythmias. The overall accuracy of classification of the proposed approach is 98.40 %. Three other transformation methods are used and the accuracy of the classification of each was compared with the slantlet system accuracy. These transformation methods are: the Fourier transform which gives 67.80% accuracy, the discrete cosine transform which gives 92.72% accuracy, and the wavelet transform (using Haar and Daubechies-4 scaling function coefficients, which give an accuracies of 96.02% and 96.25% respectively).

الخلاصة:- إن كشف و تصنيف حالات القلب المرضية مهم في تشخيص الحالات القلبية الشاذة. هذا البحث يوضح طريقة لتصنيف الحالات المرضية من تخطيط القلب و ذلك من خلال دمج التحويل (Slantlet) مع الشبكة العصبية الاصطناعية (ANN). قدرة التحويل (Slantlet) على تحليل الإشارة إلى عناصرها ذات الدقة المختلفة تسمح باستخلاص أدق للميزات التي تحملها الإشارات غير المستقرة مثل الاشكال الموجية لتخطيط القلب الكهربائي. المعاملات ذات التردد الواطيء (و التي تحتوي على أعظم نسبة من المعلومات عن الحالة المرضية) تم إختيارها من التحليل الناتج من إستخدام التحويل (Slantlet). هذه المعاملات تم تجهيزها الى شبكة عصبية اصطناعية متعددة الطبقات و التي بدورها تقوم بتصنيف الحالات المرضية. في العمل المقدم تم أخذ بيانات تخطيط القلب الكهربائي من قاعدة البيانات القياسية (MIT-BIH). إن النظام المقترح قادر على التمييز بين الحالة الطبيعية و تسعة حالات مرضية. الدقة الاجمالية للتصنيف في الطريقة المقدمة هي 98.40 %. كذلك تم استخدام ثلاث طرق تحويلات أخرى و تم مقارنة دقة التصنيف لكل طريقة مع الدقة الناتجة بإستخدام التحويل (Slantlet). هذه الطرق هي التحويل (Fourier) الذي يعطي دقة 67.80%, التحويل (discrete cosine) و الذي يعطي دقة 92.72% و التحويل (Wavelet) [بإستخدام معاملات دالة الحجم (Haar) و (Daubechies-4) و التي أعطت دقة 96.02% و 96.25% على التوالي].

KEYWORDS

Slantlet Transform, Neural Networks, ECG Features Extraction and Classification.

INTRODUCTION

Electrocardiogram (ECG) measurements are used to monitor the contraction of the cardiac muscles by measuring the propagation of electrical depolarization and repolarization in the atria and ventricles. The ECG waveform is divided into P, Q, R, S, T and U elements. **Fig. 1** shows the components of a typical ECG signal. The P wave corresponds to atrial depolarization that shows contraction of both left and right atria. The QRS complex represents the depolarization of the ventricles. The T wave represents ventricles repolarization which setting up the cardiac muscle for another contraction. Sometimes it will follow by U wave that represents the Purkinje fibers repolarization. A highly sensitive electrocardiograph tools can help cardiologists to detect various heart irregularities, cardiac diseases and damages. The ECG interpretation is important for cardiologists to decide diagnostic categories of cardiac problems [1].

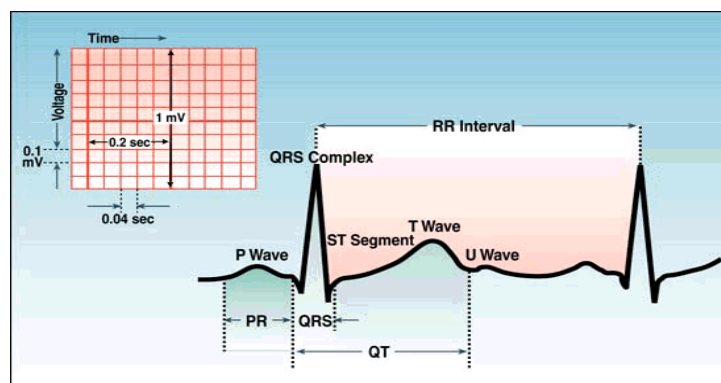


Fig. 1: Components of a typical ECG signal

Classification of ECG is an important area in biomedical signal processing, several algorithms have been developed for classification of ECG beats. These techniques extract features, which are either temporal or transformed representation of the ECG waveforms. The extracted features are used in the pattern recognition system to classify the ECG beats. The subject of pattern recognition can be divided into two main areas of study (1) features extraction and (2) classifier design, as summarized in **Fig. 2**, where $x(t)$ is the input signal.

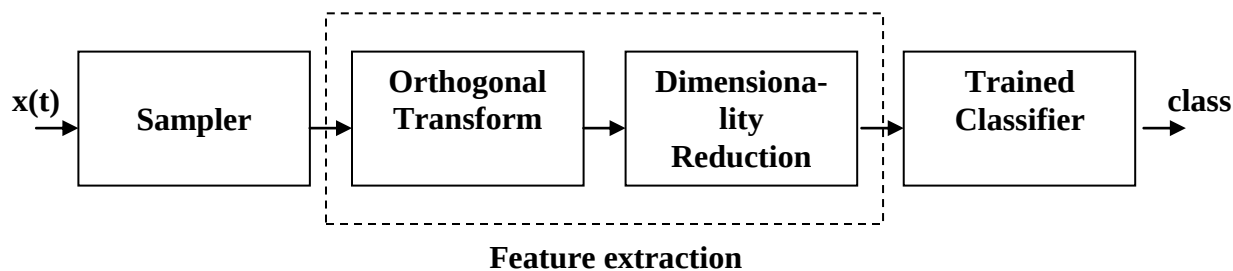


Fig. 2 : Pattern recognition system

The paper presents a slantlet based approach to extract features from the non-stationary ECG signal. The slantlet transform allows improved time-frequency localization of the signal. A supervised artificial neural network (ANN) is developed to recognize and classify the nonlinear morphologies.



ANN trained with back propagation algorithm, classifies the applied input ECG beat to appropriate class.

- WAVELET TRANSFORM

Wavelet transforms (WT) are used to decompose the original signal into a set of coefficients that describe the signal's frequency content at given times. The wavelet transform is designed to give good time resolution and poor frequency resolution at high frequencies and good frequency resolution and poor time resolution at low frequencies. This approach makes sense especially when the signal at hand has high frequency components for short durations and low frequency components for long durations, which is the case in most biological signals, mainly the Electroencephalogram (EEG), Electromyogram (EMG), and ECG signals [2]. Wavelets are functions defined over a finite interval and having an average value of zero. The basic idea of the wavelet transform is to represent any arbitrary function of time as a superposition of a set of such wavelets or basis functions. These basis functions or baby wavelets are obtained from a single prototype wavelet called the mother wavelet, by dilations or contractions (scaling) and translations (shifts) [3].

The Continuous Wavelet Transform

Wavelet functions generated from one single function ψ , which is called mother wavelet, by the scaling factor a and the translation factor b is given by:

$$\psi_{a,b}(t) = |a|^{-1/2} \psi\left(\frac{t-b}{a}\right) \quad (1)$$

Where a : is the scaling factor, and b : is the translation factor

Where ψ must satisfy:

$$\int_{-\infty}^{\infty} \psi(t) dt = 0 \quad (2)$$

The basic idea of wavelet transform is to represent any arbitrary function f as a decomposition of the wavelet basis or write f as an integral over a and b of $\psi_{a,b}$.

The continuous wavelet transform of a signal $f(t)$ is defined by [4]:

$$C(a,b) = \int_{-\infty}^{+\infty} f(t) \psi_{a,b}(t) dt \quad (3)$$

The Discrete Wavelet Transform

The DWT of a signal x is calculated by passing it through a series of filters. First the samples are passed through a low pass filter with impulse response g resulting in a convolution of the two, as shown in equation below [5]:

$$y[n] = (x * g) = \sum_{k=-\infty}^{+\infty} x[k]g[n-k] \quad (4)$$

The signal is also decomposed simultaneously using a high-pass filter h .

The outputs give the detail coefficients (from the high-pass filter) and approximation coefficients (from the low-pass). It is important that the two filters are related to each other and they are known as a

quadrature mirror filter. However, since half the frequencies of the signal have now been removed, half the samples can be discarded according to Nyquist's rule.

For many signals, the low-frequency content is the most important part, which gives the signal identity. The high-frequency content, on the other hand, imparts details or noise. In wavelet analysis, all the speaking is about the approximations and details. The approximations are the high-scale, low-frequency components of the signal. The details are the low-scale, high-frequency components. The filter outputs are then down-sampled by 2, as shown in the following equations:

$$y_{low}[n] = \sum_{k=-\infty}^{+\infty} x[k].g[2.n - k] \quad (5)$$

$$y_{high}[n] = \sum_{k=-\infty}^{+\infty} x[k].h[2.n - k] \quad (6)$$

This decomposition has halved the time resolution since only half of each filter output characterizes the signal. However, each output has half the frequency band of the input so the frequency resolution has been doubled.

Discrete Wavelet Transform Using Filter Bank Structure

The DWT is calculated as described above, the structure uses the high pass filter, low pass filter and subsampling is called Filter Bank. This decomposition is repeated to further increase the frequency resolution and the approximation coefficients decomposed with high and low pass filters and then down-sampled. This is represented as a binary tree with nodes representing a sub-space with different time-frequency localization, the tree is known as a bank and is shown in **Fig. 3**.

At each level in **Fig. 3** the signal is decomposed into low and high frequencies. Due to the decomposition process the input signal must be a multiple of (2^n) where n is the number of levels [5].

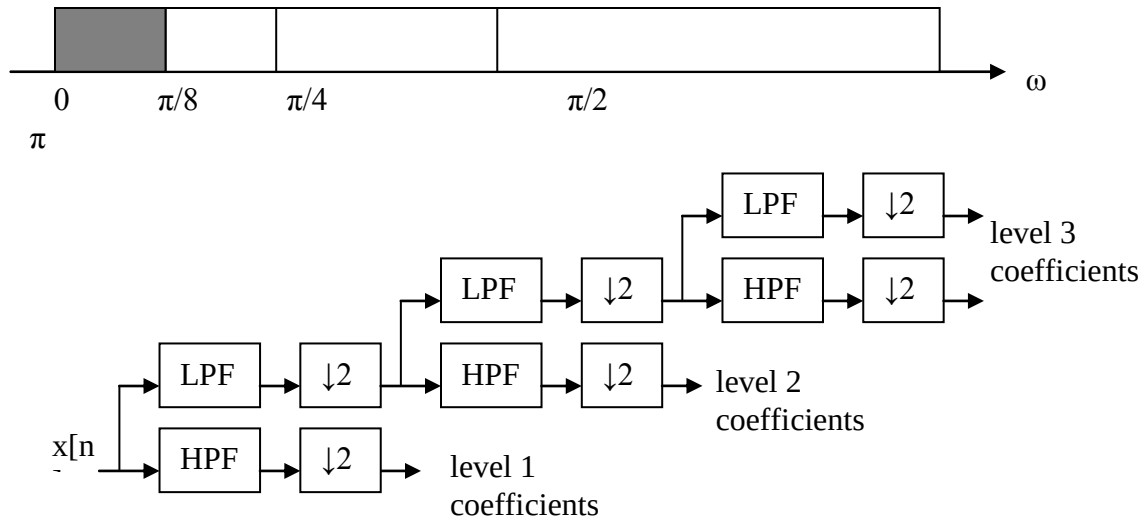


Fig. 3: A 3-level filter bank (A 3-level DWT)

For most physical signals the signal energy is concentrated in the lower frequency bands, thus this representation gives the energy compaction. Many of the resulting wavelet coefficients, especially in the higher frequency bands, are either zero or close to zero. By taking only the larger coefficients, many bits are already discarded without losing significant information [6].

- SLANTLET TRANSFORM

The slantlet transform is an orthogonal discrete wavelet transform with two zero moments and with improved time localization, the construction of the slantlet is based on a filter bank structure where different filters are used for each scale. Let us consider a usual two-scale iterated DWT filter bank shown in **Fig. 4 (a)** and its equivalent form **Fig. 4 (b)**. The slantlet filter bank employs the structure of the equivalent form shown in **Fig. 4 (b)** but it is occupied by different filters that are not products. With this extra degree of freedom obtained by giving up the product form, filters of shorter length are designed satisfying orthogonality and zero moment conditions [7].

For two-channel case the Daubechies filter is the shortest filter which makes the filter bank orthogonal and has K zero moments. For $K=2$ zero moments the iterated filters of **Fig. 4 (b)** are of lengths 10 and 4 but the Slantlet filter bank with $K=2$ zero moments shown in **Fig. 4 (c)** has filter lengths 8 and 4. Thus the two-scale Slantlet filter bank has a filter length which is two samples less than that of a two-scale iterated Daubechies-2 filter bank. This difference grows with the increased number of stages. Some characteristic features of the Slantlet filter bank are orthogonal, having two zero moments and has octave-band characteristic. Each filter bank has a scale dilation factor of two and provides a multiresolution decomposition. The slantlet filters are piecewise linear. Even though there is no tree structure for Slantlet it can be efficiently implemented like an iterated DWT filter bank. Therefore, computational complexities of the Slantlet are of the same order as that of the DWT, but slantlet Transform gives better performance in denoising and compression of the signals [8].

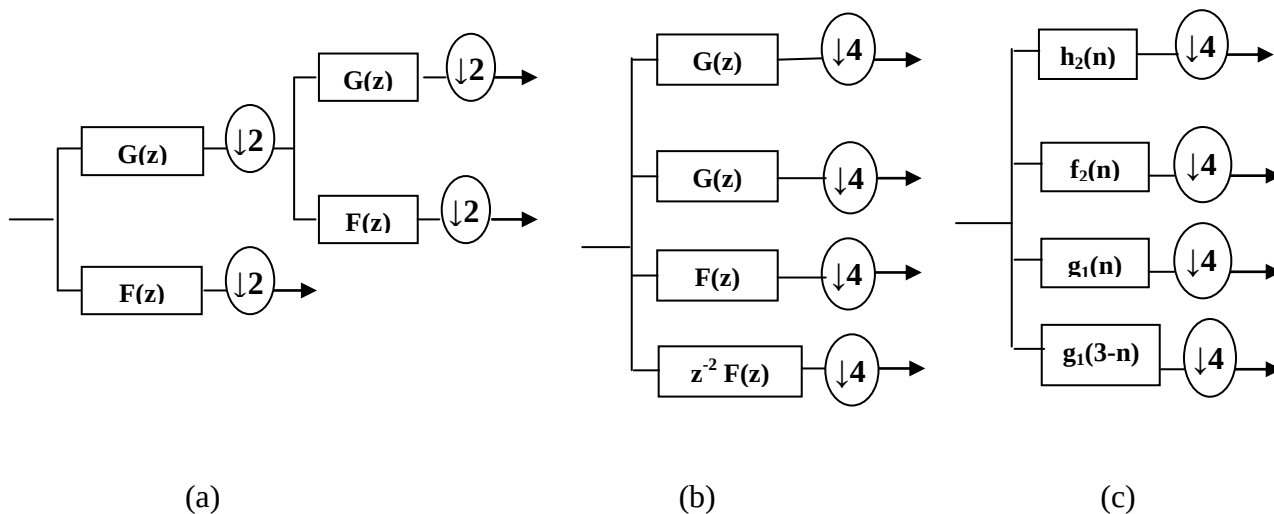


Fig. 4

- (a) Two-scale iterated filter bank DWT
- (b) Equivalent form using the DWT
- (c) Two-scale filter bank using SLT

Derivations of The Slantlet Filters Coefficients [8]

The filters that construct the slantlet filter bank are $g_i(n)$, $f_i(n)$, and $h_i(n)$. The L-scale filter bank has $2L$ channels. The low-pass filter is to be called $h_L(n)$. The filter adjacent to the low-pass channel is to be called $f_L(n)$. Both $h_L(n)$ and $f_L(n)$ are to be followed by downsampling by 2^L . The remaining $2L-2$ channels are filtered by $g_i(n)$ and its shifted time-reverse for $i=1, \dots, L-1$. Each is to be followed by downsampling by 2^{i+1} .

The sought filter $g_i(n)$ is described by four parameters and can be written as:

$$g_i(n) = \begin{cases} a_0 + a_1 n & \text{for } n = 0, \dots, 2^i - 1 \\ b_0 + b_1(n - 2^i) & \text{for } n = 2^i, \dots, 2^{i+1} - 1 \end{cases} \quad (7)$$

To obtain $g_i(n)$ such that the sought L-scale filter bank is orthogonal with 2 zero moments, requires obtaining parameters a_0, a_1, b_0, b_1 such that

$$\begin{aligned} m &= 2^i \\ s_1 &= 6\sqrt{m/((m^2 - 1)(4m^2 - 1))} \\ t_1 &= 2\sqrt{3/(m(m^2 - 1))} \\ s_0 &= -s_1 \cdot (m - 1) / 2 \\ t_0 &= ((m + 1) \cdot s_1 / 3 - m t_1)(m - 1) / (2m) \\ a_0 &= (s_0 + t_0) / 2 \\ b_0 &= (s_0 - t_0) / 2 \\ a_1 &= (s_1 + t_1) / 2 \\ b_1 &= (s_1 - t_1) / 2 \end{aligned}$$

The same approach work for $f_i(n)$ and $h_i(n)$.

$$h_i(n) = \begin{cases} a_0 + a_1 n & \text{for } n = 0, \dots, 2^i - 1 \\ b_0 + b_1(n - 2^i) & \text{for } n = 2^i, \dots, 2^{i+1} - 1 \end{cases} \quad (8)$$

$$f_i(n) = \begin{cases} c_0 + c_1 n & \text{for } n = 0, \dots, 2^i - 1 \\ d_0 + d_1(n - 2^i) & \text{for } n = 2^i, \dots, 2^{i+1} - 1 \end{cases} \quad (9)$$

Where

$$\begin{aligned} m &= 2^i \\ u &= 1 / \sqrt{m} \\ v &= \sqrt{(2m^2 + 1) / 3} \\ a_0 &= u \cdot (v + 1) / (2m) \\ b_0 &= u \cdot (2m - v - 1) / (2m) \\ a_1 &= u / m \\ b_1 &= -a_1 \end{aligned}$$

$$q = \sqrt{3/(m.(m^2 - 1))} / m$$

$$c_1 = -q.(v - m)$$

$$d_1 = -q.(v + m)$$

$$d_0 = d_1.(v + 1 - 2m) / 2$$

$$c_0 = c_1.(v + 1) / 2$$

- NEURAL NETWORK

A generic artificial neural network can be defined as a computational system consisting of a set of highly interconnected processing elements, called neurons, which process information as a response to external stimuli. The inputs received by a single processing element, see **Fig. 5**, can be represented as an input vector $X = (x_1, x_2, \dots, x_m)$, where $i=1, \dots, m$ and x_i is the signal from the i th input. The weights connected to the neuron can be represented as a weight vector of the form $W = (w_1, w_2, \dots, w_m)$, which represents the weight associated to the connection between the input vector X , and the processing element. A neuron contains a threshold value that regulates its action potential which is called the bias (x_0) and the weight of the connection is w_0 . While action potential of a neuron is determined by the weights associated with the neuron's inputs, a threshold modulates the response of a neuron to a particular stimulus confining such response to a pre-defined range of values [9].

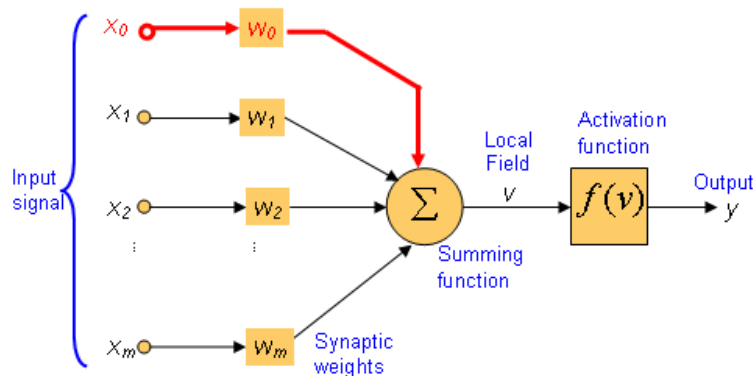


Fig. 5: Basic Model of a Single Neuron

The equation below describes the summation of weighted input process of the active neuron as shown in **Fig. 5**.

$$v = \sum_{i=1}^m x_i w_i \quad (10)$$

The equation below shows the y output of a neuron as an activation function f of the weighted sum of m inputs.

$$y_k = f\left(\sum_{i=1}^m x_i w_i\right) \quad (11)$$

The activation function, denoted by $f(v)$, defines the output of a neuron in terms of the induced local field v .

Structure of ANN [9]

Neural networks are typically arranged in layers. Each layer in a layered network is an array of processing elements or neurons. Information flows through each element in an input-output manner. In other words, each element receives an input signal, manipulates it and forwards an output signal to the other connected elements in the adjacent layer.

Back Propagation Algorithm [10]

Different network topologies with powerful learning strategies to solve nonlinear problems have been reported. For the present application, back propagation with momentum is used to train the feed forward neural network. The output units (y_k units) have weights w_{jk} and the hidden units have weights w_{ij} . During the training phase, each output neuron compares its computed activation y_k with its target value d_k to determine the associated error E for the pattern with that neuron, i.e.,

$$E = \sum_{k=1}^m (d_k - y_k)^2$$

(12)

Where m is the number of the output neurons

The ANN weights and biases are adjusted to minimize the least-square error. The minimization problem is solved by the gradient technique. This is achieved by back propagation of the error. When using momentum, the net is proceeding not in the direction of the gradient, but in the direction of a combination of the current gradient and the previous direction of weight correction. Convergence is sometimes faster if a momentum term is added to the weight update formula.

The BPA is a supervised learning algorithm, in which a mean square error function is defined, and the learning process aims to reduce the overall system error to a minimum. The connection weights are randomly assigned at the beginning and progressively modified to reduce the overall system error. The weight updating starts with the output layer and progresses backward. The weight update is in the direction of 'negative descent', to maximize the speed of error reduction.

For effective training, it is desirable that the training data set be uniformly spread throughout the class domains. The available data can be used iteratively, until the error function is reduced to a minimum.

The accuracy of the neural network classifier depends on several factors, such as the size and quality of the training set, the method of the training imparted and also the parameters chosen to represent the input.

- SYSTEM DESIGN STAGE

The problem under study is to classify the ECG signals into normal cases and nine abnormal cases depending on the features of the ECG signals. In this work the physionet database of biological signals is used as the source of ECG records, namely the MIT-BIH ECG Database. This database is accessible on the internet and is widely used in experimental works on classification of ECG signals and biological signals in general [11].

The data files were recorded with different sampling frequencies, so it is needed to resample the records to a unified frequency. The unified frequency used in the proposed work is 360 Hz.



The proposed work is done on ten classes where the data used are collected from the following databases in the MIT-BIH ECG database: Arrhythmia, Atrial fibrillation, Malignant Ventricular Ectopy, Supraventricular Arrhythmia, Normal Sinus rhythm, and the PTB (Physikalisch-Technische Bundesanstalt, i.e. The National Metrology Institute of Germany) Diagnostic ECG Database.

- PROPOSED FLOW DIAGRAM

The general block diagram for the proposed system of the classification is shown in **Fig. 6**. In the present work, MATLAB software package version 7.4.0.287 (R2007a) is used to implement the software design and algorithms. The main components of the system are the sampling block in which the sampling rate of the signal is made 360 Hz so if the sampling rate of input signal is not equal to 360 Hz then re-sampling is done. The data files used consists of time stamps and values recorded from two electrodes, some of these files contain more than two electrodes records. The PTB Diagnostic ECG Database consists of time stamps and values recorded from 15 leads, each record includes 15 simultaneously measured signals: the conventional 12 leads (I, II, III, aVR, aVL, aVF, V1, V2, V3, V4, V5, V6) together with the 3 Frank lead ECGs (VX, VY, VZ). Each signal is digitized at 1000 samples per second. For each record the sampling rate is mentioned in its associated header file. The records used are taken from lead II to find the ECG beats that are used in the pattern recognition system. After the sampling block, the beat detection block is introduced in which one beat of the signal is extracted. The extracted beat is introduced to the feature extraction block for dimensionality reduction and for the creation of the feature vector. The feature vector creation process is done by using SLT, DWT, DCT and FFT. The new feature vector is used as an input to the BP-NN to classify them into normal and abnormal ECG beats. Some of the extracted beats are used for the training of the neural network and others are used for the testing. The classifier performance was evaluated by calculating accuracy of the network in classification process.

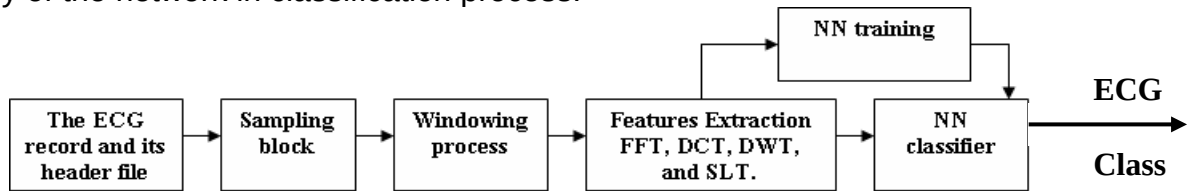


Fig. 6: Flow Diagram for classification and analysis of ECG signals

The Input ECG Signal

The ECG record that needs to be classified must be taken with its header, where the ECG record contains the ECG signals from a number of leads and the header file contains the sampling rate used to sample that signal. For the used records in this work the sampling rate for the Arrhythmia data base is 360 Hz, for the Atrial fibrillation recodes, Malignant Ventricular Ectopy, Supraventricular Arrhythmia, and Normal Sinus rhythm, is 250 Hz and for the PTB Diagnostic ECG Database the sampling rate is 1000 Hz [11].

Sampling Block

The sampling rate must be 360 Hz for whole records in order to make the ECG record suitable for the processing stages following this stage. The sampling rate change depends on the information contained in the header file of the record.

Windowing Process

First of all, one lead must be chosen to extract the ECG beat, the lead chosen in the proposed work is lead II since most of the rhythms are seen in this lead record. As the shape of each beat in ECG waves is asymmetric, P-QRS-T complexes are selected by using windows with a range of 100 samples before the R-wave maximum point and 155 samples after the R-wave

maximum thus the number of samples in each extracted beat is 256 samples. This is to extract a single beat ECG signal from the multi-beat data. The flow chart for the windowing process is shown in **Fig. 7**. The extracted beat is now ready for the feature extraction step. **Fig. 8 (a)** shows the record (103) from the MIT-BIH arrhythmia database which contains the normal beats this record is from the modified lead II (MLII) and lead V2. The record from lead II is used to extract only one beat from it. **Fig. 8 (b)** shows the extracted beat (normal beat).

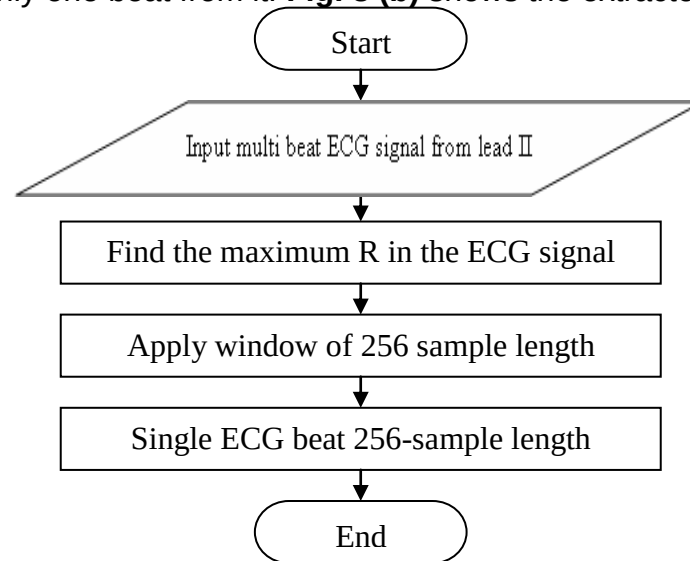


Fig. 7 : Flow chart describing windowing process

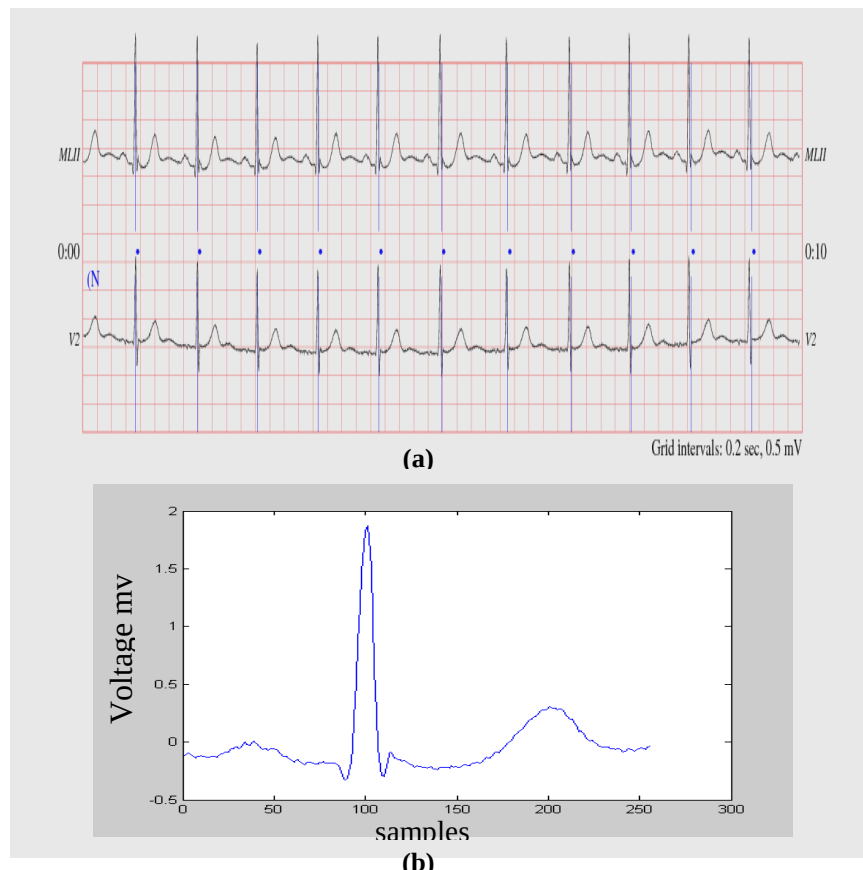


Fig. 8 (a) The ECG record (Normal Sinus Rhythm)(b) The Extracted single beat
Features Extraction

A- Feature Selection

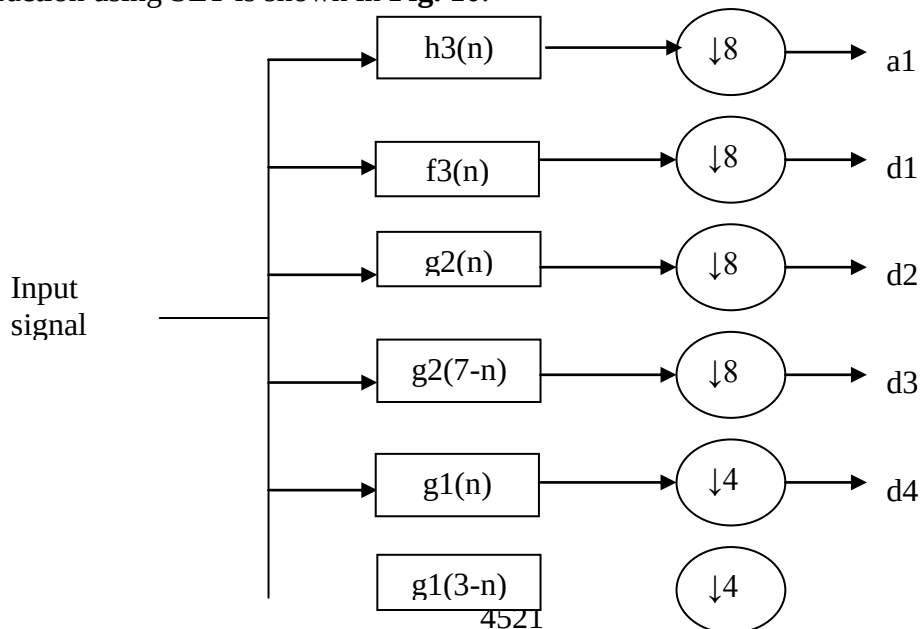
It is basically impossible to apply any classification method directly to the ECG samples, because of the large amount and the high dimension of the samples necessary to describe such a big variety of clinical situations. A set of algorithms from signal conditioning to measurements of average wave amplitudes, durations, and areas, is usually adopted to perform a quantitative description of the signal and a parameter extraction. On this set of extracted ECG parameters, several techniques for medical diagnostic classification are then applied, such as probabilistic approaches, heuristic models, and knowledge-based systems. The aim of this work was to determine suitable input feature vectors which would discriminate between normal and different types of heart diseases.

B. DWT Coefficients Extraction

In the present work Db4 and Haar wavelets have been used as the mother wavelets. For achieving good time-frequency localization, the preprocessed ECG signal is decomposed by using the DWT up to the third level. The 3-level wavelet decomposition structure is shown in **Fig. 3**, where the result is 4 different subsets, three subsets for the details (the wavelet function coefficients) and the forth is the approximation subset (the scaling function coefficients). Since most of the information is concentrated in the low frequency components only the 32 samples result from the level-3 low pass filter will be considered as the features of the input signal.

C. SLT Coefficients Extraction

The slantlet filter bank used to extract the features of the ECG signal is 3-scale ($L=3$) filter bank. The structure of this filter bank is shown in **Fig. 9**, where 6 different filters are used. These filters are constructed using the derivations explained previously. The low pass filter $h_3(n)$ output is the approximation of the signal and the other outputs are the details so it can be efficient to take only the coefficients of the low pass filter as features of the signal and discard the remaining coefficients without losing many information about the signal. Since the slantlet transform gives better time localization the results of the classification will be better using this transformation method. The features extraction using SLT is shown in **Fig. 10**.



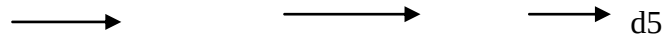


Fig. 9 : 3-scale slantlet filter bank

Where:

- a1: is 32 samples which are the outputs of the low pass filter h3 after down sampling by 8. Only this vector will be used as the features of the ECG beat.
- d1: is 32 samples which are the outputs of the band pass filter f3 after down sampling by 8.
- d2: is 32 samples which are the outputs of the band pass filter g2 after down sampling by 8.
- d3: is 32 samples which are the outputs of the band pass filter (shifted time reverse of g2) after down sampling by 8.
- d4: is 64 samples which are the outputs of the band pass filter g1 after down sampling by 4.
- d5: is 64 samples which are the outputs of the band pass filter (shifted time reverse of g1) after down sampling by 4.

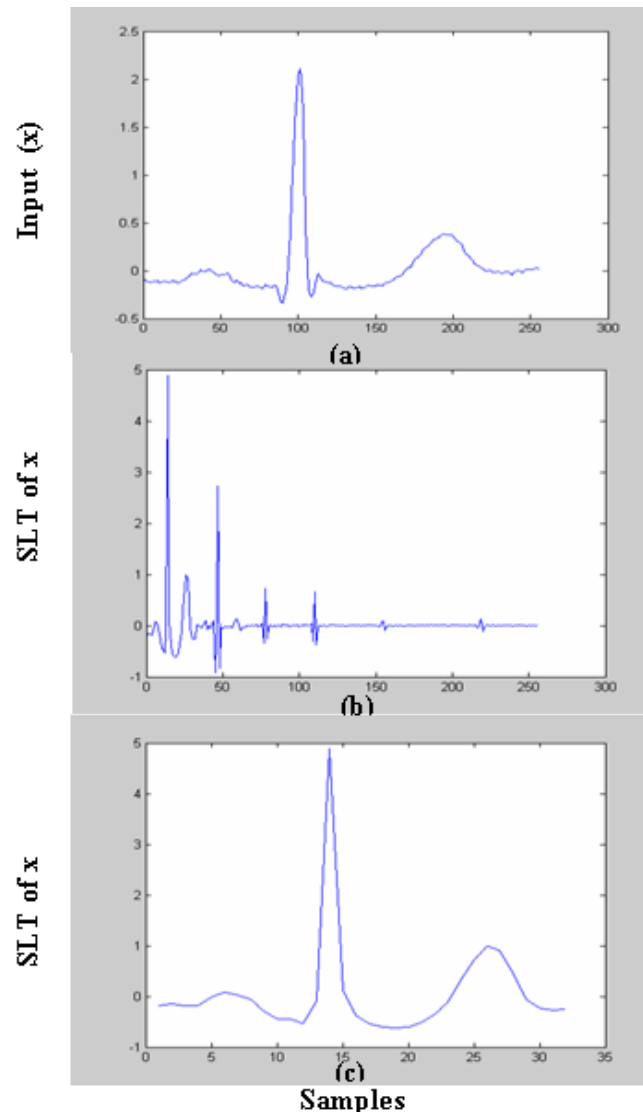


Fig. 10 (a) ECG beat (Normal) (b) SLT of the ECG beat (c) 32 samples of the SLT

D. DCT Coefficients Extraction

The discrete cosine transform has an important property that its basis vectors closely approximate the original signal with a little number of coefficients. The DCT is an orthogonal transform and most of the energy of the signal transformed is concentrated in the low frequency components. To extract the features of the ECG signal only the 32 samples in the lower part of the coefficients will be used.

E. FFT Coefficients Extraction

The amplitude of the signal using FFT is symmetrical so it is enough to consider only one side of the coefficients resulted to extract the features of the signal. The phase coefficient with dimensionality reduction will not give efficient result when the number of classes is large, so that the phase will not be used. It is important to notice that the features extracted using the FFT contains only the amplitude information. For dimensionality reduction first 32 samples are used as the features of the input signal.

Neural Network Classifier

The ECG record contains number of beats, this number of beats in each record is different according to the recording time, also the sampling rate in some records different from that of the other record. To extract one beat from the multi beat record the re-sampling is done if the sampling rate is not 360 Hz, then the windowing process is done. After the extraction of one beat, the features of each beat are found using transformation methods and dimensionality reduction to obtain an acceptable number of features that can be used in the neural network.

The neural network used as the classifier uses the features obtained from the feature extraction process for training and testing. The neural network structure used in the proposed work consists of 32 neuron input layer, 20 neuron hidden layer and 1 neuron output layer is shown in **Fig. 11**, and its specifications are illustrated in **Table 1**.

The activation function for the input layer and the hidden layer neurons is the Tan-sigmoid function, the activation function for the output layer neuron is the Linear function.

The neural network after identifying its parameters [identifying the number of layers and the activation functions] was trained using the BPA. After the training process of the neural network, the testing process was done to test the performance of the neural network in classifying the input patterns. The maximum number of iterations for the neural network used in this work is 1000.

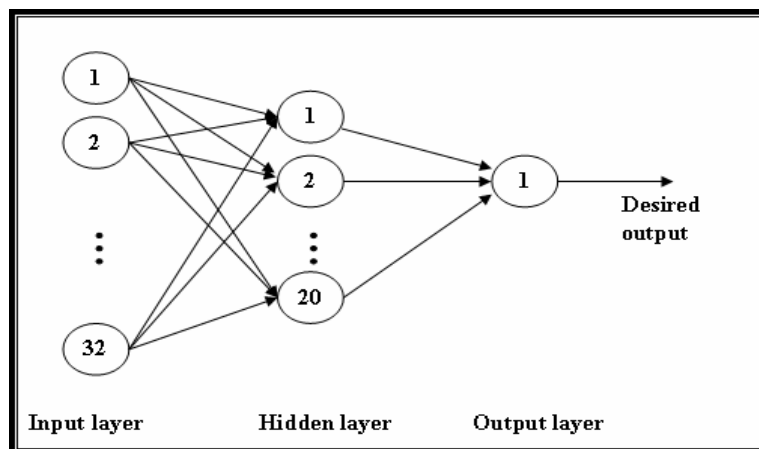


**Fig. 11** : Structure of ANN**Table 1** : Neural Network specifications

No.	Item	Value
1	Training pattern vectors number	670
2	Layers number	3
3	No. of neurons in the input layer	32
4	No. of neurons in the hidden layer	20
5	No. of neurons in the output layer	1
6	Goal MSE	0
7	Maximum no. of iterations	1000

- RESULTS AND DISCUSSION

Data Manipulation

The system has been applied on ten classes of ECG beats, one of them is the normal beats class and the others were some of the heart arrhythmias. These ten classes and their corresponding number of beats are shown in **Table 2**.

Table 2: The ECG classes and their corresponding number of beats

Class number	Class name	Symbol of the class	The total number of beats used
1	Normal	N	708
2	Paced beat	P	247
3	Right Bundle Branch Block	R	128
4	Left Bundle Branch Block	L	103
5	junctional escape beat	j	19
6	Premature Ventricular contraction	V	28
7	Ventricular tachycardia	VT	50
8	Supraventricular	S	40
9	Atrial Fibrillation	A	92
10	Inferior Myocardial	IMI	134

	Infarction		



The number of beats of each class has been divided into two parts:

- a- One part of these beats is used for the training of the neural network called (training beats), the training of ANN starts by computing the local errors from the output of the network towards the input. At first, the data sample is sent through the network to find an output and then calculate the error introduced at the output layer and reflect it to find the overall error, all weights are updated until the required performance is obtained.
- b- The other part is used for the testing of the network called (testing beats), at the completion of training, the testing beats are tested on the feed forward network and their resultant error is used to give the measure of the generalization ability of the network.

Whole results obtained after classification are shown in **Table 3**, where the number of errors result from the classification process is different according to the type of the transformation method used to extract the features of the signal.

Table 3 : Results of classification for all systems

No	Beat type	training beats	testing beats	FFT errors	DCT errors	DWT(H) errors	DWT(db4) errors	SLT errors
1	N	300	408	100	2	0	1	6
2	P	100	147	106	47	0	0	0
3	R	50	78	26	0	2	6	1
4	L	50	53	15	6	5	4	0
5	j	9	10	0	0	0	0	0
6	V	10	18	8	5	1	3	1
7	VT	25	25	0	3	11	5	1
8	S	20	20	12	0	0	14	0
9	A	40	52	15	1	16	0	5
10	IMI	66	68	1	0	0	0	0
	Tot.	670	879	283	64	35	33	14

Performance Evaluation of Neural Network

The Neural Network used for the classification purpose in this work has the same structure overall the types of transformation methods applied to find the features of the signal, so that the complexity in all types is the same. When the comparison is done between the results obtained after testing each network the differences are affected by the transform used to find the features.

To compare the performance of the network combined with each type of transformation methods the accuracy of each one has been computed.

$$\text{Accuracy} = \frac{\text{Total number of correct classifications}}{\text{Total number of testing beats}} * 100\% \quad (13)$$

Therefore, **Table 4** is constructed to compare between the accuracy of different classification systems used in this work.

Table 4 : Accuracy of each classification system

Classification system	Total number of testing beats	Total number of correct classifications	Accuracy
FT-NN	879	596	67.80 %
DCT-NN	879	815	92.72 %
DWT-NN (Haar)	879	844	96.02 %
DWT-NN (db4)	879	846	96.25 %
SLT-NN	879	865	98.40 %

CONCLUSIONS

In this work different transformation methods are used to extract the features of the ECG beat. The pattern recognition system used to classify the ECG signals used these features as the input to the neural network classifier. The slantlet transform is one of the transformation methods used to extract the features of the ECG beat which make the recognition of the ECG beats more accurate.

It can be concluded from this work, the transformation of the ECG signal from time domain to time-frequency domain gives better results than the transformation to frequency domain. This was clear in the results of the WT and SLT. The SLT is an orthogonal transform and provides improved time localization than WT, therefore it will improve the classification results. To improve the accuracy for the heart beat recognition system, five different transformation methods are applied to find the features of the signal and a suitable neural network used for the classification. The comparison of the accuracy of the SLT system with the four other systems used in this work gives a conclusion that the SLT system gives improved accuracy for the heart beat recognition.

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MEASUREMENT THE FLUORESCENCE PARAMETERS OF THE OLIVE OIL AND COMPARING IT WITH SOME LASER DYE MATERIALS

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ABSTRACT

The verse (35) in SURA (AL- Nur) in the HOLY QURAN has inspired the author to look into the possibility of using Olive Oil as active dye laser material. Olive Oil which is classified as organic compound, having a good properties candidate it to be used as active dye laser material. The emission spectrum diagrams at some of absorption peaks (414, 536, 632 and 670) nm will be measured. These diagrams have been used to determine the Fluorescence quantum yield, Oscillator strength, Einstein coefficients for the spontaneous emission, Radiative and Fluorescence lifetime and absorption and cross sections. It has been found that fluorescence occurs at 669 nm for the entire absorption spectrum. Fluorescence of Olive Oil has been experimented using 30mW, 532nm semiconductor laser, with a beam diameter of 1.3mm. Red fluorescence has been noticed over a distance of 7cm in a glass container.

KEYWORDS: olive oil, Fluorescence, dye laser.

OLIVE OIL

Olive Oil is an organic complex compound made of (Fatty acids, Glycerides, Sterols, Erythrodol, Uvaol, Wax esters, Phenolic compounds, Aroma components, Tocopherols, Hydrocarbons, Aromatic Hydrocarbons, Xenobiotics, Unsaponifiable matter, water soluble components and microscopic bits of olive) [1]. In this research when talking on using Olive Oil as a dye laser material meaning Olive Oil as a complex compound made of all the previous component not meaning one of the compounds that soluble in Olive Oil. A pure simple of Olive Oil with concentration 1 used in this research.

OLIVE OIL SPECTRUM

The calculation of dye laser beginning by the absorption and emission diagram of the material. The absorption diagram of olive oil obtained by (shimadzu UV-1601PC spectrophotometer). From absorption diagram figure 1 some absorption peaks chosen to taste the emission when excited at that peaks wavelength by (ELICO SL174 spectrofluorometer). The absorbance peak appear at selected wavelengths 414nm, 536nm, 632nm, 670nm and there emission peak when the material excited at that wavelengths shown in figures 2,3,4,5. From the emission peaks it could be seen that the maximum emission value appears when material excited at 670nm as shown in figure 5. Peak of emission to all selected absorbance wavelength being at 669nm.

CALCULATION OF SOME BASIC DYE LASER PARAMETERS OF OLIVE OIL MATERIAL

From the previous absorption, emission diagrams value of Olive Oil laser parameters could be calculated

Assume that an incident beam of high energy photons of wavelength λ_a falls on a substance for a given time interval, and during that time, lower energy (fluorescence) photons are emitted by the substance. The quantum yield ϕ_f is then defined in [1].

The oscillator strength of the absorption bands can also be calculated easily by the free-electron model. Transition moments along and normal to the long molecular axis are connected with the oscillator strength f of the absorption band [1,2]

And can be calculated using the electron gas wave functions of the eigenstates between which the transition occurs. The relative strengths of the x and y component also yield the orientation of the transition moment in the molecule.

One finds good agreement on comparing the f values obtained from the absorption spectrum of the dye using the relation

$$f = 4.32 \times 10^{-9} \int \epsilon(\nu) d\nu \quad (1)$$

Where ϵ is the numerical value of the molar decadic extinction coefficient measured in liter/(cm • mole), and ν is the numerical value of the wave number measured in cm^{-1} [1,2].

The one process that is directly used in dye lasers is the radiative transition from the first excited singlet state S_1 to the ground state G if this emission termed fluorescence occur spontaneously its radiative lifetime t_{rf} is connected with the Einstein coefficient for spontaneous emission A and the oscillator strength f of the pertinent absorption band by eq.(2)

$$A \approx 1/t_{rf} = (8\pi\mu^2 e_o^2 / mc) \nu^2 f \quad (2)$$

Where μ is the refractive index of the solution, e_o is the charge and m is the mass of the electron, c is the velocity of light, and ν denotes the wave number of the centre of the absorption band. The radiative lifetime t_{rf} is typically of the order of a few nanoseconds. Generally, however, the

fluorescence spectrum is broad and shows considerable Stokes shift. In this case the radiative lifetime can be computed with the aid of eq.(3)

$$1/t_{rf} = 2.88 \times 10^{-9} \mu^2 \frac{\int F(\nu) d\nu}{\int \nu^{-3} F(\nu) d\nu} \int \frac{\epsilon(\nu) d\nu}{\nu} \quad (3)$$

Where $F(\nu) = dQ/d\nu$ is the fluorescence spectrum (in quanta Q per wave number) and $\epsilon(\nu)$ is the molar decadic extinction coefficient.

The fluorescence quantum yield ϕ_f is described by the ratio of the observed fluorescence lifetime t_f and the calculated natural radiative lifetime t_{rf} . In practice one usually knows and wants to gain knowledge about the actual fluorescence lifetime [3,4,5].

The absorption cross-section σ_a can be determined from the molar decadic extinction coefficient ϵ by eq.(4).

$$\sigma_{a} = 0.385 \times 10^{-20} \times \epsilon \quad (4)$$

Where σ_a is given in cm^2 , if ϵ is measured in $\text{liler}/(\text{mole} \cdot \text{cm})$ [1].

From the physical calculation used for liquid dye laser material, it could be found that these results give as a positive indication that Olive Oil could be used as a dye laser material where the fluorescence quantum yield for the tested wavelengths ranged between (0.0248 and 0.9681) and this is a good range compared to other types of dye material, the radiative life time and fluorescence life time laying in a good range from micro seconds to mille seconds, suitable threshold pumping power and energy threshold compared to other laser types (Table1). The range of radiative life time, fluorescence life time and the normal value of threshold pumping power and energy threshold give wide range of suitable pumping sources that could be used.

EMISSION EXPERIMENT

In this experiment has been found that when a green laser radiation at wave length 532nm and power 30mw and beam diameter 1.3mm incident onto a glass container that contained Olive Oil red fluorescence noticed inside the Olive Oil and these properties could be noticed:

- The red fluorescence did not appear instantaneously but there was a delay time which was less than one second.
- 2) The intensity of the red fluorescence varies directly with the intensity of the incident laser radiation.
- The red fluorescence disappears when the intensity of the green laser radiation reduced to a 17mw, which means that this value is the threshold which is needed to induce this fluorescence.
- The red fluorescence vanishes after a distance 7cm inside the Olive Oil.

CONCLUSIONS

- A new candidate laser material has been discovered this material is Olive Oil
- Tow of Olive Oil organic compound (Linoleic , Linolenic)lye under condition that material classified according to dye materials.
- When Olive oil tested in the spectrofluorometer according to the peaks of the absorption diagram it will be obtained fluorescence peaks for each excited wavelength tested, all excited wavelength give an emission peak at wavelength 699 nm in different values.
- From the Basic Dye Laser Parameters calculations used for liquid dye laser material, it could be found that these results give a positive indication that Olive Oil could be used as a laser material compared to other types of dye materials as shown in table 1
- A quenching material need to be add to the active medium in dye laser system but its not necessary to add a quenching material to Olive Oil because it have in nature dissolved oxygen in its organics compound which could be used as a quencher to reduce triplet state effect.

Table1. Typical values of photo-physical parameters for Olive Oil and some organic compounds

	Pumping wavelength	f	ϕ_f	t_{rf} ns	t_f ns	A s ⁻¹	σ_a cm ²
Olive Oil	414nm	1.1×10^{-5}	0.0345	36×10^4	1.264×10^4	2.72×10^3	5.594×10^{-21}
	536nm	1.65×10^{-7}	0.9681	2.58×10^7	2.5×10^7	38.680	2.429×10^{-22}
	632nm	1.06×10^{-8}	0.5689	3.03×10^8	1.85×10^8	3.06	1.885×10^{-23}
	670nm	7.11×10^{-7}	0.4563	3.963×10^6	1.808×10^6	252.36	1.472×10^{-21}
	Rhodamine 6G (in water)	0.55577	0.95	100	5.4	10^7	0.5×10^{-16}
	Rhodamine B (Methanol)	0.310	0.62	6.1	4.23	2.36×10^8	2.57×10^{-16}
	Eosine	0.493089	0.67	1.3	2.58	7.61×10^8	-
	Flourescein, ethanol	1.35124	0.79	4.184	3.036	2.39×10^8	-

Olive oil material can be used as a dye laser material because of :

*The condition for dye materials that its organic compound must have a two π electron bound, or two double bound called conjugated or higherso material in this condition called dye material. Olive oil contained many organic compounds. Tow of its lye under dye material condition

where these two compounds are:

a) Linoleic polyunsaturated (two double bound) (C₁₇H₂₉COOH) or CH₃-(CH₂)₄-CH=CH-CH₂-CH=CH-(CH₂)₇-COOH



b) Linolenic, which is polyunsaturated (three double bound)



So a condition to this olive oil could considered as a dye material compound.

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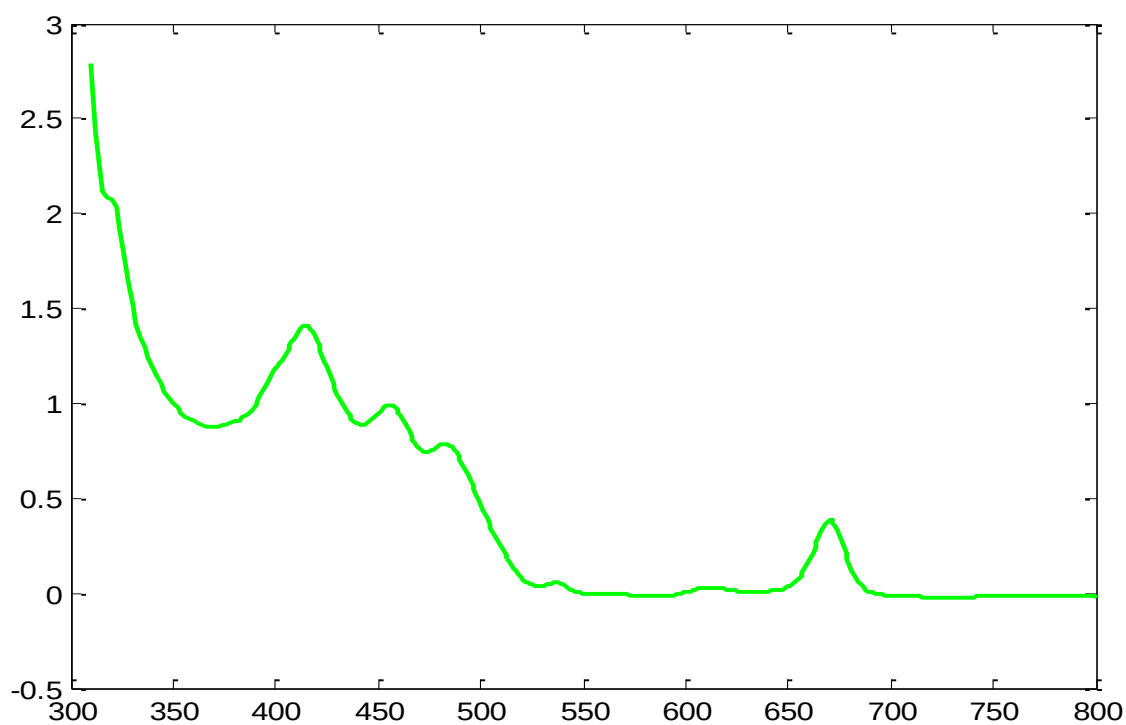


Figure (1) Absorption diagram of Olive Oil

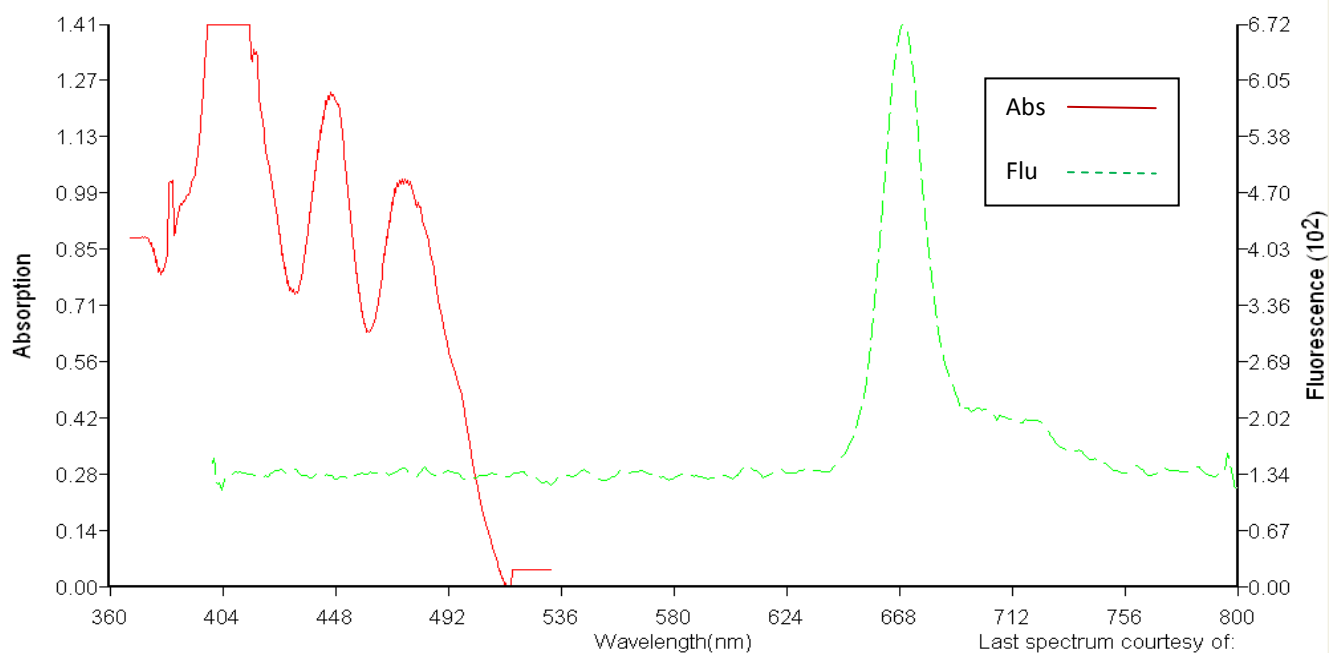


Figure (2) the absorbance peak appear at wavelength 414nm and its emission peak when the material excited at that wavelength

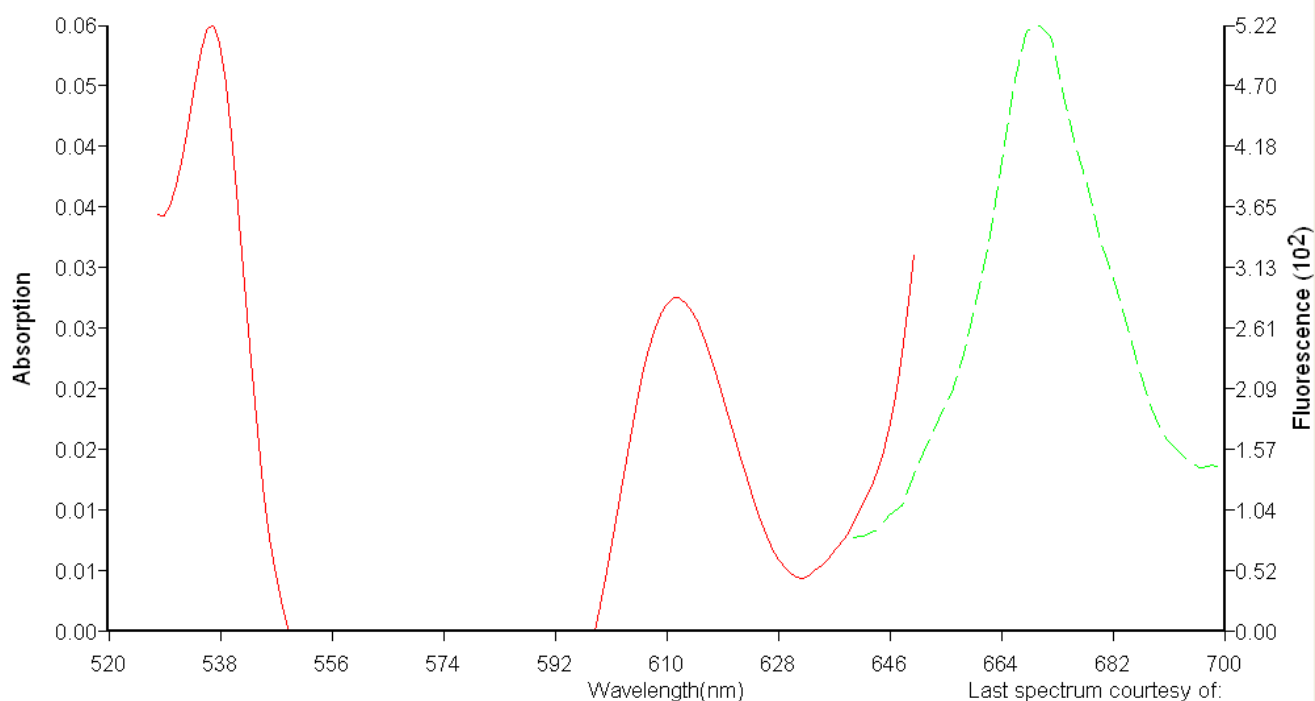


Figure (3) the absorbance peak appear at wavelength 536nm and its emission peak when the material excited at that wavelength

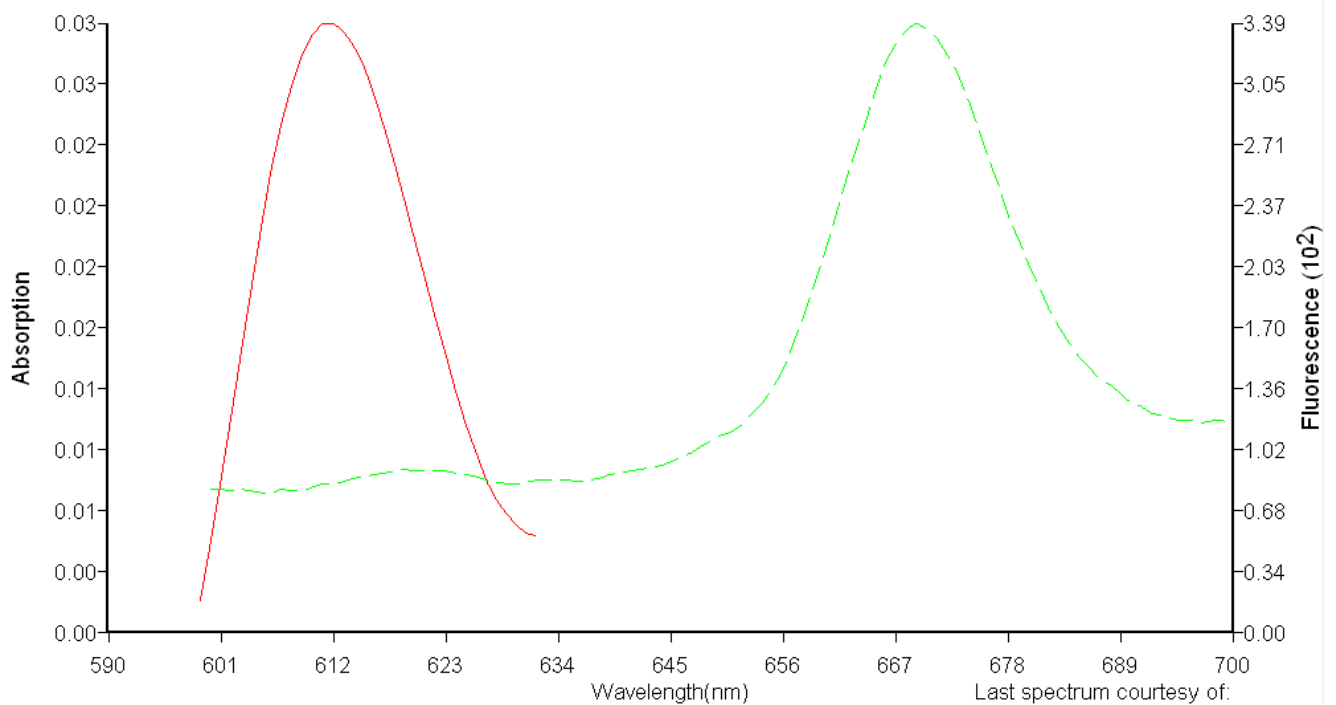


Figure (4) the absorbance peak appear at wavelength 632nm and its emission peak when the material excited at that wavelength

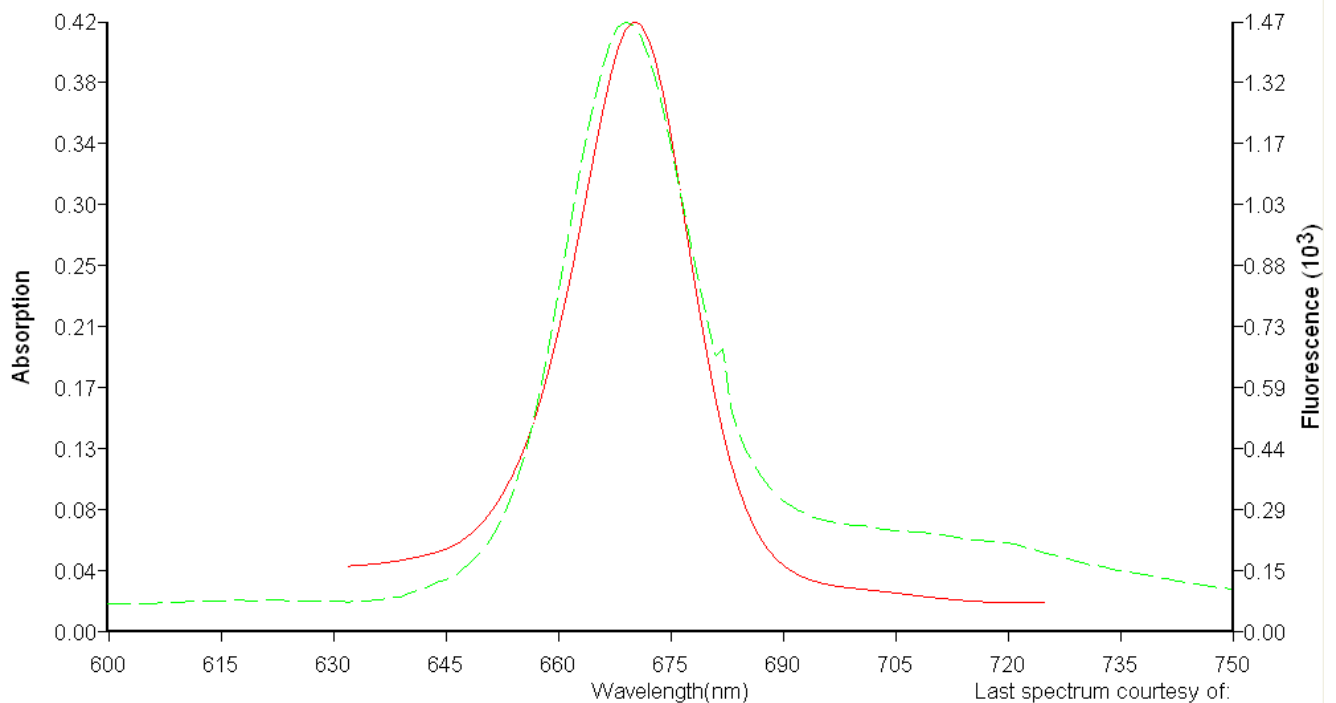


Figure (5) the absorbance peak appear at wavelength 669nm and its emission peak when the material excited at that wavelength

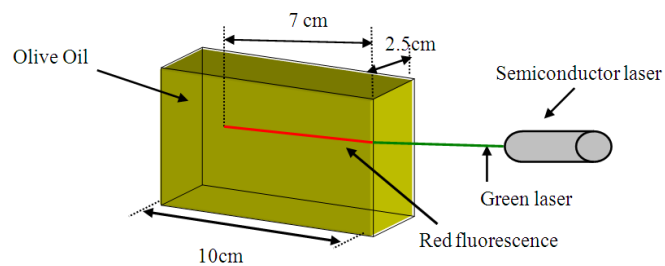


Figure (6) Olive Oil emission experiment



EFFECT OF EXISTING FLANGE OPENINGS AND COLD JOINTS ON STRENGTH OF RC T-BEAMS

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ABSTRACT

In the construction of modern buildings, a network of pipes and ducts is necessary to accommodate essential services like water supply, sewage, air-conditioning, electricity, telephone, and computer network. Passing these services vertically required creating openings in slab (Flanges of T-Beams) after or before construction.

New researches show that the concrete flanges provide a certain level of shear resistance above a certain width. Therefore, due to existing of these openings or cold joints in slab (Flange) and abrupt changes in the sectional configuration, opening corners are subject to high stress concentration that may lead to reduction in stiffness of the T-Beam and produced cracking and excessive deflection.

In the present research, shear behavior of reinforced concrete T-Beams which contains vertical opening (Flange openings) or cold joints at the flanges are studied as well as the effect of openings or cold joints locations. Eight beams were tested, one of which were constructed without any openings or cold joints (reference beam), while, the others were constructed with openings or cold joints in different locations.

Experimental results show that the presence of flange openings reduce the shear capacity about (22% to 32%) for beams containing one opening and about (17%-39%) for beams containing two openings. For beams containing cold joints, the shear capacity decreased about (27%) in comparison with reference beam.

الخلاصة

يعتبر نظام البلاطات و العتبات من اكثر النظم المستخدمة في انشاء الارضيات و السقوف الخرسانية، وفي معظم هذه المنشآت تكون بلاطة الارضيات و السقوف جزءا متكامل (Integral Part) من العتبة الحاملة وهكذا، يصبح مقطع العتبة على شكل حرف (T) هناك بعض المتطلبات الخدمية، مثل مد شبكة انابيب تجهيز الماء الصافي او التاسيسات الصحية او الكهربائية او منظومات التدفئة و التبريد تتطلب عمل فتحات بالاتجاه العمودي لسقف كل طابق. في معظم الحالات تخترق هذه الشبكات البلاطات الخرسانية عند الاطراف و التي تمثل الشفة (Flange) في العتبات الخرسانية المسلحة ذات المقطع (T) مما يجعل وجود هذه الفتحات اماكن ضعف تتركز فيها الاجهادات.

اثبتت الدراسات الحديثة ان وجود الشفة (Flanges) يساعد بدرجة معينة على زيادة مقاومة القص في العتبات الخرسانية المسلحة ذات المقطع (T) عند مقارنتها مع العتبات الخرسانية المسلحة المستطيلة.

اعدت هذه الدراسة لتتقيم تأثير وجود الفتحات او المفاصل (في منطقة الشفة) على سلوك القص في العتبات الخرسانية المسلحة ذات المقطع (T)، تم اجراء سلسلة من الفحوصات المختبرية على ثمانية عتبات خرسانية مسلحة ذات مقطع (T)، كانت العتبة الاولى بدون اية مفاصل او فتحات (العتبة المرجعية) اما البقية فكانت تحتوي على مفاصل انشائية او فتحات في مواقع مختلفة. اظهرت النتائج المختبرية نقصان في مقاومة القص بحدود (22%-32%) في العتبات التي تحتوي على فتحة واحدة في الشفة، ونقصان بحدود (17%-39%) في العتبات التي تحتوي على فتحتين في الشفة. بالنسبة للعتبات التي تحتوي على مفاصل انشائية، اظهرت النتائج المختبرية نقصان في مقاومة القص بحدود (23%) عند مقارنتها مع العتبة المرجعية.

KEY WORDS: T-Beam, Flange, Opening, Cold joints, Shear, Slab, Concrete

INTRODUCTION

Reinforced concrete system normally consists of slab and beams that is placed monolithically and as a result T-Beams (T-Shaped Beam) created and the two parts act together to resist the applied loads.

In the construction of modern buildings, a network of pipes and ducts is necessary to accommodate essential services like water supply, sewage, air-conditioning, electricity, telephone, and computer network. Usually, these pipes and ducts are placed underneath the beam soffit or penetrate vertically the slabs and, for aesthetic reasons, are covered by a suspended ceiling or by special decoration, Figure (1).

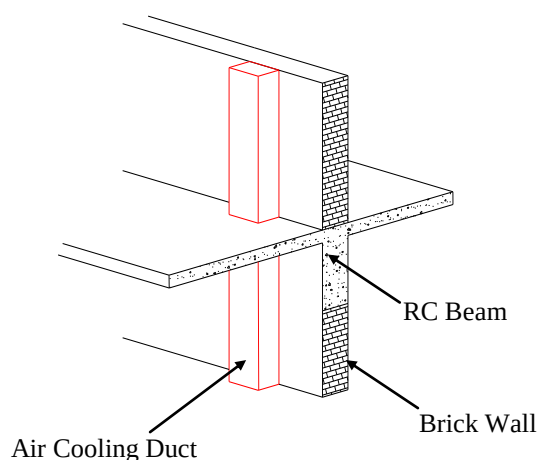


Fig. (1) Air Cooling Duct through the Slab (Flange)

Passing these ducts through vertical (or transverse) openings in the floor beams leads to a reduction in the dead space and results in a more compact design multiplied by the number of stories can represent a substantial saving in total height, length of air-conditioning and electrical ducts, plumbing risers, walls and partition surfaces, and overall load on the foundation.

It is obvious that inclusion of openings in T-beams alters the simple beam behavior to a more complex one. Due to abrupt changes in the sectional configuration, opening corners are subject to high stress concentration that may lead to cracking unacceptable from aesthetic and durability viewpoints.

Since the strength of concrete in tension is considerably lower than its strength in compression, design for shear becomes of major importance in all types of concrete structures.

The reduced stiffness of the beam may also give rise to excessive deflection under service load and result in a considerable redistribution of internal forces and moments in a continuous beam unless special reinforcement is provided in sufficient quantity with proper detailing, the strength and serviceability of such a beam may be seriously affected.



Several researches are interest in transverse openings (web openings) in the rectangular floor beams under the effect of flexural or torsion loads, (Mansure, M. A., 2006) and (Dainel H.R., and McMullen A.E, 1977).

New researches show that the concrete flanges provide a certain level of shear resistance above a certain width, (Giaccio et. al., 2003). Also, the current codes of practice such as(ACI 318-08), do not include an increase in shear strength resulting from the inclusion of a flange.

Generally, shear mode of failures are divided into four categories of failure and depends mainly on shear span to effective depth ratio, (Wang, C. K. and Salmon, C. G., 1994). The possible modes of failure are (1) Shear-tension failure; (2) Shear-compression failure; (3) Flexural failure; (4) Arch-rib failure.

In the present research, shear behavior of reinforced concrete T-Beams which contains vertical opening (Flange openings) or cold joints at the flanges will be studied as will as the effect of openings or cold joints locations.

EXPERIMENTAL STUDY

Experimental Program

Tests were carried out on eight T-Shaped beams, simply supported under the effect of single point loading. All beam specimens were reinforced with tension (flexural) bars at bottom. To eliminate the shear resisting contribution of stirrups and to ensure the specimens to fail in shear mode of failure, the tested beams were made without shear reinforcement (stirrups).

The variables were the number and location of slab (flange) openings and cold joints. The span, cross-section, concrete strength, and reinforcement were kept constant for all tested specimens.

Specimen Details

Each beam is designated in a way to indicate the T-Shaped beam, the dimensions and properties of tested specimens are shown in Table (1) and Figure (2), the locations of cold joints and openings are shown in Figure (3). Based on the classification presented by (Wang, C. K. and Salmon, C. G., 1994), all tested beams are classified as short beams ($1 < a/d < 2.5$).

Table (1) Properties of Test Beams

Beam Designation	Dimensions (mm)				a/d	Reinforcement	Number and Location of Openings or cold joints
	b_f	t_f	t_w	h			
TB-1*	220	50	60	250	2.17	$2 \phi 8$	None
TB-2							One opening at L/3 (350mm) from the beam edge
TB-3							Two adjacent openings at L/3 (350mm) from the beam edge
TB-4							Two opposite openings at L/3 (350mm) from the beam edge
TB-5							One opening at L/2 (500mm) from the beam edge

TB-6							Two adjacent openings at L/2 (500mm) from the beam edge
TB-7							One cold joint at L/3 (350mm) from the beam edge
TB-8							Two opposite cold joints at L/3 (350mm) from the beam edge

* Reference Beam (T-Beam without Openings or Cold joints)

** Diameter of Opening is (50mm)

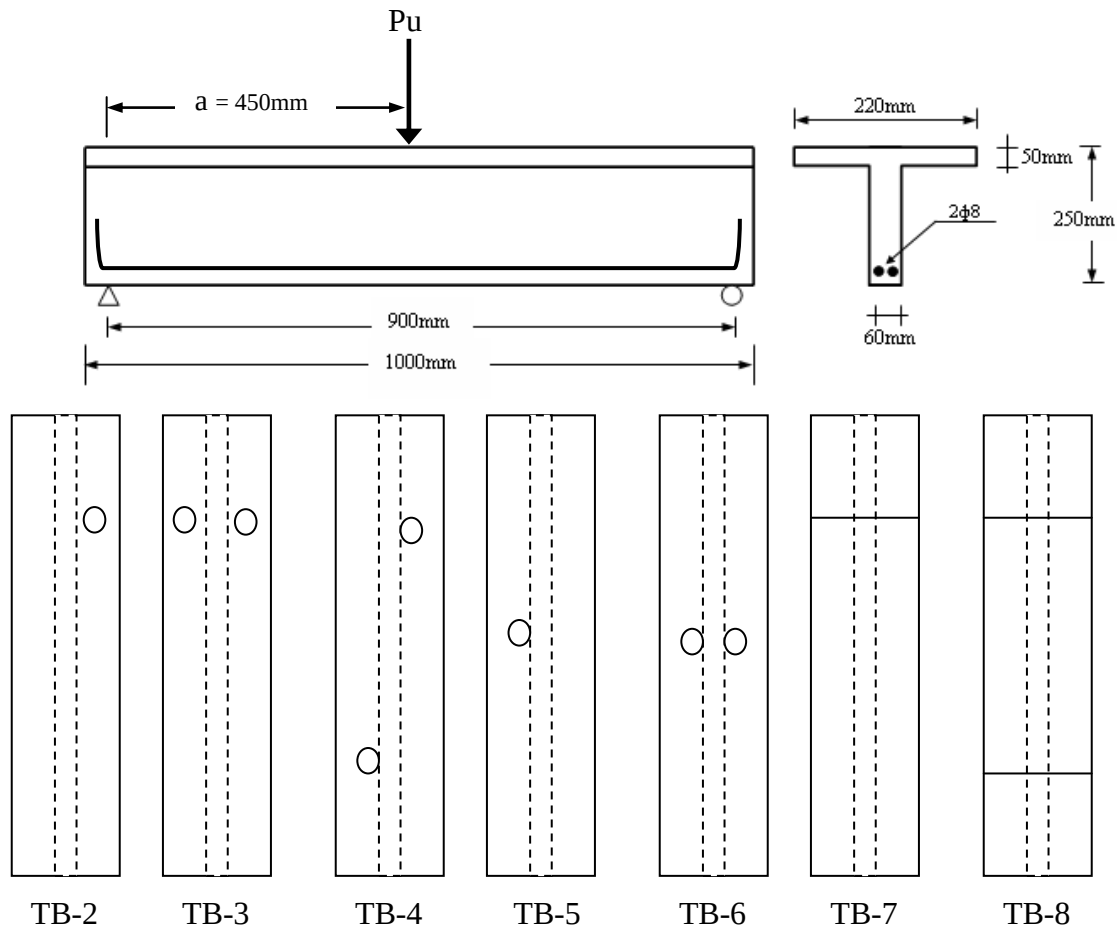


Fig. (3) Locations of Cold joints and Openings (Top View)

Materials

In manufacturing the test specimens, the properties and description of used materials are reported and presented in Table (2); and the concrete mix proportions are reported and presented in Table (3).

**Table (2) Description of Construction Materials**

Material	Descriptions
Cement	Ordinary Portland Cement (Type I)
Sand	Natural sand from Al-Ukhaider region with maximum size of (4.75mm)
Gravel	Crushed gravel with maximum size of (12mm)
Reinforcing Bars	(ϕ 8 mm) deformed steel bars, having (424 MPa) yield strength (f_y)
Water	Clean tap water

Table (3) Proportions of Concrete Mix

Parameter	Quantity
Water/cement ratio	0.45
Water (Liter)	168
Cement (kg/m^3)	420
Fine Aggregate (kg/m^3)	600
Coarse Aggregate (kg/m^3)	1200

Test Measurements and Instrumentation

Hydraulic universal testing machine (MFL system) was used to test the beams specimens as well as control specimens. Central deflection has been measured by means of (0.01mm) accuracy dial gauge (ELE type) and (30mm) capacity. The dial gauges were placed underneath the bottom face of each span at mid.

Test Results of Specimens

Test results of mechanical properties of specimens are summarized in Table (4). Compressive strength for cylinders was carried out on concrete with ASTM-C39. Tensile strength (Split cylinder) test were carried out in accordance with ASTM-C496 and tensile strength in flexural (modulus of rupture) were carried out in accordance with ASTM-C78

Table (4) Mechanical Properties of Concrete

Property (MPa)	Value
Cylinder compressive strength (f'_c)*	32
Split cylinder (f_{ct})**	3.5
Modulus of rupture (f_r)***	3.3

*Average of three samples by using (152x305mm) cylinders. ** Average of three samples by using (152x305mm) cylinders.

*** Average of three samples by using (100x100x500mm) prisms.

Test Procedure

All slab specimens were tested using universal testing machine (MFL system) with monotonic loading to ultimate states. The tested beams were simply supported over an effective span of (900mm) and loaded with a single-point load; Figure (4) shows the setup of beam specimens.

The beams have been tested at ages of (28) days. The beam specimens were placed on the testing machine and adjusted so that the centerline, supports, point load and dial gauge were in their correct or best locations.

Loading was applied slowly in successive increments. At the end of each load increment, observations and measurements were recorded for the mid-span deflection and crack development and propagation on the beam surface.

When the beams reached advanced stage of loading, smaller increments were applied until failure. They fail abruptly without warning (sudden failure) and the diagonal cracks that develop becomes wider and as a result, the load indicator stopped recording any more and the deflections increased very fast without any increase in applied load.

The developments of cracks (crack pattern) were marked with a pencil at each load increment.



Fig. (4) Setup of T-Beam specimens

RESULTS AND DISCUSSION

As mentioned before, the main objectives of this study are to examine or assess the shear behavior of reinforced concrete T-shaped beams containing openings or cold joints at different locations of beams flanges.

During the experimental work, ultimate loads, load versus deflection at mid-span for each beam were recorded. Photographs for the tested beams are taken to show the crack pattern and some other details.

The recorded data, general behavior and test observations are reported as well as recognizing the effects of various parameters on the shear behavior.

General Behavior

Photographs of the tested beams are shown in Figure (5) and test results are given in Table (5). All beams of this category were designed to fail in shear, which was characterized by sudden failure and diagonal wide cracks which extended from supports towards the load or openings or cold joints locations. The general behavior of the tested beams can be described as follows:

At early stages of loading, several cracks initiated in the mid span of tested beams (flexural cracks), with further loading, these cracks extended upwards and became wider in shear span. One or more cracks propagated faster than the others and reached the compression flange (near applied load or openings or cold joints), where crushing of the concrete near the positions of applied loads had occurred due to high concentrated stresses under load and presence of weak locations in the flange (openings or cold joints).

As expected, the main cracks (diagonal cracks) for all tested beams commenced at the shear span and all beams exhibited sudden failure. It is may be noted that, at advanced stage of loading, some parts of tested T-Beams were crushed and subjected to defragmentation , this is may be due to high concentrated of stresses and absents of steel reinforcement to hold these parts in the transverse direction.

Mode of Failure

The experimental evidences show that the diagonal cracks extended horizontally along the tension reinforcement and eventually, the failure take place due to crushing failure in the concrete near the compression face (near applied load) and this mode of failure called “Shear-Compression” failure.



Fig. (5) Crack Patterns for T-Beams

Ultimate Strength (P_u)

The recorded ultimate loads of the tested beams are presented in Table (5). As expected, test results show that the reference beams (TB-1) has the maximum ultimate strength in comparison with the rest beams. This may be due to combination of ability of flanges to sustain larger compressive force at advanced stages of loading and absent of any leak (openings or joints) in the flange. The compression flanges can carry any load increment prior to failure, and this depends mainly on the ultimate compressive strength of the concrete in the flange.

For tested beams (TB-2) and (TB-5), which had one opening in flanges, the decreased in shear strength was (22%-32%). The presence of openings in compression flange lead to decrease the stiffness of tested beams, and this leads to an decrease in carrying capacity.

For tested beams (TB-3), (TB-4) and (TB-6), which had two openings in flanges, the decrease in shear strength were (39%), (17%) and (17%) respectively.

For tested beams (TB-7) and (TB-8), which had one or two cold joints in flanges, the decrease in strength was (27%), which indicated that an increase in number of cold joints (adding another cold joint in opposite direction) not affected on the reduction of ultimate capacity.

Generally, it can be seen that the tested beams containing a certain number of openings or cold joints in the flanges exhibit smaller ultimate strength than other beams (which made fully without any openings).

Table (5) Ultimate Loads and Mode of Failure of Tested Beams

Specimens Designation	Ultimate Load (P_u) (kN)	Shear Force (kN)		Mode of Failure
		V_u	$(V_u)_i / V_u$	
TB-1 *	41	20.5	1	Shear-Compression Failure
TB-2	32	16	0.78	
TB-3	25	12.5	0.61	
TB-4	34	17	0.83	
TB-5	28	14	0.68	
TB-6	34	17	0.83	
TB-7	30	15	0.73	
TB-8	30	15	0.73	

* Reference Beam, $V_u = 20.5$ kN

Effect of Openings and Cold joints on Ultimate Strength

As shown in Table (5), presence of openings or cold joints in compression flange lead to decreases the stiffness of tested beams due to removed concrete parts, and this leads to decrease in carrying capacity.

Due to abrupt changes in the sectional configuration, opening corners are subject to high stress concentration that may lead to reduction in stiffness of the T-Beam and produced cracking and excessive deflection, see Figures (6) and (7).

Effect of Openings and Cold joints location on Ultimate Strength

As shown in Table (5), when the flange's opening shifted from ($L/3$) to ($L/2$) (see TB-2 and TB-5), the ultimate shear strength decreased from (22%) to (32%). When the openings shifted towards the applied load (from ($L/3$) to ($L/2$)), rapid progressive of cracks were take place due to passing of openings directly within the path of diagonal cracks.

The decreasing in ultimate load was (27%) for both (TB-7) and (TB-8), which have one and two cold joints respectively. This means that the location of cold joint not affected on ultimate capacity of tested beams.

Deflections

Load-deflection curves of the tested beams at mid-span at all stages of loading up to failure are constructed and shown in Figures (6) and (7).

As shown in Figures, at the beginning, all curves were identical and the tested beams exhibited linear behavior and the initial change of slope of the load-deflection curves occurred between (6 kN to 15kN), which may be indicated the first crack loads. Beyond the first crack loading, each beam behaved in a certain manner. Behavior of reference T-Beam (TB-1) exhibited greater loads and deflections in comparison with the other beams. This beam had the greatest stiffness due to absent of openings and cold joints in flange.

Load-deflection curves for the tested beams (TB-2, TB-3, TB-4, TB-5 and TB-6) exhibits smooth increase in both applied loads and deflections. Presence of flange openings caused decreasing in the load carrying capacity beyond the first cracking and this was reflected on the corresponding deflections. For T-Beams (TB-7 and TB-8), slight increase in ultimate deflection of beam (TB-8) was observed by comparing with (TB-7). This is may be due to presence of two cold joints in the beam (TB-8) which lead to decreasing of beam stiffness and as a result, slight increases in deflection take place.

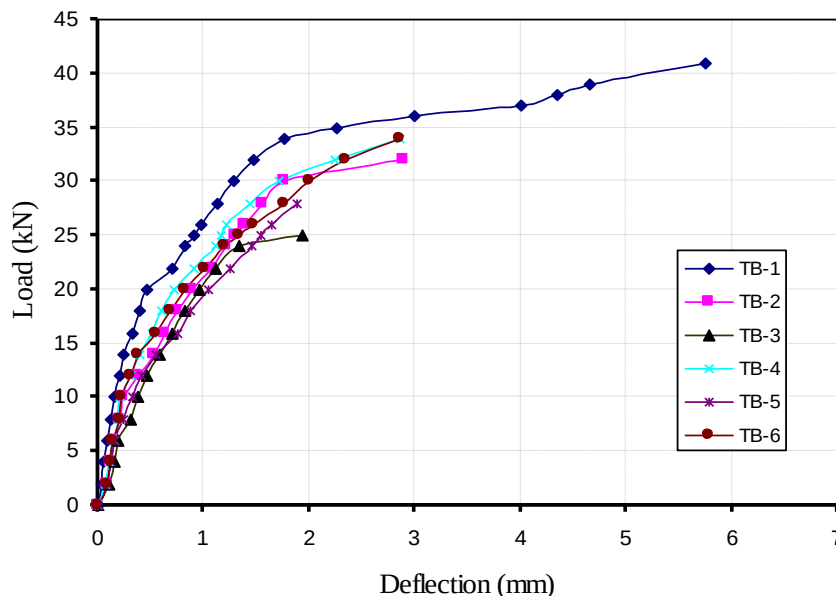


Fig. (6) Load-Deflection Relationship of tested Beams containing Openings

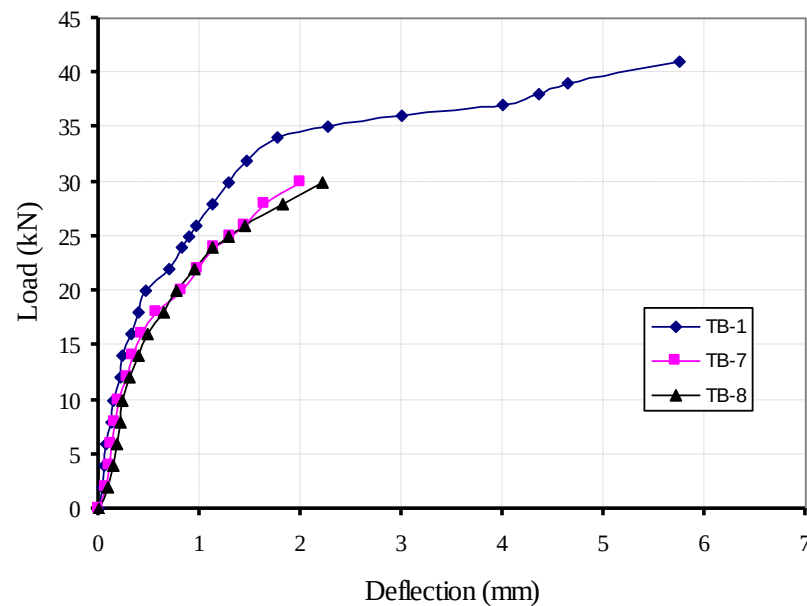


Fig. (7) Load-Deflection Relationship of tested Beams containing cold joints

CONCLUSIONS

Based on the results obtained by the experimental work, the following conclusions are presented:-

- For tested beams with one opening in flange, the ultimate strengths were decreased (22%) and (32%) for beams containing one opening at distance ($L/3$) and ($L/2$) from edges respectively. Also, the change in openings locations from edge toward the center lead to decrease the carrying capacity for about (10%). Presence of openings lead to concentrated of stress around their hollow and caused decreasing in the load carrying capacity. This evidence shows the contribution of flanges to increase the ultimate shear capacity of T-Beams in comparison with rectangular sections.
- For tested beams which have two openings in flange, the ultimate shear strengths were decreased (17%) and (39%). This marginal difference in ultimate strengths (in comparison with tested beams with one opening in flange) may be due to subjected of compression flange degree of stress concentration.
- Experimental results shows that the decreasing in ultimate load was (27%) for both (TB-7) and (TB-8), which have one and two cold joints respectively. This means that the location of cold joint not affected on the ultimate capacity of tested beams.
- 4-In all tested beams, the crack path forced to passing through the weak locations (locations of openings or cold joints). Therefore, in design, special details must be added at these locations.



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NOTATION

- a = Shear Span;
- b_f = Flange width;
- d = Effective depth of T-Beam;
- f'_c = Cylinder compressive strength of concrete;
- f_{ct} = Indirect tensile strength (splitting tensile strength);

- f_r = Flexural tensile strength of concrete (modulus of rupture);
- f_y = Yield strength of steel;
- h = Total depth of T-Beam;
- L = Effective Span
- P_u = Ultimate load;
- t_f = Flange thickness;
- t_w = Web thickness;
- V_u = Ultimate Shear Force;
- $(V_u)_i$ = Ultimate Shear Force of a certain beam;
- ϕ = Reinforced bar diameter;

EXPERIMENTAL STUDY FOR OXIDATION OF PHENOL BY FENTONS REAGENT

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ABSTRACT

The oxidation of phenol in aqueous solution was studied at atmospheric pressure in a batch reactor. Fenton reaction was used to degrade this component. Phenol (50 - 100 ppm) oxidation was carried out in the acidic medium range of (pH=2.7 - 5.8) under mild conditions of temperature (28 - 48°C), stoichiometric excess percentage of H_2O_2 (S.E $_{H_2O_2}$ %) of (0 - 100%), and Fe(II) to phenol concentrations ratio of (0 - 0.63). The results indicate that the oxidation by Fenton reaction was an efficient method to eliminate phenol, also the amount of catalyst and temperature had the large effect on the phenol degradation. Finally the simple kinetic model for the reaction was established.

الخلاصة

أكسدة الفينول في الوسط المائي تمت دراستها تحت الضغط الجوي في مفاعل دفعي. تفاعلات فنتون استخدمت لمعاملة هذا المركب. الفينول (50-100 جزء بالمليون) تمت أكسدته في وسط حامضي بين (2.7-5.8) تحت ظروف معتدلة من درجات حرارة (28-48 م°) والنسبة المئوية لكمية بيروكسيد الهيدروجين الفائضة عن التفاعل (0-100%) ونسبة أيون الحديد الثنائي الى الفينول (0-0.63). بينت النتائج ان أكسدة الفينول باستخدام تفاعلات فنتون هي عملية كفوة للتخلص من الفينول، كما بينت ان كمية العامل المساعد ودرجة الحرارة لهما تأثير كبير على عملية إزالة الفينول. أخيراً تم وضع موديل مبسط لدراسة حركية التفاعل.

INTRODUCTION

In situ chemical oxidation is an evolving technology that involves the introduction of chemical oxidants into subsurface soil and groundwater to destroy organic contaminants. This technology has promise when the contamination is amenable to mineralization to carbon dioxide and water or oxidation to a relatively less harmful form that may then be suitable for subsequent treatment. Selection of oxidation as an appropriate technology and the oxidant is dependent on the nature and type of contaminant, the level of remediation required, viability of oxidant delivery, soil conditions and hydrogeology of the site (Kluck and Achari 2003).

The development of novel treatment methods encompasses investigations of advanced oxidation processes (AOPs), which are characterized by production of the hydroxyl radical (OH $\cdot$) as a primary oxidant (Barbusiński 2005). Hydroxyl radicals are highly reactive and nonselective oxidations being able to decompose many organic compounds (Hu et al. 2002). This ability is enhanced by the presence of compounds able to activate the radical decomposition mechanisms (Chedeville et al. 2005). Fenton reaction hypothesis postulated that hydroxyl radical was the effective oxidation reagent in this reaction (Ricciardi 2006). Fenton reagent is a mixture of H_2O_2 and ferrous iron, which generates hydroxyl radical according to the reaction below:



The ferrous iron initiates and catalyzes the decomposition of H_2O_2 , resulting in the generation of hydroxyl radical. The generation of hydroxyl radical involves a completely reaction sequence in an aqueous solution (Farrokhi et al. 2003).

The use of $Fe(II)/H_2O_2$ as an oxidant for waste water treatment is attractive due to the facts that: (1) iron is a highly abundant and non-toxic element, and (2) hydrogen peroxide is easy to handle and environmentally benign (Munter 2001). Factors that influence Fenton processes are pH, contaminant character and concentration, $Fe(II)$ concentration, hydrogen peroxide quantity required for complete oxidation and temperature (Paradowska 2004).

The optimum pH of Fenton oxidations is usually reported in the acidic range between 2 and 4. Groundwater and soil may possess a high buffer capacity. Therefore, the necessity to acidify the reaction medium limits the applicability of the Fenton process in environmental technology. The main reason for the low reactivity at circumneutral pH is the precipitation of $Fe(III)$ as hydrous oxyhydroxides $Fe_2O_3 \cdot nH_2O$ which inhibits the recycling process of $Fe(III)/Fe(II)$ (Georgi et al. 2006).

The stoichiometric amount of H_2O_2 required for the total oxidation of phenol was calculated by using eq. (2) (Feng, and Le-cheng 2004).



In the kinetic study the results were obtained at different temperatures, $S.E_{H_2O_2}\%$ and $[Fe^{2+}]_0/[Ph]_0$ were used. If Fenton's reaction as mentioned by former researchers (Feng, and Le-cheng 2004, Parjan Singh 2006, Kwan 2003, and Alegría et al. 2003) was pseudo-first order, then the mention integral rate equation can be described by the eq. (3):

$$\ln \frac{[Ph]_0}{[Ph]} = K_{obs} t \quad (3)$$

At these different conditions the pseudo-first order rate constants (K_{obs}) were obtained from plotting $\ln [Ph]_0/[Ph]$ vs. t as shown in Fig. 7.

In this study, the expression of K_{obs} can incorporate the effect of H_2O_2 and $Fe(II)$ in addition to temperature effect and as follows:

$$K_{obs} = k_0 [H_2O_2]_0^\alpha [Fe^{2+}]_0^\beta \exp\left[\frac{-E_a}{RT}\right] \quad (4)$$

To calculate the values of K_{obs} , α , β , and E_a eq. (4) must be linearized in the following way:

$$\ln K_{obs} = \ln k_0 + \alpha \ln [H_2O_2]_0 + \beta \ln [Fe^{2+}]_0 - \frac{E_a}{RT} \quad (5)$$

This work deals with phenol oxidation in aqueous phase using Fenton reaction and aims to quantify the influence of feed solution acidity (pH), hydrogen peroxide stoichiometric excess percent ($S.E_{H_2O_2}\%$), iron to phenol concentration ratio, initial phenol concentration, and temperature. The reaction kinetic was also studied.

EXPERIMENTAL

Materials

Phenol with 99.5% purity was chosen as wastewater model compound and was purchased from Griffin. Ferrous sulphate ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$) with 99% purity was used as catalyst was purchased from BDH chemical LTD. Hydrogen peroxide with 99.5% purity was used as oxidizing agent was purchased from Keny chemicals-company. Sulfuric acid 95.97% purity was purchased from Fluka was used to adjust solutions acidity. All chemical work was carried out using distilled water.

Experimental Set-up And Procedure

All oxidation runs were conducted using three-neck Pyrex round-bottle flask (500 ml). One neck was used for introducing the reactants solutions and the catalyst as well as taking out the samples by Syringe. Through the second and third necks quick fit thermometer and reflux condenser were fixed. The flask was heated with a hot plate stirred magnetically (T.Jlassco (India), magnetic stirrer with hot plate), as illustrated in Fig. 1.

A volume of 500 ml of phenol solution were filled into the reaction vessel. By adding 1M H_2SO_4 the solutions were adjusted to pH 2.7, 3.7 and 4.7 to keep the medium in the acidic range. Afterwards the appropriate amount of Fe(II) was added. The hydrogen peroxide was introduced in appropriate amount to start the reaction at the suitable temperature. The liquid samples were taken periodically and immediately filtrated and analyzed.

Samples Analysis

Phenol concentration in the outlet samples was analyzed using Shimadzu model UV-160A ultraviolet/visible spectrophotometer. Prior to each oxidation experiment the phenol calibration curve of UV spectrophotometer was checked to correct deviation in the peak height, which may be occurred.

Phenol calibration curve was made by taking samples of phenol solutions in the concentration range of 0.5 to 50 ppm and measured the absorbency against each concentration, and then plotting concentrations values against them absorbency in the UV spectrophotometer device. When the sample of unknown phenol concentration input to this device, it would immediately gave that concentration.

RESULTS AND DISCUSSION

Effect Of pH Solution

The degradation of phenol at three different feed solution pH of 5.8, 4.7, 3.7 and 2.7 was studied at constant other variables: S.E. $_{\text{H}_2\text{O}_2}$ % of 0%, $[\text{Fe}^{2+}]_0/[\text{Ph}]_0$ of 0.42, temperature of 28°C, and initial phenol concentration of 50 ppm, as illustrated in Fig. 2.

The study was indicated that phenol degradation was improved at the most acidic medium (pH=2.7). Thus, at pH=2.7 the remaining phenol concentration was 4.4 ppm, while equal to 9.3, 10.1, and 10.4 ppm at for the pH 3.7, 4.7, and 5.9 respectively. Also, in the solutions with pH 5.8, 4.7 and 3.7 a precipitation of Fe(III) presumably as hydrous oxyhydroxide $\text{FeSO}_3 \cdot n\text{H}_2\text{O}$ was observed. In contrast, no precipitation occurred in the reaction solutions with pH 2.7. These results can be attributed due to low solubility of Fe^{3+} for pH higher than 3, which causes formation of Fe complexes and precipitate as hydrous oxyhydroxides $\text{FeSO}_3 \cdot n\text{H}_2\text{O}$ which inhibits the recycling process of Fe(III)/Fe(II) that can decrease the efficiency of the catalyst as represented in the reaction:



Also the acidic pH favors the formation of a stable and electrophilic structure via a solvation of a proton by an H_2O_2 molecule. These results were in agreement with Feng and Le-cheng 2004, and Kwan 2003.

Effect Of Hydrogen Peroxide Stoichiometric Excess Percent ($\text{S.E.}_{\text{H}_2\text{O}_2}\%$)

The degradation of phenol at four different $\text{S.E.}_{\text{H}_2\text{O}_2}\%$ of 0%, 50% and 100% was studied at constant other variables: pH of 2.7, $[\text{Fe}^{2+}]_0/[\text{Ph}]_0$ of 0.42, temperature of 28°C , and initial phenol concentration of 50 ppm, as illustrated in Fig. 3. It can be seen that the remaining phenol concentrations of 4.4, 3.7, and 3.6 ppm were achieved when $\text{S.E.}_{\text{H}_2\text{O}_2}\%$ equal to 0%, 50%, and 100% respectively.

A significant enhancement of phenol degradation was observed when $\text{S.E.}_{\text{H}_2\text{O}_2}\%$ was increased from 0% to 100%. It's significant to know that the oxidant H_2O_2 should be added in an optimal dosage for the reaction due to H_2O_2 itself act as a scavenger of $\text{HO}^\bullet$ radical at high oxidant concentration, as represented by the reaction:



Through parallel undesired reaction, the extra H_2O_2 moles will compete with phenol for the $\text{HO}^\bullet$. The radicals ($\text{HO}_2^\bullet$) are the result of this competitive reaction which are less reactive than $\text{HO}^\bullet$ radicals and their reaction with organic dissolved carbon is negligible. . These results were in agreement with Chedeville et al. 2005, Feng and Le-cheng 2004, and Paradowska 2004.

Effect Of Fe^{2+} To Phenol Concentration Ratio $[\text{Fe}^{2+}]_0/[\text{Ph}]_0$

The degradation of phenol at three different values of $[\text{Fe}^{2+}]_0/[\text{Ph}]_0$ 0.21, 0.42 and 0.63 was studied at constant other variables: pH of 2.7, $\text{S.E.}_{\text{H}_2\text{O}_2}\%$ of 50%, temperature of 28°C , and initial phenol concentration of 50 ppm, as illustrated in Fig. 4, in addition, the run without Fe^{2+} at the same above variables was carried out to demonstrated the importance of present Fe^{2+} ions when using H_2O_2 as oxidant. As clear in the Fig. 4 phenol concentration reaches to 3 ppm when $[\text{Fe}^{2+}]_0/[\text{Ph}]_0$ was 0.63, but at $[\text{Fe}^{2+}]_0/[\text{Ph}]_0$ equal to 0, 0.21, and 0.42 phenol concentrations were 47.2, 22.2, and 3.7 ppm respectively.

That considerable influence of Fe^{2+} concentration on the phenol elimination, because more radicals are produced, thus leading to a faster degradation. . These results were in agreement with Chedeville et al. 2005, and Feng and Le-cheng 2004.

Effect Of Temperature

The degradation of phenol at three different temperatures of 28, 38, and 48°C was studied at constant other variables: pH of 2.7, $\text{S.E.}_{\text{H}_2\text{O}_2}\%$ of 50%, $[\text{Fe}^{2+}]_0/[\text{Ph}]_0$ of 0.63, and initial phenol concentration of 50 ppm, as illustrated in Fig. 5. This figure shows that at 48°C , phenol concentration was 0.2 ppm, while at 38, and 28°C phenol concentrations were 1.09, and 3 ppm.

The temperature showed a strong effect on the phenol elimination. This kind of effect was expected because it's known that kinetic constant (either for phenol decomposition, radicals formation or iron regeneration) have exponential dependency with reaction temperature (Arrhenius law) and this has also been reported by other authors (Chedeville et al. 2005, and Paradowska 2004).

Effect Of Initial Phenol Concentration

The degradation of phenol at three different initial phenol concentrations of 50, 75, and 100 ppm was studied at constant other variables: pH of 2.7, S.E._{H₂O₂}% of 50% , [Fe²⁺]₀/[Ph]₀ of 0.63, and temperature of 28°C. It can be seen from Fig. 6 that the remaining phenol concentrations were 6.8 and 10.6 ppm when initial phenol concentrations were 75, and 100 ppm, while its 3 ppm when initial phenol concentration was 50 ppm. This study showed nonlinear dependence on phenol initial concentration and is somewhat decreased when it concentration is increased. When phenol concentration increased, the intermediate components result throughout reaction pathway increased too, and competed with phenol for the HO[•] at this conditions which were considered the best for 50 ppm phenol concentration. These results were in agreement with Chedeville et al. 2005, and Feng and Le-cheng 2004.

Kinetic Model

The analysis curves indicate the pseudo-first order with respect to phenol concentration and 0.01 and 0.25 orders with respect to H₂O₂ and Fe(II) concentrations respectively. The orders of H₂O₂ and Fe(II) demonstrated the null and considerable effects of them respectively. While the activation energy was been 8×10^3 J/mol. And frequency factor was 2×10^{17} . This result was agreed with findings of other studies were conducted (Parjan Singh 2006, and Alegria et al. 2003).

$$-r_A = 2 \times 10^{17} \exp\left[\frac{-8 \times 10^3}{RT}\right] [H_2O_2]_0^{0.01} [Fe^{2+}]_0^{0.25} [Ph] \quad (8)$$

CONCLUSIONS

The results obtained in the chosen field of study confirm that the oxidation by Fenton's reaction in an efficient method for phenol degradation in the acidic medium, so where the lowest remaining phenol concentration (0.2 ppm) was achieved under the conditions of [pH of 2.7, S.E._{H₂O₂}% of 50%, [Fe²⁺]₀/[Ph]₀ of 0.63, temperature of 48°C, and initial phenol concentration of 50 ppm,. These results suggested that catalyst amount and reaction temperature were the predominant factors on the process, while the S.E._{H₂O₂}% and phenol initial concentration effects were relatively null.

Kinetic study showed that the reaction was 1, 0.25, and 0.01 orders with respect to phenol, Fe(II), and H₂O₂ concentrations respectively, with 8×10^3 J/mol. activation energy and 2×10^{17} frequency factor.

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NOMENCLATURE

$[\text{Fe}^{2+}]_0$	Fe(II) initial concentration (mol./l).
$[\text{H}_2\text{O}_2]_0$	H_2O_2 initial concentration (mol./l).
$[\text{Ph}]_0$	The initial phenol concentration (mol./l).
$[\text{Ph}]$	The phenol concentration after a time interval t , (mol./l).
E_a	The activation energy (J/mol.).
k_0	The frequency factor (case dependent units).
K_{obs}	The pseudo-first order rate constant.
R	The universal gas constant, 8.314 (J/mol.K).
$\text{S.E.}_{\text{H}_2\text{O}_2} \%$	Stoichiometric Excess Percent.
T	Temperature (K).
t	Time (min.).
α	H_2O_2 order.
β	Fe(II) order.

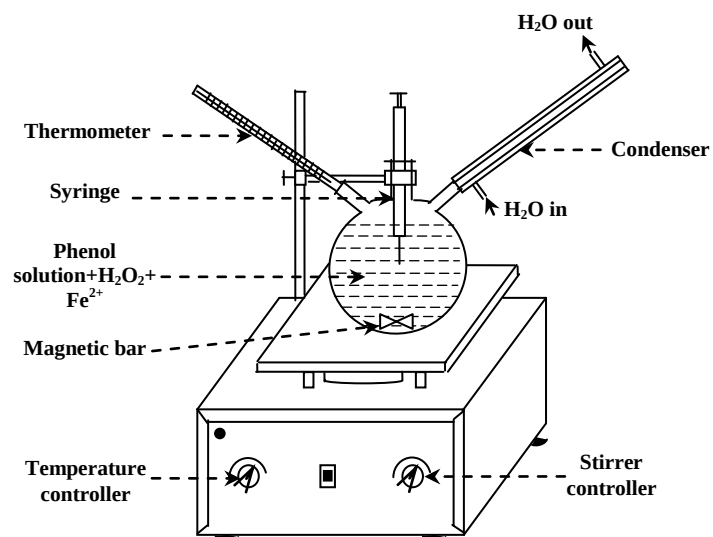


Fig. (1), Experimental set up of study

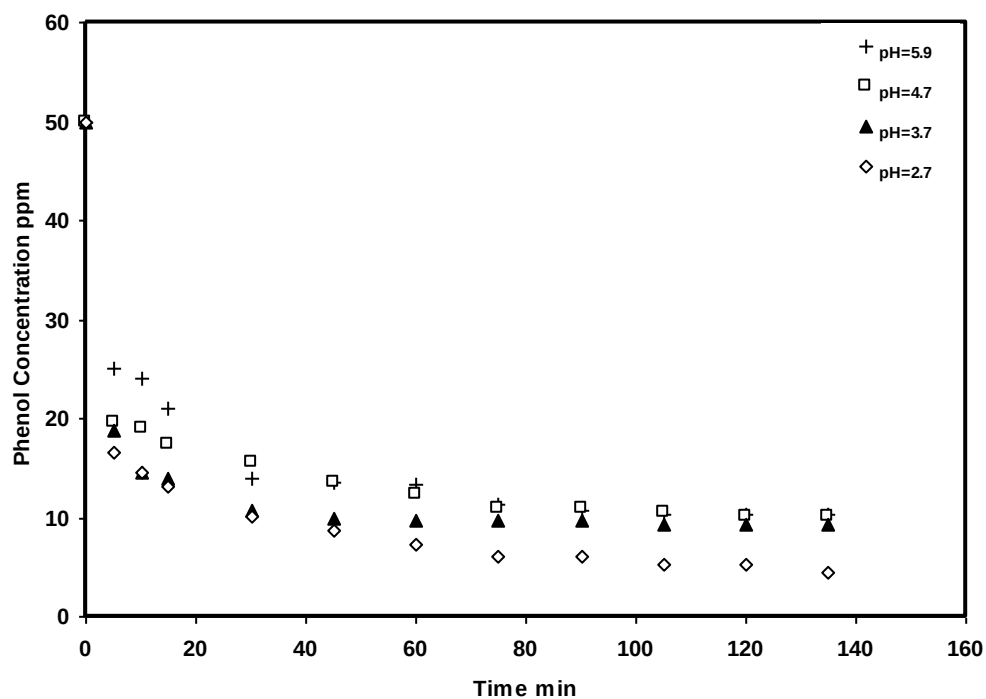


Fig. 2, Effect of feed solution pH.

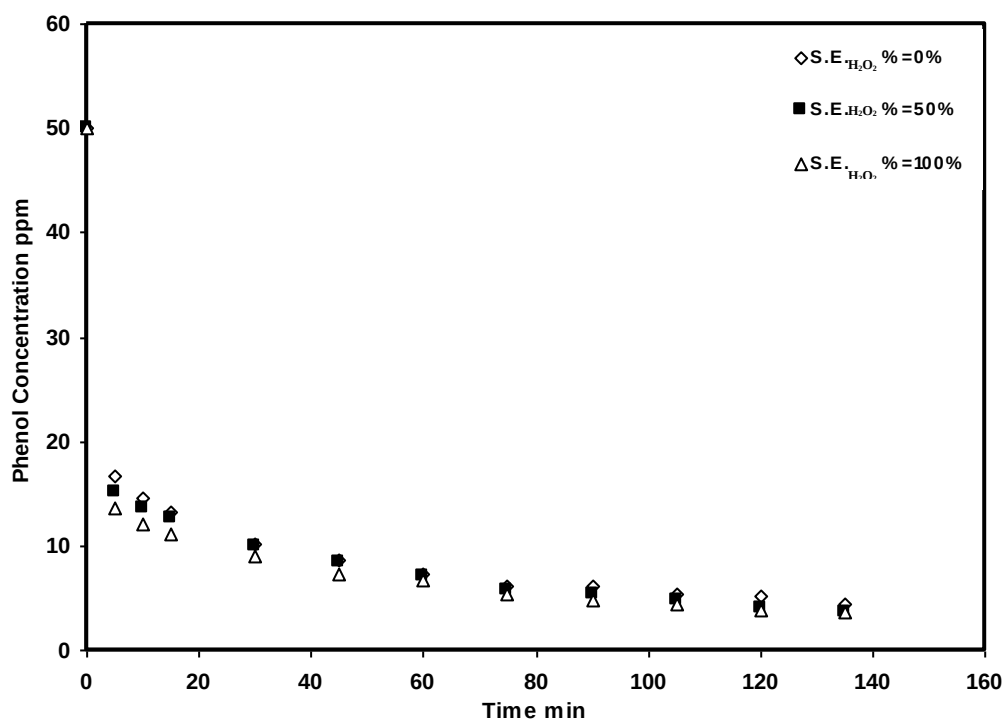
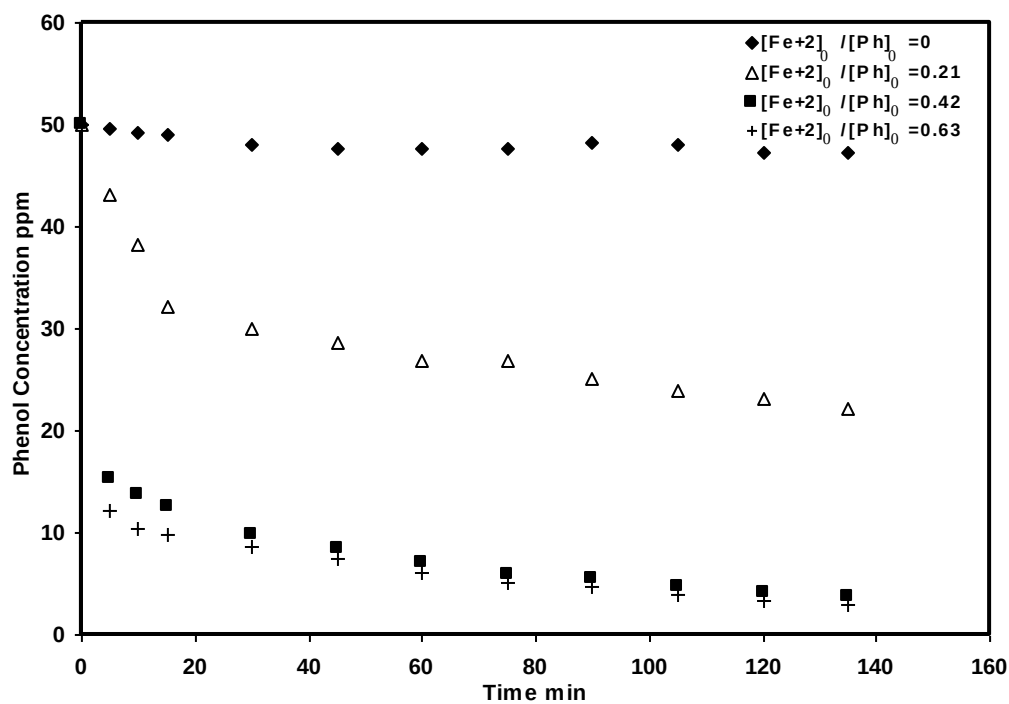


Fig. 3, Effect of hydrogen peroxide stoichiometric excess

Fig. 4, Effect of Fe^{2+} to phenol concentration ratio.

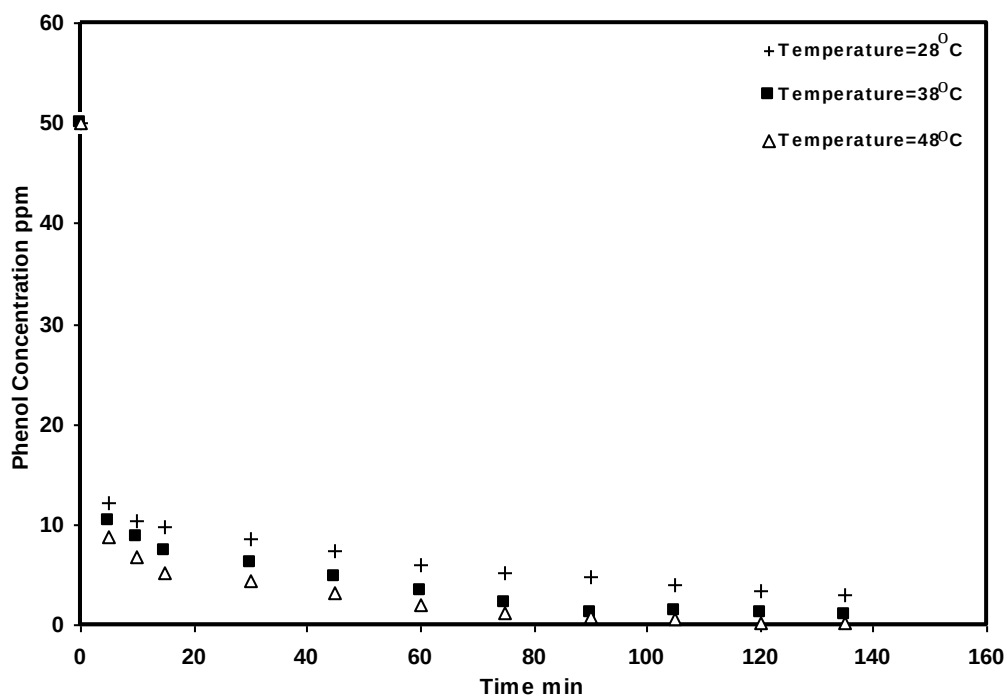


Fig. 5, Effect of temperature.

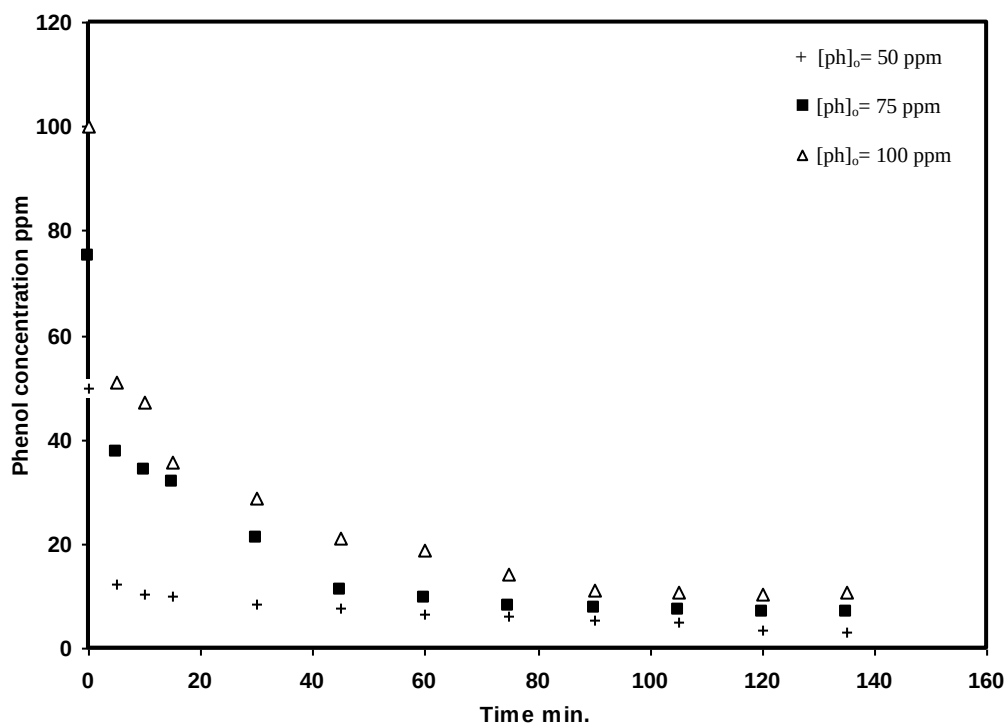


Fig. 6, Effect of initial phenol concentration.

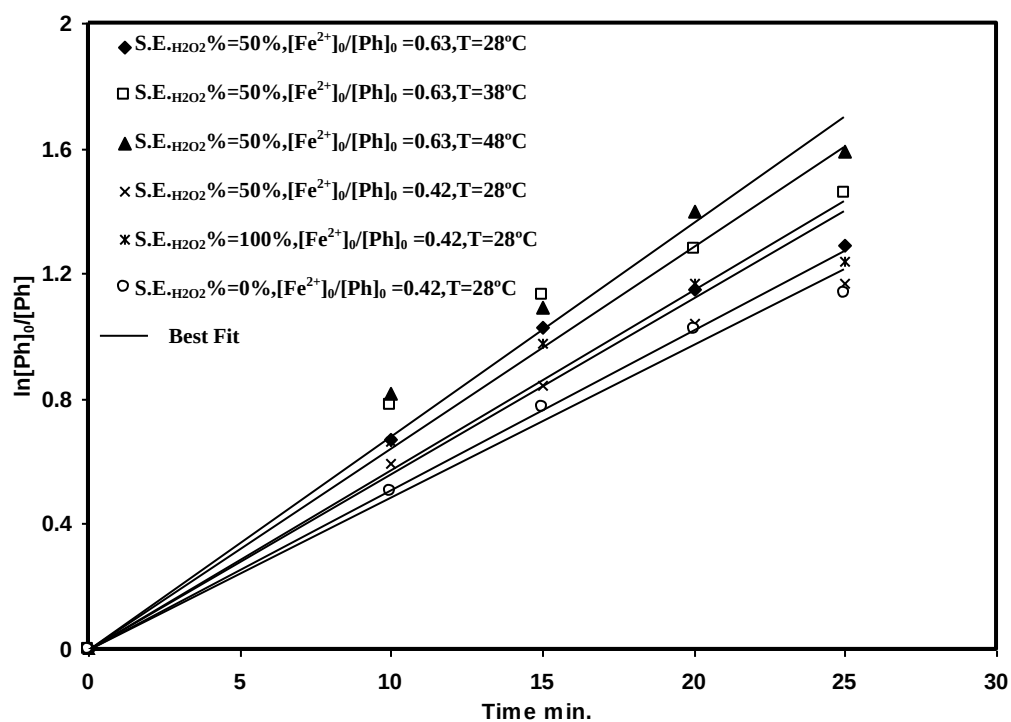


Fig. 7, $\ln[\text{Ph}]_0/[\text{Ph}]$ versus time at various conditions.

COMBINED ADJUSTED STEP SIZE LMS ALGORITHM AND ACTIVE TAP DETECTION TECHNIQUE FOR ADAPTIVE NOISE CANCELLATION

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ABSTRACT

In this paper ,a new idea to combine Adjusted Step Size Least Mean Square (ASSLMS) algorithm with standard LMS active tap detection technique is presented .Then the combined method is used for estimating unknown time-invariant (stationary) and time varying (non- stationary) Finite Impulse Response (FIR) channel for adaptive noise cancellation (ANC) application. The focus of this paper is to improve the convergence rate and low level of the error in the steady state for the popular LMS adaptive filter. The simulation results have shown improvement on the convergence rate using the combined technique over both the ASSLMS algorithm and standard LMS active tap detection technique if they are used alone.

KEYWORDS: Adaptive Noise Cancellation, Active Tap Detecting Technique, Adjusted step size LMS algorithm.

دمج خوارزمية اقل معدل للتربيع ذات معامل الخطوة المتغير زمنيا مع تقنية كشف الاوزان الفعالة لمنظومة الغاء الضوضاء المتكيفة

ملخص البحث :-

يقدم هذا البحث فكرة جديدة لدمج خوارزمية اقل معدل للتربيع ذات معامل الخطوة المتغير زمنيا مع تقنية كشف الاوزان الفعالة التي تكون قيمتها لاتساوي صفر . تم تطبيق هذه الفكرة على منظومة الغاء الضوضاء المتكيفة ولقناة غير متغيرة مع الزمن وكذلك تم تطبيقها مع قناة اخرى تكون متغيرة زمنيا" . من خلال برامج المحاكاة باستخدام الحاسوب تم الحصول على نتائج مشجعة وجيدة مقارنة مع تلك المستخلصة فيما لو تم استخدام الطرق انفة الذكر لوحدها . التحسن في الاداء كان من خلال الحصول على سرعة عالية في اداء الغاء الضوضاء والحصول على اقل مستوى لاشارة الخطاء في حالة استقرار (او المرحلة النهائية) عمل المنظومة .

INTRODUCTION

Adaptive Noise Cancellation (ANC) system is regarded as one of the method used for signal (speech) enhancement and attempts to reduce the additive noise which may arise from different sources. Noise canceling is an adaptive system that makes use of an auxiliary or reference input as shown in Fig.1 [Bernard Widrow, Samuel D. Stearns].

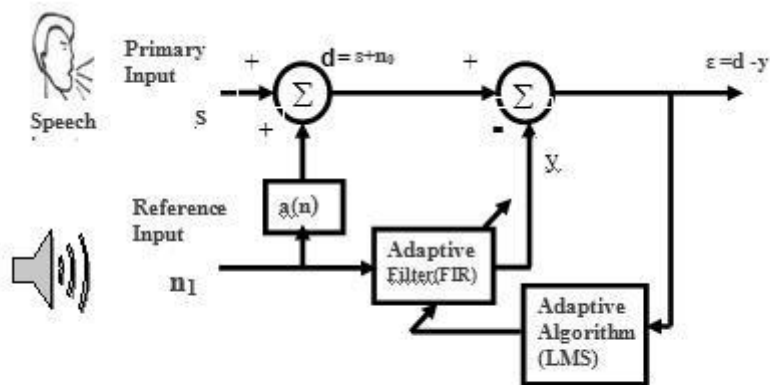


Fig.1. Concept of ANC

In this Fig., ANC has two inputs called primary and reference inputs. The reference input (n_1) is filtered using adaptive FIR filter and subtracted from a primary input which is containing both desired signal and the noise ($s+n_0$). As a result the primary noise is attenuated or eliminated by cancellation and the output signal is called error signal (e). The signal (n_0) represents the noise that is filtered through the noise channel path $a(n)$ which it is considered as FIR filter in this paper. This noise path channel has impulse response which may be stationary or non-stationary time varying. Filtering and subtraction of the ANC system must be controlled by an appropriate adaptive process that uses the error signal in order to obtain noise reduction with little risk of distorting the signal or increasing the noise level [Bernard Widrow, Samuel D. Stearns]. Many algorithms are used by ANC to adjust their impulse response. The LMS algorithm is regarded as a special case of the gradient search algorithm which was developed by Widrow and Hoff in 1959 [Bernard Widrow, Samuel D. Stearns]. This algorithm is often used for the adaptation of the ANC system because it is easy to implement and requires small number of calculations. But this algorithm suffers from slow convergence since the convergence time of LMS algorithm is inversely proportional to the step size [Bernard Widrow, Samuel D. Stearns]. However if large step size is selected then fast convergence will be obtained but this selection results in deterioration of the steady state performance (i.e. increased the misadjustment (error level)). Also if the channel to be estimated is time varying the LMS algorithm fails to track this type of channel. The LMS has also been cited and worked upon by many researchers and several modifications have been applied to it in order to optimize its performance for particular applications. Numerous modifications of the LMS algorithm have been reported [S.K., G. Zeng, J.J. Chen, R.R. Priemer, Bozo K., Zdravko U., and Ljubisa S., and R.H.Kang, E.W.Johnstone]. In these works, the optimization issue concerning the step size is discussed, and several methods of varying the step size to improve performance of the LMS algorithm especially in time varying environments are proposed. One of these modifications is to use adjusted step size LMS algorithm as proposed by [M.J. Al-Kindi, A.K. Al-Samarrie, and Th.M. Al-Anbakee]. Our proposed algorithm is called ASSLMS algorithm which is used for ANC application. Another modification of LMS algorithm is proposed by Dr.J. Homer [J. Homer]. He proposed active tap detection LMS technique for white inputs and invariant time channel. Then several improvements of this technique (i.e. active tap detection technique) are reported in order to improve the performance of this technique especially in non-stationary environments [Charles Q.Hoang, Boon L.Chock, Vanessa Edward, and Long Le, Ozgu Ozun, and Phiipp Steurer]. This paper is organized as follows; first the concept of active tap detection LMS algorithm will be present, then ASSLMS algorithm will be present. After that, simulation results with different conditions will be present. Then this paper will enclose by the conclusions.

FUNDAMENTAL OF THE LMS ALGORITHM

Basically, the idea for the adaptive transversal filter (or FIR) is to model the noise path channel and attempt to match it. The tap delay line structure for the unknown modeled channel, which gives the desired response, is shown below in Fig.2.

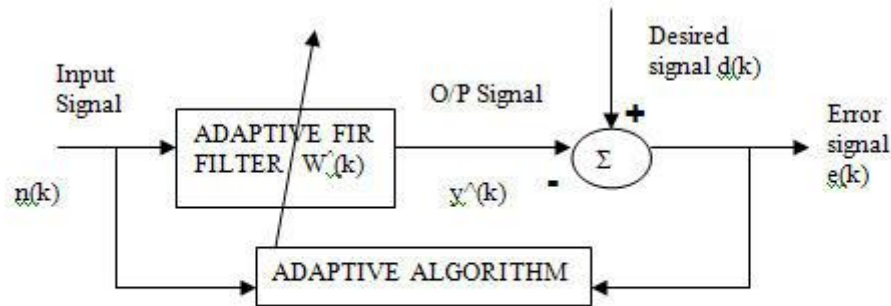


Fig.2. Adaptive FIR Filter

The weights or the impulse response of the noise path is given as:

$$W_k = [w_0 \ w_1 \ w_2 \ w_3 \ \dots \ w_{n-1}] \quad (1)$$

where n is the tap length, k is the time index. There is also the estimator (or adaptive filter) that has a similar structure:

$$\hat{W}_k = [\hat{w}_0 \ \hat{w}_1 \ \hat{w}_2 \ \hat{w}_3 \ \dots \ \hat{w}_{m-1}] \quad (2)$$

where m is the tap length. The adaptive filter has zero initial conditions as is done in practice. In general, the length of the filter (m) may be different from the length (n) of the channel. For simplicity in this paper, only the case of $n=m$ was considered. Another important aspect is that the weights or coefficients of the FIR estimator will be adjusted using the LMS algorithm to reduce mean squared error (MSE) which is a measure of the accuracy of the estimated channel. However, since the MSE requires a large amount of memory, the instantaneous squared error is used, which gives an estimate of the gradient of the MSE surface [Bernard Widrow, Samuel D. Stearns]. The estimation error can be found as:

$$e_k = (d_k + n_k) - y_k \quad (3)$$

Where noise or additive disturbance (n_k) is added to the desired signal d_k (not shown in the Fig. (2)).

From equation 3, the adaptive filter output is

$$y_k = \hat{W}_k * N_k \quad (4)$$

where n_k is the input noise signal and $*$ denotes convolution operation.

The LMS algorithm adapts the adaptive filter's vector $\hat{W}_k$ according to [Bernard Widrow, Samuel D. Stearns],

$$\hat{W}_{k+1} = \hat{W}_k + \mu N_k e_k \quad (5)$$

Where $N_k = [n_k \ n_{k-1} \ n_{k-2} \ \dots \ n_{k-m+1}]$, which represents the input noise signal to the taps of the adaptive FIR filter, and μ is fixed step size $0 < \mu < 1$.

CONCEPT OF LMS ACTIVE TAP DETECTION ALGORITHM

In adaptive estimation applications, the channel is characterized by a time domain impulse response. Using the LMS algorithm alone, extended regions of negligible response or "inactivity" may be included in the calculation of this response [Charles Q.Hoang]. The idea proposed by Dr John Homer is to apply a consistent LMS algorithm that performs estimation of nonzero or "active" taps only. This will improve the channel estimation performance (accuracy) and convergence rate. In order to detect a tap, a formula known as the least squares (LS) activity measure is used [J. Homer]:

$$X_i = \frac{\sum_{k=i+1}^D [v_k n_{k-1}]^2}{\sum_{k=i+1}^D n_{k-1}^2} \quad (6)$$

Where $v_k = d_k$, i = tap index, D is the number of samples.

Now in order for the tap to be determined as active (as opposed to inactive), the value of X_i must be above a certain minimum value called the active tap threshold condition (T_d). This is shown in the following threshold formula:

$$T_d = X_i(D) \gg \sigma_v(D) \log(D) \quad (7)$$

Where σ_v^2 is the variance of d_k or v_k .

If the value is found to be below this criterion, then it can be discarded or multiplied by a forgetting factor (i. e. fraction) just in case it is an actual spike in the next iteration. So in summary, the LS activity criterion (6), and (7) works out or detects the position of the active taps in the unknown channel or noise path and the LMS algorithm works out the strength of the active taps [J. Homer].

STANDARD LMS ACTIVE TAP DETECTION WITH SLIDING WINDOWS

By theory for a stationary channel, the length of the window which tracks the channel is the length of the number of samples. However, channels that have a time- varying nature require a window which must be adjusted to the recent channel. There are several fundamental considerations that must be understood in the implementation of the standard LMS active tap detection algorithm for time- varying channels. First of all, the LMS algorithm uses the most recent channel estimation error in (5). This, in turn, means it is not severely affected by time- varying channels. Secondly, the LS activity measure equation uses all past signal ($d(k)$, $n(k)$) samples. This leads to the LS activity measure algorithm being affected by time- varying channels. Also, since the more distant past samples are no longer relevant to the system, these particular samples can bias the value obtained for the activity measure. And so, the basic idea of the system design is to include only the more recent samples in the LS activity measure equation. This is equated to applying a sliding window to the signals [Charles Q.Hoang].

There are several types of windows that can be used to track the non-stationary taps. These can be rectangular, triangular, exponential, and such. In this paper, an exponential sliding window is considered to detect and estimate the non-stationary channels due to its superiority over the other types of windows for this type of the channel [Charles Q.Hoang]. This exponential sliding window is shown in Fig.3

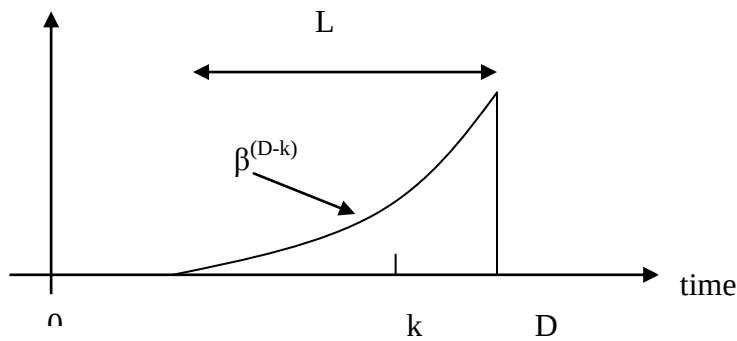


Fig.3. Exponential Window

The equivalent equations to (6), and (7) for the exponential sliding Window approaches are [Charles Q.Hoang]:

$$X_i = \frac{\sum_{k=i+1}^D [\beta^{D-k} v_k n_{k-1}]^2}{\sum_{k=i+1}^L \beta^{D-k} n_{k-i}^2} \quad (8), \quad \sigma_v^2 = \frac{\sum_{k=1}^D \beta^{D-k} v_k^2}{\sum_{k=1}^L \beta^{D-k}} \quad (9)$$

And

$$X_i > 2\sigma_v \log\left(1 - \frac{D-k}{L}\right) \quad (10)$$

Where β is the exponential factor and obeys the limit of $0 < \beta < 1$ and L is the length of the window. The main advantage of the exponential approach is more importance is placed on the most recent samples. The smaller the size of β is equivalent to a smaller effective window length (L). This means that more importance to the more recent samples will be achieved. In contrast, if the exponential factor β is large, the effective window length will be larger and importance to recent samples will be less [Charles Q.Hoang].

PROPOSED ASSLMS ALGORITHM

The proposed algorithm which is developed by us [M.J. Al-Kindi , A.K. Al-Samarrie, and Th.M. Al-Anbakee] used recursively adjusted adaptation step size based on the performance surface gradient square. This algorithm will be referred to as Adjusted Step Size LMS algorithm (ASSLMS) all over in this paper. However this algorithm is the modified version of Variable Step Size LMS algorithm that is developed in [R.H.Kang, E.W.Johnstone].The step size of the proposed algorithm is varied according to the following equation [M.J. Al-Kindi , A.K. Al-Samarrie, and Th.M. Al-Anbakee]:-

$$\mu_{k+1} = \alpha \mu_k + \sigma (e_k N_k)^2 \quad (11)$$

Where $0 < \alpha < 1$ and $\sigma > 0$, then

$$\mu_{k+1} = \mu_{\max} \quad \text{if } \mu_{k+1} > \mu_{\max}$$

$$\text{And} \quad \mu_{k+1} = \mu_{\min} \quad \text{if } \mu_{k+1} < \mu_{\min} \quad (12)$$

$$\text{Otherwise} \quad \mu_{k+1} = \mu_{k+1}$$

Then eq. (5) can be rewritten as follows:-

$$\hat{W}_{k+1} = \hat{W}_k + \mu_k N_k e_k \quad (13)$$

From equations (11) and (13), μ_k is time varying step size, which is adjusted according to the gradient square of the performance surface $(e_k N_k)^2$. The motivation of this algorithm is that a large gradient square will cause the step size to increase to provide faster tracking while small gradient square will decrease the step size to yield smaller error level. The value of $\mu_{\min}$ is chosen to provide minimum level of error level at steady state, and $\mu_{\max}$ ensures the stability of this algorithm.

THE MODELING OF A NON-STATIONARY CHANNEL

There are various ways in which the non-stationary or time-varying channel can be modeled. The channel can vary with respect to either the strength of each active tap, the position of each active tap, or both. Also, the rate at which the channel changes with time is another parameter [Charles Q. Hoang]. The variation of the strength of the known channel taps is one approach for modeling a non-stationary condition. There are two standard models which incorporate these ideas:

- The random walk process.
- 1st autoregressive process.

However in this paper only the first one is used. The random walk theory is defined by the following [Charles Q. Hoang];

$$W_{k+1} = \sum W_k \bullet \text{random\_number} \bullet \sigma_\delta \quad (14)$$

Where $\bullet$ denotes multiplication, $W_k = [w_{0,k}, w_{1,k}, \dots, w_{n-1,k}]$ is the response of the channel at time index k .

$$W_{k+1} - W_k = \delta_k = [\delta_{0,k}, \delta_{1,k}, \dots, \delta_{n-1,k}] = W(k) \bullet \text{random\_number\_2} \bullet \sigma_k$$

$\delta_{i,k}$ is zero mean with variance σ_δ^2 (measure the speed of parameters change) and independence of $\delta_{j,k}$ $\{i \neq j\}$; δ is sometimes known as a Gaussian White Noise [Charles Q. Hoang];

$$\sigma_\delta = \frac{\text{random\_number} \bullet \sigma_\delta - 1}{\text{random\_number\_2}}$$

$$E[\delta_{i,k}] = 0; \quad E[\delta_{i,k}^2] = \sigma_\delta^2 \quad \{\forall i\}; \quad E[\delta_{i,k} \delta_{j,k}] = 0$$

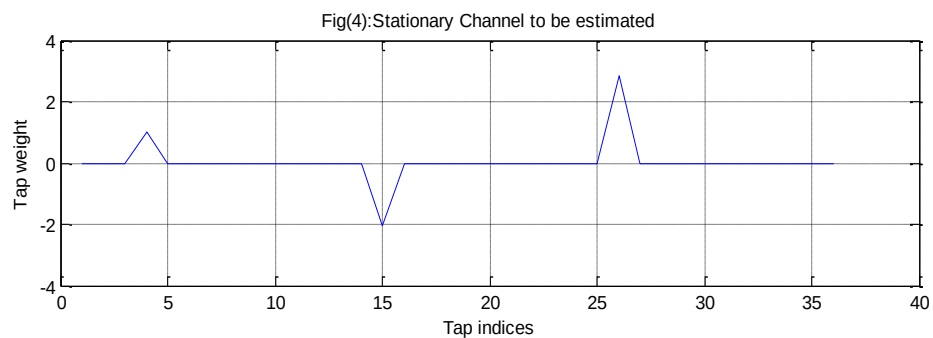
SIMULATION RESULTS

Fig.1 is simulated under the following conditions:

- The desired input signal (S) is sine wave.
- The reference input (n1) is White Gaussian Noise with variance of 1.0 and zero mean.
- The signal to noise ratio is equal to approximately to (-15 db) for all simulation tests.
- The tap vectors (W) of the noise path a(n) is stationary and is shown in Table (1) and Fig.4. There are three active taps in the system: at the 4th tap, the strength is 1; at the 15th tap, the strength is -2; and at the 26th tap, the strength is 3. The channel also had a total tap length of 36 (i.e. $m = 36$ taps and then $n = 36$ as discussed previously).

Table (1) The tap vectors (W) of the noise path a(n) to be estimated.

Tap Number	Type	Strength
4 th	Active	1
15 th	Active	-2
26 th	Active	3



- Standard LMS alone with step size equal to (0.005) is applied to the ANC. Then the estimated channel taps are estimated very well as shown in Table (2) and Fig.5, but this algorithm provides noisy estimates of the 7, 19, 22, 24, and 35 inactive taps.

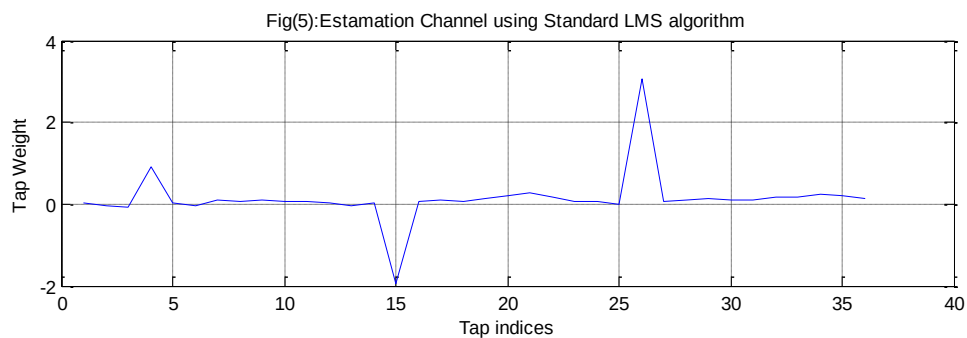
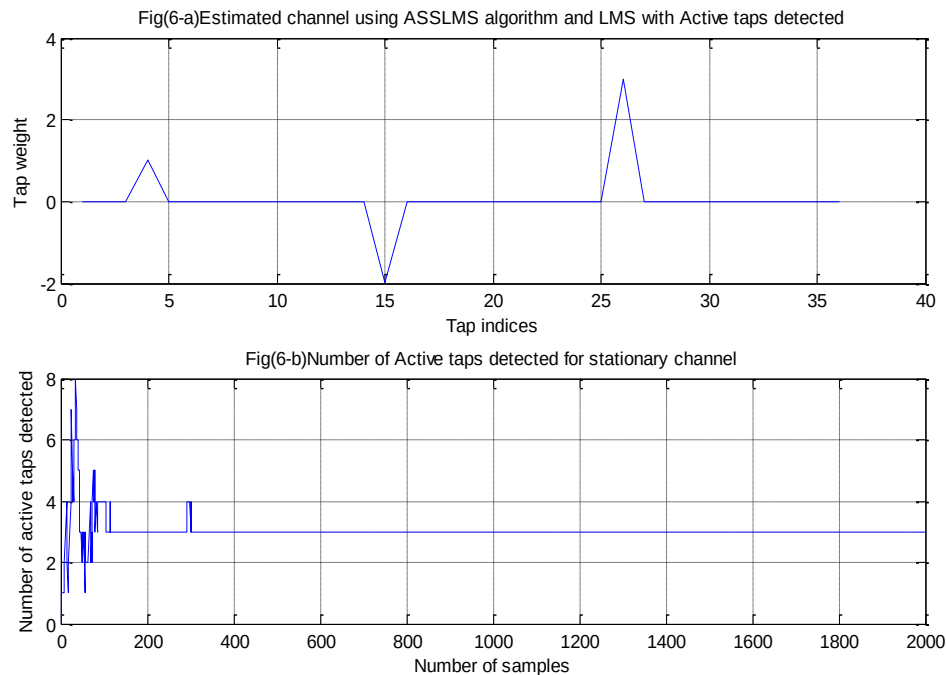


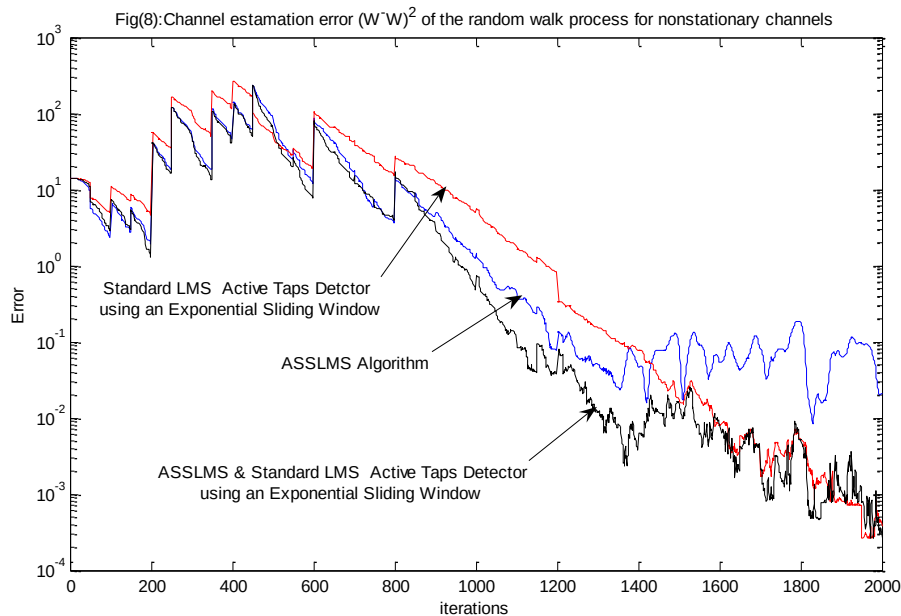
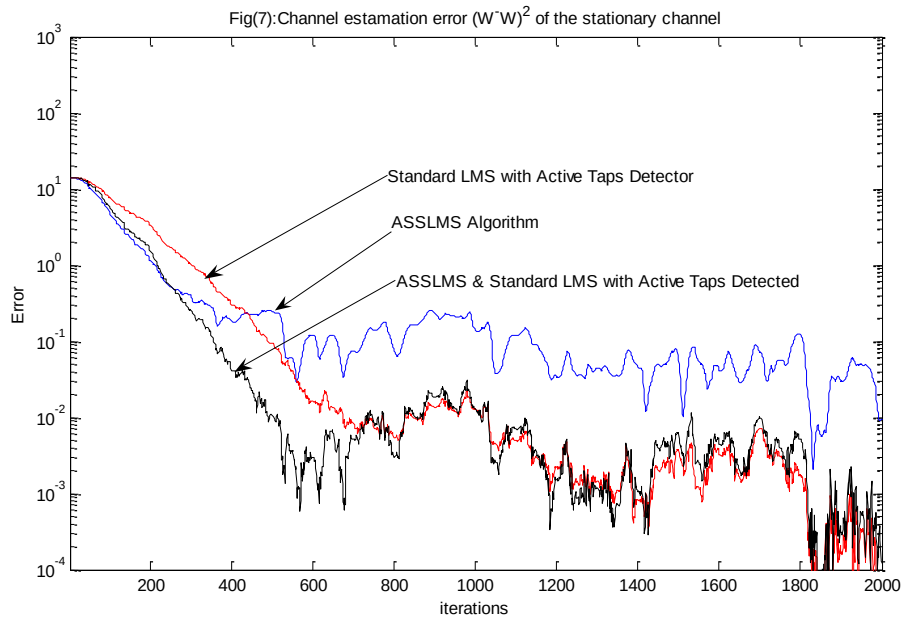
Table (2) The estimated tap vectors (W) of the noise path a(n) using LMS algorithm only

Tap Number	Type	Strength
4 th	Active	1
7 th	inactive	0.3
15 th	Active	-2
19 th	inactive	0.5
22 th	inactive	0.7
24 th	inactive	0.2
26 th	Active	3
35 th	inactive	0.5

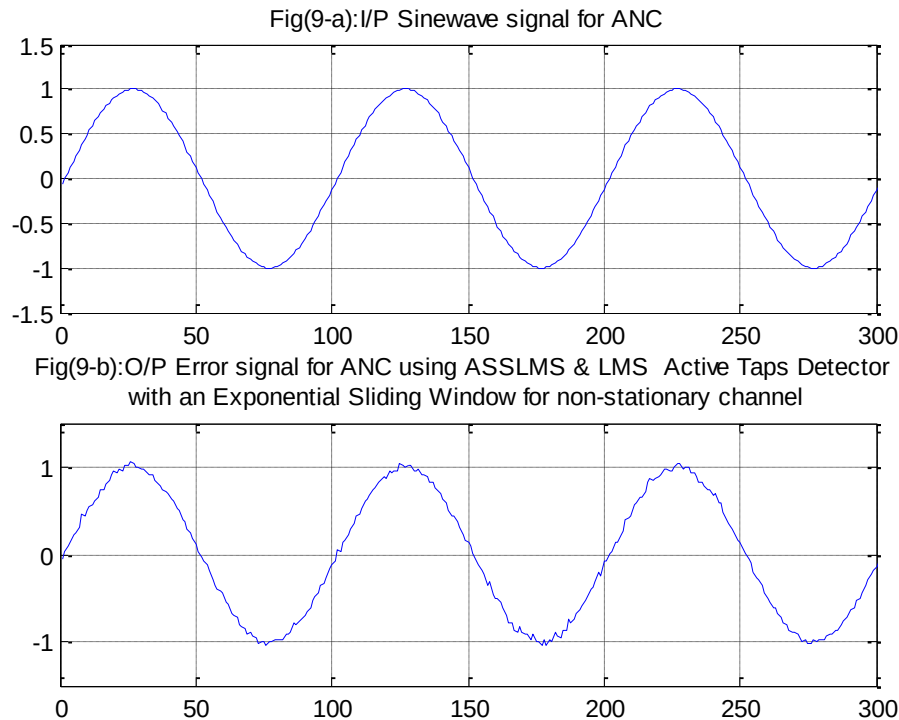
- Combined ASSLMS algorithm and LMS with active taps detector is applied then the estimated channel response is obtained in Fig. (6-a) which is similar to desired response of the stationary channel noise path and no estimation error occurred in this case.
- Also Fig. (6-b) shows that Active taps detector technique success to detect the number of active taps which it is equal to (3) after 100 iterations.
- The values of the parameters used for ASSLMS are as follows: $\mu_{\max} = 0.005$, $\mu_{\min} = 2 \times 10^{-6}$, $\alpha = 0.0001$, and $\sigma = 0.1$.



- Fig. (7) shows the channel estimation error $(W-W^{\wedge})^2$ for all algorithms that are used in this paper with the stationary channel. As shown in this Fig. ASSLMS algorithm has fast convergence time (600 iterations) than standard LMS with active taps detector (700 iterations) but it suffers from high error in the steady state compared to the standard LMS with active taps detector. This is because optimum parameters must be chosen carefully. However, if combined ASSLMS and standard LMS with active taps detector is used then both fast convergence (400 iterations) and low level of error is achieved and the performance of the system is improved compared with that if only standard LMS with active taps detector is used lonely.
- Fig. (8) shows the same result as in Fig. (7) when non-stationary channels that is modeled using random walk process. As shown in this Fig. when combined ASSLMS and standard LMS with active taps detector with an exponential sliding window is used then fast convergence time (1100 iterations) and low level of the error at the steady state is achieved, while ASSLMS has convergence time equal to (1300 iterations) and standard LMS with active taps detector has convergence time equal to (1500 iterations).
- The slight “bumps” in the beginning area of the curves between (200 and 800 iterations) in the Fig. (8) are due to high noise effect of the non-stationary channel.



- In this simulation the rate change (speed) of the non- stationary channel model parameters is equal to 50 iterations. And since the total number of the iterations is 2000, then the total number of the change is 40 times. Also the exponential factor β of the exponential sliding window is equal to 0.98.
- Fig. (9-a) shows the last 300 samples (i.e. from 1700 to 2000 samples) of the input sinewave that is applied to the ANC for the non-stationary channel. Fig.(9-b) shows the corresponding output error signal of the ANC for the last 300 samples using the combined ASSLMS and LMS active taps detector with an exponential sliding window. As shown in this Fig. the output error signal has good estimate of the desired input signal with very low level of the noise at this steady state region.



CONCLUSIONS

This paper presents new idea which has combined ASSLMS algorithm that is developed by us in 1997 and standard LMS algorithm active taps detector technique with an exponential sliding window that developed by dr. J. Homer. Then this combined method is applied to the ANC system to measure its performance for both stationary and non-stationary environments. Although dr. J. Homer suggests his method for only white input noise in adaptive echo canceller, but here in this paper ANC sinewave input signal is applied instead of white noise. The simulation results shows that the combined method gives faster convergence time than the method that suggested by dr. homer, which it is important factors in the adaptive systems. Also the combined method provides lower level of the error in the steady state. However, ASSLMS algorithm alone also has faster convergence time than the method of dr. J.Homer but it is suffers from high level of error at the steady state.

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CALCULATION OF SOIL WATER DIFFUSIVITY USING A MODEL FOR SOIL MOISTURE PROFILE UNDER DIFFERENT SALINITY CONDITIONS

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ABSTRACT

A closed formed model modified from that of van Genuchten (1980) was used to fit the data of soil moisture profile (θ vs. λ) from which the slope $d\lambda/d\theta$ can be evaluated and then the soil water diffusivity $[D(\theta)]$ can be calculated. Diffusivity was calculated for three soil textures under different salinity conditions.

The results showed that the model fitted the data very well with 1% confidence level ($R^2 > 0.93$). $D(\theta)$ increased sharply with soil moisture for all soils but its values were lower when the texture got finer. At a certain sodium adsorption ratio (SAR), $D(\theta)$ increase with the increase of salt concentration (C) of the water infiltrating. Increasing SAR of water caused a decrease in $D(\theta)$ at any level of C. Same trends were obtained for the values of weighted mean diffusivity $\bar{D}$.

حساب الانتشارية المائية للتربة باستخدام انموذج لمنحنى المقد الرطوبي تحت ظروف ملحية مختلفة

الخلاصة

استخدم انموذج مغلق محور عن انموذج (van Genuchten (1980 لمطابقة بيانات منحنى المقد الرطوبي (θ vs. λ) لتقييم ميل منحنى المقد الرطوبي ($d\lambda/d\theta$) والذي باستخدامه تم حساب الانتشارية المائية للتربة. حسبت الانتشارية لثلاث ترب مختلفة النسجة وتحت ظروف ملحية مختلفة لماء الغيض. اظهرت النتائج بأن الانموذج طابق البيانات التجريبية لمنحنى مقد رطوبة التربة بدرجة كبيرة عند مستوى قناعة 1% ($R^2 > 0.93$). ازدادت الانتشارية بشدة بزيادة رطوبة التربة لكافة الترب ولكن قيمها انخفضت عندما تصبح التربة اكثر نعومة. عند مستوى واحد من SAR ازدادت الانتشارية بزيادة التركيز الملحي للماء الغائص. زيادة SAR في التربة ادت الى انخفاض قيم الانتشارية بثبوت التركيز. تم الحصول على نفس التوجه في سلوك قيم معدل الانتشارية الموزون ($\bar{D}$).

INTRODUCTION

The rate of water movement through the soil is of considerable importance in many aspects of agricultural and urban life. The entry of water into soil, the movement to plant roots, the flow of water to drains and wells, and the evaporation of water from soil surface are but a few of the various situations, in which the rate of movement plays an important role (Klute and Dirksen, 1986). The soil properties that determine the behavior of soil water flow system are the hydraulic conductivity, water- retention characteristics, and soil water diffusivity. These properties are often called soil hydraulic properties. Soil water diffusivity $[D(\theta)]$ as a function of volumetric water content (θ) , is the ratio of hydraulic conductivity $K(\theta)$ to the differential water capacity $C(\theta)=d\theta/d\psi$, may be used to analyze the behavior of soil water system. Because of the importance of soil water diffusivity, a lot of work has been done to evaluate, calculate, or predict this transport function. Hence, several empirical and physically-based methods were proposed for this purpose (Gardner and Mayhugh, 1958; Gardner, 1962; Dirksen, 1975; Hillel, 1980).

Soil water diffusivity is calculated directly with some known methods, but can be derived easily from measured conductivity data and water content-suction head relationship (Childs and Collis-George, 1950 and Gardner and Mayhugh, 1958) as the follows:

$$D(\theta) = -K(\theta)/C(\theta) = -K(\theta) d\psi/d\theta \quad \dots\dots\dots(1)$$

The soil-water diffusivity appears in the diffusion form of the one-dimensional (x-direction) horizontal flow equation with time t (Philip, 1957). This equation can be written in the following form:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x} \left[D(\theta) \frac{\partial \theta}{\partial x} \right] \quad \dots\dots\dots(2)$$

with the following initial and boundary conditions:

$$\theta(0, t) = \theta_1 \quad ; \quad \theta(x, 0) = \theta_0 \quad \dots\dots\dots(3)$$

The Boltzmann variable, $(\lambda = xt^{-1/2})$, was used to transform Eq.(1) to an ordinary differential equation. Integrating, using the given boundary conditions in Eq.(2), yield the following equation in terms of soil–water diffusivity:

$$D(\theta) = -\frac{1}{2} \left(\frac{d\lambda}{d\theta} \right) \int_{\theta_0}^{\theta} \lambda d\theta \quad \dots\dots\dots(4)$$

where $D(\theta)$ and $d\lambda/d\theta$ are evaluated at any value of water content θ , as it will be explained later in this introduction.

Bruce and Clute (1956) described a method in which the spatial distribution of water content, determined by destructive gravimetric sampling at a fixed time (t) in a horizontal infiltration flow system, was used to calculate the diffusivity function $[D(\theta)]$.

Whisler et al. (1968) described a method in which the water content as a function of time at a fixed position (soil-water transient) was measured. This procedure requires a nondestructive method of determining the water content in the soil column, such as gamma attenuation.

The water content versus position (θ vs. x) at a series of fixed times, or the water content vs. time (θ vs. t) at a series of fixed positions can be used to construct a plot of λ vs. θ . If the flow is described by the nonlinear diffusion equation and the boundary and initial water contents are constant, the transformed water content – distant – time data should give a unique $\lambda(\theta)$ function. The derivative and integral in Eq.(4) can then be evaluated from the plot of λ vs. θ .

If λ in Eq.(4) is substituted by $xt^{-1/2}$ (Boltzmann variable) in the derivative and integral and arranging the terms result in:

$$D(\theta) = -\frac{1}{2t} \left(\frac{dx}{d\theta} \right) \int_{\theta_0}^{\theta} x d\theta \dots\dots\dots (5)$$

In this case $dx/d\theta$ needs to be evaluated for the calculation of $D(\theta)$.

The variable λ can be calculated from the data of x and t data ($\lambda = xt^{-1/2}$) and plotted vs. θ to obtain a curve of λ vs. θ . Fitting these data resulted in an equation from which the derivative can be obtained and evaluated and so can be the integral term.

This procedure may be done graphically, numerically, or by analytical means if an equation for the fitted curve is available. So, the diffusivity as a function of water content $D(\theta)$ can then be calculated using Eq.(4) or Eq.(5).

A closed form model similar to that used by van Genuchten (1980) for the soil moisture characteristic curve was used to describe the data of θ vs. λ (can also be used for the data of θ vs. x). This model can be written in the following form:

$$\theta = a + b[1 + (c\lambda)^n]^{-m} \dots\dots\dots (6)$$

Where a , b , c , n , and m are fitted parameters, and m has no relation with n . Taking the derivative of Eq.(6) with respect to λ ($d\theta/d\lambda$) resulted in:

$$d\theta/d\lambda = -bcnm (c\lambda)^{n-1} [1 + (c\lambda)^n]^{-(m+1)} \dots\dots\dots (7)$$

Also, Solving [Eq. (6)] for λ results in:

$$\lambda = (1/c) \{[(\theta - a)/b]^{-1/m} - 1\}^{1/n} \dots\dots\dots (8)$$

Equations (6) and (8) were used by Aoda et al. (2005) and Younan (2008) and resulted in very successful results in terms of fitting the soil moisture profile data [either $\theta(\lambda)$, or $\theta(x)$].

Taking the derivative of λ with respect to θ of Eq.(8), $(d\lambda/d\theta)$ can be obtained and calculated for each value of θ as follows:

$$d\lambda/d\theta = (-1/bcnm) \{[(\theta-a)/b]^{-1/m} - 1\}^{(1-n/n)} [(\theta-a)/b]^{-(1+m/m)} \dots\dots\dots(9)$$

This derivative can also be obtained by taking the reciprocal of Eq.(7).

Weighted mean diffusivity ($\bar{D}$) was calculated using the following equation (Crank, 1956):

$$\bar{D}(\theta) = 5/3 [1/(\theta_s - \theta_0)]^{5/3} \int_{\theta_0}^{\theta_s} (\theta - \theta_0)^{2/3} D(\theta) d\theta \dots\dots\dots(10)$$

Where θ_s is the volumetric water content at the inlet end of soil column.

The objective of the work reported here is to use an empirical model [Eq.(6)] to describe the relationship between λ and θ and then to find the slope $d\lambda/d\theta$ [Eq.(7)] which is required in Eq.(4) for calculating soil-water diffusivity as a function of volumetric water content [$D(\theta)$]. Values of soil water diffusivity was used as a hydraulic property to study the effect of the salinity and sodicity of irrigation water on soil water diffusion.

MATERIALS AND METHODS

Three different soil samples of different texture (namely, sandy loam, loam, and clay loam) were collected from the surface layer (0 – 30 cm) from Jadriya location in Baghdad. These soils were classified under the subgroup of Typic torrifluvents. Samples were air-dried and sieved through 2-mm sieve openings. Chemical and physical properties of these samples were determined using the procedures given by Page et al. (1982) and Klute et al. (1986), respectively (see table 1).

Water of different salinity [$C=50, 100$ and 200 meq/l] and sodicity [$SAR = 0, 10$, and $20 \text{ (mmole/l)}^{1/2}$] were used for performing the flow experiments. Nine combinations of C and SAR plus the control treatment ($C=0, SAR=0$) were used to run horizontal infiltration experiments in uniform soil columns packed homogeneously (see Aoda, 1982), with the three different soil textures. Plexiglas columns of 40-cm long and 3.17-cm inside diameter were constructed by combining tightly the rings of 2-cm length using transparent tape. One end of the column was closed by a perforated Perspex glass plate, while the other end was connected to the water applicator (see Al- Douri, 2002).

Horizontal water flow experiments were performed to obtain the required data for calculating soil water diffusivity following the procedure of Bruce and Klute (1956). Volume of water infiltrated into the soil and wet front advance with time were recorded until the wet front reached a distance of 30 cm from the inlet end of the column. At this instance, water entry was cut off and the column was sectioned by sharp blade to determine the water content and bulk density for each ring. Bulk density was also



determined for each ring to test the uniformity of the whole column. The column was rejected if the coefficient of variability (C.V) exceeded 2% (Nofziger and Swartzendruber, 1976).

Soil water diffusivity $[D(\theta)]$ was calculated using Eq.(4) where the derivative $d\lambda/d\theta$ was calculated from the proposed equation [Eq.(7)]. The procedure and calculation were done for ten different water qualities for each soil texture.

Table 1: Some physical and chemical properties of the soils used.

Soil property	Soil texture		
	Sandy loam	Loam	Clay loam
Sand (g/Kg)	663.8	490.7	364.2
Silt (g/Kg)	252.3	326.1	330.9
Clay (g/Kg)	83.9	183.2	304.9
Bulk density (Mg/m^3)	1.500	1.447	1.410
EC_e^* (dS/m)	0.82	1.60	2.40
pH	7.82	7.78	7.60
Carbonates (g/Kg)	195.6	204.8	232.8
Gypsum (g/Kg)	Nil	3.8	4.00
Organic matter (g/Kg)	11.17	13.07	13.67
CEC^{**} (cmole charge/Kg)	15.85	19.20	21.80
Total porosity (m^3/m^3)	0.434	0.454	0.468
Mean weight diameter (mm)	0.252	0.309	0.482

* EC_e is the electrical conductivity of the extract soil saturated paste .

** CEC is the cation exchangeable capacity.

RESULTS AND DISCUSSION

Table 2 shows the results of fitting Eq.(6), θ vs. λ . The parameters a,b,c,m, and n are listed in the table along with the values of residual mean squares of θ ($RMS\theta$) and the coefficient of determination (R^2). The fitting was done by using the Statistical Analysis System (Statistica) . The model fitted the data very well (0.01 level) indicated by the high values of R^2 and the small values of $RMS\theta$. This finding is the same for the three soils and for all experiment combination of salinity (salt concentration ,C) and sodicity (sodium adsorption ratio, SAR).

Values of parameter a in table 2 represent the values of the initial volumetric water content θ_0 , and the values of b in the table represent the values of θ behind the wet front θ_m minus the values of θ_0 (i.e., $b = \theta_m - \theta_0$). If parameter a is added to parameter b, the

result is θ_m . If this θ_m is divided by the total porosity (f) for each soil (Table 1), the result is the saturation ratio(S). When this is done using tables 2 and 1, the percentage of saturation was about 83% ,85%,and 87% for sandy loam, loam, and clay loam soils , respectively.Values similar to these were found by van Duin (1955) , Aoda (1982) and Aoda et al.(1993). Some good consistence for the c and n values

Table 2: Results of fitting Eq.(6) for all experiments of salinity combinations.

Texture	SAR	Conc.	a	b	c	n	m	RMS θ	R ²
Sandy Loam	0	0	0.0260	0.3400	0.4679	26.854	73.396	6.052*10 ⁻⁴	0.93657**
		50	0.0270	0.3390	0.4605	26.845	96.005	6.134*10 ⁻⁴	0.93545**
		100	0.0270	0.3390	0.4552	27.069	106.990	6.125*10 ⁻⁴	0.93548**
		200	0.0270	0.3390	0.4427	27.031	143.901	5.998*10 ⁻⁴	0.93669**
	10	50	0.0260	0.3402	0.4701	26.475	89.430	6.159*10 ⁻⁴	0.93567**
		100	0.0270	0.3396	0.4622	26.741	89.939	6.026*10 ⁻⁴	0.93668**
		200	0.0270	0.3390	0.4527	27.038	81.807	6.235*10 ⁻⁴	0.93435**
	20	50	0.0256	0.3414	0.4798	26.991	103.912	6.227*10 ⁻⁴	0.93492**
		100	0.0260	0.3401	0.4683	26.720	90.979	6.267*10 ⁻⁴	0.93432**
		200	0.0270	0.3390	0.4527	26.775	84.806	6.208*10 ⁻⁴	0.93462**
Loam	0	0	0.0282	0.3588	0.5740	27.174	77.428	6.783*10 ⁻⁴	0.93572**
		50	0.0282	0.3588	0.5703	27.366	77.020	6.709*10 ⁻⁴	0.93645**
		100	0.0286	0.3584	0.5637	27.144	78.755	6.656*10 ⁻⁴	0.93677**
		200	0.0283	0.3587	0.5514	27.658	61.967	6.902*10 ⁻⁴	0.93445**
	10	50	0.0280	0.3598	0.6103	27.794	90.493	6.730*10 ⁻⁴	0.93632**
		100	0.0280	0.3595	0.5903	27.983	81.623	6.995*10 ⁻⁴	0.93377**
		200	0.0280	0.3590	0.5702	27.359	76.058	6.852*10 ⁻⁴	0.93502**
	20	50	0.0281	0.3589	0.6429	27.473	88.964	6.809*10 ⁻⁴	0.93557**
		100	0.0280	0.3593	0.6169	27.355	91.416	6.821*10 ⁻⁴	0.93531**
		200	0.0280	0.3590	0.5971	27.134	83.897	6.673*10 ⁻⁴	0.93683**
Clay Loam	0	0	0.0300	0.3760	0.6967	27.466	98.834	7.947*10 ⁻⁴	0.93080**
		50	0.0320	0.3750	0.6924	27.173	92.915	7.468*10 ⁻⁴	0.93437**
		100	0.0300	0.3780	0.6811	27.174	102.943	7.663*10 ⁻⁴	0.93369**
		200	0.0323	0.3757	0.6471	27.058	75.557	7.391*10 ⁻⁴	0.93528**
	10	50	0.0300	0.3780	0.7888	27.634	114.939	7.686*10 ⁻⁴	0.93336**
		100	0.0300	0.3790	0.7468	27.135	88.897	7.492*10 ⁻⁴	0.93513**
		200	0.0300	0.3780	0.7084	26.720	98.729	7.434*10 ⁻⁴	0.93548**
	20	50	0.0300	0.3790	0.8743	27.851	104.316	7.311*10 ⁻⁴	0.93674**



	100	0.0300	0.3800	0.8258	27.079	96.382	7.253×10^{-4}	0.93620**
	200	0.0290	0.3810	0.7951	26.549	106.695	7.561×10^{-4}	0.93537**

** Significant at 0.01 level

were found for each soil. Wide variations in values of parameter m were found even in the same soil texture.

Results of table 2 suggest that the model is quite capable of describing the data of θ vs. λ with more than 93% (values of R^2). This finding indicates the capability of using this model to describe the slope $d\theta/d\lambda$ and hence $d\lambda/d\theta$ of Eq.(4), therefore, the parameters listed in table 2 can be used in Eq.(8) to find $d\theta/d\lambda$ and hence $d\psi/d\theta$ or in Eq.(9) to find $d\lambda/d\theta$ directly. The slope $d\lambda/d\theta$ can then be used in Eq.(4) along with the integral term to calculate the soil water diffusivity $[D(\theta)]$.

Soil water diffusivity as a function of water content was calculated for all treatment combinations listed in table 2 (30 experiments). Diffusivity was then plotted against the relative water content (θ/θ_m). Plotting the three curves representing the three soils on one figure resulted in total of ten figures. Three typical examples of these figures are shown in Figures 1, 2, and 3.

It is obvious from all figure that $D(\theta)$ increases sharply with water content and the increase becomes sharper near saturation. This finding has also been found by Aoda et al.(1993). This increase was explained by Bruce and Klute (1956) on the basis of the gradual increase in the radii of water conducting pores and consequently a decrease in tortuosity of the actual flow path when the water content increases towards saturation.

For each concentration, an increase in SAR caused a decrease in D for all levels of θ especially near saturation. This decrease is more pronounced for low concentration and high SAR levels. This can be explained by the theory of diffuse double layer when applied to mixed electrolyte systems in the following manner: at a given water content, the distance between clay particles increase with the increase in SAR and decrease in C . For a constant total soil volume, changes in spacing between clay platelets result in changes in pore size geometry(Aoda et al.,1993).An increase in spacing would, therefore, cause a decrease in ratio of macro to micropores. Then, at a given θ , D decrease with an increase in SAR and a decrease in C .

Values of weighted mean diffusivity ($\bar{D}$) calculated by Eq.(10) for all treatment combinations are listed in table 3. Increasing salt concentration(C) caused a significant increase (at 0.01 level) in $\bar{D}$ for a certain SAR level and the increase was higher for higher C levels. At each level of C , $\bar{D}$ was higher with lower level of SAR. For example, for sandy loam soil, at $C=100$ meq/l, $\bar{D}$ was decreased in the following order : 0.3303, 0.3251, 0.3162 cm^2/min when SAR increase from 0, 10, and 20 respectively. Similar trend is more clear for the other two soils. The results of $\bar{D}$ decreased due to the increase in SAR indicates again the deterioration of pores and this

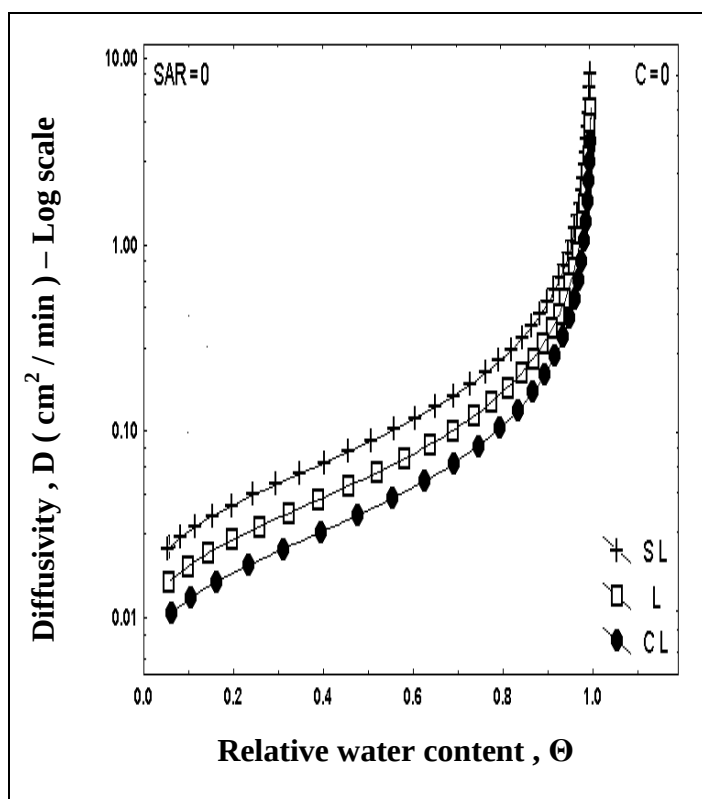


Figure 1: Soil water diffusivity vs. relative water content for the three soils ($C=0, \text{SAR}=0$)

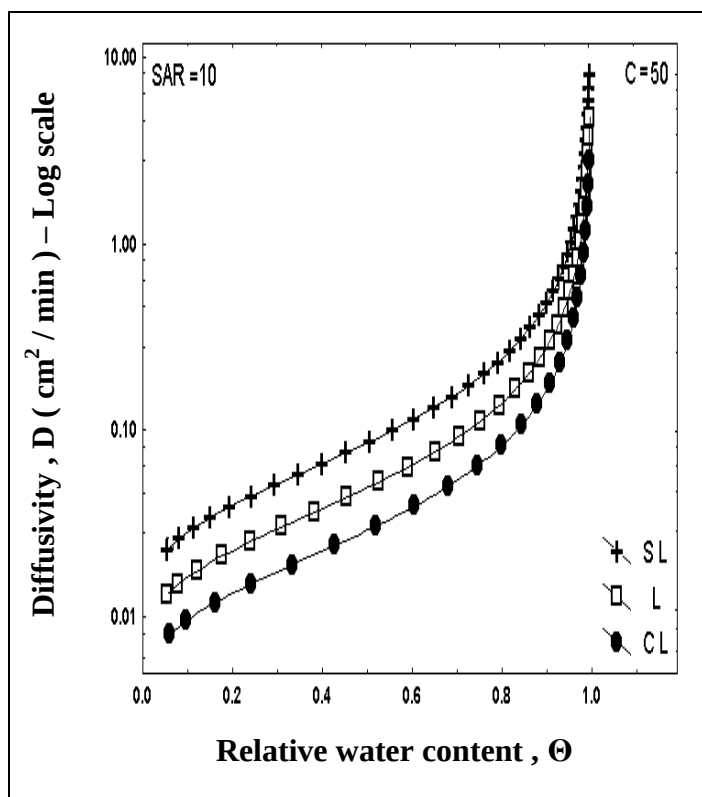


Figure 2: Soil water diffusivity vs. relative water content for the three soils ($C=50, \text{SAR}=10$)

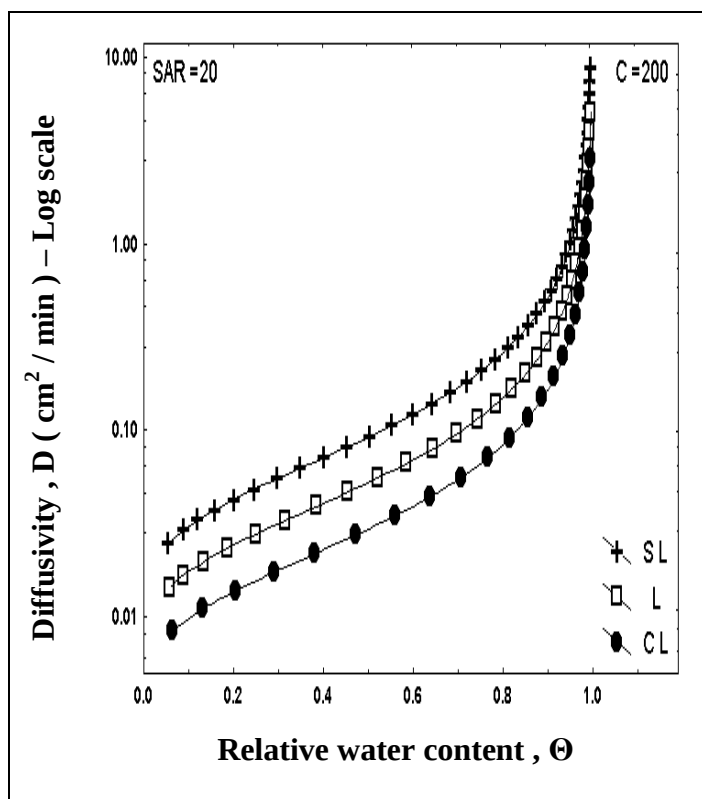


Figure 3: Soil water diffusivity vs. relative water content for the three soils (C=200,SAR=20)

deterioration is reduced by increasing salt concentration (C) . For example, when C=50 meq/l, $\bar{D}=0.2095\text{cm}^2/\text{min}$ for SAR=0 while $\bar{D}=0.1602\text{cm}^2/\text{min}$ for SAR=20 in the loam soil. Same conclusion is obtained for the other two soils. It is clear from the table that at the same level of SAR, increasing C would increase the values of $\bar{D}$. This finding is very important in leaching alkali soils using saline water which would protect soil pores from being deteriorated.

Table 3: Mean weighted diffusivity for the three soils and all salinity combinations.

SAR (mmol/l) ^{1/2}	C (meq/l)	Weighted Mean Diffusivity, $\bar{D}(\theta)$ cm ² .min ⁻¹		
		Texture		
		Sandy Loam	Loam	Clay Loam
0	0	0.3213	0.2073	0.1342
	50	0.3257	0.2095	0.1380
	100	0.3303	0.2156	0.1417
	200	0.3409	0.2272	0.1616
10	50	0.3155	0.1777	0.1014
	100	0.3251	0.1914	0.1175
	200	0.3408	0.2097	0.1315
20	50	0.2959	0.1602	0.0815
	100	0.3162	0.1713	0.0943
	200	0.3400	0.1897	0.1028

*LSD**0.001**0.0007**0.0004*

CONCLUSIONS

From this study it can be concluded :

- The suggested model fitted the data of soil moisture profile very well and so it can be used to evaluate the slope $d\lambda/d\theta$ which is required for the determination of soil water diffusivity $[D(\theta)]$.
- Increasing the salt concentration (C) of the water infiltration at constant level of sodium adsorption ratio (SAR) increased the values of $D(\theta)$.
- Increasing SAR at constant C of the water infiltration decreased the values of $D(\theta)$.

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DEMULSIFICATION OF CUTTING FLUID BEFORE DISPOSAL TO THE ENVIRONMENT

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ABSTRACT

In this research the treatment of 7201 cutting fluid was carried out to decrease its environmental impact on water resources after being used and being less effective due to the action of contaminants.

The breaking of emulsion was carried out using two methods: The first method was by using acid and/or heat. 1 molar sulfuric acid was used to decrease pH to 1.5 whth heating the emulsion to 90 °C. It was found that the acid is the dominating factor in emulsion breaking and the maximum efficiency achieved was 85% after one day using (10335 ppm) sulfuric acid. The second method was by using two different types of coagulants calcium chloride (CaCl₂) and ferric chloride (FeCl₃) at different emulsified oil concentrations (2, 4, 6, 8, 10% by volume.), and the residual oil concentration in water layer was measured for each experiment.

It was found that using ferric chloride (FeCl₃) gave the best emulsion breaking and least residual oil concentration in water layer for all emulsified oil concentrations.

الخلاصة

تم في هذا البحث معالجة سائل القطع نوع 7201 المنتج في مصفى الدورة في بغداد لتقليل تأثيره السيء على البيئة المائية بعد تلفه نتيجة الاستعمال وتكاثر الاحياء المجهرية فيه وقد تمت المعالجة بطريقتين تتمثل الاولى بكسر استحلاب سائل القطع بواسطة حامض الكبريتيك (بتركيز 1 مولاري) مع التسخين لغاية 90 درجة مئوية وقد وجد بان التأثير الاكبر كان للحامض وليس للحرارة ولم تتعدى كفاءة الفصل بهذه الطريقة 85 % بعد مرور يوم كامل باستعمال حامض كبريتيك بكمية (10335) جزء بالمليون. الطريقة الثانية كانت باستعمال كلوريد الكالسيوم وكلوريد الحديدك وباستعمال عدة تراكيز للزيت المستحلب (2, 4, 6, 8, 10% حتما). وقد وجد بان استعمال كلوريد الحديدك يعطي افضل نتائج في كسر الاستحلاب باستعمال كمية اقل منه وان تركيز الزيت في الطبقة المائية يكون اقل ايضا.

KEY WORD

Demulsification, cutting fluid, environment,

INTRODUCTION

Metal working fluids are engineering materials that are employed in metal working processes. In manufacturing activities metal working fluids used for material removal processes are known as cutting and grinding fluids .

Cutting fluid pumps over the cutting site of machines such as lathes, milling machines, shapers and saws for cooling the tool, work piece and chips or for lubricating

A variety of cutting fluids are available to satisfy the requirements of machining processes. The four basic types of cutting fluids are as follows:

Straight oils, synthetic fluids, semi-synthetic fluids and emulsifiable cutting fluid which are the largest type of cutting fluids.

After being used the fluids become less effective because of their thermal degradation and contamination by substances in suspension therefore they must be replaced periodically, generating a waste stream called spent cutting oil (José, 2002). It is desirable then to separate the oil phase from the water phase, in order to minimize the disposal costs and to minimize the negative impact of fluid disposal on the environment (Ian, 2005).

Spent metal cutting fluids may be considered hazardous wastes due to the products formulation or by absorbing contaminants through metal working operations (Joseph, 1999).

The environmental impact of metal working wastes can be acute. Heavy metals, acids, surfactants and oils are all highly toxic to aquatic life. Serious stream degradation results from the direct discharge of insufficiently treated metal wastes.

Oils in drinking water sources cause objectionable taste and odours, turbidity and film, and make filtration treatment difficult. Bioassay data indicate that oil is toxic to fish. In greater quantities, it limits oxygen transfer, hindering biological activity (Abid, 2004).

In general, no single treatment process or commercial device will remove all forms of oil (free, emulsified or dissolved) in oil-water mixtures.

The most commonly used method to break the emulsion is chemical treatment (chemical addition). (Dennis, 1982).

Process wastewater from metal working operations contains free or suspended oil and emulsified oil. These oils originate mainly from parts washer overflow and machining coolant dumping, and the concentration typically ranges from 1,000 - 10,000 ppm as emulsified oil and perhaps 30,000 ppm as free suspended and floating oil (Gealer, 1980).

The breaking of emulsions is necessary in many industrial operations, million of dollars are being spent each year in preventing or breaking an emulsion

Emulsion breaking can be very complex, because no two emulsions are alike. Even emulsions from a single source can vary over time. The result is that emulsion breakers, or demulsifiers, must be selected, and even formulated on a case-by-case basis (champ, 2008).

There are different actions of chemicals in breaking of emulsion which include:

- a - Balance or reverse interfacial surface tension, (addition of other type of surfactant).
 - b- Precipitate emulsifying agents, traditionally sulfuric acid has been used in oily waste treatment plants as the first step in emulsion breaking.
 - c- Neutralize stabilizing electrical charges. The accumulated electric charges on the emulsified droplet are neutralized by introducing a charge opposite to that of the droplet
- Chemical emulsion breakers provide this opposite charge and cause flocculation to form larger particles for subsequent removal.

The dielectric characteristics of water and oil cause emulsified oil droplets to carry negative charges. Therefore, to destabilize an oil-in-water emulsion, a cationic (positive charge) emulsion breaker should be used (Kemmer, 1988).

A common method of determining relative emulsion stability of water-in-oil or oil-in-water is a simple bottle test method (batch separation test). This batch method is an attractive method for the study of separation behavior of emulsions due to its simple and inexpensive experiments.

This method is recommended by Fuchs Lubricating Company, Nalco Water Company and Others (FUCHS, 2005 , Shweta, 2005, Christine, 2001, Taylor, 1994). This test measures the time required for an oil-water mixture to separate by gravity as well as quantity of residual oil remain in the water layer after separation and finding the best required time to complete the demulsification process (separation time) and the effect of emulsified oil concentration.

Experimental work and procedure.

Preparation of 7201 oil emulsion (10% by vol.):

The emulsion was prepared by adding 150 ml of cutting oil (7201) to 600 ml of deionized water (as recommended by oil manufacturer) followed by mixing for 5 minutes using mechanical stirrer at 1500 rpm. 750 ml of deionized water was added gradually while mixing for 10 min at 1500 rpm to form 1.5 liter of emulsion (Kutweel. 2007)

The mixture was diluted by mixing with deionized water to produce other concentrations of cutting fluid (8%, 6%, 4% and 2%) by volume respectively.

Breaking the emulsion of 7201 cutting fluid using sulfuric acid:

This was done by adding 1 molar sulfuric acid to 100 ml of emulsion until pH equal to 1.5 while heating it until reaches 90C° and kept at this temperature for 15 minutes. The mixture was placed into graduated cylinder to measure the volume of the separated oil layer. The evaluation is based on the volume of the separated layer (Figure 1).



Fig. 1 Emulsion breaking evaluation was based on the volume of the separated layers.

Breaking the emulsion of 7201 cutting fluid using coagulants:

This procedure was carried out as following:

- a- solution of 10% by wt. of ferric chloride (FeCl_3) was made (each 10 gm was dissolved in 90 ml of deionized water). For (CaCl_2) solution of 20% by wt. was made (each 20 gm was dissolved in 80 ml of deionized water).
- b- specific quantity of coagulant solution was added to 100 ml 2% by vol. emulsion at 25 °C and mixed for one minutes using magnetic stirrer. The mixture was poured into graduated cylinder which was placed in a water bath at 25 °C. The volume of separated oil layer was measured at intervals for 30 minutes.
- c- The evaluation of the emulsion breaking was based on the volume of the separated oil layer (if the volume of separated oil layer was less than the initial emulsified oil concentration (2% by vol.) then the quantity of coagulant was increased and the procedure was repeated until the volume of the separated oil layer equal to the initial emulsified oil concentration.
- d- When the separated oil layer volume was equal to the initial emulsified oil concentration a sample (10-15 ml) was taken from the water layer for the determination of pH and the residual oil concentration in water layer using U.V spectrophotometer.
- e- The procedure was repeated for emulsified oil concentration of 4%, 6%, 8%, 10% vol. respectively.
- f- The procedure (steps by step) was repeated for both types of coagulants.
- g- The evaluation of the emulsion breaking was based on both of the volume of separated layer as well as the residual oil concentration in water layer.

Analytical method

Determination of Oil Concentration

Ultraviolet spectrophotometer (UV) was used for measuring oil concentrations directly at 204 nm . Calibration curve was carried out using different concentrations of emulsion of (25, 50, 75, 100, 125, 150) ppm. Absorbance of these samples was measured. (Figure 2). The calibration curve for these concentrations against absorbance was plotted as shown in Figure (3).

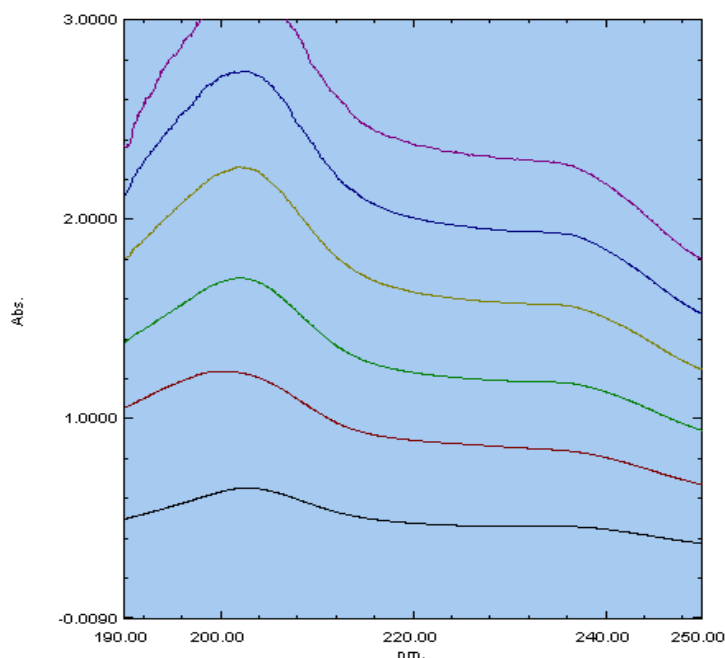


Fig. 2 Reading of U.V using different concentrations of emulsified oil.

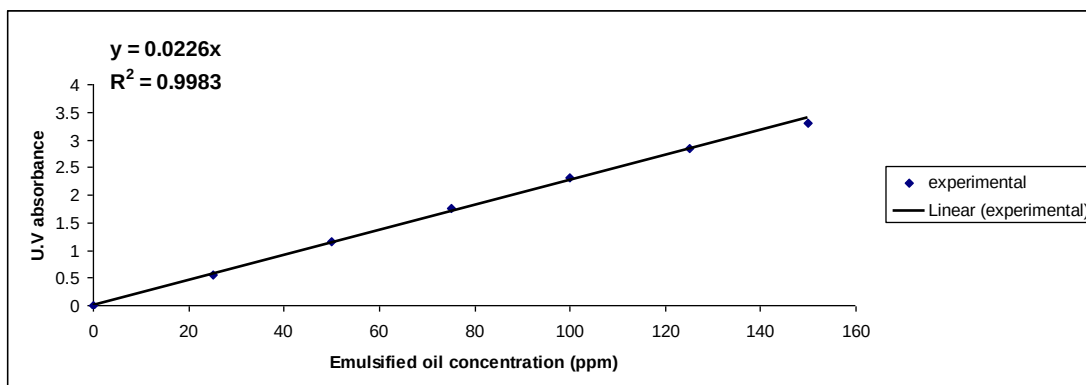


Fig. 3 Calibration curve for different concentrations of emulsified oil against absorbance of U.V.

RESULTS AND DISCUSSION

Effect of using sulfuric acid and/or heat to break 7201 cutting fluid emulsion:

The first experiment was done using heat only, the temperature was raised gradually to 100 °C (it takes 30 minutes) the volume of the separated oil layer was 1.2 ml (equal to 12% of oil).

The second experiment was carried out using 1 molar sulfuric acid to decrease the pH of 10% by vol. emulsion to 1.47. The volume of the separated oil layer was 6.3 ml (equal to 63% of oil), at temperature 33 °C.

The third experiment was done using 1 molar sulfuric acid to decrease the pH of the emulsion to 3 and the temperature was raised gradually to 100 °C. The volume of the separated oil was 2.5 ml (equal to 25% of oil). The heating was stopped and the volume was observed with time for 40 minutes. The final volume was 3 ml (equal to 30% of oil) (Figure. 4). After 5 days at room temperature the volume of the separated oil layer was 4 ml (equal to 40% of oil).

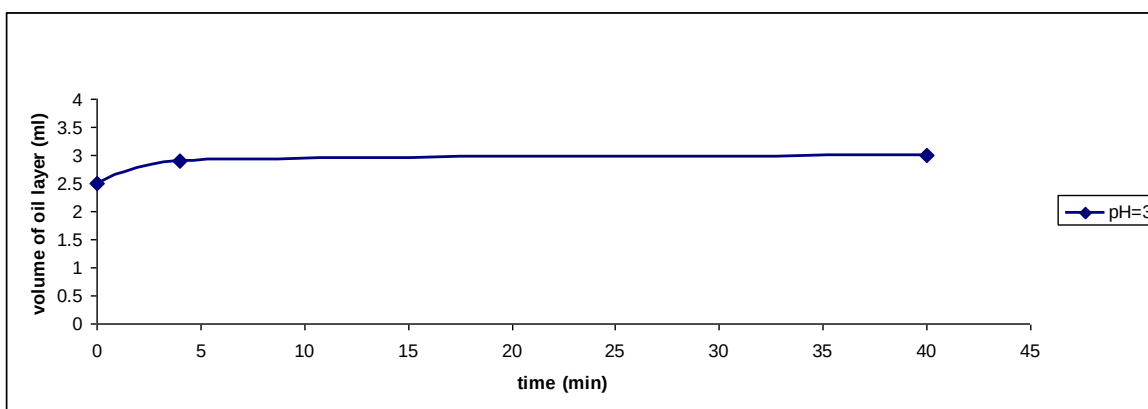


Fig. 4 Effect of sulfuric acid and heating (100 °C) to break emulsion.

The fourth experiment was carried out using 1 molar sulfuric acid to decrease the pH of 10% by volume emulsion to 1.5 and the temperature was raised gradually to 90 °C and kept at this

temperature for 15 minutes. The volume of the separated oil layer was 7.2 ml (equal to 72% of oil). After 1 day at room temperature the volume of the separated oil layer was 8.5 ml.

Examining experiment one and two it can be seen that the emulsion breaking efficiency for heating is only 12% while the emulsion breaking efficiency for sulfuric acid is 63%.

These efficiencies are low compares with using heating and acid together as in experiment four.

The third experiment showed that using heat and acid at pH=3 together lead to increases the emulsion breaking from 12% -25%.

These results indicated progress in the efficiencies compared with first experiment.

The fourth experiment indicated that by decreasing pH from 3 to 1.5 leads to increase in the emulsion breaking efficiency from 25% to 72 % even so decreasing the temperature from 100C° to 90 °C. This behavior showed that the acid is the dominating factor in emulsion breaking.

All the experiments which were carried out as mentioned above showed low efficiencies (72% after 15 minutes), knowing that best experiment consumed 9 ml of 1 molar sulfuric acid for 100 ml of 10% by vol. emulsion (equal to 10335 ppm of acid) which is a high quantity compared to the quantity of coagulants .

The other disadvantage of using acid is that the water layer is highly acidic and needs a treatment to raise pH before discharging to water streams by using suitable alkaline materials like sodium hydroxide (NaOH) solution. As well as the risk of using, handling and storing of highly corrosive and hazardous materials (sulfuric acid and sodium hydroxide).

From above it was clear that using acid and heat were not the best choice to treat the 7201 cutting fluid emulsion where the efficiency of emulsion breaking didn't exceed 85% after 5 days.

Therefore the experiments were shifted to the following experiments to achieve higher efficiencies.

Effects of coagulation to break 7201 cutting fluid emulsion:

The decision was made to carry out the research by studying the factors effecting emulsion breaking by coagulation process with different types of coagulants calcium chloride (CaCl₂) and ferric chloride (FeCl₃). Knowing that for using these coagulants, any experiment which did not give an oil layer volume equal to the initial oil volume in emulsion or did not reach the steady state within 30 minutes was rejected.

The coagulation process depends strongly on the charge of particles (droplets); the maximum rate of flotation can be achieved when the zeta potential of the particles is zero.

The addition of chemicals overcomes the repulsive effects of the electrical double layers to allow the finally sized oil droplets to form larger droplets through coalescence.

Using calcium chloride as coagulant:

Different oil in water emulsion concentrations (2%, 4%, 6%, 8%, 10% by volume) were studied by using 20% wt solution of CaCl₂ as coagulant because it is highly soluble salt.

The experimental results were plotted in Figures (5 - 9) as oil layer volume (visual observation) with time. These figures showed that the oil layer volume increased with time.

Examining figures (5 - 7) it can be seen that adding 1 ml of 20% by wt CaCl₂ will break emulsion for oil concentration 2%,4%,6% respectively while adding 1.1 ml and 1.3 ml will break emulsion of oil concentration 8% , 10% respectively (Figures 8 and 9). Therefore it is clear that the use of CaCl₂ had low efficiency at low oil concentration.

The experimental results showed also that the residual oil concentrations in water layer are proportional to the initial oil concentration (Figure 10).

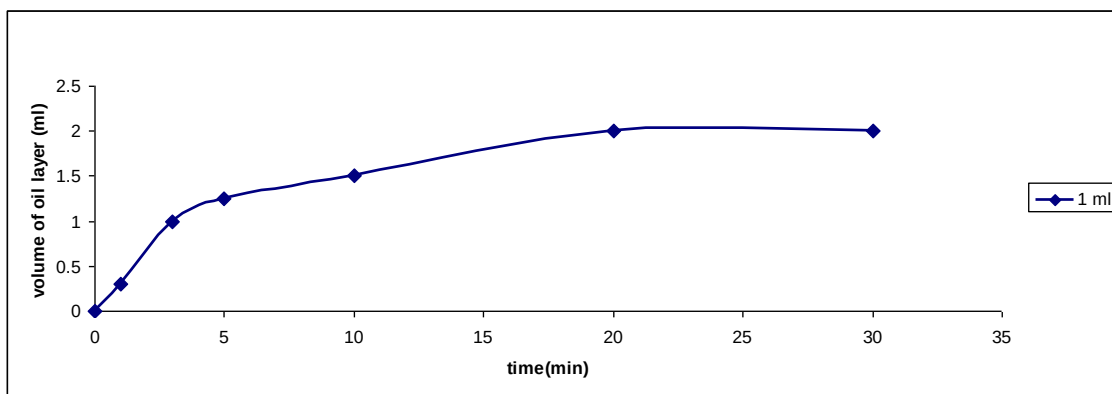


Fig. 5 Effect of using 20% by wt. CaCl_2 to break 2% by vol. emulsion at 25 °C.

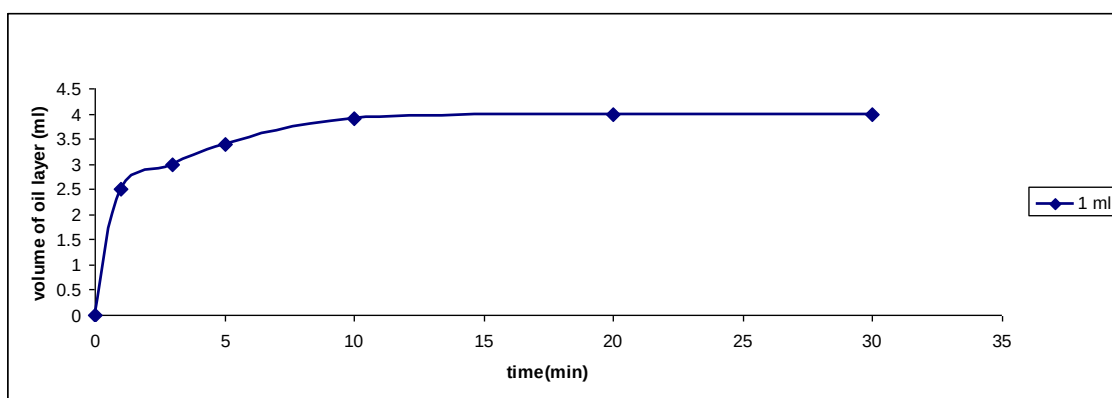


Fig. 6 Effect of using 20% by wt. CaCl_2 to break 4% by vol. emulsion at 25 °C.

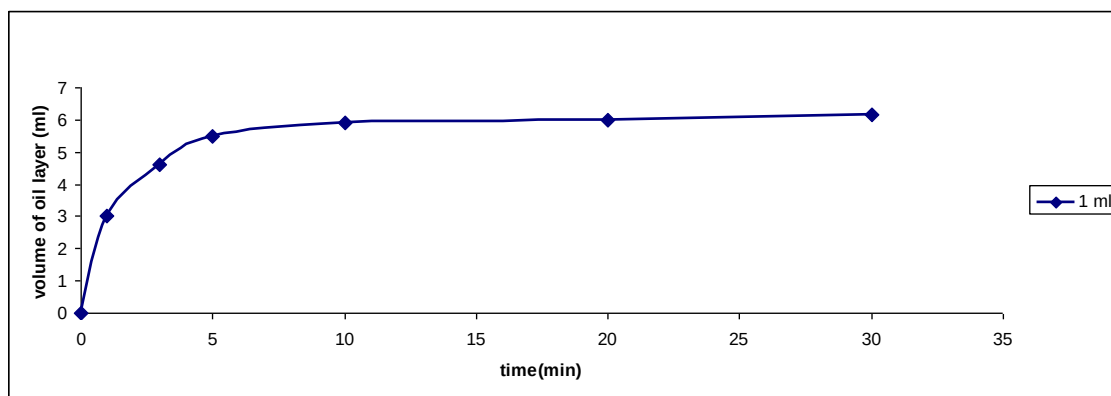


Fig. 7 Effect of using 20% by wt. CaCl_2 to break 6% by vol. emulsion at 25 °C.

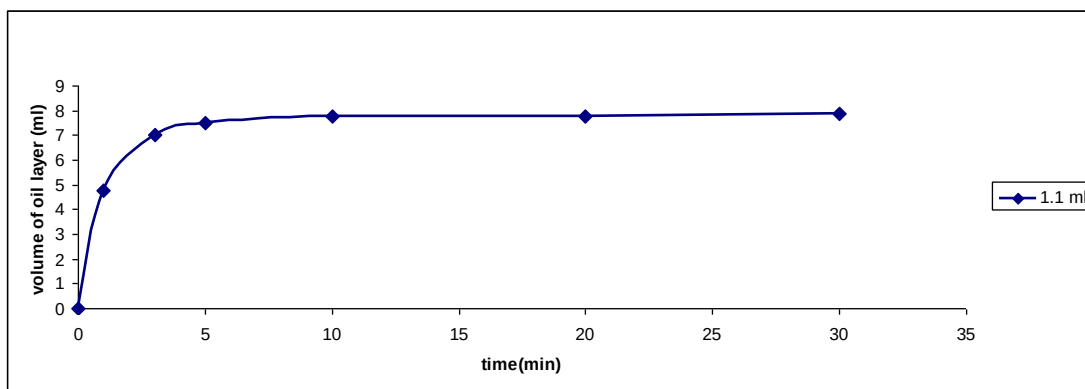


Fig. 8 Effect of using 20% by wt. CaCl_2 to break 8% by vol. emulsion at 25 °C.

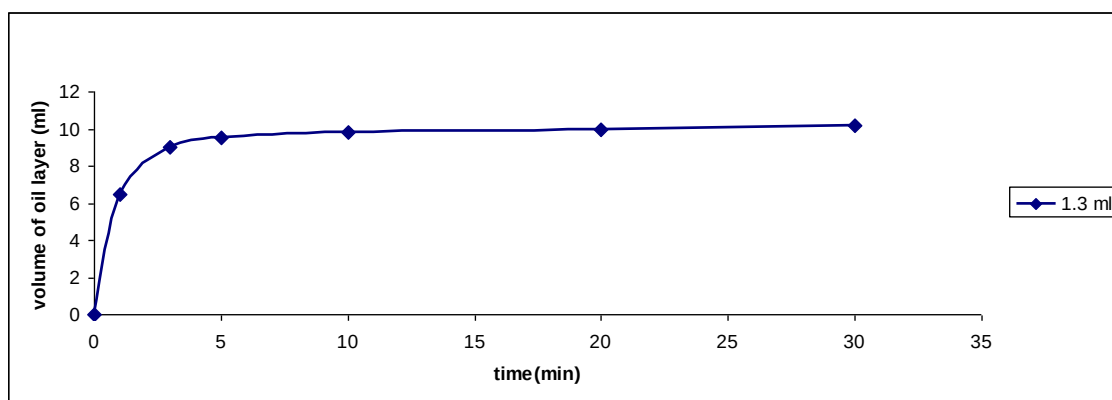


Fig. 9 Effect of using 20% by wt. CaCl_2 to break 10% by vol. emulsion at 25 °C.
Effects of oil in water emulsion concentration on CaCl_2 quantity as coagulant.

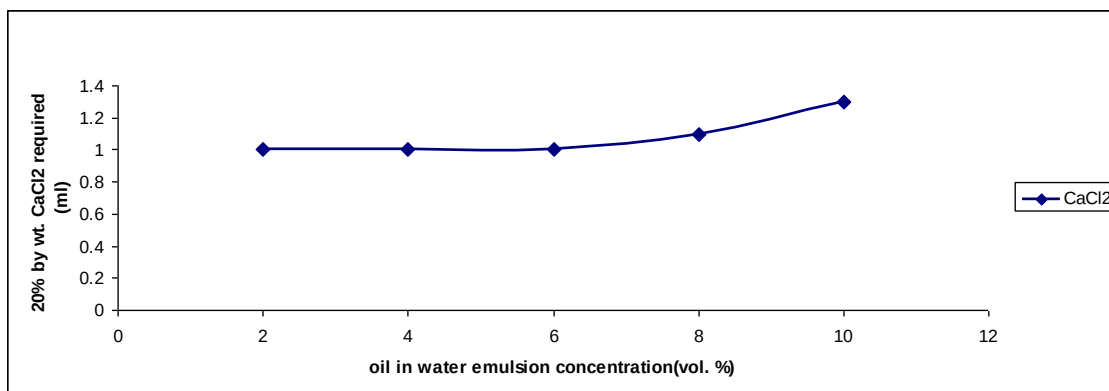


Fig. 10 Effect of using 20% by wt. CaCl_2 to break emulsion with various concentrations at 25 °C.

Effects of CaCl_2 on oil concentration in water layer after coagulation (The quantity of residual oil):

The quantity of residual oil in water layer after coagulation using 20% by wt. CaCl_2 to break emulsion is proportional to the initial emulsified oil (Figure 11).

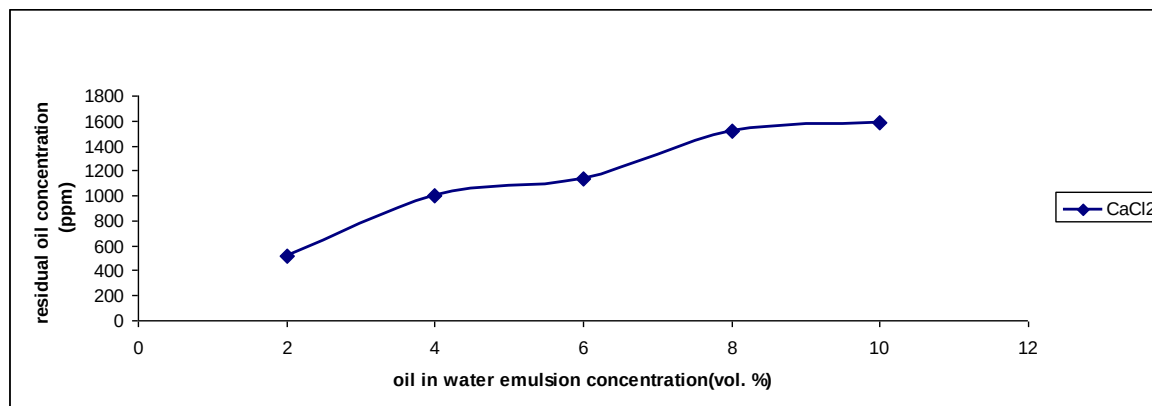


Fig. 11 Effect of using 20% wt. CaCl_2 to break emulsion with various concentrations on residual oil at 25 °C.

USING FeCl_3 AS COAGULANT:

Different oil in water emulsion concentrations (2%, 4%, 6%, 8%, 10% by volume) were studied by using 10% by wt. solution of FeCl_3 as coagulant.

The experimental results were plotted in Figures (12 – 18) as oil layer volume (visual observation) with time. These figures showed that the oil layer volume increased with time.

Examining Figures(12 -16) it can be seen that adding (0.5, 0.6, 0.9, 1.1 and 1.2 ml) of 10% by wt. FeCl_3 will break emulsion for oil concentration 2%, 4%, 6%, 8% and 10% respectively (Figure 17). The experimental results showed also that the residual oil concentrations in water layer are proportional to the initial oil concentration (Figure 18).

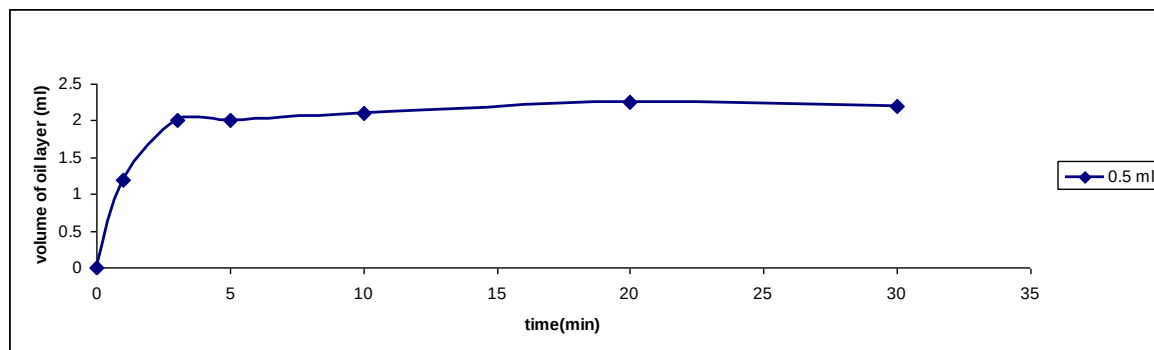


Fig. 12 Effect of using 10% by wt. FeCl_3 to break 2% by vol. emulsion at 25 °C.

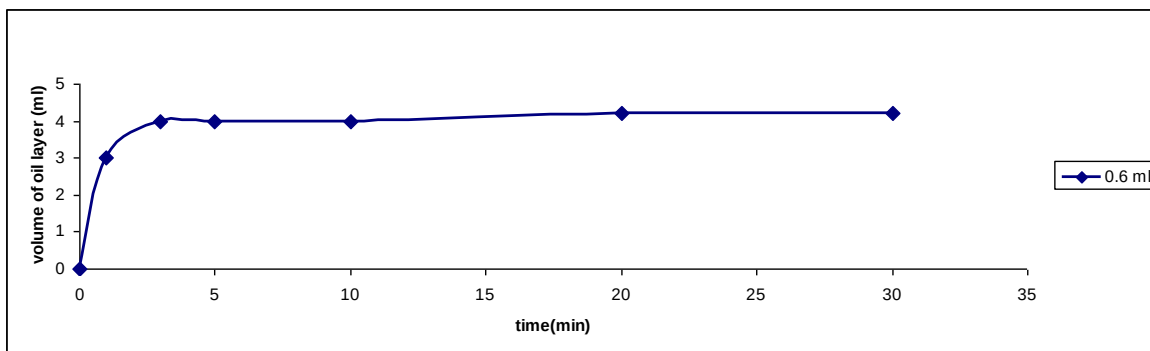


Fig. 13 Effect of using 10% by wt. FeCl₃ to break 4% by vol. emulsion at 25 °C.

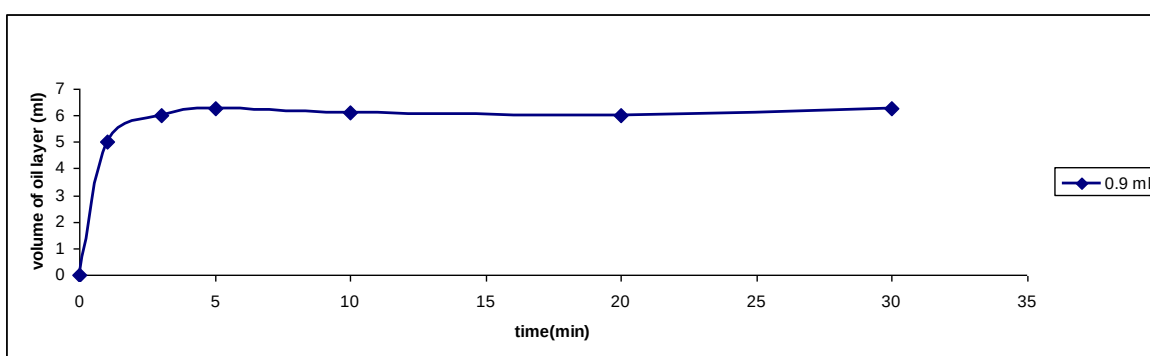


Fig. 14 Effect of using 10% by wt. FeCl₃ to break 6% by vol. emulsion at 25 °C.

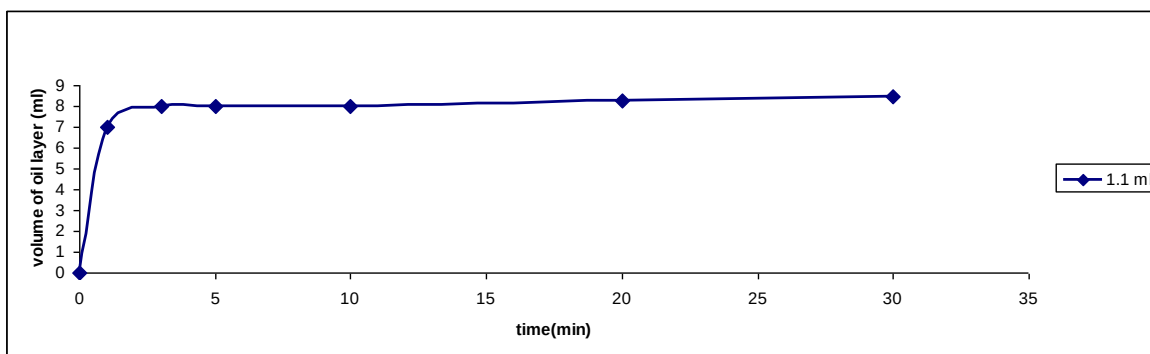


Fig. 15 Effect of using 10% by wt. FeCl₃ to break 8% by vol. emulsion at 25 °C.

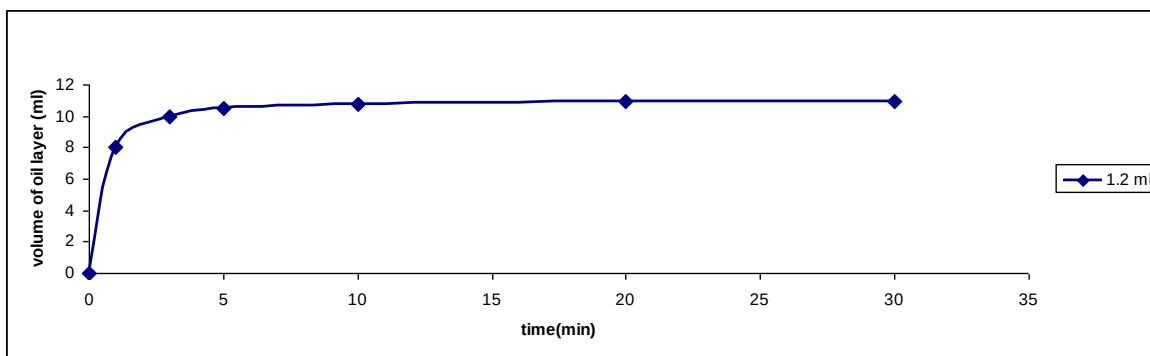


Fig. 16 Effect of using 10% by wt. FeCl₃ to break 10% by vol. emulsion at 25 °C.

Effects of oil in water emulsion concentration on FeCl₃ quantity required as coagulant.

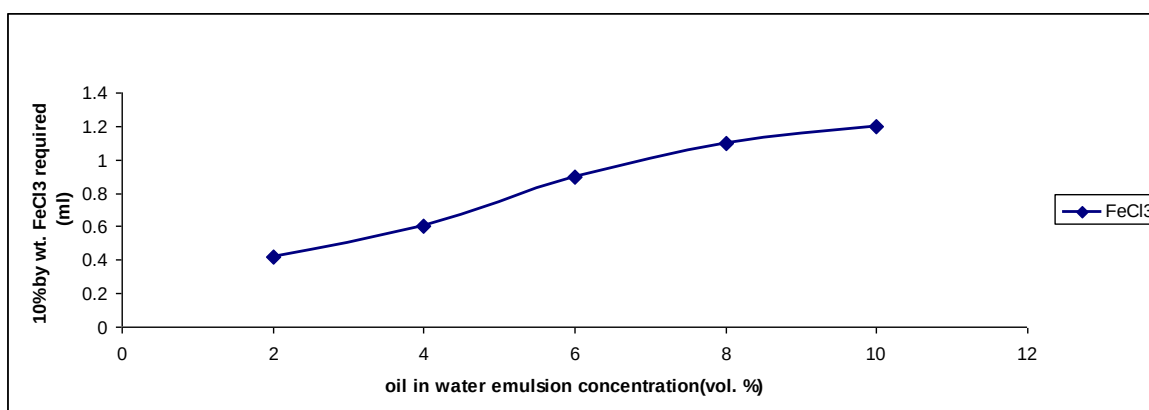


Fig. 17 Effect of using 10% by wt. FeCl₃ to break emulsion with various concentrations at 25 °C.

Effects of FeCl_3 on oil concentration in water layer after coagulation (the quantity of residual oil):

The quantity of residual oil in water layer after coagulation using 10% by wt. FeCl_3 to break emulsion is proportional to the initial emulsified oil (Figure 18).

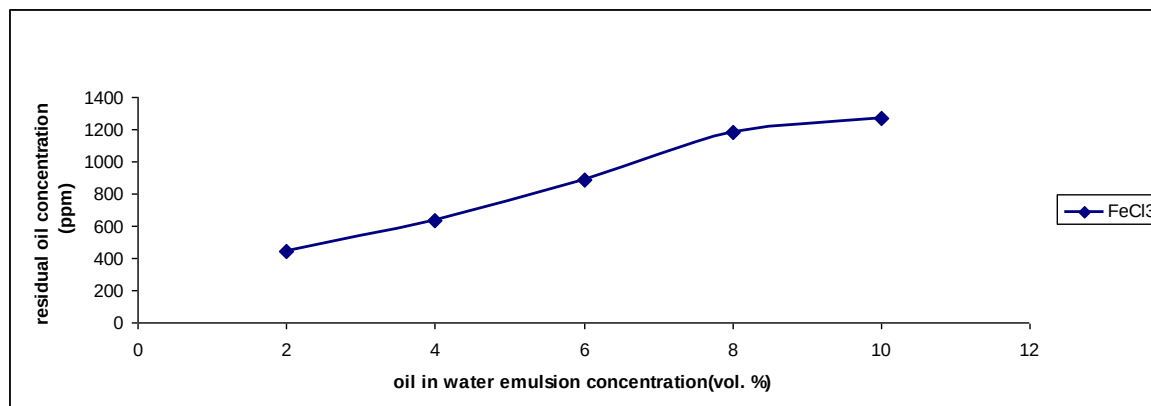


Fig. 18 Effect of using 10% by wt. FeCl_3 to break emulsion at various concentrations on residual oil at 25 °C.

CONCLUSIONS:

- For 7201 cutting fluid emulsion sulfuric acid and heating up to 90°C will break about 85% of the emulsion. But this method consumes time for heating, breaking and for cooling the liquid layer before further treatment. It consumes high quantity of acid and alkaline materials in addition to the risk of handling, using and storing of these materials. So this method is not the best choice to treat the oily wastewater generated from spent 7201 cutting fluid.
- 2-The use of coagulant will save heating power, time, and chemical materials
- 3-The required time to finish the coagulation, coalescence and the separation processes is only 20 minutes if high mixing speed or long mixing time (3 minutes) is used.
- 4- The use of CaCl_2 was less effective compared with FeCl_3 but it has a very good advantage because it does not decrease pH, so it is less harmful to pipes and equipments, and water layer needs no neutralization step after separation.

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ADDING PERFECT FORWARD SECRECY TO KERBEROS

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ABSTARCT

Kerberos system is a powerful and widely implemented authentication system. Despite this fact it has several problems such as the vulnerability to dictionary attacks which is solved with the use of public key cryptography. Also an important security feature that is not found in Kerberos is perfect forward secrecy. In this work the lack of this feature is investigated in Kerberos in its original version. Also a public key based modification to Kerberos is presented and it is shown that it lacks the prefect forward secrecy too. Then some extensions are proposed to achieve this feature. The extensions are based on public key concepts (Diffie-Hellman) with the condition of keeping the password based authentication; this requires little modifications to the original Kerberos. Four extensions are proposed; two of them modify the (Client-Authentication Server) exchange achieving *conditional perfect forward secrecy*, while the remaining two modify the Client-Server exchange achieving *perfect forward secrecy* but with increased overhead and delay.

الخلاصة

نظام Kerberos هو نظام قوي و فعال و مستخدم بصورة واسعة. لكن هناك عدة مشاكل يعاني منها هذا النظام، إحداها ضعفه أمام هجمات القاموس و قد تم حل هذه المشكلة بالاعتماد على التشفير بالمفتاح العام (public key). لكن هناك خاصية أمنية مهمة غير متوفرة في هذا النظام وهي السرية الأمامية التامة (أو السرية المستقبلية التامة). هذا البحث يقوم بدراسة النظام من ناحية وجود هذه الخاصية أم لا بالإضافة إلى دراسة أحد الأنظمة المحورة عن النظام الأصلي باستخدام التشفير بالمفتاح العام (public key)، ويظهر البحث افتقار النظامين الأصلي و المحسن لهذه الخاصية. ثم يقدم البحث مقترحات تتضمن بعض التعديلات على نظام (Kerberos) من أجل تحقيق السرية الأمامية التامة. التعديلات تستند على مبادئ التشفير بالمفتاح العام (public key) طريقة (ديفي-هلمان) بشرط المحافظة على خاصية التعريف بالاعتماد على كلمة السر و هذا يضمن كون التعديلات قليلة على النظام الأصلي و سهولة التطبيق. يعرض البحث أربعة تعديلات، اثنتان منها تغير الحوار بين العميل و خادم التعريف (Client-Authentication Server) محققة السرية الأمامية الشرطية، بينما تغير الاثنتان الأخرى الحوار بين العميل و الخادم (Client-Server) محققة السرية الأمامية التامة لكن مع زيادة التأخير.

KERBEROS, Public Key, Forward Secrecy, Authentication, Diffie-Hellman, Security

INTRODUCTION

Kerberos is an authentication system developed at Massachusetts Institute of Technology (MIT) as part of Project Athena [Miller et al,1987]. There are two versions of this system: Kerberos v4 and Kerberos v5. The later solved some of the problems found in v4. It is based on symmetric encryption and trusted third party. Several problems are found in Kerberos, but dictionary attacks is the most known attack and the one that has got a lot of attention in trying to reduce its risk. One of the proposed extensions to solve this attack, known as Public Key Cryptography for Initial Authentication in Kerberos (PKINIT), modifies the basic protocol to allow public-key authentication; in the process, it adds a fair amount of complexity to the protocol [Cervesato et al,2008]. Other solutions are the use of the Secure Remote Password (SRP) protocol [Wu,1999], and the Public key based Kerberos for Distributed Authentication (PKDA) [Sirbu and Chuang,1997]. Other directions that are taken by some researchers is to use Elliptic Curve Cryptography (ECC) and Elliptic Curve Diffie Hellman (ECDH) as the public key mechanism in Kerberos [Zhu et al, 2008][Ozkan, 2003] and the same mechanisms can be used in the extensions that will be proposed in this paper.

A security feature that is not found in Kerberos is “*perfect forward secrecy*”, which means that the compromise of long term secret keys leads to the compromise of all past session keys [Menezes et al,1996], a problem that is considered serious in some environments, and it is the main focus of this work. The reason is that it was not a feature in the original design, so it uses long term symmetric keys to encrypt the session keys. The details of the protocol will be shown in section 2. In section 3, one of the extensions presented in PKINIT will be shown for comparison with the extensions that will be proposed in this paper in section 4 to add perfect forward secrecy to Kerberos. A comparison is made between the proposed extensions in section 5.

KERBEROS V5

It is well known that Kerberos is based on symmetric encryption and trusted third party. Figure (1) shows the exchanges of the original Kerberos v5. The client (C) shares with the authentication server (AS) a long term key; and truly speaking the secret is a password (K_U shared between the “User” on the client machine and AS).

- The password is used to encrypt a timestamp and sent by the client to AS which decrypts and checks for time synchronization, this step is used to authenticate the user.
- AS sends a key ($K_{C,TGS}$) to be used between the client (C) and ticket granting server (TGS), this key is sent encrypted using K_U . AS also sends the client a ticket granting ticket (TGT) which contains the same key, ($K_{C,TGS}$), encrypted using a long term key shared between AS and TGS. Steps 1 and 2 represent the authentication phase exchange.
- The next phase, steps 3 and 4, are carried between the client (C) and TGS. In this phase the client authenticates itself to TGS by sending a timestamp encrypted using $K_{C,TGS}$. The client also sends the ticket TGT granted by AS, also it sends the name of the server S that it wants to communicate with.
- TGS decrypts the ticket TGT using the key shared with AS ($K_{AS,TGS}$), and it extracts the key $K_{C,TGS}$. Then it decrypts the message sent by the client and checks the timestamp to see the authenticity of client. Then TGS creates a session key ($K_{C,S}$) to be used between C and S. In this exchange the key ($K_{C,TGS}$) is used to authenticate C to TGS in step 3 and used in step 4 to encrypt the session key $K_{C,S}$. TGS also sends the client a ticket (TKT_S) to be used with the server (S). This ticket TKT_S contains the same key, ($K_{C,S}$), encrypted using a long term key shared between TGS and S.
- Steps 5 and 6 represent the last phase at which the exchange occurs between the client and server. In step 5 the client authenticates itself to the server by sending a timestamp encrypted under the session key ($K_{C,S}$). The client also sends TKT_S to the server.

- The server decrypts TKT and extracts the key ($K_{C,S}$), and use this key to check the authenticity of client message. Then the server authenticates itself to client by sending a timestamp encrypted under the same session key.

Since the client passes through steps 3 and 4 for each server it wants to contact, the key ($K_{C,TGS}$) is sometimes called a multisession key, because $K_{C,TGS}$ is used to encrypt many session keys. The concept of perfect forward secrecy is lost by encrypting the session keys using the multisession keys, and by encrypting the multisession keys using the password derived keys. So the compromise of multisession key causes the compromise of all session keys encrypted under it. Also the compromise of the password derived key (K_U) causes the compromise of the multisession key and consequently the session keys.

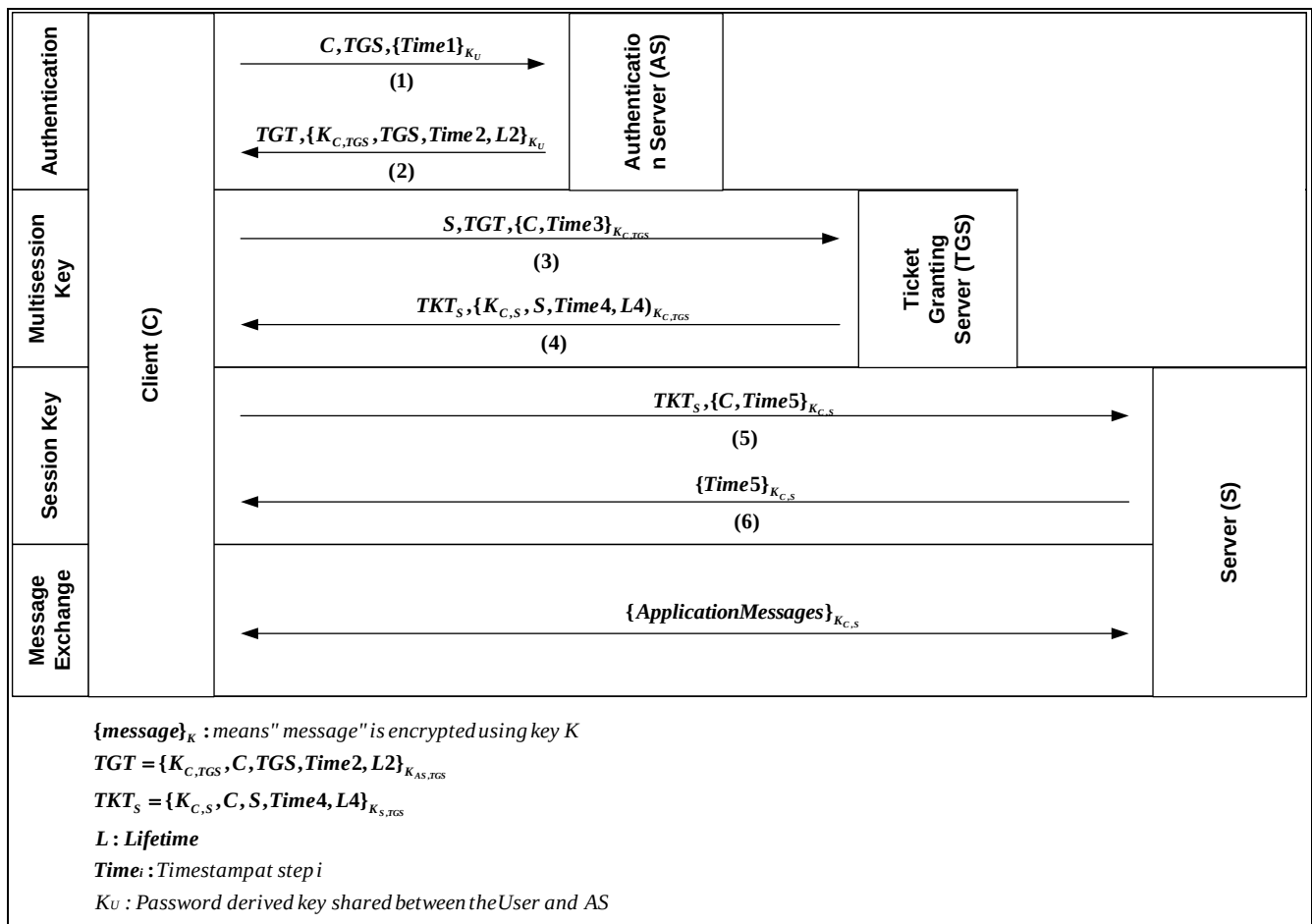


Fig. 1 Original Kerberos v5 Exchange

PKINIT

Public-Key Kerberos PKINIT [Zhu and Tung, 2006] is an extension to Kerberos v5 that uses public key cryptography to avoid shared secrets between a client and AS; it modifies the authentication exchange but not other parts of the basic Kerberos v5 protocol. The long-term shared key (K_U) in the traditional exchange is typically derived from a password, which limits the strength of the authentication to the user's ability to choose and remember good passwords; PKINIT does not use K_U and thus avoids this problem.

In PKINIT, the client (C) and AS each has a pair of public-private key (PK_C, SK_C) and (PK_{AS}, SK_{AS}). $Cert_C$ and $Cert_{AS}$ are certificates that prove the authenticity of PK_C and PK_{AS} because they

are signed by a trusted Certificate Authority. PKINIT can operate in two modes namely public key encryption mode and Diffie-Hellman mode. The keys are used during the authentication phase only. But they are used in different ways according to the mode. The Diffie-Hellman mode is investigated here and shown in Figure (2) because it achieves conditional perfect forward secrecy.

Diffie-Hellman [Diffie and Hellman,1976] key agreement provided the first solution to allow two parties, without shared keys, to establish a secret key by exchanging messages over unsecured channel. But it does not achieve authentication. Authentication is achieved here using the certificates. The key ($K_{C,TGS} = g^{ab}$) cannot be derived from Diffie-Hellman (D-H) exponents g^a and g^b which are sent publicly. Which means that AS will not send the key to the client encrypted under any key. So the compromise of the client's long term key (SK_C) will not help to get the key ($K_{C,TGS}$). This provides perfect forward secrecy. But ($K_{C,TGS}$) is also found in TGT encrypted under the long term key ($K_{AS,TGS}$) shared between AS and TGS. This yields the fact that the compromise of ($K_{AS,TGS}$) causes ($K_{C,TGS}$) to be compromised, meaning that perfect forward secrecy is not achieved. That's why we call it conditional perfect forward secrecy, because under the assumption that ($K_{AS,TGS}$) is shared between two well protected servers, the possibility of compromise is small but not impossible.

This extension involves several time consuming operations at both the client side and AS side because the goal was to deal with dictionary attacks on passwords.

Client Side

- Evaluating g^a .
- Digital signature creation using SK_C .
- Digital signature verification of $Cert_{AS}$.
- Digital signature verification using PK_{AS} .
- Evaluating g^{ab} .

AS Side

- Digital signature verification of $Cert_C$.
- Digital signature verification using PK_C .
- Evaluating g^b .
- Evaluating g^{ab} .
- Digital signature creation using SK_{AS} .

PROPOSED EXTENSIONS

The PKINIT using Diffie-Hellman achieves conditional perfect forward secrecy, but it involves many public key operations and the requirement of certificate authority. This adds many changes to the original Kerberos. In the following sections some extensions are proposed to achieve perfect forward secrecy or conditional perfect forward secrecy with as ***little changes to Kerberos*** as possible. The extensions also consider ***the reduction of public key operations*** as possible. Four extensions are proposed, two of them modify the Client-AS exchange achieving *conditional perfect forward secrecy*, while the remaining two modify the Client-Server exchange achieving *perfect forward secrecy*. The solutions ***assume the password based authentication*** even that it has some weaknesses, but it stills the main authentication approach in most systems, so ***certificates are avoided***. By that we minimize the changes made to Kerberos which simplifies its implementation in the future.

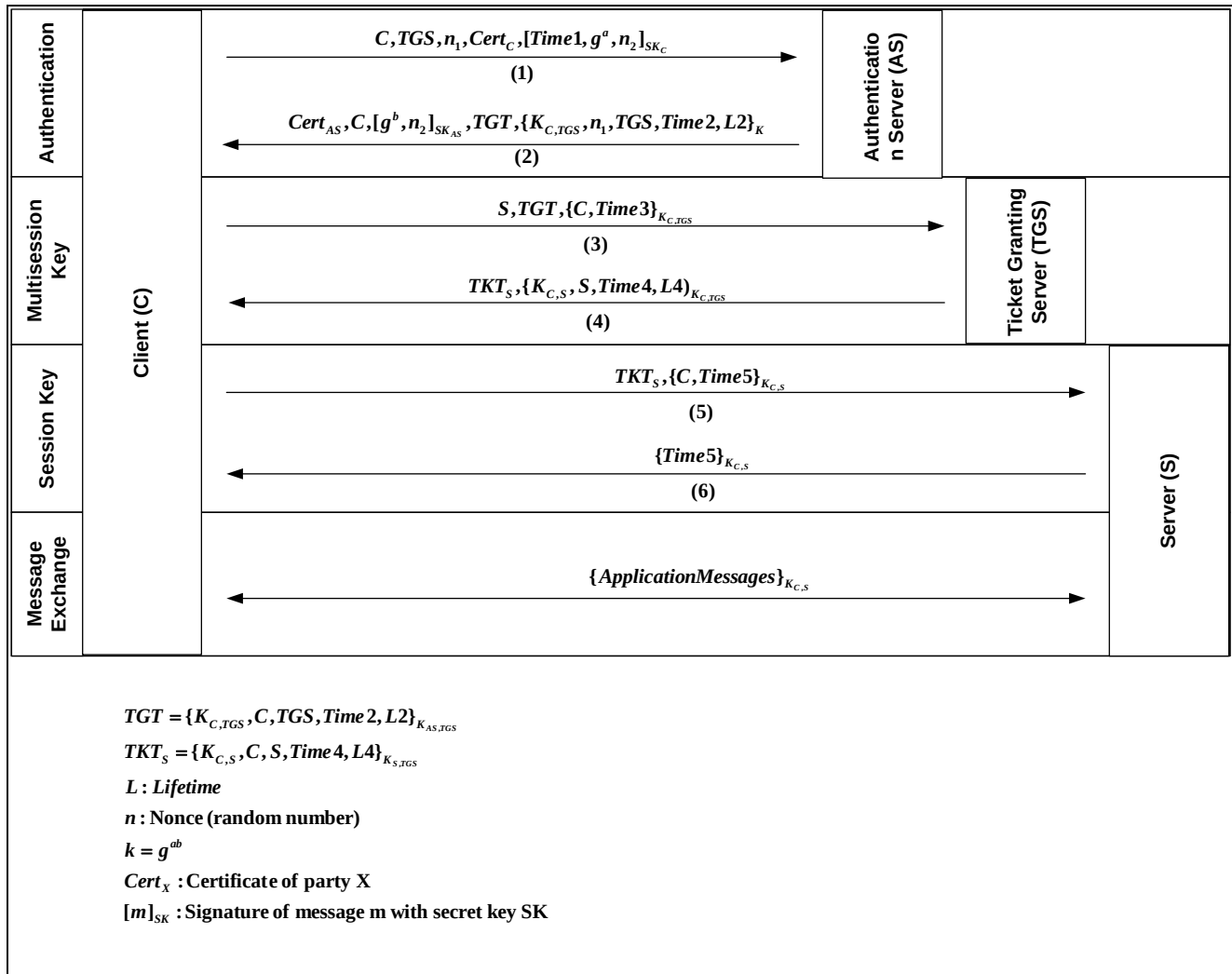


Fig. 2 Diffie Hellman based PKINIT exchange

Changing The Client-AS Exchange (First Extension Group)

The first extension group changes the exchange between the client and the authentication server (AS); this group has two extensions which are presented in part A and B below.

A) The extension uses the same concept of PKINIT with Diffie-Hellman but without the use of certificates. Figure (3) shows this extension, where only steps 1 and 2 are modified. The idea is to get $(K_{C,TGS})$ without being sent encrypted under a long term key. To accomplish this, the client generates private information (a) and sends public information (g^a). AS generates (b) and sends (g^b). Then both calculate g^{ab} , while no one other than the two can find this value because the publicly known info is only g^a and g^b , this achieves perfect forward secrecy. $h(g^a)$ represents the hash of g^a , and is sent encrypted under K_U such that AS can be sure of the authenticity of g^a . On the other hand $h(g^a, g^b)$ is sent encrypted under K_U to prove the authenticity of g^b to the client, and to acknowledge the reception of g^a . The hash is sent instead of the information itself because it is smaller in size. The size of the hash output depends on the algorithm used and not on the size of input information. Some hash functions that can be used are MD5, SHA-1, and SHA-2. The recommended one is the SHA-2 in its various sizes. Also the National Institute of Standards and Technology (NIST) has launched a public competition to develop a new cryptographic secure hash algorithm, which NIST is naming "SHA-3" which is expected to be finally presented in year 2012 [William, 2008].

Like PKINIT in previous section, this approach achieves *conditional perfect forward secrecy*, since $K_{C,TGS}$ is sent encrypted using $K_{AS,TGS}$ inside the TGT. Since certificates are not required it gives some advantages concerning the computational load on the two parties, and the communication cost. The time consuming operations are given below:

Client Side

- Evaluating g^a .
- Evaluating g^{ab} .

AS Side

- Evaluating g^b .
- Evaluating g^{ab} .

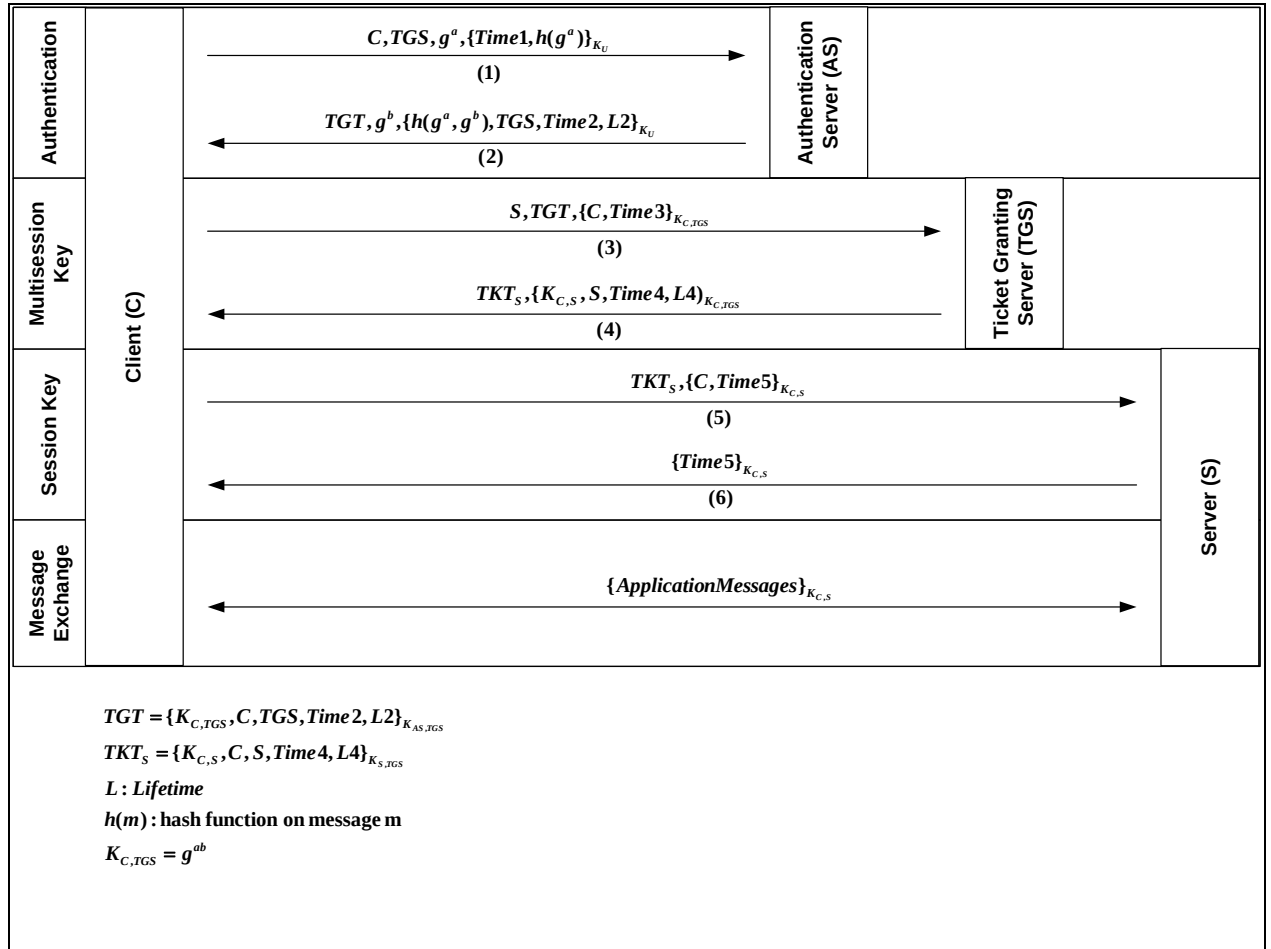


Fig. 3 Client-AS Modified Kerberos Proposed Exchange

B) A simple modification to the previous extension is to send the public D-H exponents (g^a) and (g^b) encrypted under K_U , as shown in figure (4). This adds additional security in the sense that D-H security is based on the concept that knowing (g^a) and (g^b) it is impossible to find g^{ab} . Here, (g^a) and (g^b) are not public so the problem becomes harder on the adversary. This modification keeps the same advantages of the previous solution with small increase in computational time caused by the encryption and decryption of (g^a) and (g^b). Since (g^a) is sent encrypted under K_U then AS will be sure of the authenticity of (g^a), so it is not necessary to calculate $h(g^a)$ and send it encrypted under the same key. In the same manner in the second step it is not required to send the hash of (g^b) encrypted under K_U . The message in the first step is smaller in size than in the previous extension by the size of $h(g^a)$. On the other hand the second

step is of same size as previous extension because $h(g^a, g^b)$ has the same size as $h(g^a)$ by the definition of hash functions.

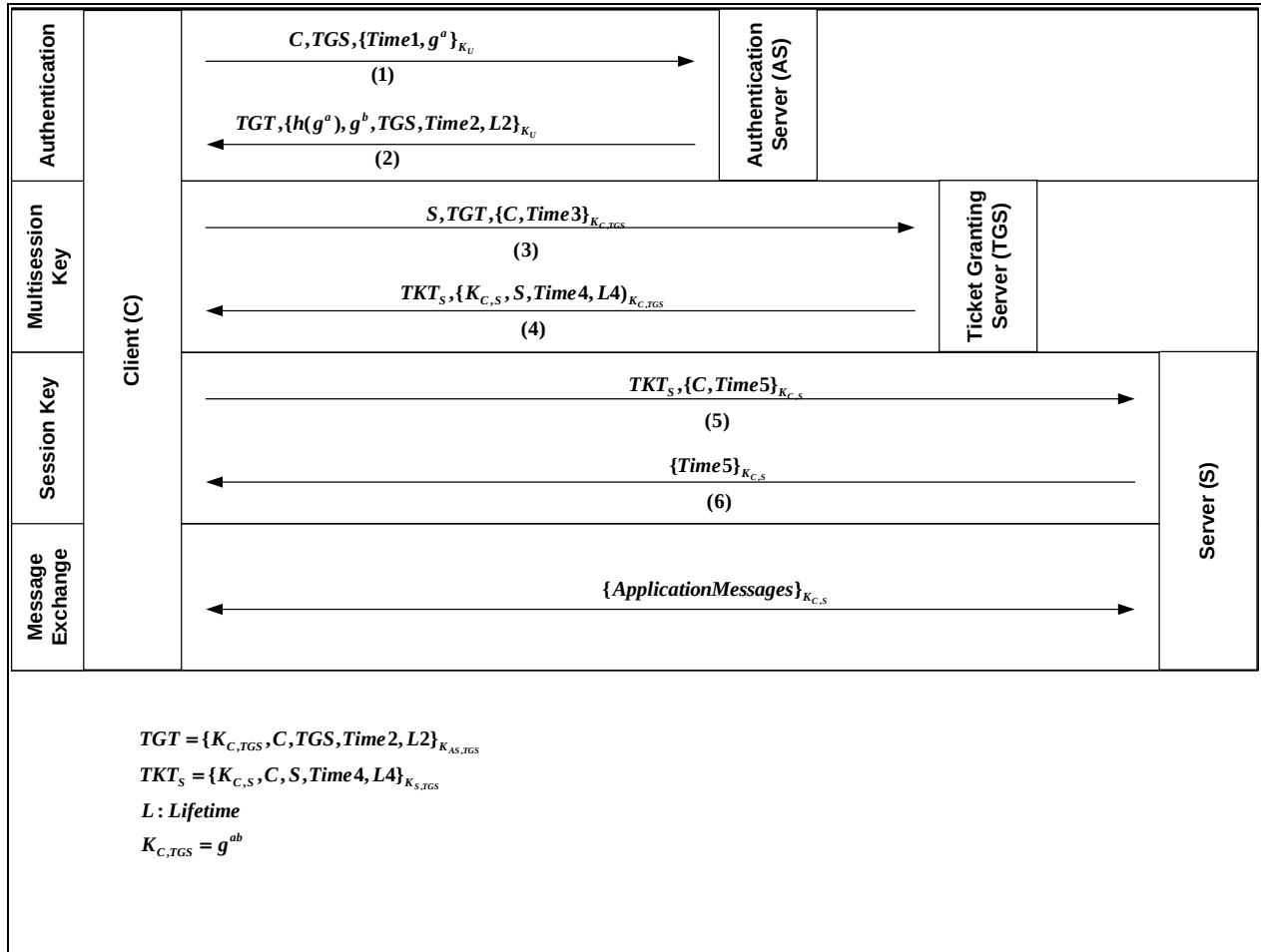


Fig. 4 Client-AS Modified Kerberos Proposed Exchange With Encrypted Public Exponents

Changing The Client-Server Exchange (Second Extension Group)

This group changes the messages exchanged between the client and the server, it also has two possible algorithms presented in A and B below.

A) In this algorithm the steps 1 to 4 of the handshake are kept the same as the original Kerberos. The change occurs in the handshaking between the client and server to get the session key as shown in figure (5). Here the session key is derived using D-H which adds *perfect forward secrecy*, because the session key cannot be compromised when any one of (K_U , $K_{C,TGS}$, $K_{AS,TGS}$, $K_{TGS,S}$, or $K_{C,S}$) is compromised. This is more secure than the previous one due to perfect forward secrecy and due to the fact the session key is only known by the two communicating parties, client and server. Where the role of other parties (AS and TGS) is only authenticating the client. While in previous cases the AS and TGS are involved in the generation of the session keys.

The hash values are used as in subsection 4.1 to achieve message authenticity of g^a and g^b and to acknowledge the reception of g^a .

The computational load on the client is the same as in previous section. But the overhead in computation is now on the server and not on AS as above.

Client Side

- Evaluating g^a .
- Evaluating g^{ab} .

Server Side

- Evaluating g^b .
- Evaluating g^{ab} .

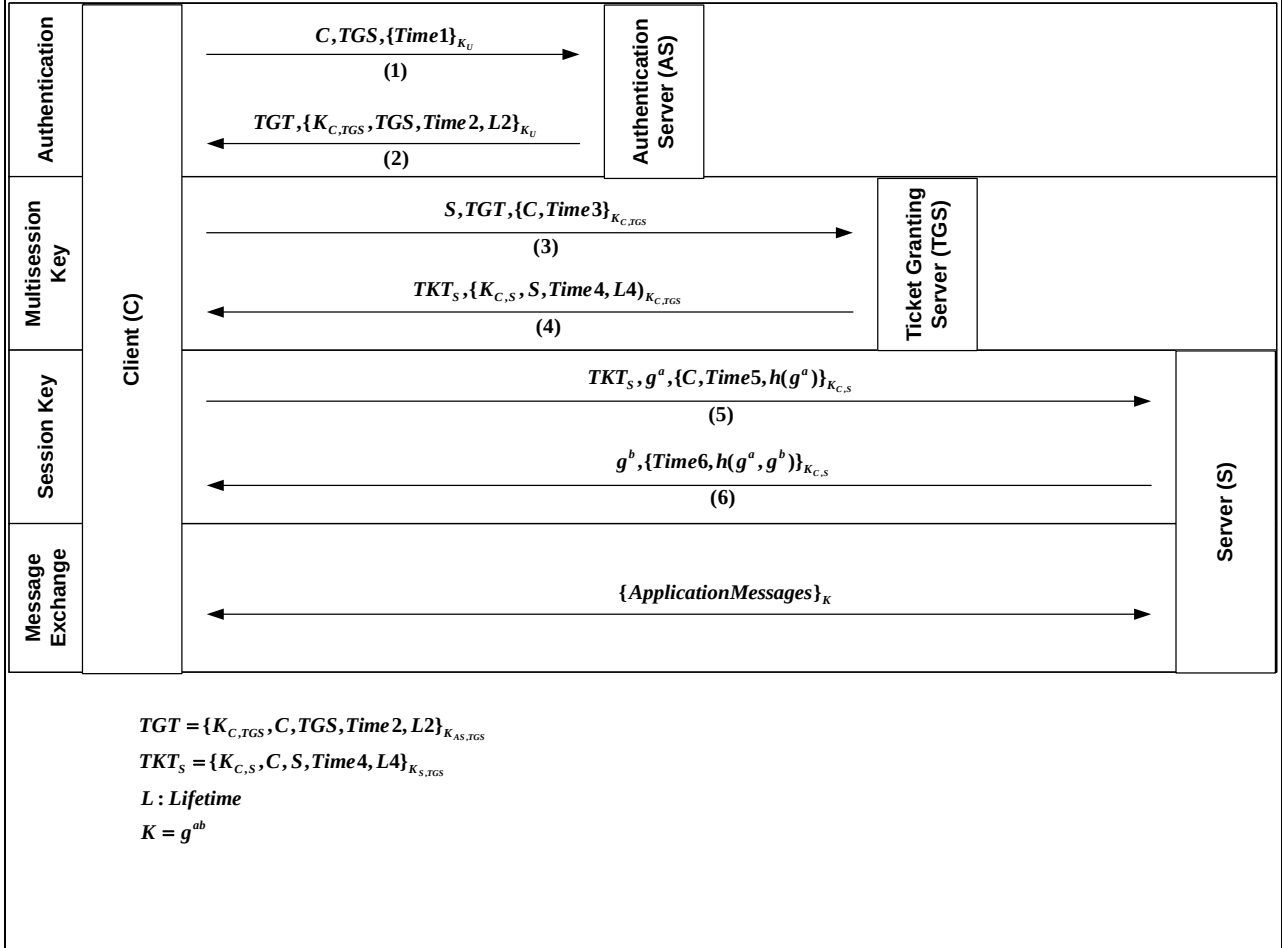


Fig. 5 Client-Server Modified Kerberos Proposed Exchange

B) Simple modifications can be made in a similar way to the modifications in part B of previous subsection 4.1. This is shown in figure (6). The Diffie-Hellman computations are the same as in part A, but the data to be symmetrically encrypted is larger in size which means more computational time. But this time increase is very small when compared with public key operations.

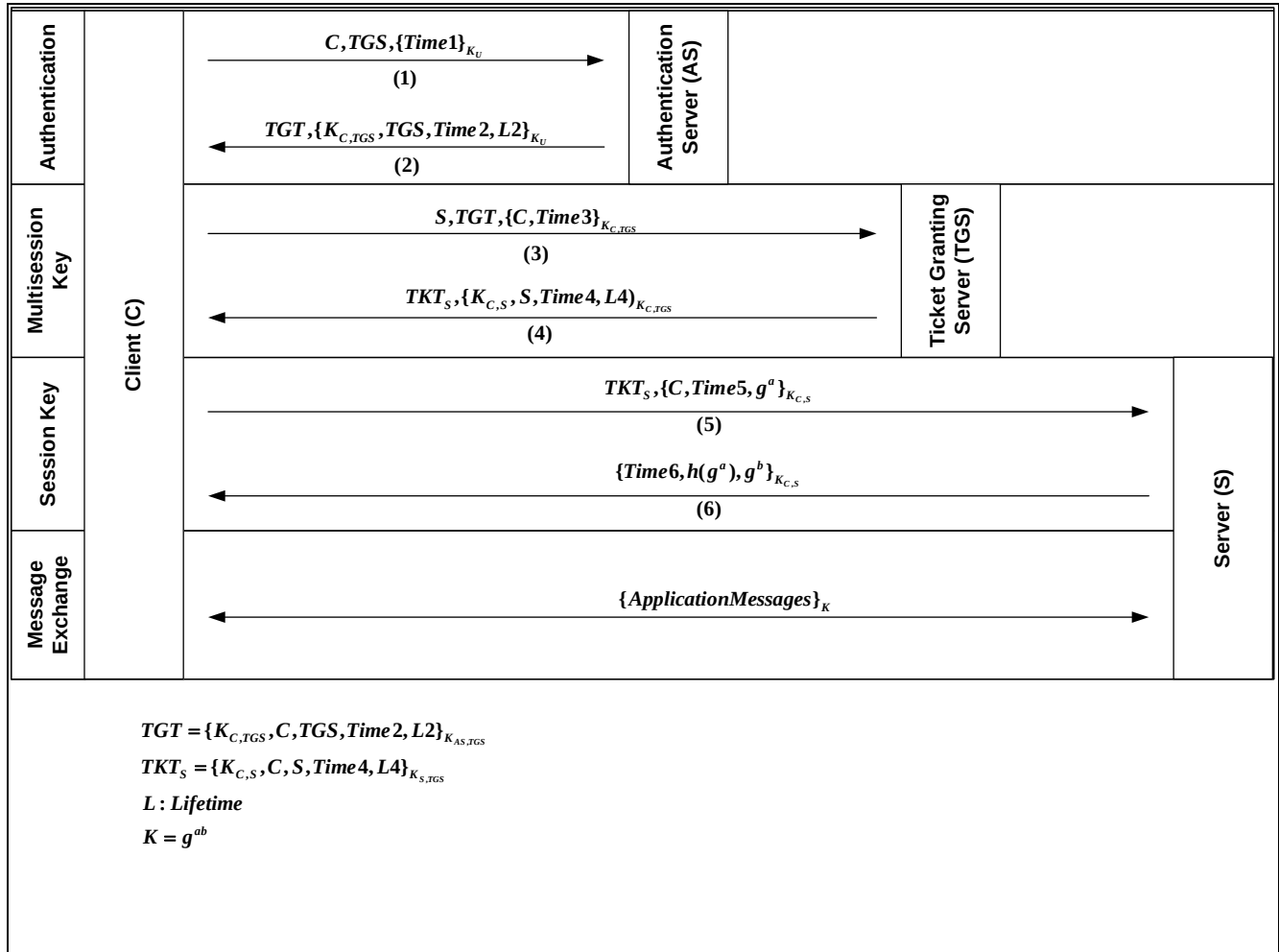


Fig. 6 Client-Server Modified Kerberos Proposed Exchange With Encrypted Public Exponents

COMPARISON BETWEEN FIRST AND SECOND GROUP

To make the comparison the two groups presented in section 4.1 and 4.2, the following assumptions are considered: M clients, N servers, one AS, and one TGS. Figure (7) shows the keys generated for each client. The comparison will be taken from security and performance perspectives.

From A Security Perspective

For the first proposed extension the $K_{C,TGS}$ is generated using D-H, $K_{C,TGS} = g^{ab}$. This key is the base for all the keys for each client ($K_{C1,S1}$, $K_{C1,S2}, \dots$, $K_{C1,SN}$, and session keys), so the compromise of K_{U1} will not compromise the derived keys because $K_{C1,TGS}$ is not dependent on it. But this extension achieves conditional perfect forward secrecy because $K_{C1,TGS}$ is sent encrypted inside the TGT encrypted under $K_{AS,TGS}$ so the compromise of the later key compromises $K_{C1,TGS}$ and then all other keys ($K_{C1,S1}$, $K_{C1,S2}, \dots$, $K_{C1,SN}$, and session keys) are compromised. The compromise of $K_{AS,TGS}$ is not always considered a problem since it may be difficult to achieve because it is shared between AS and TGS which can be highly secured. And in many cases these two parties are implemented in the same server which reduces the risk of compromise. A possible enhancement is to periodically change this shared key, thus compromise of $K_{AS,TGS}$ will compromise only the keys created during the period of validity of this key (before it changes). This is not a difficult change since it involves two parties only, AS and TGS.

For the second extension, the session key is the one generated using D-H while all other keys remain as in the original Kerberos, $K = g^{ab}$. So the compromise of any key (K_U , $K_{C,TGS}$, $K_{AS,TGS}$, or $K_{C,S}$) will not compromise the session key K . This gives perfect forward secrecy.

Client 1	Client 2	Client M	
Authenticate using K_{U1} & get $K_{C1,TGS}$	Authenticate using K_{U2} & get $K_{C2,TGS}$	Authenticate using K_{UM} & get $K_{CM,TGS}$	AS
Authenticate using $K_{C1,TGS}$ & get $K_{C1,S1}$ Authenticate using $K_{C1,TGS}$ & get $K_{C1,S2}$ Authenticate using $K_{C1,TGS}$ & get $K_{C1,SN}$	Authenticate using $K_{C2,TGS}$ & get $K_{C2,S1}$ Authenticate using $K_{C2,TGS}$ & get $K_{C2,S2}$ Authenticate using $K_{C2,TGS}$ & get $K_{C2,SN}$	Authenticate using $K_{CM,TGS}$ & get $K_{CM,S1}$ Authenticate using $K_{CM,TGS}$ & get $K_{CM,S2}$ Authenticate using $K_{CM,TGS}$ & get $K_{CM,SN}$	TGS
Authenticate using $K_{C1,S1}$ & get session key	Authenticate using $K_{C2,S1}$ & get session key	Authenticate using $K_{CM,S1}$ & get session key	S1
Authenticate using $K_{C1,S2}$ & get session key	Authenticate using $K_{C2,S2}$ & get session key	Authenticate using $K_{CM,S2}$ & get session key	S2
Authenticate using $K_{C1,SN}$ & get session key	Authenticate using $K_{C2,SN}$ & get session key	Authenticate using $K_{CM,SN}$ & get session key	SN

Fig. 7 Key Generation Steps in Environment With M Clients, N Servers, one AS, and one TGS

From A Performance Perspective

The computational load on all parties can be found by locating the public key operations (exponentiations). For the first extension where $K_{C,TGS} = g^{ab}$ and according to the model shown in the figure:

- Each client will evaluate g^a and g^{ab} once for the entire login time, so it sums to 2 operations by each client.
- AS will evaluate g^b and g^{ab} once for each client which means $2M$ operations.
- All other parties have no comparable computational load.

For the second extension where the final session key between client and server is g^{ab} :

- Each client will evaluate g^a and g^{ab} once for each server, which gives $2N$ operations by each client.
- AS and TGS have no comparable computations.
- Each server will evaluate g^b and g^{ab} once for each client, then each server has to do $2M$ operations.

It is clear that the first extension has overall lower computations than the second extension. The first has less load on both the clients and servers, with higher load on the AS. So in general the first case outperforms the second one, keeping in mind that the former gives only conditional perfect forward secrecy, while the later gives perfect forward secrecy. But there are three main points that must be taken into account.

The first point that must be considered is that the first extension has a high load on the AS, but in the second extension the load is the same as in original Kerberos, and it is negligible when compared with public key operations. The high load on AS can be a serious problem in some situations, because AS may become a bottleneck. This case can happen on the system startup, where all clients try to authenticate themselves to AS at the same time.

The second point is the fact that not all clients will communicate with all servers. So the load in first extension is mainly on AS and is highly constant at $2M$. While in second extension the load is mainly on clients and servers. The load on client depends on its communication demand, i.e. load increases linearly with the number of server it needs to connect. The load on server depends on the clients' demands, i.e. load increases linearly with the number of clients needing to communicate with that server. And in general it is not likely that these communication requests occur simultaneously, i.e. the requests are generally randomly distributed in time and among servers. As opposed to the requests to AS which may happen simultaneously. This distribution gives a reduced effect on the servers at any moment.

The last point is that the second group of extensions gives the clients and servers the flexibility to agree to use the extension or stay in the original Kerberos mode. This is a per session decision between client and server to achieve perfect forward secrecy or to achieve higher performance with lower security.

CONCLUSIONS AND FUTURE WORK

Throughout this work, analysis of Kerberos has been made in its original and PKINIT forms. The analysis focuses on the concept of perfect forward secrecy and on the performance of the algorithms. Two extensions have been proposed to achieve perfect forward secrecy without changing the authentication based on passwords, which differentiates them from PKINIT.

The two extensions proposed are similar in the basic idea that they use Diffie-Hellman to achieve the goal, but they differ in the steps where the change is done. The first extension makes the change at the Client-AS phase and achieves conditional perfect forward secrecy while the other extension achieves perfect forward secrecy by changing the last phase. In general, the first one outperforms the second, while the second has better security.

There are many implementation details that are out of the scope of this work, but are important to discuss. These details include the size of the keys used and the software implementation of the operations in addition to other optimizations in the cryptographic operations.

Another issue to be investigated is how to expand the Kerberos system to be used over larger networks that are separated by firewalls and proxies, a problem that original Kerberos suffers from.

An interesting issue is to develop a system that integrates several authentication systems based on different cryptographic operations, such as the certificate authorities, SSL, and Kerberos.

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STUDY OF CO AND NO_x EMISSIONS OF S.I.E FUELED WITH SUPPLEMENTED HYDROGEN TO GASOLINE

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ABSTRACT

This paper include study of CO and NO_x emissions exhausted from single cylinder, 4-stroke S.I. engine, Ricardo E6, with variable compression ratio, spark timing and equivalence ratio, worked by supplementary hydrogen to gasoline.

The speed of 25 rps and higher useful compression ratio (HUCR) were chosen in studying the effect of wide range of equivalence ratios and spark timing on CO and NO_x emissions submitted from engine.

The study showed that exhaust gas emissions depend mainly on equivalence ratio. The higher value of NO_x concentrations was in lean side near the stoichiometric equivalence ratio, and reduced when getting far from this ratio.

CO concentrations were too small in the lean side, and the effect of equivalence ratio on it was too small in this side also, it increased in the rich side.

It was observed that retarding spark timing reduces the NO_x concentrations by a large percentage; there was no effect of spark timing on CO concentrations.

The effect of speed on NO_x concentrations was studied, and it was observed that these emissions became higher at medium speeds and reduced in higher and low speeds, CO concentrations increased with increasing speed also.

NO_x concentrations increased with increasing hydrogen volumetric ratio in mixture while CO concentrations reduced by this increase.

دراسة ملوثات CO و NO_x لمحرك اشتعال بالشرارة يعمل بإضافة الهيدروجين للجازولين

الخلاصة

تضمن البحث دراسة ملوثات CO و NO_x الناتجة من محرك أحادي الأسطوانة رباعي الأشواط يعمل بالشرارة، نوع (Ricardo E6/US)، ذي نسبة انضغاط وتوقيت شرر ونسبة مكافئة وسرعة متغيرة، عند إضافة الهيدروجين للجازولين بنسب حجمية متغيرة.

تركزت الدراسة في بحث تأثير متغيرات رئيسية على ملوثات عادم المحرك، وهي نسبة الانضغاط والنسبة المكافئة وتوقيت الشرر والسرعة، وقد حددت بعض المتغيرات، فقد اختيرت السرعة (25rps) ونسبة الانضغاط النافعة العليا في دراسة تأثير مدى واسع من النسب المكافئة وتوقيت الشرر.

أظهرت نتائج الدراسة أن ملوثات الغاز العادم تعتمد بالأساس على النسبة المكافئة، وقد شملت الملوثات المدروسة أكاسيد النيتروجين وأول أكسيد الكربون.

تكون تراكيز NO_x في أعلى قيمة لها في الجانب الضعيف قرب النسبة الكيميائية الصحيحة، وتقل التراكيز بالابتعاد عن تلك النسبة لجانب الخليط، أما تراكيز CO فتكون قليلة في الجانب الضعيف، وتتأثر قليلاً بالنسبة المكافئة، وتزداد في الجانب الغني وتتأثر كثيراً بالنسبة المكافئة في هذا الجانب، كما لوحظ أن تأخير توقيت الشرر يقلل من تراكيز NO_x بنسبة كبيرة، ولم يلاحظ أي تأثير لتوقيت الشرر على تراكيز CO.

درس تأثير السرعة على تراكيز NO_x ولوحظ أنها تكون أعلى عند السرعة المتوسطة، وتنخفض هذه التراكيز للسرع المنخفضة والعالية، كما تزداد تراكيز CO بزيادة السرعة.

تزداد تراكيز NO_x بزيادة نسبة الهيدروجين الحجمية بالخليط، بينما تقل تراكيز CO بهذة الزيادة.

KEY WORDS

Hydrogen, gasoline, emission, nitric oxides, NO_x, carbon monoxide, CO, compression ratio, equivalence ratio, spark timing, speed.

INTRODUCTION

Motor vehicle presently powered by conventional petroleum fuels consume about one-third of the world's oil consumption. The fast rates of depletion on the global oil supply system possess a threat to the transportation sector. Therefore, for the safe survival and growth of the existing vehicular network, substitutes to conventional petroleum fuels must be discovered (Akehurst, 2002).

Besides suffering from the problem of scanty global supply, the modern transportation system that is built on internal combustion engines also happens to be the major source of several health threatening pollutants. Therefore, an ideal long-term substitute to petroleum fuels should possess an infinite source potential and the least environmental pollution characteristics. Hydrogen fuel exactly caters to such need (Vianna, 2005).

A neat hydrogen – operated engine gives out water as main combustion product, It does not produce significant amount of CO, HCs, SO_x, smoke, lead or other toxic metals, sulfuric acid deposition, ozone and other oxidants, benzene and other carcinogenic compounds, formaldehyde, CO₂ and other greenhouse gases. In a well designed neat hydrogen fueled engine a very small portion of the lubricant cauting on the chamber walls is burnt thus producing negligtable amount of hydrocarbon and carbon monoxide. However, in hydrogen- supplemented engines, some of these pollutions could be presents in proportions much smaller than that of the corresponding petroleum fueled engine (Das, 2005).

Oxide of nitrogen (NO_x) happened to be the only major pollutant of concern, whether it is hydrogen specific or hydrogen supplemented engine (Shasby, 2004).

In addition to the above mentioned pollutant, a very small amount of hydrogen peroxide is also given out by a hydrogen engine under specific operation conditions (Das, 1991).

In this paper, however, we restricted to the effect of some major pollutants (CO and NO_x), and the influence of some operational and designing parameters on them with respect to hydrogen supplemented engines.

The damaging effects of CO in preventing oxygen transport from the blood into the tissues are too well known to be further emphasized. Also, it has been found that CO also plays a critical role in increasing the concentration of several greenhouse gases and thus disturbs the climate effect (Vianna, 2005).

The present global level of CO is increasing and motor vehicles account for the major part of CO emissions in urban areas. It has been estimated that the level of CO in the lower atmosphere is increasing between 0.8 and 1.4% by year. CO and unburnt hydrocarbons (UBHC) will be intrinsically absent in a total hydrogen operated engine, however, they could be caused in hydrogen supplemented systems (Das, 1990).

(MacDonald, 1976) in his investigation studied the effect of CO emissions from hydrogen supplemented multi cylinder engine, it was observed that the CO level decreased within equivalence ratio of 0.55 and was increased with further leaning. This decrease in CO emission level was contrary to usual expectations. The possible explanation of such a trend, as given out by the investigator were that perhaps a hydrogen rich combustion seriously influenced "temperature and specific profile in the combustion chamber quench layer", thereby resulting in a change of the origin of CO. Additionally this situation could have "increased the hydroxyl radical concentration" which help in increase the rate of oxidation of CO to CO₂.

(Li Jing-ding and Lu Ying- qing, 1984) observed extremely low quantities of CO in the exhaust emitted out of their experimental engine set up, even though theoretically, no CO is supposed to be present, the CO emission level get decreased as the load is reduced in a practical operating engine system. It is a very difficult to get a perfect homogenous mixture.

This gives rise to some amount of CO. In addition, high temperature conditions and the dissociation effects of hydrogen in the engine cylinder result in resolving CO₂ to CO.

Recent research indicates that ozone (O₃) in the troposphere is the main gradients of smog. This gas is created in sunlight driven reactions involving nitrogen oxides (NO_x). Controlling NO_x is also essential to reduce the deposition of citric acid, which happen to be a principal component of acid rain (Das, 2005).

Mobile sources are responsible for the major contribution of NO_x levels to the environment. Unfortunately, NO_x happen to be the major pollutant of concern from hydrogen engines. Whether the engine is operating on a net hydrogen fuel or it happens to be a hydrogen-supplemented system, there is bound to be some level of NO_x emissions (Murray, 1971).

The level of NO_x emissions depend on combustion temperature, availability of oxygen, and time available for its kinetic process. It has been discovered that NO_x level peak around stoichiometry due to higher combustion temperature and availability of sufficient oxygen. NO_x emission is greatly influence by changes in equivalence ratio. It was also experimentally determined that spark timing which proved to be extremely important parameter for NO_x production (Varde, 1984).

The compression ratio was observed to be influencing the level of NO_x concentration. An increase in compression ratio results in higher level of NO_x because of increase temperature conditions. This situation also leads to high flame speeds, which in consequence reduces the residence time. However, it was observed that between the two factors, such an increased temperature and decrease residence time, the effect of the former predominate thereby resulting in a high NO_x level which higher compression ratio (Das, 1987).

The results reported by (Parks, 1976) on hydrogen enrichment observed that NO_x reached a peek value at an equivalence ratio of around 0.8, as an overall effect of combustion temperature coupled with sufficient oxygen availability. As the mixture leaned beyond an equivalence ratio 0.8 and more oxygen became available, NO_x still showed a decreasing trend because of lower combustion temperatures. It was thus observes, in general, leaner operation allowed by hydrogen addition to gasoline will reduce NO_x emissions. However, the phenomenon of high flame temperature associated with hydrogen does influence its combustion temperature, which causes the increase of NO_x emission at a given equivalence ratio.

A part from excessive spark advance (Murray, 1971), exhaust gas recirculation (Das, 1991), water injection (Das, 1987) and use of exhaust gas reduction catalysts (Das, 1990) have been successfully adopted for NO_x control. Results of detailed study on the effects of diluents shows that both water injection and EGR are equally effective in reducing NO_x levels (Das,1990).

EXPERIMENTAL TECHNIQUE

The investigation were carried out on single cylinder ,4-stroke spark ignition Ricardo E6/US engine with variable compression ratio, spark timing and equivalence ratio , operated with

hydrogen enriched gasoline, hydrogen was supplied to air manifold by means of nozzles system and pressure regulator to achieve mixing rate.

The following instruments were used for the analysis of the emissions:

- A non – dispersing infrared analyzer for CO.
- A magnetic oxygen analyzer for O₂.
- A chemiluminescence analyzer for NO and NO₂.

The engine was operated with pure gasoline , pure hydrogen and with hydrogen – gasoline mixtures, a wide range of equivalence ratio effect on emission concentrations at HUCR and 25 rps engine speed.

Engine performance studied to get HUCR for each fuel and for the mixtures, then start studying addition of hydrogen on volume basis where (hydrogen volume fraction, $HVF = V_{H_2} / (V_{H_2} + V_{gasoline})$).

DISCUSSION

- CR Effect

Engine was operated in different compression ratios starting from 6:1 to 9.0:1, with OST and 25 rps engine speed, for wide range of equivalence ratios, to study the effect of hydrogen supplementation for three volumetric fractions ($HVF=0.3, 0.6, 0.9$) to gasoline on NO_x concentrations.

The results shows constant effect, increasing hydrogen volumetric fraction increases NO_x concentrations in lean side, and reduces in rich side, the maximum value of these concentrations increased. This is obvious in **fig. (1)**, which was chosen as a sample for this constant behavior, where 9:1 is HUCR for hydrogen – gasoline mixtures and HUCR for gasoline alone was 8:1.

The increase of NO_x concentrations in lean side because of three parameters: oxygen availability and high combustion speed because of hydrogen presence, and the high heating value of gasoline on volume basis. The decrease in NO_x concentration in rich side because of oxygen lack, dissociation reactions with low reaction rate freeze, reaction time shortage , it also appear from the figure that mixture influenced in great manner with hydrogen supplementation.

Compression ratio effect on mixture seems to be constant also, NO_x concentrations increased in lean side and reduced in rich side with CR increase, because CR improves Combustion operation and increase flame spreading velocity, and NO_x concentration limited by two other parameters, which are oxygen availability and available reaction time.

Fig. (2) shows the effect of changing CR from 6:1 to 9.0:1 on NO_x concentration maximum value, for different hydrogen volumetric fractions in fuel, at OST and 25 rps engine speed.

Increased HVF in fuel increases the maximum value of NO_x concentration for $HVF=90\%$, after that NO_x reduces when engine operated with hydrogen fuel alone, this indicates the influence of high heating value of gasoline on volume basis.

Increasing CR causes reduction in maximum value of NO_x concentration, that is because of reduction in time available where OST retarded to get the best engine power and to avoid knock.

Hydrogen was supplied in four volumetric fractions ($HVF= 0.3, 0.6, 0.8, 0.9$) to gasoline, and the study done for four different compression ratios (6, 7, 8, 9) to examine CO concentrations for wide range of equivalence ratios.

The results conduct constant effect, hydrogen increase in mixture reduces CO concentration in exhaust gas, in rich side where CO concentrations are obvious, because of the reduction in carbon – to hydrogen atoms percentage in whole fuel.

This is obvious in **figs (3 and 4)**, which was chosen as a sample for this constant behavior, where 8:1 is the HUCR for gasoline, and 9:1 is the HUCR for mixtures used in research.

From the figures it is apparent that increasing CR increases CO concentrations in exhaust gas, because of reversed dissociation for CO₂ molecule to CO with increasing combustion temperature.

Equivalence Ratio Effect

Fig. (1) appears equivalence ratio effect on NO_x concentrations, where NO_x maximum value is at ($\phi=0.96$) with gasoline use, and with HVF increase in fuel it reaches ($\phi=0.82$) at HVF=0.9.

The fast reaction of hydrogen oxygen causes apparent lack of oxygen in combustion chamber, at the same time, this reaction gives very high temperature for equivalence ratios from $\phi=0.8$ to $\phi=0.9$, That is why the maximum NO_x concentration is layed at values leaner than ($\phi=0.96$) when hydrogen added to gasoline.

Engine works at equivalence ratio leaner than $\phi=0.7$ gives very low NO_x concentrations.

Figs. (3and 4) conduct that CO concentration in exhaust gas are very low for equivalence ratios less than $\phi=0.96$, it reached approximatly zero at very lean equivalence ratios less than $\phi=0.8$, and it increased after this ratio; hydrogen addition reduces these concentrations as it been mentioned above.

Fig. (5) shows hydrogen addition effect on NO_x concentrations, for specific chosen equivalence ratios when working with HUCR and 25 rps.

From the figure, increasing HVF increase NO_x levels in lean side in large and obvious rate, this is appeared in equivalence ratios $\phi=0.7$ and $\phi=0.8$ curves, because of fulfillment of the following parameters: Oxygen availability, high combustion rate caused by hydrogen fast burning velocity and gasoline high heating value on volume basis, the later appeared to be the reason for NO_x increase at $\phi=0.8$ more than that at $\phi=0.7$ although the two equivalence ratios are lean.

NO_x levels decrease for equivalence ratios ($\phi=1, 1.1, 1.3$) although HVF increase, because of lack of oxygen needed for reactions and dissociation reactions increase.

- Speed effect

Figs. (6 to 8) show the effect of different speeds on NO_x, for wide range of equivalence ratios, at different HVF's in fuel, at HUCR=9:1 and OST.

NO_x concentrations were higher at medium speeds (25-30rps), and decrease at low speed (20 rps) and high speed (35 rps).

The maximum cycle temperature is low at low speeds, because of increased dilution and long combustion time, but in medium speeds NO_x concentration increases, because of high cycle temperature, and in high speeds these concentrations go down because of shortage of time needed for oxygen and nitrogen reaction, also chemical dissociation increases because of high-rise in maximum cycle temperature.

Figs. (from 9 to 11) illustrate different speeds effect on CO levels for wide range of equivalence ratios and for different HVF's in fuel at HUCR and OST.

CO concentrations decrease with HVF increase in mixture, but with speed increase CO levels increase in exhaust gases, because of combustion temperature increase with speed increase, what increases in return dissociation reactions for CO₂ gas to CO, also, the short time required to oxide all CO gas to CO₂, lack of oxygen in combustion chamber in rich side.

- Spark timing effect

Spark timing give an advantage to gasoline – hydrogen mixtures, compared with hydrogen alone, when they are used in SIE. The engine operated with neat hydrogen as fuel need to change spark timing always to fit working equivalence ratio. Therefore, range of spark timing changing is very narrow and limited with existence of high-pressure rates before top dead centre, when timing is advanced away from its OST by few degrees and with hydrogen-air mixture pre-ignition when retarding the timing by few degrees. Pre-ignition do not happen to gasoline – hydrogen –air mixture, when retarding spark timing in any circumstances, but it happened only if high-pressure rates occur before top dead centre. In this case, a very high heat produced in combustion chamber causing hydrogen – gasoline mixture to burn before the spark plug ignited. Therefore, spark timing effect on NO_x levels can be studied in hydrogen supplementation system, although it cannot be studied in neat hydrogen case.

Fig. (12) shows the relation between NO_x concentrations and spark timing degrees for three definite equivalence ratios ($\phi=0.7, 0.8, 1.3$) for mixture of air-gasoline and hydrogen, HVF=90%. This fraction was chosen because it gave the maximum NO_x concentration at HUCR and 25 rps.

Retarding spark timing at equivalence ratio ($\phi=0.7$) by 15 degrees cause decrease in NO_x concentration about 40%. At equivalence ratio $\phi=0.8$ where the maximum NO_x levels laid near , retarding spark timing about 15 degrees cause decrease about 35%, but at $\phi=1.3$ NO_x concentration reduced with same retarding degrees about 2.5%.

Retarding spark timing is a very important parameter for limiting and reduces NO_x concentrations.

There was no effect of spark timing in CO concentrations.

CONCLUSIONS

- NO_x concentrations increased with hydrogen supplementations to gasoline-air mixture at lean side for about 10 times, and decreased in rich side about 30%, the maximum value of this emission increased about 40% also.
- CO concentrations reduce with hydrogen supplementation to gasoline-air mixture in obvious manner at rich side at about 65%.
- NO_x concentrations increase with CR increase in lean side and reduce in rich side. Also, the maximum concentrations reduce with hydrogen supplementation to gasoline-air mixture.
- CO concentrations in exhaust gas increase with CR increase.
- NO_x concentration increase with speed increase from low (20 rps) to medium (25-30 rps) speeds, these concentrations decreases with speed increase from medium to high (35 rps) speed. In addition, CO concentration increases with speed increase.
- Retarding spark timing reduces NO_x concentration in high percentage for lean equivalence ratio (about 40% at $\phi=0.7$), and for maximum values (35% at $\phi=0.8$) . NO_x concentrations reduce also in rich side for a little extent (about 2.5% at $\phi=1.3$).
- Spark timing do not affect CO concentrations.

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NOMENCLATURE

CO	carbon monoxide
NO _x	Nitrogen oxides
Rps	revolution per second
CR	compression ratio
OST	optimum spark timing
Ø	equivalence ratio= $(A/F)_{\text{stoichiometric}} / (A/F)_{\text{actual}}$

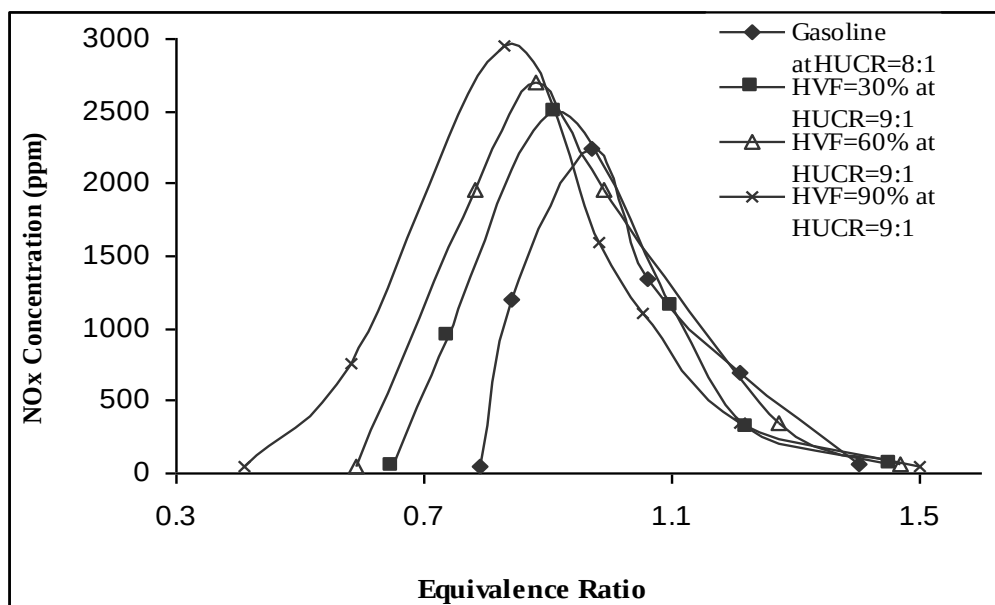


Fig. (1), the effect of hydrogen supplementation for three volumetric fractions to gasoline on NO_x concentrations for wide range of equivalence ratios at HUCR and OST

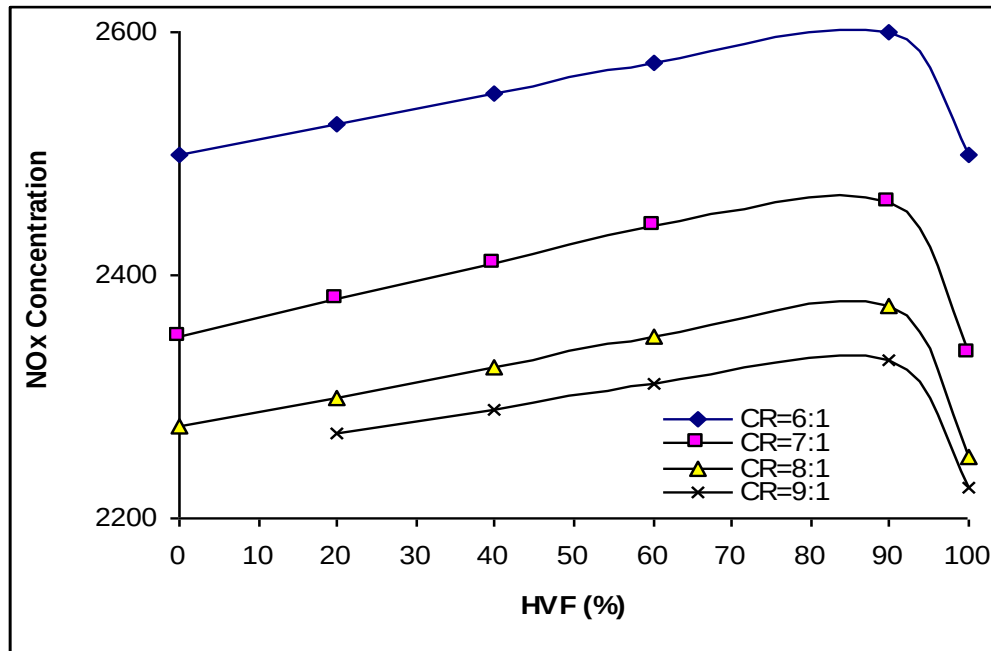


Fig. (2), the effect of changing CR from 6:1 to 9.0:1 on NO_x concentration maximum value, for different hydrogen volumetric fractions in fuel, at OST and 25 rps engine speed

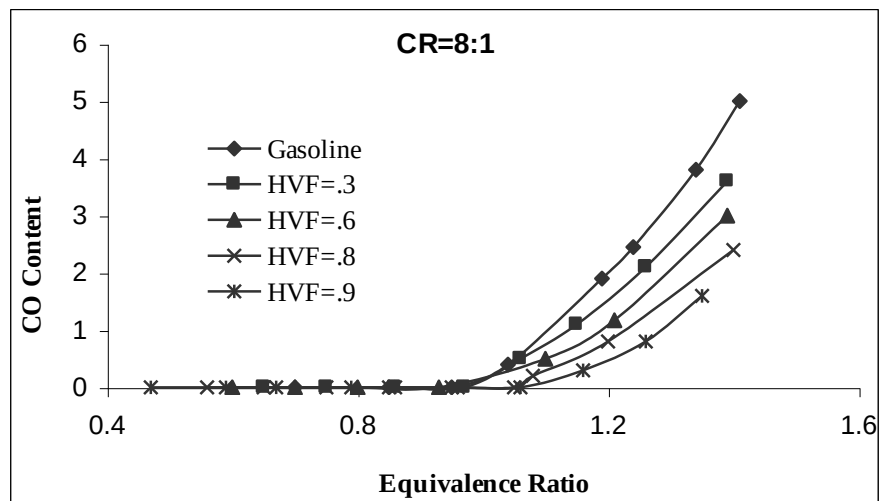


Fig. (3), the effect of hydrogen supplementation for four volumetric fractions to gasoline on CO concentrations for wide range of equivalence ratios at CR=8:1, OST and 25 rps

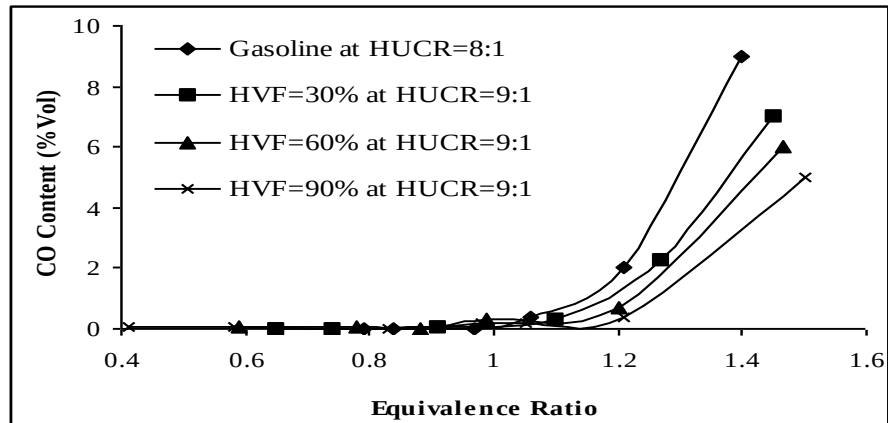


Fig (4), the effect of hydrogen supplementation for three volumetric fractions to gasoline on CO concentrations for wide range of equivalence ratios at HUCR=9:1, OST and 25 rps

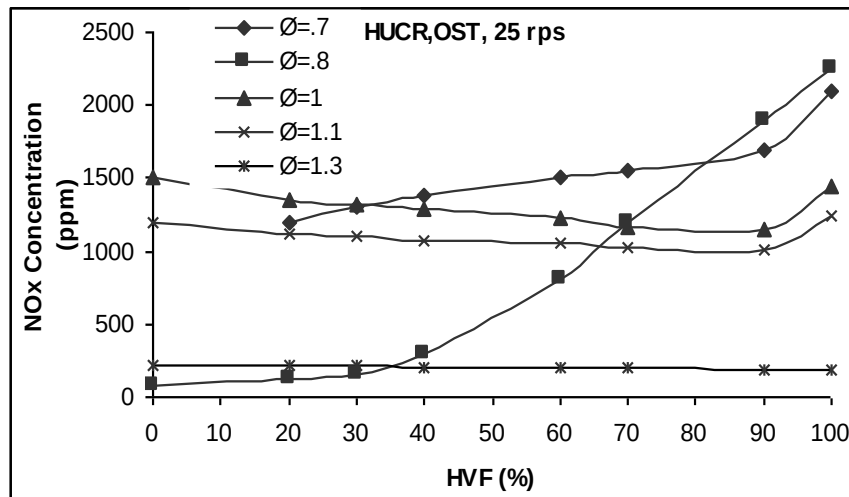


Fig. (5), hydrogen addition effect on NOx concentrations, for specific chosen equivalence ratios when working with HUCR for each HVF and 25 rps.

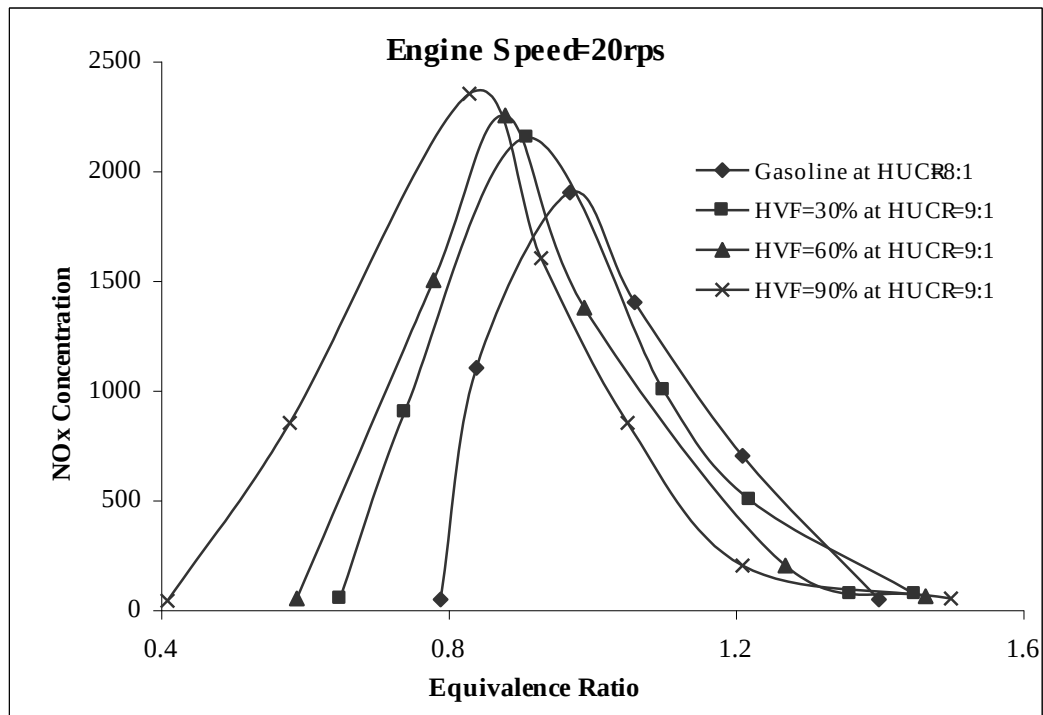


Fig (6), the effect of low speed (20 rps) on NO_x concentrations, for wide range of equivalence ratios, at different HVF's in fuel, HUCR and OST.

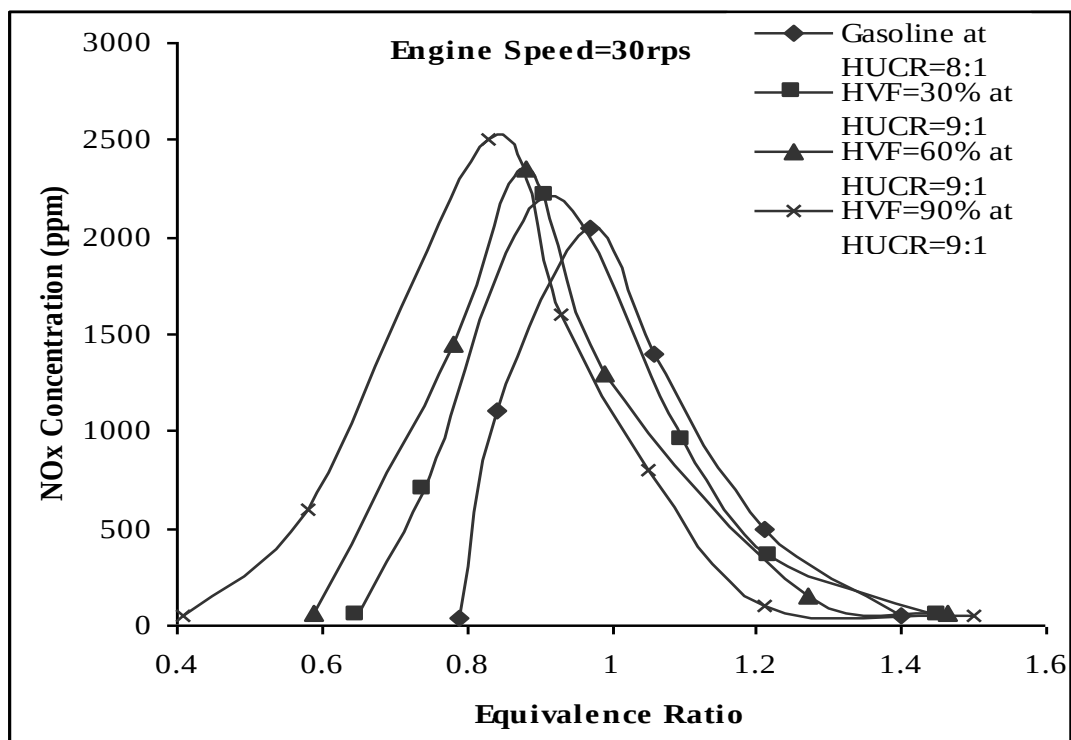


Fig. (7), the effect of medium speed (30 rps) on NO_x concentrations, for wide range of equivalence ratios, at different HVF's in fuel, HUCR and OST.

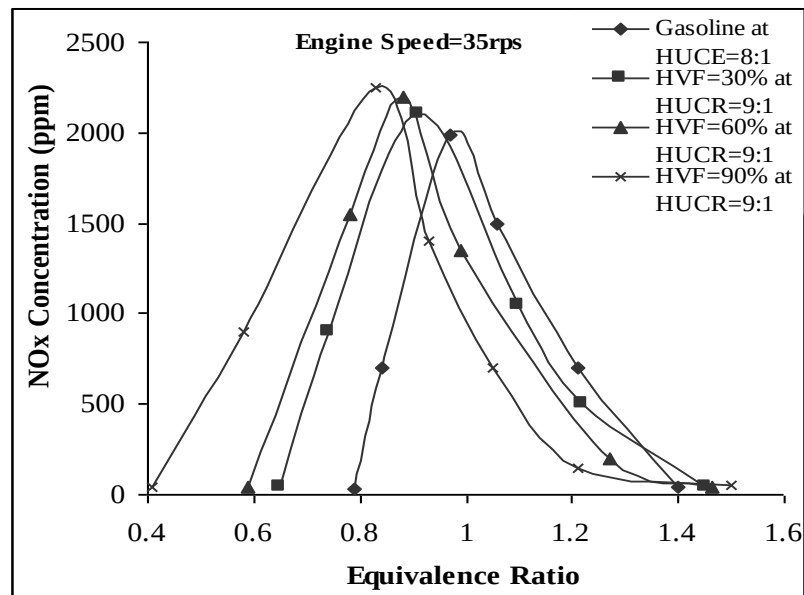


Fig. (8), the effect of high speed (35 rps) on NOx concentrations, for wide range of equivalence ratios, at different HVF's in fuel, HUCR and OST.

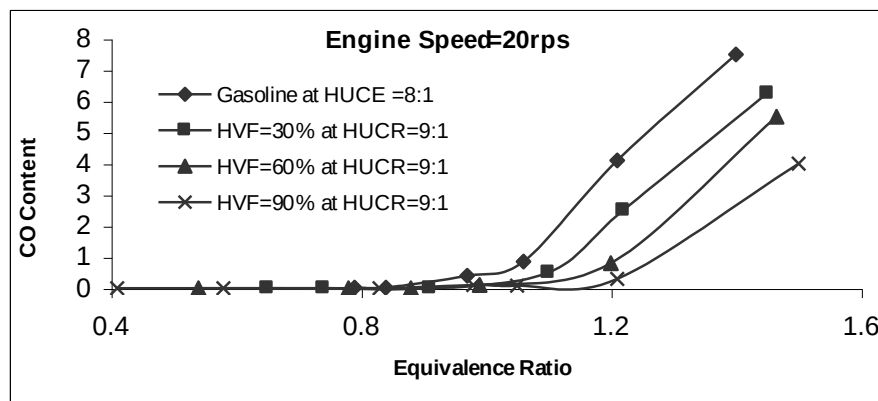


Fig. (9), the effect of low speed (20 rps) on CO concentrations, for wide range of equivalence ratios, at different HVF's in fuel, HUCR and OST.

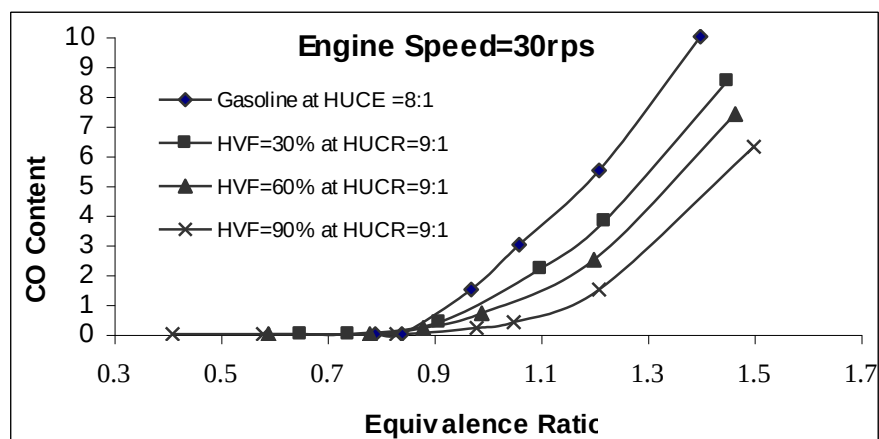


Fig. (10), the effect of meduim speed (30 rps) on CO concentrations, for wide range of equivalence ratios, at different HVF's in fuel, HUCR and OST.

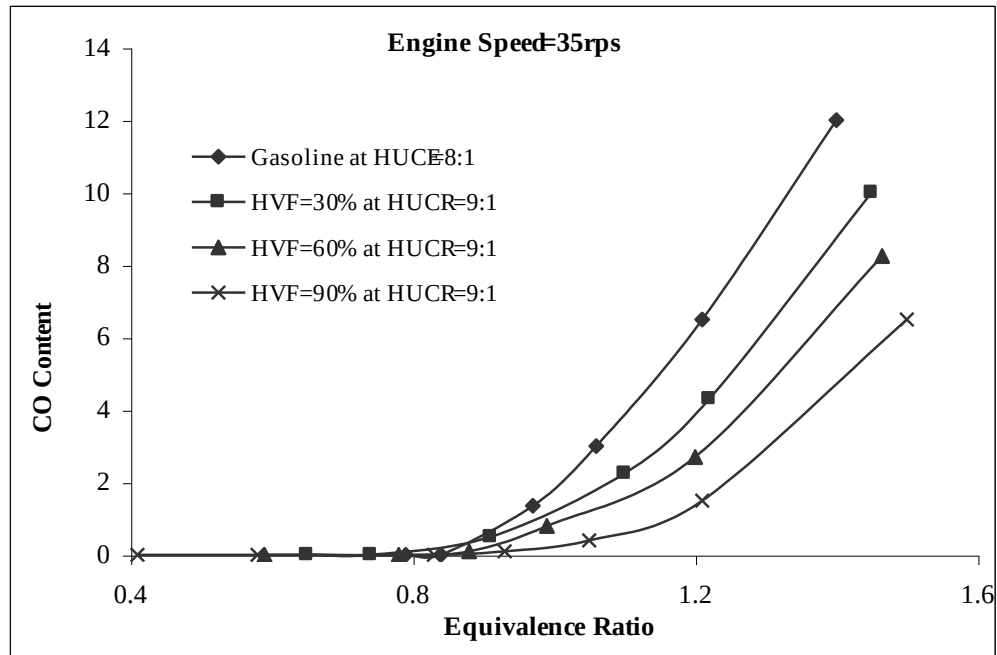


Fig. (11), the effect of high speed (35 rps) on CO concentrations, for wide range of equivalence ratios, at different HVF's in fuel, HUCR and OST.

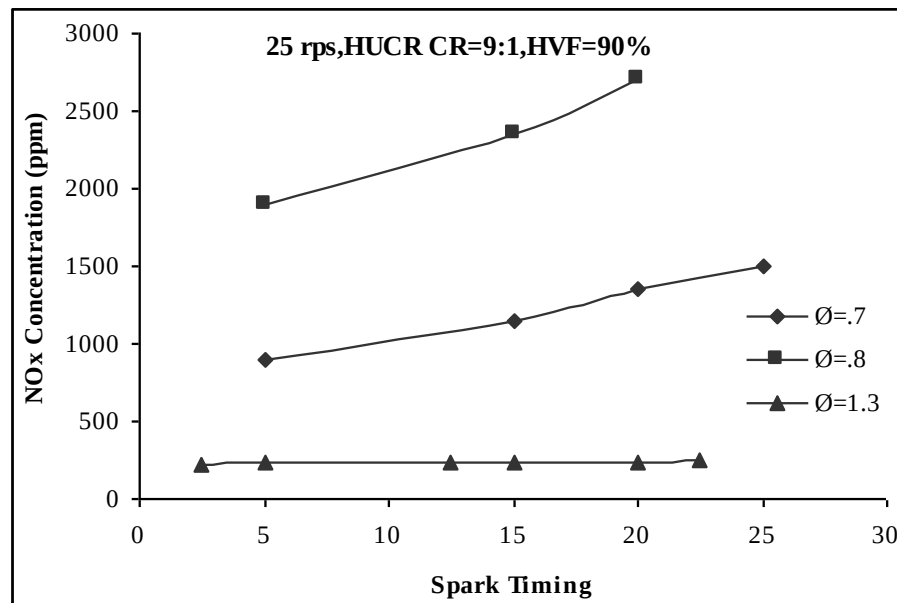


Fig. (12), the relation between NO_x concentrations and spark timing degrees for three definite equivalence ratios (Ø=0.7, 0.8, 1.3) for mixture of air-gasoline and hydrogen, HVF=90%

RESIDUAL STRESS DISTRIBUTION FOR A SINGLE PASS WELD IN PIPE

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ABSTRACT

Heat input due to the welding of mild steel pipe causes a temperature gradient in the parent metal. After welding and temperature cooling down, residual stresses appear around welding zone which reduces the weld strength. Residual stresses are a result of the temperature gradient and the dependency of material properties on the temperature, such as yield strength, elasticity modulus, and thermal expansion coefficient.

In this study, a typical flat joint of a single pass weld in a thin pipe was studied analytically and numerically. Analytical approach is performed by exploring a simple method to calculate the magnitude of residual stress in terms of the weld shrinkage behavior. Numerical analysis is performed by applying non-linear transient heat transfer analysis using welding parameters, such as heat generation, free or forced convection with ambient, are performed using a general purpose FE package ANSYS 8.0 in order to obtain the temperature distribution in the welded parts. A non-linear thermal-elastic-plastic stress analysis is then performed using the same package to predict the stress fields during and after welding.

الخلاصة

أن الحرارة الناتجة عن لحام الأنابيب الفولاذي يسبب تغير في درجات الحرارة للمعدن الأصل. بعد اللحام و نتيجة لانخفاض درجات الحرارة تظهر إجهاد متبقية حول منطقة اللحام مما تؤدي الى انخفاض في مقاومة المعدن. أن الإجهادات المتبقية تظهر نتيجة التغير في درجات الحرارة وتبعية خصائص المادة على درجة الحرارة، مثل مقاومة الخضوع، معامل المرونة، ومعامل التمدد الحراري. تم في هذا البحث دراسة الإجهادات الناتجة عن لحام الأنابيب الرقيقة تحليليا وعدديا. المنهج التحليلي تم فيه استخدام طريقة بسيطة لحساب مقدار الإجهاد المتبقي من ناحية سلوك إنكماش اللحام. أما المنهج العددي تم فيه استعمال تحليل نقل الحرارة العابر للاختط مع عوامل اللحام المختلفة مثل الحرارة المتولدة، و معامل الانتقال الحراري مع الجو المحيط، باستعمال برنامج التحليل العددي متعدد الأغراض ANSYS 8.0 لكي نحصل على توزيع درجة الحرارة في الأجزاء الملحومة. ثم استخدام تحليل الإجهاد البلاستيكي الحراري للاختط باستعمال نفس البرنامج لتوقع الإجهاد أثناء وبعد عملية اللحام.

KEYWORDS: Residual Stress, Weld Pipe, Thermo-elasto-plasticity.

INTRODUCTION:

In fusion welding, a weldment is locally heated by the welding heat source. Due to the non-uniform temperature distribution during the thermal cycle, incompatible strains lead to thermal stresses. These incompatible strains due to dimensional changes associated with solidification of the weld metal, metallurgical transformation, and plastic deformation, are the sources of residual stresses and distortion.

Welding-induced residual stresses and distortion can play a very important role in the reliable design of welded joints and welded structures. However, the welding process itself is a very complex phenomenon, which has not been fully understood, so that distribution and magnitude of residual stress is not readily available from the literature [Wu, 2001]. Residual stress distribution and distortion in a welded pipe are strongly affected by many parameters and by their interaction. In particular, there are structural, material, and welding factors. The structural parameters include geometry of the pipes, thickness and diameter and joint type. Among the material parameters mechanical and physical properties and type of process employed, welding procedure, current, voltage, arc travel speed, and arc efficiency. As a consequence of the non-uniform temperature distribution, parts of materials close to the weld are subject to different rates of expansion and contraction developing a three dimensional complex residual stress state.

The stresses at hoop welds in pipes have been investigated by many previous workers. The most recent researches implemented a welding simulation methodology and experimentally validated to predict residual stresses on multipass welds. The simulation involves performing thermo-elasto-plastic analysis using a consistent element activation approach in the mechanical analysis [Panagiotis, 1997].

In this paper, mathematical model and finite element simulation of the single pass welding process yielding the welding-induced residual stresses in a welded pipe is presented.

RESIDUAL STRESS DUE TO PIPE WELDING:

Residual stresses are formed by the plastic deformations during the thermal cycle of welding. Before welding, the structure is assumed to be at room temperature and free of stresses. During the weld thermal cycle, material mechanical properties change drastically, especially when material approaches melting point temperature. Therefore, due to the temperature dependence of material properties and the large deformation in fusion welding, material and geometrical non-linearity have to be taken into account. The initial expansion material due to the temperature increase is constrained by material placed away from the heat source, therefore generating compressive stress. At a temperature higher than material critical temperature, the material starts exhibiting thermal softening where heating results in decrease of flow stress. As phase change occurs deviatoric stress becomes zero and considerable plastic deformation occurs in the weld metal and the base metal regions near the weld. As temperature decreases during the cooling phase, the stress in the solidifying material increases, and becomes tensile due to the positive temperature gradient. The region placed away from the weld line, will therefore, be in compression since the resultant force and the resultant moment induced by residual stress evaluated in any plane section must satisfy translation and rotational equilibrium. The plastic strains resulting from the heating causes stress, which in turn produce internal forces that may cause buckling, bending, and rotation. These displacements are in general called distortion. The residual stress combined with distortion and

degradation of the material mechanical properties influence the buckling strength and fatigue life of welded structure [Meo, 2003].

MATHEMATICAL MODEL:

In a girth-welded pipe, shrinkage of the weld in the circumferential direction induces shearing force, Q , and bending moments, M , to the pipe as shown in Fig. (1). the angular distortion caused by butt welding also induces bending moment. Distribution of residual stresses is affected by the following [Koichi, 1980]:

- 1-The diameter and wall thickness of the pipe.
- 2-The joint design (square, butt, vee, x etc).
- 3-The welding procedure and sequence (welded on outside only, welded on both sides, outside first, or welded on both sides, inside first).
- 4-The welding parameters (current, voltage, speed, electrode diameter, type of electrode...etc).
- 5-Material properties.

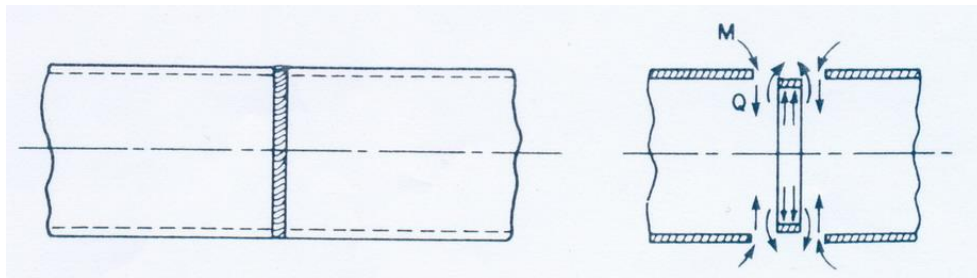


Fig. 1 Residual stresses in a welded pipe [Norman, 1984]

The tendon force locked into a weld is defined as the imaginary line load which would produce the observed shrinkage parallel to the weld, and is approximately independent of restraint. It may therefore be estimated on the basis of the assumption of infinite restraint against any hoop wise expansion of the heat material during welding. Then, the residual hoop stress at any point is a function of the maximum temperature reached, and the hoop tendon force is obtained by integrating the stress distribution.

For a surface weld bead, the maximum temperature as a function of the distance r from the weld centerline is given approximately by [Norman, 1984]:

$$T_{\max.} = \frac{2}{e\pi} \frac{\zeta q}{vr^2 \rho C_p} \quad (1)$$

Where ζ is the arc efficiency, q the weld power, v the weld travel speed, and ρC_p the volumetric specific heat.

Inside the region where the thermal strain $\alpha T_{\max}$ is greater than twice the yield strain σ_y/E , yield occurs in compression during heating, and then again in tension during cooling. For thermal strains between

$2\sigma_y/E$ and σ_y/E , the material yields in compression during heating, but unloads to a sub-yield tensile strain during cooling. Material whose maximum thermal strain is less than σ_y/E does not yield, and ends at zero stress for the idealized conditions of infinite hoop wise restraint.

The width of the zone containing yield magnitude tensile stresses (Fig. (2)) can be found by substituting $T_{\max.} = 2 \sigma_y / E \alpha$ in eq. (1):

$$r = \sqrt{\frac{E \alpha}{e \pi \sigma_y \rho C_p} \frac{\zeta q}{v}} \quad (2)$$

Where E modulus of elasticity, α thermal expansion coefficient, and σ_y yield strength of the pipe material.

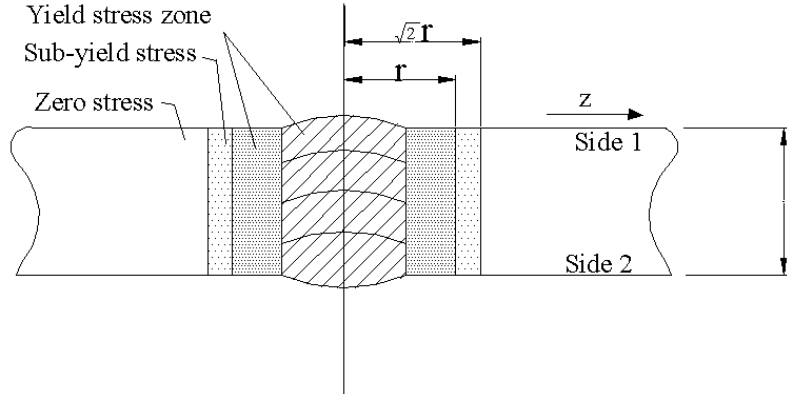


Fig. 2 Hoop tensile zone at girth weld

The total force locked into the tensile zone is given by:

$$F = A_w \sigma_{yw} + (1.17 \cdot 2t_0 r - A_w) \sigma_y \quad (3)$$

Where A_w and σ_{yw} are the area and yield strength of the weld, and the factor **1.17** allows for the sub-yield tensile stresses between r and $\sqrt{2} r$.

The inward radial deflection of a circular cylindrical shell loaded symmetrically with respect to its axis [Timoshenko, 1959]:

$$y = \frac{-e^{-\beta z}}{2\beta^3 D} [\beta M_o (\cos \beta z \quad \sin \beta z) + Q_o \cos \beta z] \quad (4)$$

And hence:

$$\frac{dy}{dz} = \frac{e^{-\beta z}}{2\beta^2 D} [2\beta M_o \cos \beta z + Q_o (\cos \beta z + \sin \beta z)] \quad (5)$$

$$\frac{d^2 y}{dz^2} = \frac{-e^{-\beta z}}{2\beta D} [2\beta M_o (\cos \beta z + \sin \beta z) + 2Q_o \sin \beta z] \quad (6)$$

Where $\beta = \left[\frac{3(1-\nu^2)}{R^2 t^2} \right]^{1/4}$, $D = \frac{Et_o^3}{12(1-\nu^2)}$, and R radius of the pipe.

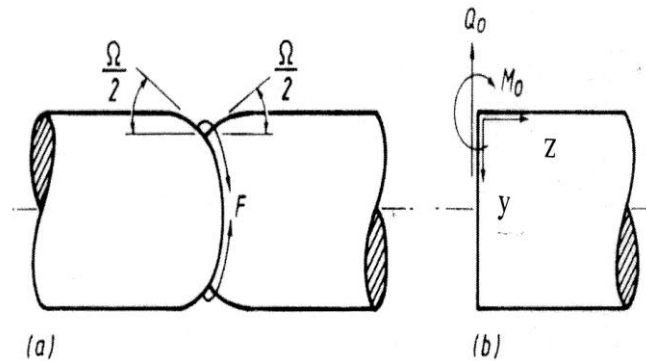


**Fig. 3 (a) Shrinkage parameters Ω and F
(b) Corresponding loads at weld centerline**

In order to model the deflections due to a hoop weld centered at $z=0$, the applied force Q_o and moment M_o are related to the angular distortion Ω and tendon force F which characterize the shrinkages of the weld.

The radial shear force is related to the tendon force F by considering radial equilibrium at $z=0$ [Timoshenko, 1959]:

$$Q_o = \frac{-F}{2R} \quad (7)$$

The bending moment M_o is found by setting $\frac{dy}{dz} = \frac{-\Omega_w}{2}$ at $z=0$ in eq. (5). Hence:

$$M_o = \frac{-1}{2\beta} (\beta^2 D \Omega_w + Q_o) \quad (8)$$

Substitution for Q_o and M_o in eqs. (4), (5) and (6) gives the radial deflection and its derivatives at any distance from the weld.

The axial bending stresses σ_{zb} on the inner and outer surfaces at any section inside or outside the tensile zone are a function of the curvature:

$$\sigma_{zb} = \mp \frac{Et}{2(1-\nu^2)} \frac{d^2 y}{dz^2} \quad (9)$$

FINITE ELEMENT MODELING PROCEDURES:

The FE analysis was carried out in two steps. A non- linear transient thermal analysis was conducted first to obtain the global temperature history generated during and after welding process.

A stress analysis was then developed with the temperatures obtained from the thermal analysis used as loading to the stress model.

The general purpose FE package ANSYS 8.0 was used for both thermal and stress analysis performed sequentially. The mesh used in the stress analysis was compatible to that in the thermal analysis. The material properties of the weld metal and base metal are assumed to be the same in this analysis and it is temperature dependent. The thermal and mechanical material properties are listed in table (1) & (2) respectively.

In the thermal analysis, the heat was input in four load steps as shown in figure (4). The nodal temperature solution obtained from the thermal analysis were read as loading into the stress analysis. In order to capture the residual stress induced due to the heating and cooling cycle, the temperature history needed to be read at a sufficient large number of time points, especially where the temperature gradient is large. However, the greater the number of the thermal solution steps used, the greater the computational time and the larger store space required.

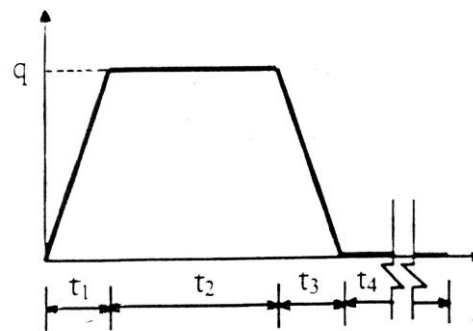


Fig. 4 Heat function input during welding [Wu, 2001]
($t_1=.5$ sec, $t_2=3$ sec, $t_3=.5$ sec, $t_4=396$ sec)

Table 1 Thermal material properties used in model [Brown, 1992]

NO.	T Temperature °C	K Thermal Conductivity W/m°C	Cp Specific heat J/Kg° C	h Convection heat Transfer coefficient W/m ² .C
	25	51.9	450	3
	100	51.1	486	5.4
	200	49	519	6.4
	300	46.1	557	7.0
	400	42.7	599	7.0
	500	39.4	662	7.7
	600	35.6	749	7.7
	700	31.8	816	7.7
	800	26	950	8.2
	1000	27.2	950	8.5
	1500	29.7	400	8.5
	1600	29.7	847	9.1

Table 2 Mechanical properties used in model [Brown, 1992]

NO.	T Temperature °C	σ_y Yield stress MPa	ν Poisson ratio	E Young's Modulus GPa	α Thermal Expansion $10^{-6} / ^\circ \text{C}$
	25	290	0.3	200	10
	100	260	0.31	200	11
	200	230	0.33	200	11.5
	300	200	0.35	200	12
	400	150	0.37	150	13
	500	120	0.39	110	14
	600	110	0.4	88	14
	700	9.8	0.42	20	14
	800	9.8	0.44	20	14
	1000	9.8	0.48	8	15
	1500	0.98	0.48	0.2	15
	1600	0.0098	0.48	0.00002	15

RESULTS AND DISCUSSIONS:

The sample of calculations was made on a single span ASTM214-71 mild steel pipe with (1 m) length, (25.4 mm) radius, (1.5 mm) thickness. The welded pipe was formed by joining two (0.5 m) pipes by single pass fusion arc welding. The amount of heat input was found as the product of arc efficiency, voltage, and current (Power arc welding $= f_1 f_2 VI$), Where: f_1 =heat transfer efficiency, f_2 =melting efficiency, V =voltage, and I =current. We take $f_1=0.9$, $f_2=0.6$, $V=30$ volt, $I=300$ Amp, using an electrode type E7010-G to make a straight pipe 1m length with welding on its mid span.

Fig. (5) Shows the temperature time history at a point in the center of welding. Fig. (6) Shows the temperature time history at a path along the length of the pipe at times during and after welding predicted by FE analysis. Fig. (7) Shows the nodal solution of the temperature distribution along the pipe. It was seen that max. Temperature in a center line of welding equal (1566 °C) at the moment of end welding then decreased and distributed along the pipe.

During the welding process, the temperature is locally increased to the melting point of mild steel. Moreover, in the heat affected zone of the weld, the temperature reaches high values. The mechanical properties of mild steel such as yield strength and elasticity modulus are highly depending on the temperature. After welding, the heat energy is dissipated due to convection with ambient air causing the steel to cool down and consequently gain its original yield strength. During this process of increasing and decreasing the temperature, residual stresses and plastic strains are developed.

Fig. (8) Shows the longitudinal stress time history at a path along the length of the pipe at times during and after welding predicted by FE analysis. The nodal solution of residual stress distribution

in Z-direction during and after welding along the top surface predicted by FE analysis is shown in fig. (9). It can be seen from these figures that the stress is changed from compression at the centerline of weld and tension away from the weld centerline at the end of welding ($t=3.5$ sec) to tension at the centerline of weld and compression away from the weld centerline when it cooled ($t=400$ sec), which are a good agreement between the analytical and numerical results with the published results [Wu, 2001; Erika, 2002].

The Von Mises residual stress distribution is shown in fig. (10) at time equal 400 sec. Fig. (11) Illustrates the results of residual stress distribution along the pipe due to welding. It is clear that the predicted residual stress by FE analysis is very close to the analytical analysis at the center of welding. It shows a tension peak of $\sigma_z=225$ MPa at weld line and adjacent parent metal going into compressive at about $Z=10$ mm from weld centerline and then blending into the background elastic distribution at about $Z=30$ mm from weld centerline. At position remote from the weld, the stresses didn't go to zero, but tend towards a steady value of about 10 MPa compressions. These results agree well with theoretical studies of residual stresses, at girth welds in pipes [Norman, 1984].

Fig. (12) Shows time variation of plastic strain at a centerline of welding. It is clear that the plastic strain increases rapidly during welding and then still constant during cooling.

The average values of thermal properties over the applied temperature distribution were used to study the effect of temperature dependent material properties on the final residual stress results. The residual stress obtained from the FE analysis using constant thermal properties show a significant difference from the obtained using temperature dependent thermal and mechanical properties as shown in fig. (13), especially in the heat affected zone due to the fact that the yield strength variation at higher temperature has less effect. This suggested that care must be taken to identify correctly the temperature-dependent yield strength of material which is often not easily determined.

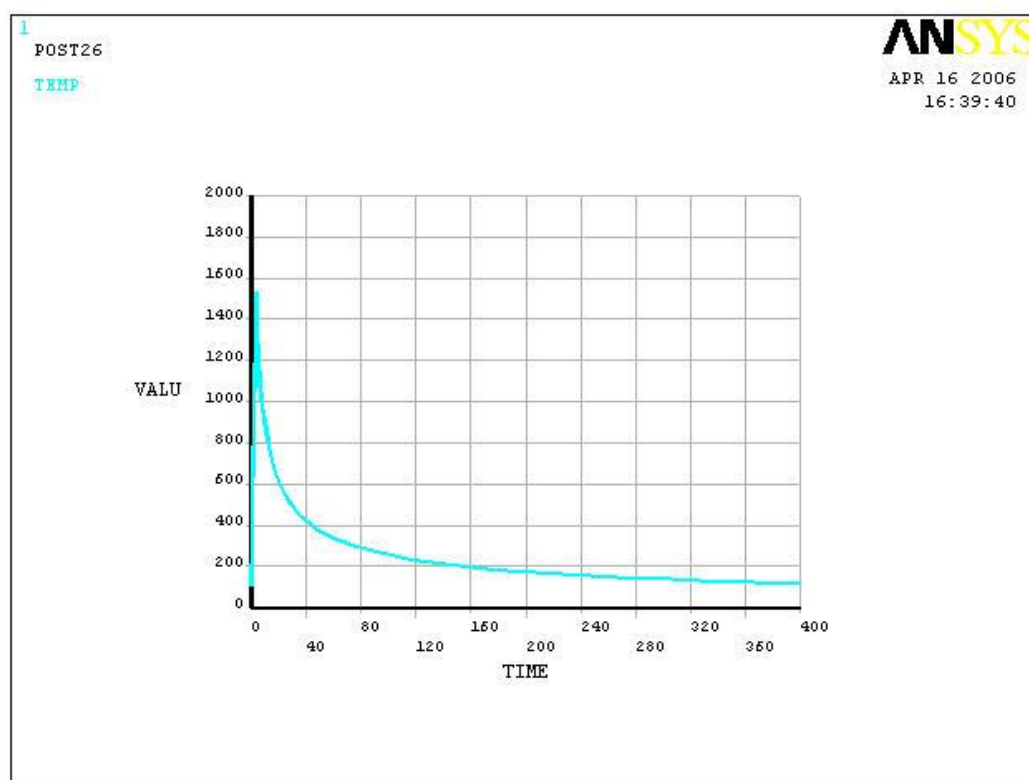


Fig. 5 Temperature time history at a point in the center of welding

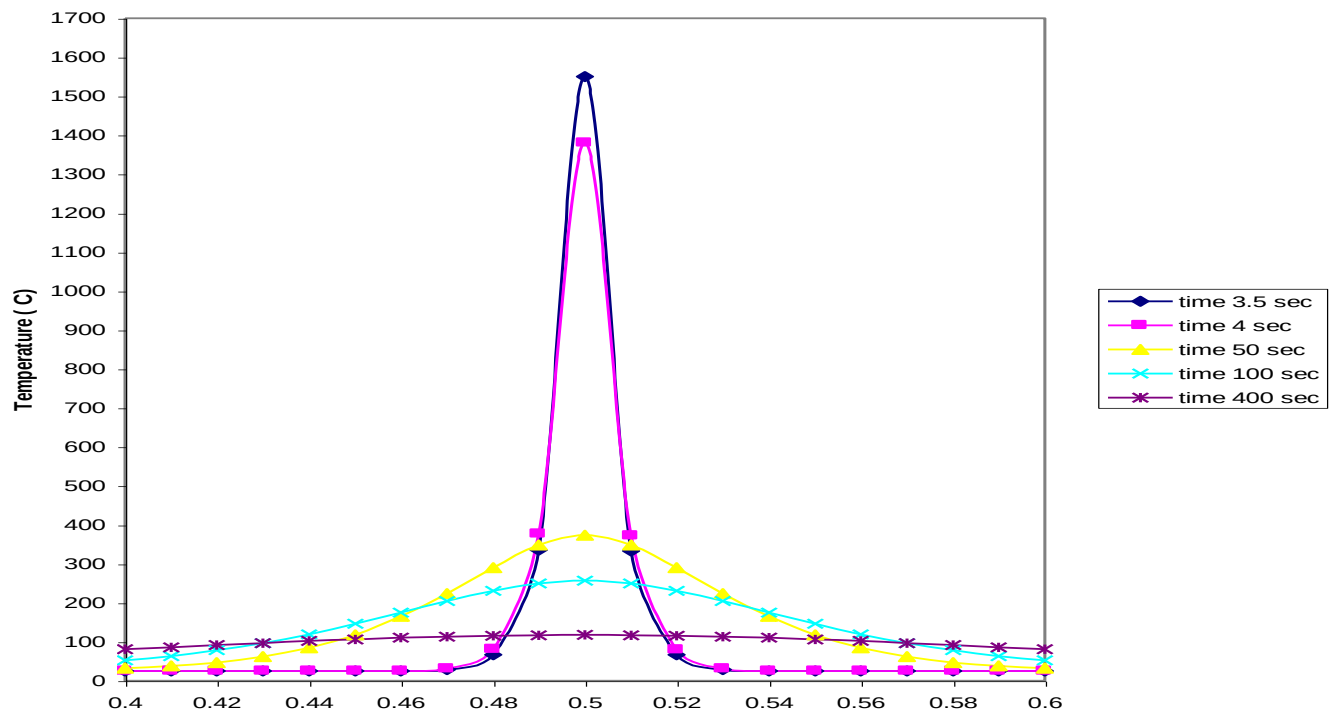


Fig. 6 Temperature distributions along welded pipe at different times

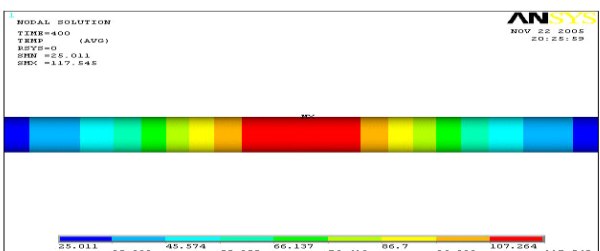
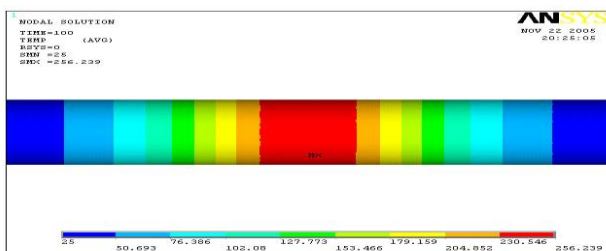
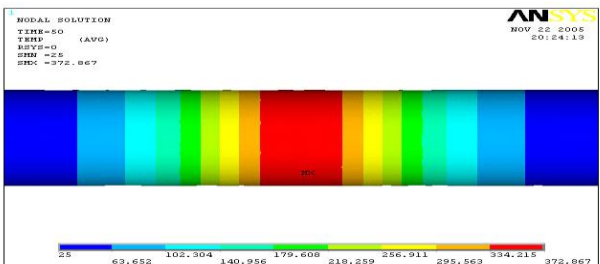
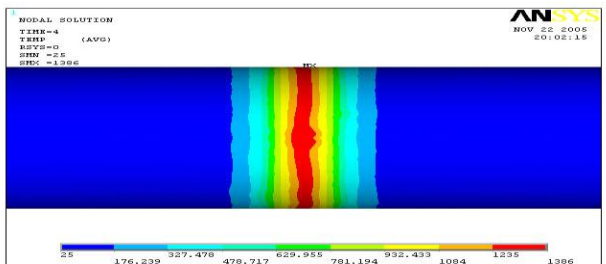
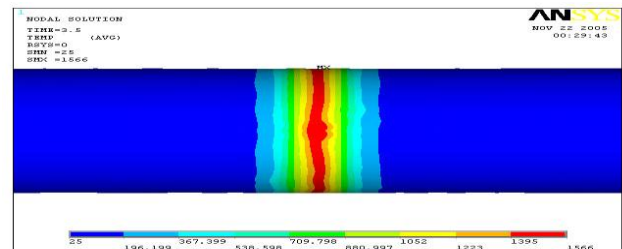
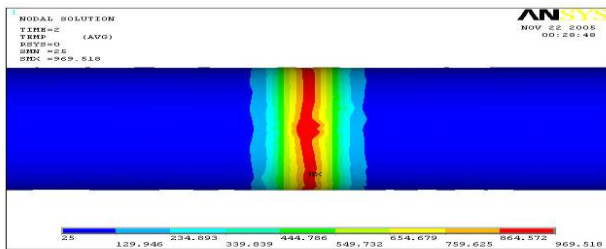


Fig. 7 Temperature distribution during and after welding

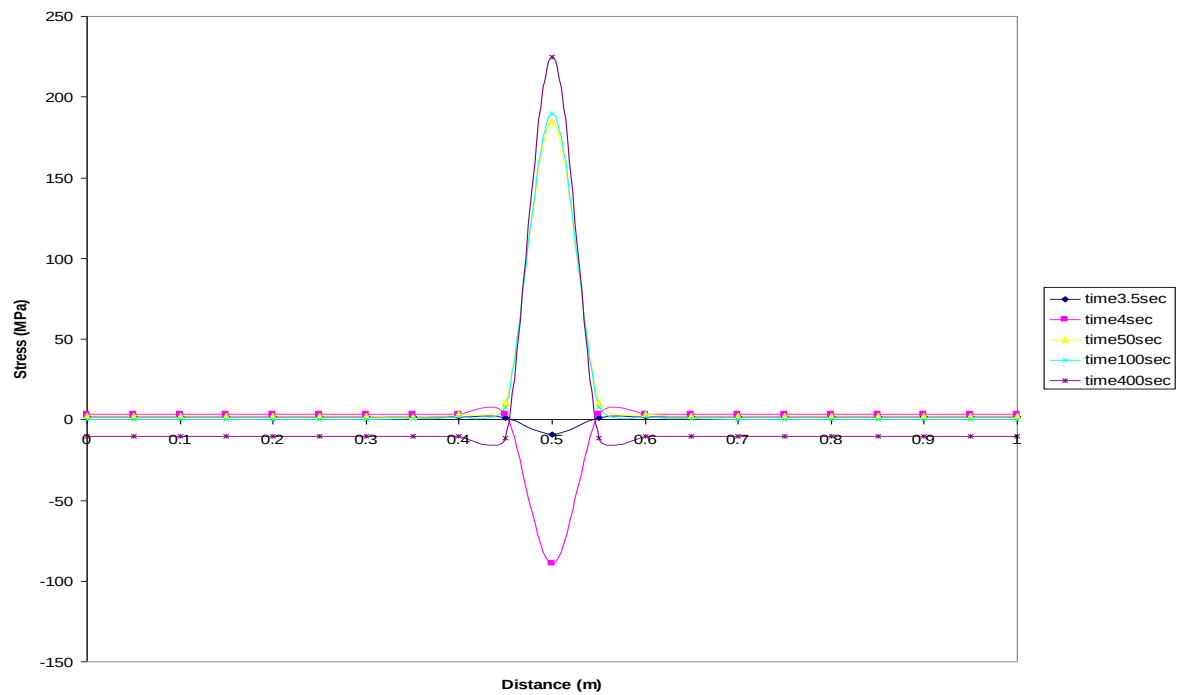


Fig. 8 Residual stress distributions along welded pipe at different times

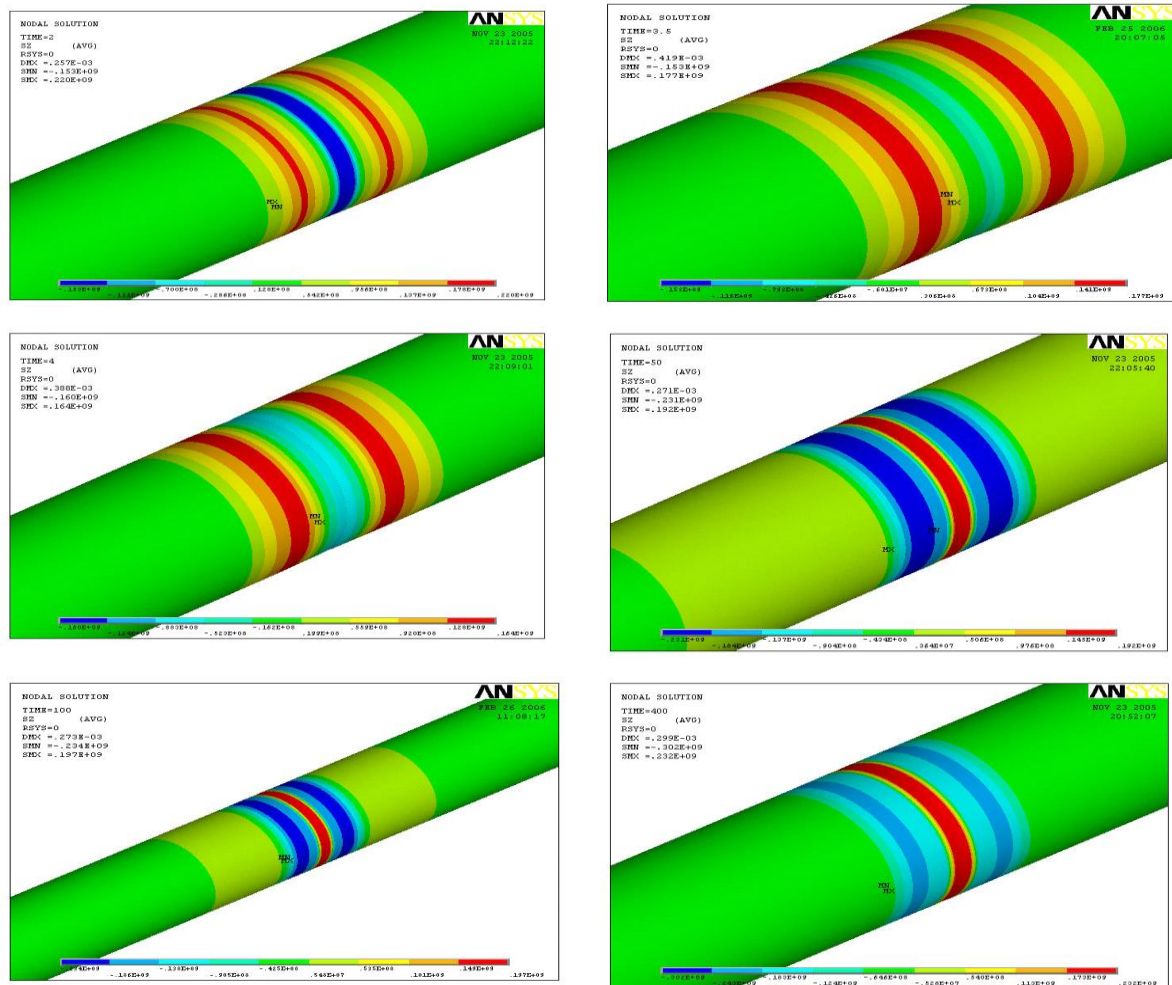


Fig. 9 Residual stress distribution along welded pipe during and after welding

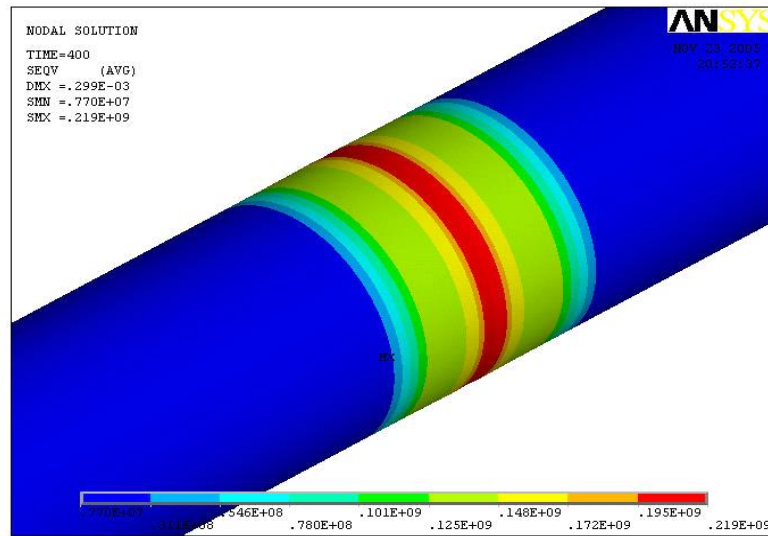


Fig. 10 Von Mises residual stress distribution in a welded pipe

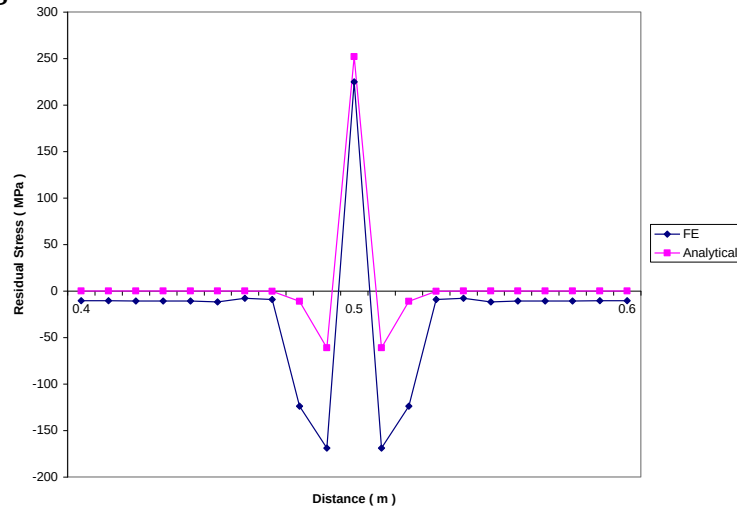


Fig. 11 Residual stress distribution along welded pipe

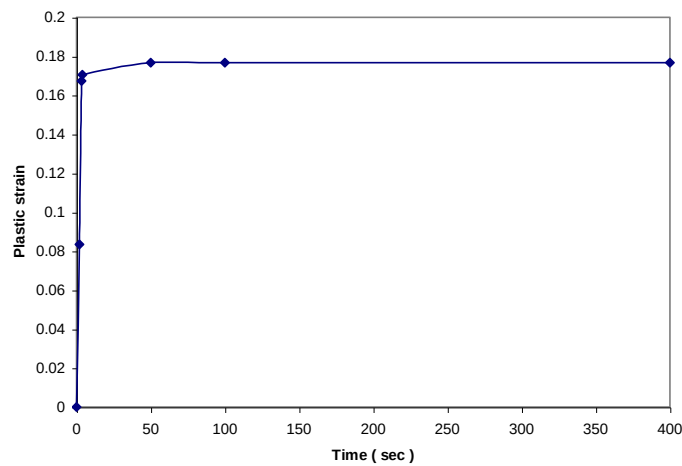


Fig. 12 Plastic strain in a centerline of weld

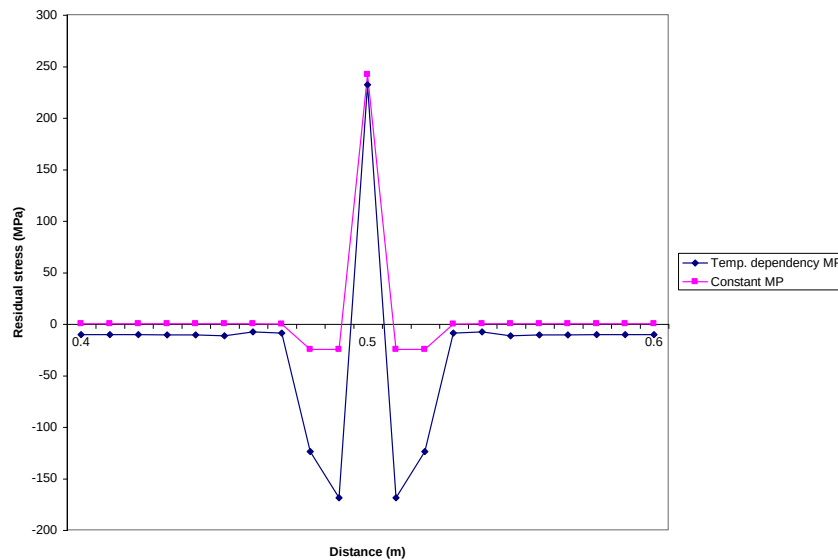


Fig. 13 Effect of temperature dependency material properties on the residual stress along a weld pipe

CONCLUSIONS:

Analytical and finite element analysis are used to determine the residual stresses resulting from the single pass welding of mild steel pipe of 25.4 mm radius, 1.5 mm thickness. Following the main summarized conclusions raised by this paper:

- 1- Welding of a pipe induced residual stresses. It has been seen that these stresses changed from compression at the centerline of welding and tension away from the weld centerline at the end of welding to tension at the centerline of weld and compression away from the weld centerline when it cooled.
- 2- The residual stress obtained by using constant thermal and mechanical properties show significant difference from that obtained using temperature dependent thermal and mechanical properties especially in the heat affected zone.

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NOMENCLATURE

<i>Symbols</i>		<i>Units</i>
A_w	Area of the weld	m^2
C_p	Specific heat of pipe material	$J/Kg^{\circ}C$
E	Modulus of elasticity	N/m^2
F	Tendon force	N/m
M_o	Bending moments	Nm
Q_o	Shear force	N
q	Weld power	$watt$
R	Radius of the pipe	mm
T_{max}	Maximum temperature at the weld	$^{\circ}C$
t_o	Thickness of the pipe	mm
v	Weld travel speed	m/sec
ζ	Arc weld efficiency	
ρ	Density of pipe material	Kg/m^3
α	Thermal expansion	$^{\circ}C$
σ_y	Yield stress of a pipe metal	N/m^2
σ_{yw}	Yield stress of the weld	N/m^2
σ_{zb}	Axial bending stress	N/m^2
Ω_w	Angular distortion	

SHORT TERM DEFLECTION OF ORDINARY, PARTIALLY PRESTRESSED AND GFRP BARS REINFORCED CONCRETE BEAMS

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ABSTRACT

The behavior of structural concrete beams is studied under short-term loading. A computer program developed originally by Oukaili to evaluate curvature is modified to evaluate the deflection for flexural structural concrete members. The program deals with actual stress-strain relationships of concrete and steel. The analysis is based on requirements of equilibrium and compatibility of strain in concrete and reinforcement. The proposed model is used in conjunction with the step by step analysis for small loading increments that allows the determination of the history of strain and stress in concrete with prestressing steel or non-prestressing reinforcement only or prestressing and non-prestressing reinforcement together. The evaluation of curvatures for the structural member involves iterations for computing the strains vectors at each analysis step. Newmark's numerical integration is used to evaluate the deflection of the member depending on the curvature values. The stress-strain model that was proposed by (Korpenko et al. 1986) is used and compared with experimental data and other analytical models for each of concrete and steel. The comparison showed good agreement between the model used and the experimental data. This relationship is used in SECTION program and presented in this study. The analytical results for load-deflection diagram are compared with available experimental data. The comparison has shown good agreement.

الهطول قصير الأمد للعتبات الخرسانية المسلحة العادية والمسبقة الجهد جزئياً و المسلحة بقضبان ألياف الزجاج

الخلاصة

في هذا البحث درست سلوكية العتبات الخرسانية تحت تأثير الأحمال قصيرة الأمد. حيث تم تطوير برنامج أقترحه سابقاً العقيلي لغرض حساب قيم الهطول لأعضاء الخرسانة الإنشائية المعرضة للإنحناء. إن البرنامج المعتمد يأخذ في الاعتبار مخططات الإجهاد-الإنفعال الفعلية في الخرسانة والحديد. إن طبيعة التحليل تعتمد على شروط الإلتزان و التوافق في الإنفعالات في الخرسانة وفي التسليح. يقترن النموذج المدروس مع التحليل الخطوي و ذلك بإستخدام التحميل على مراحل صغيرة مما يتيح إمكانية دراسة تزايد الإنفعال و الإجهاد في المقطع الخرساني وحديد التسليح الموجود، سواء كان الحديد المستخدم مجهود سابقاً أو حديد غير مجهود سابقاً فقط، أو حديد قسم مجهود سابقاً وقسم غير مجهود سابقاً سوية. إن أسلوب تحديد التقوس (curvature) للعنصر الإنشائي يتضمن عمليات تكرارية هدفها إيجاد قيمة الإنفعالات العمودية في كل مرحلة تحميل. تم إستخدام طريقة Newmark لغرض التكامل لقيم التقوس للمقاطع المدروسة على إمتداد العتبة لغرض إيجاد قيم الهطول لكل نقطة على طول العتبة. تمت مقارنة النتائج الخاصة بقيم الإجهاد-الإنفعال لكل من الخرسانة و الحديد مع بيانات مخبرية ونماذج نظرية لباحثين آخرين، وقد وجد إن الأنموذج المستخدم لتمثيل الإجهاد-الإنفعال و المقترح من قبل الباحث Korpenko وآخرين يعطي توافقاً جيداً لكلا المادتين.

أستخدم هذا الأنموذج في البرنامج المقدم (SECTION program) . إن النتائج النظرية الخاصة بقيم الحمل-الهطول للعتبات تمت مقارنتها أيضاً مع نتائج مخبرية متوفرة . لقد وجد إن هناك توافقاً جيداً بين النتائج العملية و النظرية لقيم الهطول.

KEYWORDS: Beam, Reinforced concrete, Prestressed concrete, GFRP, Deflection, Curvature, Stress-Strain, Korpenko, Newmark

INTRODUCTION

Deflection is defined according to (ACI 116, 2000) as a movement of a point on a structure or structural element, usually measured as a linear displacement or as succession of displacements transverse to a reference line or axis. There are many empirical and analytical methods for computing deflection of structural concrete members. In this paper an analytical method is modified to compute the deflection of a structural concrete member based on the materials stress-strain relationships, the curvature of the cross-section is determined according to these stress-strain relationships, and then integration is made for the cross-section curvatures along the beam to determine the deflection. It must be mentioned that this analytical method takes into consideration the effect of tension stiffening after cracking of concrete. This analytical model is compared to the available experimental data and hand calculations.

STRESS-STRAIN MODEL

Stress-strain model for concrete

In 1986, Korpenko published a descriptive relationship for $\sigma - \epsilon$ diagrams, which became very famous because of its overcoming of major deficient problems as shown in Fig. (1).

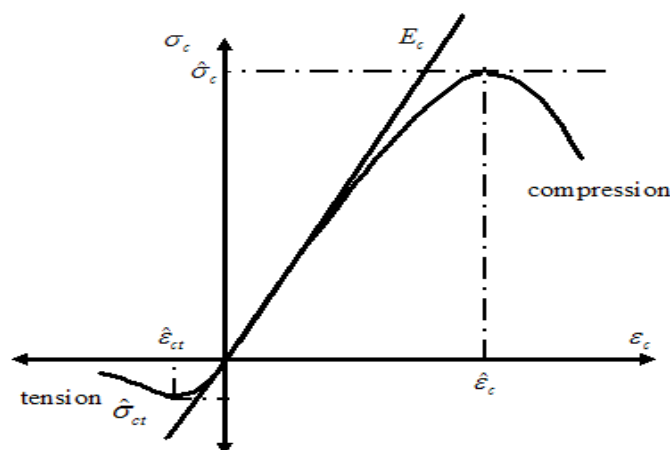


Figure (1) Stress-strain diagram for concrete in compression and tension (Korpenko et al., 1986)

It is taken that σ_c be the stress, ϵ_c the relative strain, E_c the initial modulus of elasticity, c referring to concrete in compression, and ct to concrete in tension.

Instead of using σ_c and ϵ_c , it is easier to use the level of each one according to the relationship indicated below:

$$\tilde{\sigma}_c = \left| \frac{\sigma_c}{\hat{\sigma}_c} \right| ; \tilde{\varepsilon}_c = \left| \frac{\varepsilon_c}{\hat{\varepsilon}_c} \right| \quad (1)$$

where: $\tilde{\sigma}_c$ =concrete stress level, $\tilde{\varepsilon}_c$ =concrete strain level, $\hat{\sigma}_c$ =ultimate compressive strength of concrete, $\hat{\varepsilon}_c$ =the concrete strain corresponding to $\hat{\sigma}_c$.

At the beginning of $\sigma - \varepsilon$ diagram, a linear portion can be recognized which extends up to the stress $\sigma_{c,el}$ and the strain $\varepsilon_{c,el}$ or even until their levels $\tilde{\sigma}_{c,el}$ which is equal to $\frac{\sigma_{c,el}}{\hat{\sigma}_c}$ and $\tilde{\varepsilon}_{c,el}$ which is equal to $\frac{\varepsilon_{c,el}}{\hat{\varepsilon}_c}$. The stress in concrete can be expressed as:

$$\sigma_c = \varepsilon_c E_c \nu_c \quad (2)$$

ν_c is concrete elastic modulus factor that expresses the ratio of elastic strains to the total strains.

$$\nu_c = 1 \quad \text{if} \quad |\sigma_c| \leq |\sigma_{c,el}| \quad (3)$$

$$\nu_c^2 \left[1 + \frac{e_{2c} (\nu_o - \hat{\nu}_c)^2 \cdot \tilde{\varepsilon}_c^2}{\hat{\nu}_c (1 - \tilde{\sigma}_{c,el})^2} \right] - \nu_c \left[2\hat{\nu}_c - \frac{\tilde{\varepsilon}_c (\nu_o - \hat{\nu}_c)^2}{\hat{\nu}_c (1 - \tilde{\sigma}_{c,el})} \left(e_{1c} - \frac{2e_{2c} \tilde{\sigma}_{c,el}}{1 - \tilde{\sigma}_{c,el}} \right) \right] + \hat{\nu}_c^2 - (\nu_o - \hat{\nu}_c)^2 \left[1 + \frac{e_{1c} \tilde{\sigma}_{c,el}}{1 - \tilde{\sigma}_{c,el}} - \frac{e_{2c} \tilde{\sigma}_{c,el}^2}{(1 - \tilde{\sigma}_{c,el})^2} \right] = 0 \quad \text{if} \quad |\sigma_c| > |\sigma_{c,el}| \quad (4)$$

By solving the second degree formula, two roots are obtained from the formula; the larger root is taken for ν_c .

$$\tilde{\sigma}_c = \left| \frac{\sigma_c}{\hat{\sigma}_c} \right| ; \tilde{\varepsilon}_c = \left| \frac{\varepsilon_c}{\hat{\varepsilon}_c} \right| , \quad \eta_c = \frac{\sigma_c - \sigma_{c,el}}{\hat{\sigma}_c - \sigma_{c,el}} = \frac{\tilde{\sigma}_c - \tilde{\sigma}_{c,el}}{1 - \tilde{\sigma}_{c,el}} \leq 1 , \quad \hat{\nu}_c = \left| \frac{\hat{\sigma}_c}{\hat{\varepsilon}_c} \right| E_c$$

where: $\hat{\nu}_c = \nu_c$ value when $\sigma_c = \hat{\sigma}_c$ (at the top of stress-strain diagram).

ν_o factor which depends on stress level in the material (concrete in this case).

$$\nu_o = 1 \quad \text{if} \quad \tilde{\varepsilon}_c \leq 1$$

$$\nu_o = 2.05 \hat{\nu}_c \quad \text{if} \quad \tilde{\varepsilon}_c > 1$$

e_{1c}, e_{2c} are factors which express the type of the concrete.

$$e_{1c} = 1.72 - 1.82 \hat{\nu}_c \quad \text{if} \quad \tilde{\varepsilon}_c \leq 1$$

$$e_{1c} = 1.95 \hat{\nu}_c - 0.138 \quad \text{if} \quad \tilde{\varepsilon}_c > 1$$

$$e_{2c} = 1 - e_{1c}$$

From the conditions of Eq. (4) that is $e_{1c} < 2$

$$\left| \hat{\varepsilon}_c \right| \approx 0.002 \quad ; \quad \tilde{\sigma}_{c,el} = 0 \quad ; \quad \tilde{\varepsilon}_{c,el} = 0 \quad , \quad \tilde{\sigma}_c = \tilde{\varepsilon}_c \nu_c / \tilde{\nu}_c$$

Stress-strain model for steel

σ_s is written to be the stress, ε_s the relative strain (elongation), E_s the initial modulus of elasticity for steel, and s to refer to the steel.

When mild steel enters the stiffness region, it is advised to use the bilinear diagram that is of two branches, one ends at the point of yield region (with coordinates $\varepsilon_s = \hat{\varepsilon}_s$, $\sigma_s = \hat{\sigma}_s$), and the other begins from the end of the first branch to reach the point of coordinates $\sigma_s = \sigma_s^*$, $\varepsilon_s = \varepsilon_s^*$, which corresponds to the ultimate strength or failure limit as shown in Fig. (2).

Mild steel can be represented by the following equations:

$$\sigma_s = \varepsilon_s E_s \nu_s \quad (5)$$

$$\nu_s = 1 \quad \text{if} \quad |\sigma_s| \leq |\sigma_{s,el}| \quad (6)$$

$$\begin{aligned} & \nu_s^2 \left[1 + \frac{e_{2s} (\nu_o - \hat{\nu}_s)^2 \cdot \tilde{\varepsilon}_s^2}{\hat{\nu}_s (1 - \tilde{\sigma}_{s,el})^2} \right] - \nu_s \left[2\hat{\nu}_s - \frac{\tilde{\varepsilon}_s (\nu_o - \hat{\nu}_s)^2}{\hat{\nu}_s (1 - \tilde{\sigma}_{s,el})} \left(e_{1s} - \frac{2e_{2s} \tilde{\sigma}_{s,el}}{1 - \tilde{\sigma}_{s,el}} \right) \right] \\ & + \hat{\nu}_s^2 - (\nu_o - \hat{\nu}_s)^2 \left[1 + \frac{e_{1s} \tilde{\sigma}_{s,el}}{1 - \tilde{\sigma}_{s,el}} - \frac{e_{2s} \tilde{\sigma}_{s,el}^2}{(1 - \tilde{\sigma}_{s,el})^2} \right] = 0 \end{aligned} \quad \text{if} \quad |\sigma_s| > |\sigma_{s,el}| \quad (7)$$

By solving the second degree formula, two roots are obtained from the formula; the larger root is taken for ν_c . Thus:

$$e_{1s} = \frac{(\nu_o - \hat{\nu}_s)^2 (\eta_{s(c)}^2 - 1) + (\nu_{s(c)} - \hat{\nu}_s)^2}{(\eta_{s(c)}^2 - \eta_{s(c)})(1 - \hat{\nu}_s)^2} \leq 2$$

$$\sigma_{s(c)} \approx 1.2\sigma_y, \varepsilon_{s(c)} = 0.05 + \frac{\sigma_{s(c)}}{E_s}, \eta_{s(c)} = \frac{\sigma_{s(c)} - \hat{\sigma}_s}{\sigma_s^* - \hat{\sigma}_s}, \nu_{s(c)} = \frac{\sigma_{s(c)}}{E_s \varepsilon_{s(c)}}$$

$$\eta_s = \frac{\sigma_s - \sigma_{s,el}}{\hat{\sigma}_s - \sigma_{s,el}} = \frac{\tilde{\sigma}_s - \tilde{\sigma}_{s,el}}{1 - \tilde{\sigma}_{s,el}} \leq 1, \tilde{\sigma}_s = \frac{\sigma_s}{\sigma_s^*}, \tilde{\varepsilon}_s = \frac{\varepsilon_s}{\varepsilon_s^*}, \nu_o = \frac{\hat{\sigma}_s}{E_s \hat{\varepsilon}_s}, \hat{\nu}_s = \frac{\sigma_s^*}{E_s \varepsilon_s^*},$$

$$\hat{\varepsilon}_s = \frac{\hat{\sigma}_s}{E_s} + \lambda_y, \lambda_y = \text{yield plateau length} = (0.008-0.015) \text{ according to steel type.}$$

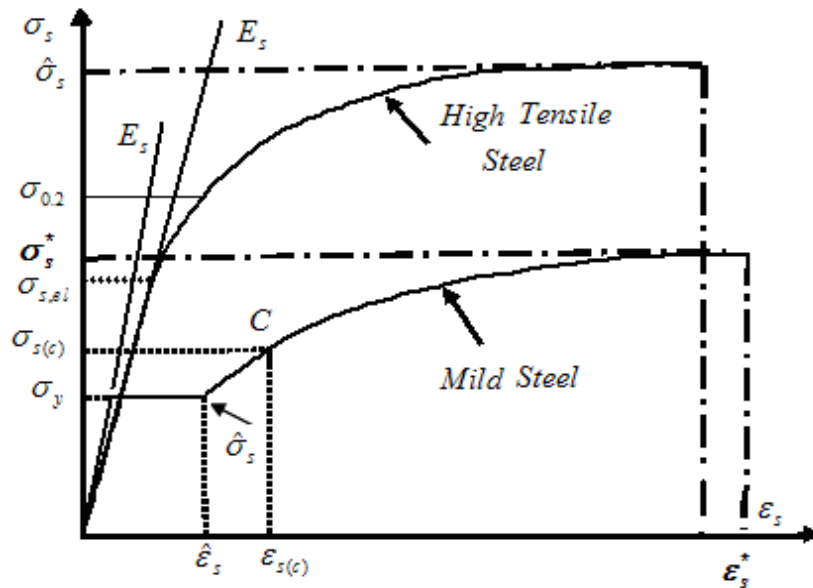


Figure (2) Stress-strain diagram of mild and high strength steel (Korpenko et al., 1986)

For high strength steel the same equations (5, 6, 7) are used but

$$e_{1s} = \frac{(\nu_o - \hat{\nu}_s)^2 (\eta_{0.2}^2 - 1) + (\nu_{0.2} - \hat{\nu}_s)^2}{(\eta_{0.2}^2 - \eta_{0.2})(1 - \hat{\nu}_s)^2} \leq 2$$

$$\varepsilon_{0.2} = \frac{\sigma_{0.2}}{E_s} + 0.002, \quad \nu_{0.2} = \frac{\sigma_{0.2}}{E_s \varepsilon_{0.2}}, \quad \eta_{0.2} = \tilde{\sigma}_{0.2} \frac{1 - \beta_{el}}{1 - \beta_{el} \cdot \tilde{\sigma}_{0.2}},$$

$$\hat{\nu}_s = \frac{\hat{\sigma}_s}{E_s \hat{\varepsilon}_s}, \quad \sigma_{s,el} = \beta_{el} \cdot \sigma_{0.2}, \quad \nu_o = 1$$

$$\eta_s = \frac{\sigma_s - \sigma_{s,el}}{\hat{\sigma}_s - \sigma_{s,el}} = \frac{\tilde{\sigma}_s - \tilde{\sigma}_{s,el}}{1 - \tilde{\sigma}_{s,el}} \leq 1, \quad \tilde{\sigma}_s = \frac{\sigma_s}{\hat{\sigma}_s}, \quad \tilde{\varepsilon}_s = \frac{\varepsilon_s}{\hat{\varepsilon}_s},$$

Stress-strain model for FRP

The stress-strain diagram for FRP is assumed linearly elastic until failure stage as shown in (Fig. 3).

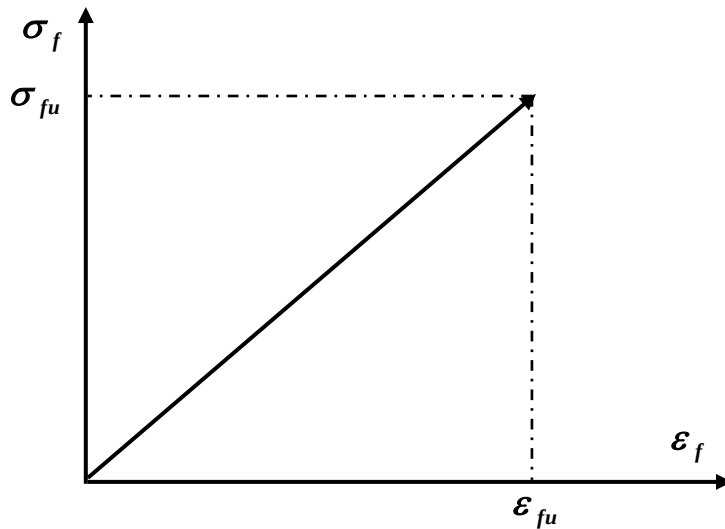


Figure (3) Stress-strain diagram for FRP

Comparison of the stress-strain relationships of the materials

The proposed stress-strain model is compared to other models by using available experimental data for concrete (LSC, NSC, HSC) and for steel with its types mild; high strength; and high strength for prestressing as shown in Figures from (4) to (12).

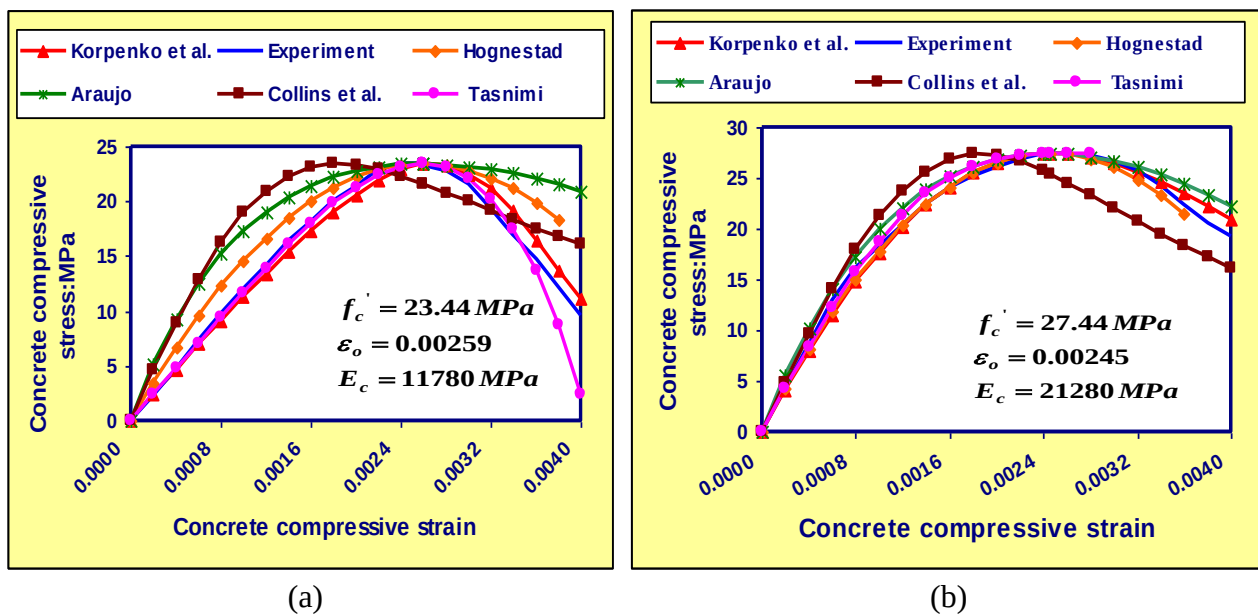
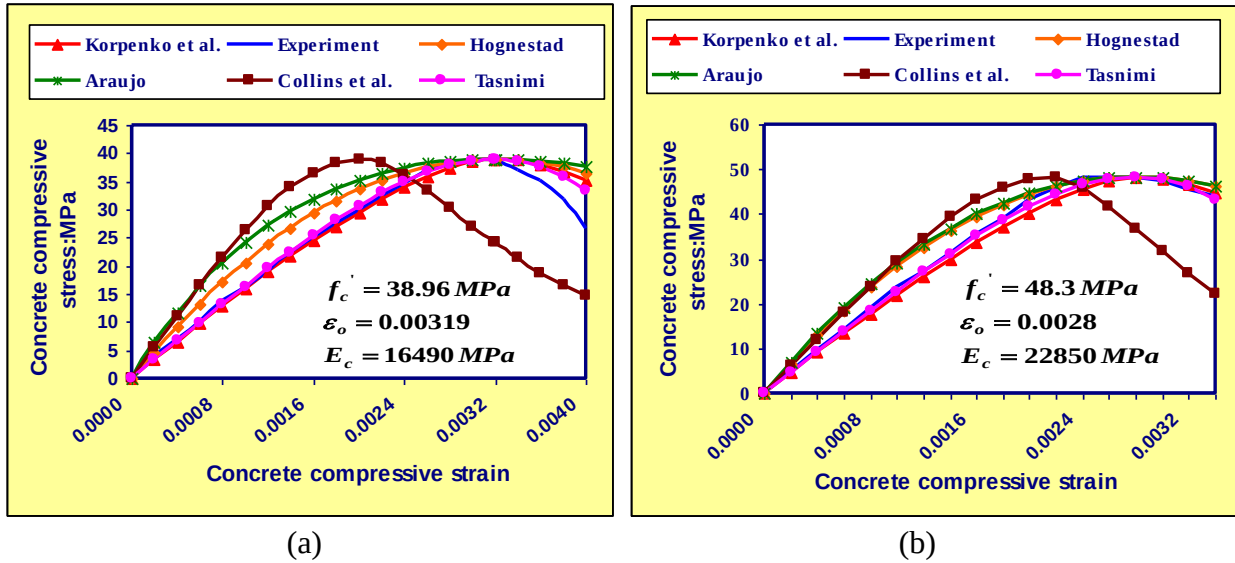
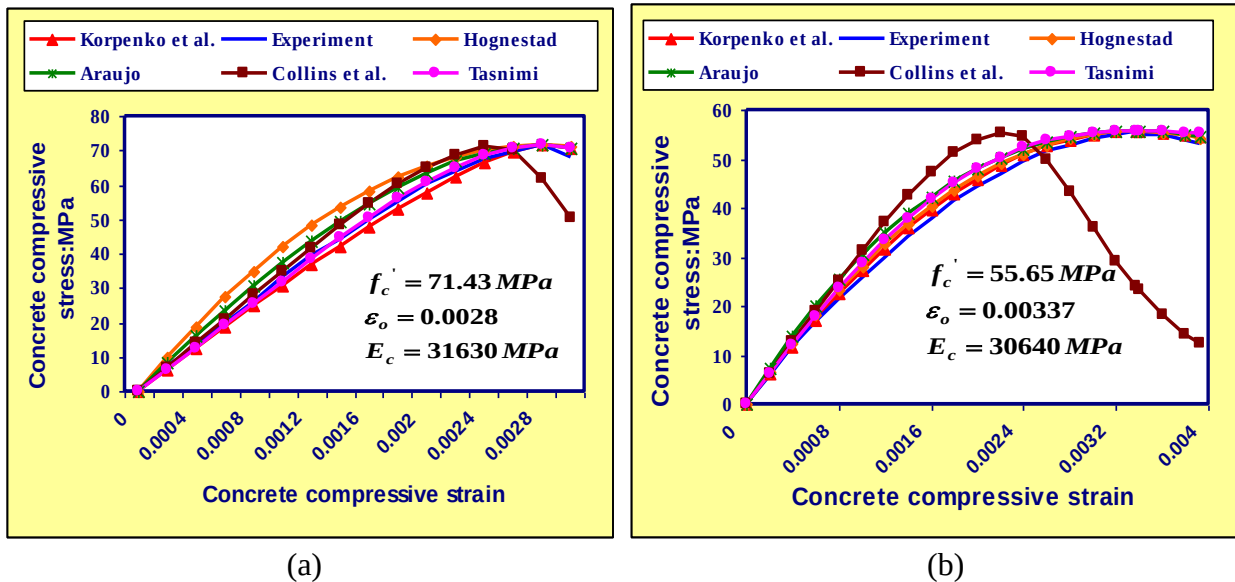
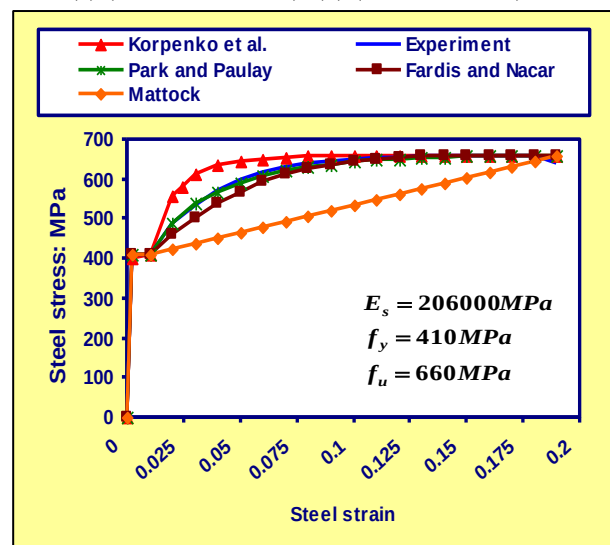
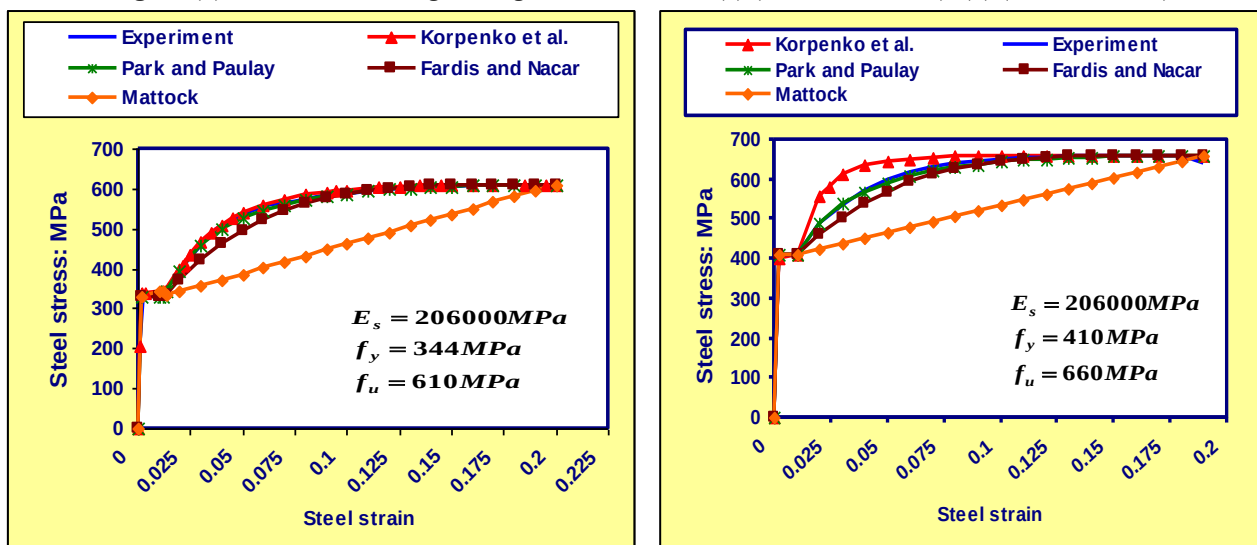


Figure (4) Stress-strain for low strength concrete LSC:
(a) (Wang et al., 1978), (b) (Tasnimi, 2004)

**Figure (5)** Stress-strain for normal strength concrete NSC:

(a) (Wang et al., 1978), (b) (Slate et al., 1986)

**Figure (6)** Stress-strain for high strength concrete HSC: (a) (Slate et al., 1986), (b) (Tasnimi, 2004)

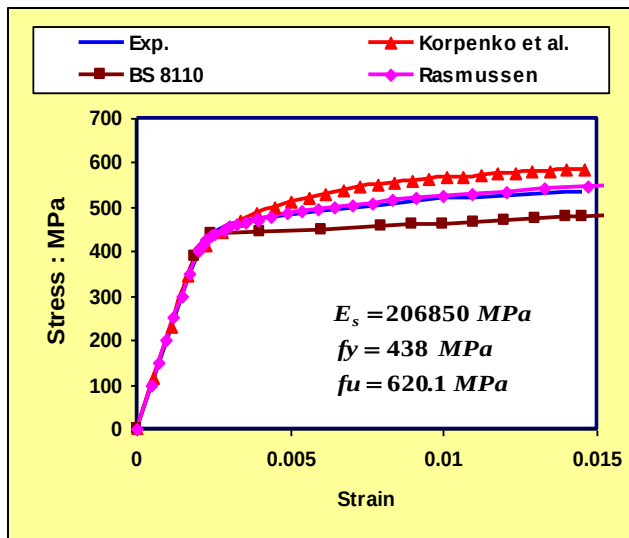


Figure (9) Stress-strain for mild steel
(Tompos and Frosh, 2002)

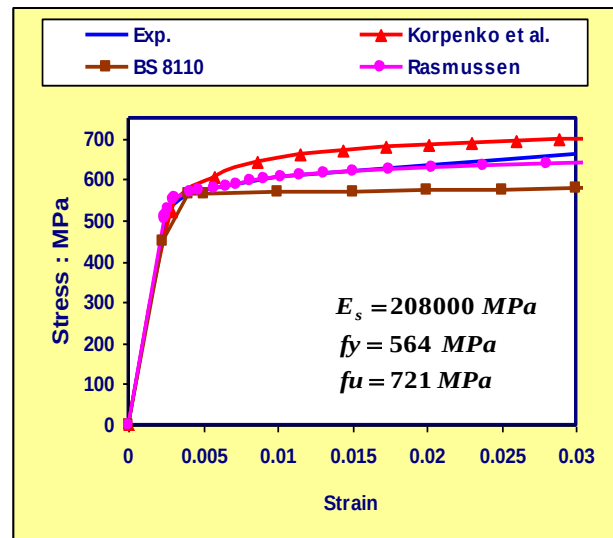


Figure (10) Stress-strain for mild steel
(Kenel et al., 2005)

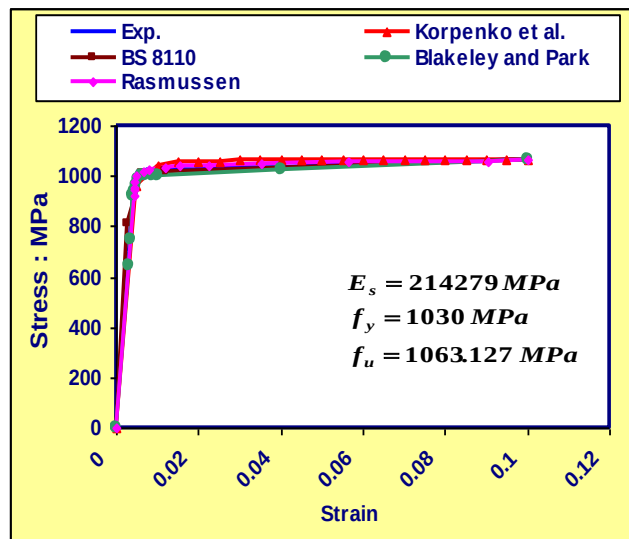


Figure (11) Stress-strain for HSS with prestressing
(California Prestressing Manual, 2005)

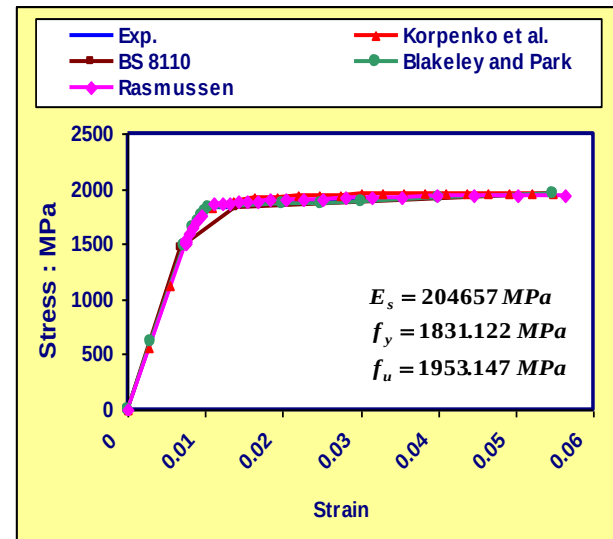


Figure (12) Stress-strain for HSS with prestressing
(Canfield, 2005)

MODEL ASSUMPTIONS

The proposed model for calculating the deflection depends on the following assumptions:

- Strain in the concrete and reinforcement is proportional to the distance from the neutral axis (plane cross sections remaining plane after bending).
- Concrete behavior in compression and in tension and steel behavior are assumed to follow Korpenko's model Fig. (1) and Fig. (2).
- The tensile behavior of the FRP reinforcement is linearly elastic until failure stage. (Fig. 3).
- All stresses in concrete and steel are related to secant modulus of elasticity.
- Shear and torsion stresses are ignored.
- Perfect bond exists between concrete, steel reinforcement and FRP bars.

- Concrete is divided into a group of small cells with its number related to the required accuracy. Beside that, the longitudinal steel and FRP bars in the section are divided into a group of elements, with their numbers equal to the numbers of steel and FRP elements. Thus the structural element acts as a system of linear elements exposed to compression and axial tension.
- The beam is considered as simply supported with symmetrical shape along the vertical centerline of the beam. This includes the type of loading and the beam cross section.
- Newmark's numerical procedure is used to determine the deflection from the section curvatures along the beam.
- In the case of fully or partially prestressed concrete members, the positive value of deflection indicates downward displacement, and the negative sign indicates that the displacement is upward (i. e. camber).
- The component of the prestress along the beam axis is assumed constant, but the distance from the prestressing center of gravity to the global axis is taken according to the prestressing steel position in each section.

MOMENT-CURVATURE MODEL

A partially prestressed concrete member is taken as a case study for determining the moment-curvature relation of structural concrete members. The concrete is distinguished by the subscript (c), prestressed steel by (ps), non-prestressed steel by (s), and (f) for FRP.

The space that is occupied by the section is assigned by the symbol Ω . In this space, there are areas occupied by concrete, prestressed steel, nonprestressed steel, and FRP which are symbolized as A_c , A_{ps} , A_s , and A_f respectively, as shown in (Fig. 13).

$$\Omega = A_c + A_{ps} + A_s + A_f \quad (8)$$

The external force, which is either normal force (prestressing force) or applied load, leads to change the general form of the element causing strain distribution at individual sections.

The strain energy per unit length is determined by the following formula:

$$U^{(l)} = \frac{1}{2} \int_{\Omega} (\sigma \varepsilon + \tau \gamma) d\Omega \quad (9)$$

where

σ , ε =normal strain and stress, respectively; γ , τ =shear strain and stress, respectively.

The equation that relates the stress to strain is as follows:

$$\sigma = \bar{E} \varepsilon \quad (10)$$

where $\bar{E}$ = secant modulus of elasticity of the material, which takes into account the initial stresses and strains, and its calculation is based on $\sigma - \varepsilon$ diagrams for the materials as shown in Figs. (14) and (15).

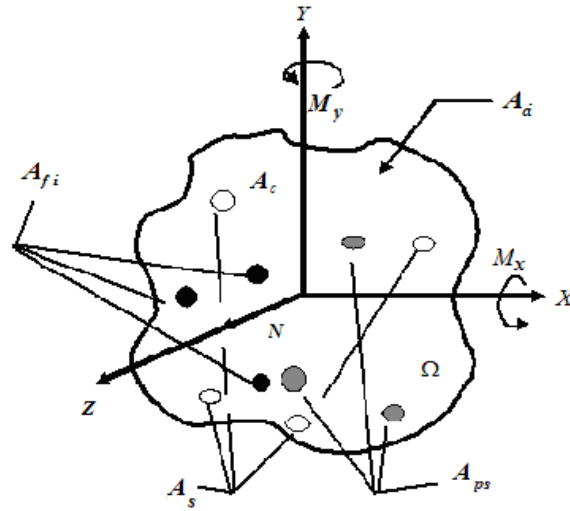


Figure (13) Cross-section of the structural element

$$\bar{E} = \begin{cases} \bar{E}_c, & x, y \in A_c \\ \bar{E}_{ps}, & x, y \in A_{ps} \\ \bar{E}_s, & x, y \in A_s \\ \bar{E}_f = E_f, & x, y \in A_f \end{cases} \quad (11)$$

Eq. (10) is substituted in Eq. (9). Shear stress and strain which appear in Eq. (9) are neglected (assumption No. 5).

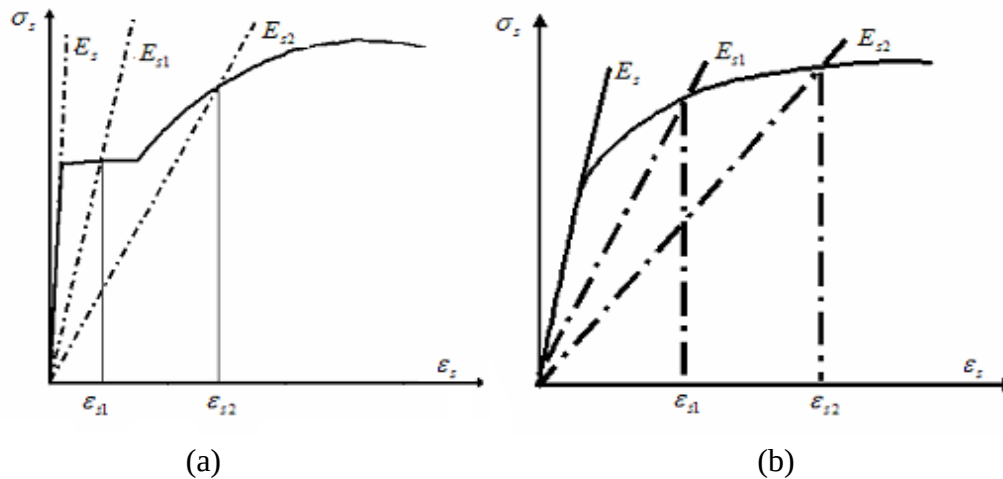


Figure (14) Variation of secant modulus of elasticity, (a) for mild steel, (b) for high strength steel

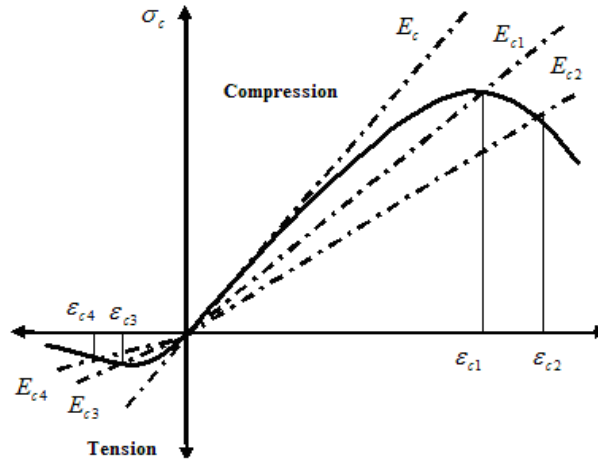


Figure (15) Variation of secant modulus of elasticity for concrete

So Eq. (9) takes the following form:

$$U^{(t)} = \frac{1}{2} \int_{\Omega} \epsilon \bar{E} \epsilon d\Omega \quad (12)$$

Because a linear strain distribution across the cross-section is assumed, so the third order vector will simulate the strain increment as in Eq. (13):

$$\epsilon = \lambda^T Z \quad (13)$$

in which $\lambda = (\epsilon_o, K_x, K_y)^T$, $Z = (1, y, x)^T$, λ = axial strain vector, ϵ_o = axial strain, K_x = curvature of the member longitudinal axis in OYZ plane, K_y = curvature of the member longitudinal axis in OXZ plane, x , y = the distance from the center of gravity of concrete, prestressed, non-prestressed steel, and FRP in the cross-section, to the selected reference coordinates.

By the assumption that a plane cross section before bending remains plane after bending, the strain at any point can be expressed by the following relationship:

$$\epsilon = \epsilon_o + K_x y + K_y x \quad (14)$$

Considering Eq. (13), then Eq. (12) becomes as:

$$U^{(t)} = \frac{1}{2} \int_{\Omega} \lambda^T Z \bar{E} Z^T \lambda d\Omega \quad (15)$$

A matrix C is defined as:

$$C = \int_{\Omega} Z \bar{E} Z^T d\Omega \quad (16)$$

C = stiffness matrix relative to the selected reference coordinates.

To identify the loads related to the resultant axial strains, partial differentiation of the strain energy equation is taken as:

$$\frac{\partial U^{(\ell)}}{\partial \varepsilon_o} = N = C_1 \lambda, \quad \frac{\partial U^{(\ell)}}{\partial K_x} = M_x = C_2 \lambda, \quad \frac{\partial U^{(\ell)}}{\partial K_y} = M_y = C_3 \lambda \quad (17)$$

where

N = Longitudinal force; M_x = bending moment in OYZ plane; M_y = bending moment in OXZ plane; C_1 = general axial stiffness vector; C_2 = general flexural stiffness vector in OYZ plane; C_3 = general flexural stiffness vector in OXZ plane.

The general axial stiffness vector C_1 is determined by the following equation:

$$C_1 = \left(\int_{\Omega} \bar{E} d\Omega, \int_{\Omega} \bar{E} y d\Omega, \int_{\Omega} \bar{E} x d\Omega \right) \quad (18)$$

The flexural stiffness vectors C_2 and C_3 are limited by Eq. (19) and Eq. (20).

$$C_2 = \left(\int_{\Omega} \bar{E} y d\Omega, \int_{\Omega} \bar{E} y^2 d\Omega, \int_{\Omega} \bar{E} x y d\Omega \right) \quad (19)$$

$$C_3 = \left(\int_{\Omega} \bar{E} x d\Omega, \int_{\Omega} \bar{E} x y d\Omega, \int_{\Omega} \bar{E} x^2 d\Omega \right) \quad (20)$$

The direct integration of stiffness vectors elements C_1 , C_2 , and C_3 is unknown (not explicit) theoretically because the secant modulus of elasticity depends on the value of the resulted strains, and the strain gradient which is not equal to zero. Accordingly, numerical methods should be used. Therefore, the cross section is covered by a mesh mostly with perpendicular lines. Average value of the stress (strain) is taken in each cell. So the infinite summation of the elements of section stiffness matrix is substituted by a finite summation, that its maximum value is equal to the number of developed mesh cells.

Based on this, the matrix elements take the following form:

$$C_{11} = \sum_{i=1}^k \bar{E}_{ci} A_{ci} + \sum_{i=1}^m \bar{E}_{si} A_{si} + \sum_{i=1}^n \bar{E}_{psi} A_{psi} + \sum_{i=1}^j \bar{E}_{fi} A_{fi} \quad (21)$$

$$C_{12} = C_{21} = \sum_{i=1}^k \bar{E}_{ci} A_{ci} y_{ci} + \sum_{i=1}^m \bar{E}_{si} A_{si} y_{si} + \sum_{i=1}^n \bar{E}_{psi} A_{psi} y_{psi} + \sum_{i=1}^j \bar{E}_{fi} A_{fi} y_{fi} \quad (22)$$

$$C_{13} = C_{31} = \sum_{i=1}^k \bar{E}_{ci} A_{ci} x_{ci} + \sum_{i=1}^m \bar{E}_{si} A_{si} x_{si} + \sum_{i=1}^n \bar{E}_{psi} A_{psi} x_{psi} + \sum_{i=1}^j \bar{E}_{fi} A_{fi} x_{fi} \quad (23)$$

$$C_{22} = \sum_{i=1}^k \bar{E}_{ci} A_{ci} y_{ci}^2 + \sum_{i=1}^m \bar{E}_{si} A_{si} y_{si}^2 + \sum_{i=1}^n \bar{E}_{psi} A_{psi} y_{psi}^2 + \sum_{i=1}^j \bar{E}_{fi} A_{fi} y_{fi}^2 \quad (24)$$

$$C_{23} = C_{32} = \sum_{i=1}^k \bar{E}_{ci} A_{ci} x_{ci} y_{ci} + \sum_{i=1}^m \bar{E}_{si} A_{si} x_{si} y_{si} + \sum_{i=1}^n \bar{E}_{psi} A_{psi} x_{psi} y_{psi} + \sum_{i=1}^j \bar{E}_{fi} A_{fi} x_{fi} y_{fi} \quad (25)$$

$$C_{33} = \sum_{i=1}^k \bar{E}_{ci} A_{ci} x_{ci}^2 + \sum_{i=1}^m \bar{E}_{si} A_{si} x_{si}^2 + \sum_{i=1}^n \bar{E}_{psi} A_{psi} x_{psi}^2 + \sum_{i=1}^j \bar{E}_{fi} A_{fi} x_{fi}^2 \quad (26)$$

where:

C_{11} = axial stiffness, which depends on the loading level and the geometrical properties of the cross section, C_{12} = axial-flexural stiffness, which reflects the reciprocal influence of the longitudinal force with the bending moment in the direction of Y-axis, and it depends on the geometrical properties of the cross section, on the resultant stress-strain developments and on the location and direction of selected coordinates axes, C_{13} = axial-flexural stiffness, which reflects the reciprocal influence of the longitudinal force with bending moment in the direction of X axis, C_{22} = flexural stiffness in the direction of Y axis, C_{23} = the stiffness, which reflects the reciprocal influence of bending in the direction of the axes X and Y, and depends on the geometrical properties of the section, on the strain level and on the location of selected coordinates, C_{33} = flexural stiffness in the direction of X-axis, k = number of effective cells (strips) in concrete, A_{ci} = cross-sectional area of the concrete strip i , x_{ci}, y_{ci} = the distance from the center of gravity of the concrete strip i to the selected coordinates, m = the number of non-prestressed longitudinal steel bars in the cross section, A_{si} = the cross-sectional area of non-prestressed longitudinal steel bar i , x_{si}, y_{si} = the distance from the center of gravity of non-prestressed longitudinal steel bar i to the selected coordinates; n = number of prestressed longitudinal steel bars in the cross-section; A_{psi} = the cross-sectional area of prestressed steel bar i ; x_{psi}, y_{psi} = the distance from the center of gravity of prestressed longitudinal steel bar i to the selected coordinates, A_{fi} = the cross-sectional area of the FRP bar, x_{fi}, y_{fi} = the distance from the center of gravity of longitudinal FRP bar i to the selected coordinates, j = number of longitudinal FRP bars in the concrete cross-section.

The secant modulus of elasticity $\bar{E}$ can be expressed as:

$$\bar{E} = E \nu \quad (27)$$

where

E = the initial modulus of elasticity for the material (concrete, steel, or fiber);

ν = elastic strain factor and it expresses the ratios between the elastic strains to total strains (as given before).

The system (17) can be rewritten in another form to become:

$$\{F\} = [C(\lambda)] * \{\lambda\} \quad (28)$$

where $\{F\}$ = loads vector; $[C(\lambda)]$ =stiffness matrix of the section; $\{\lambda\}$ = strains vector.

The nonlinear system (28) is considered for determining the curvature of any cross-section in the concrete structural members. The elements of Eq. (28) change with changing the location of coordinates axis, it means that the axes rotate by an angle with certain value or at the time of moving the axes parallel to the existing axes (Fig. 13).

5. Evaluation of Strain Vector at Different Loading Cycles:

The solution of the nonlinear system (Eq. (28)) with the third order, which is specified to determine the curvature of any cross-section in the structural concrete members, depends on the iterative methods of numerical analysis. There are several numerical methods for converting the nonlinear Eq. (28) to linear. One of these methods is called the direct iterative technique (Cook, 1981), with its iteration diagram for solving Eq. (28), takes the following form as shown in Fig. (16).

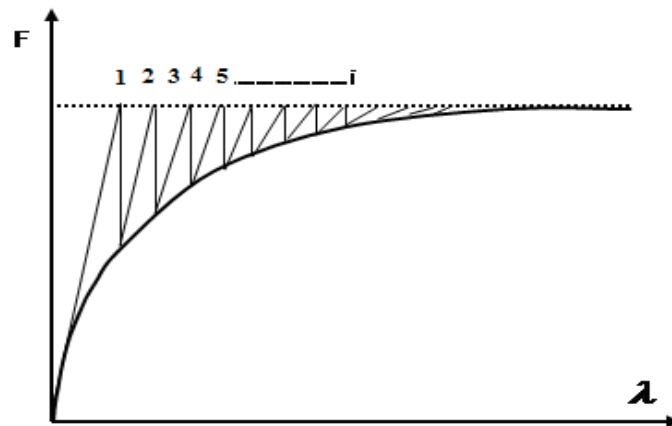


Figure (16) Iterative technique for solving the nonlinear equation (Cook, 1981)

In this method, full load is applied once at the first iteration and then a new stiffness matrix has to be formed in each iteration. Then the full system of Eq. (28) is solved in each iteration to evaluate the strain vector $\{\lambda\}$. Initially, a value of $\{\lambda\} = \{\lambda_o\}$ is assumed, then an improved approximation is obtained as:

$$\left. \begin{aligned} \lambda_i &= C^{-1} (\lambda_{i-1}) * F \\ \lambda_o &= 0 \\ i &= 1, 2, 3, \dots, \dots \end{aligned} \right\} \quad (29)$$

where λ_{i-1}, λ_i = axial strains vector in previous and current iteration cycles at one loading level, respectively.

To solve Eq. (29), a correction to the stiffness matrix should be done at each iteration cycle with fixing the vector of external applied loads.

NEWMARK NUMERICAL INTEGRATION

In the case of a symmetrical simply supported beam, the following Eqs. (30) can be used by considering the following symbols: ϕ referring to the curvature M/EI , $\bar{\phi}$ referring to the equivalent concentrated load (or curvature in the real beam), $slope_{(i)}$ referring to the shear (or average slope in the real beam between the points i and $i+1$, Δ referring to deflection, subscript i referring to section number, c referring to section number in the center of the beam, and Δx refers to segment length which is equal to the distance between two concentrated loads.

For a simply supported beam, there are no known values of $\bar{\phi}$ and slope in both ends; therefore these values can be substituted by zero.

$$\Delta_{(i)} = \sum_{j=2}^i (slope_{(j)}) \Delta x \quad (30)$$

where $i=1,2,3,\dots,c-1$

$$slope_{(j)} = \sum_{k=2}^{c-1} \bar{\phi}_{(k)} + \bar{\phi}_{(c)} / 2, \text{ where } slope_{(j)} \text{ is dimensionless}$$

$$\bar{\phi}_{(k)} = \frac{\Delta x}{6} (\phi_{(k-1)} + 4\phi_{(k)} + \phi_{(k+1)}) \text{ for straight line curvature } (M/EI).$$

$$\bar{\phi}_{(k)} = \frac{\Delta x}{12} (\phi_{(k-1)} + 10\phi_{(k)} + \phi_{(k+1)}) \text{ for 2}^{nd} \text{ degree parabolic curvature } (M/EI).$$

Since the beam is symmetric the values of deflection for other half of the beam is determined according to the following formula:

$$\Delta_{p+1} = \Delta_{n-p}$$

where $p=1,\dots,c-1$, n = number of sections along the beam.

APPLICATIONS AND RESULTS

Ordinary reinforced concrete beams

Beam SB1-2 is tested by Thandamoorthy (1999). This beam had 150*300 mm section, 3m span length, the ultimate compressive strength for concrete ($f'_c = 41.58 \text{ MPa}$). The beam is reinforced with 3 Φ 12 bars in tension with an effective depth of 261 mm and 2 Φ 8 bars in compression with depth of 37 mm and with E_s equal to 200000 MPa. The beam has been loaded in two points. Loading points have been located at 500 mm on either side of midspan. Moment-curvature and load-deflection diagrams of this beam are shown in Figs. (17 and 18).

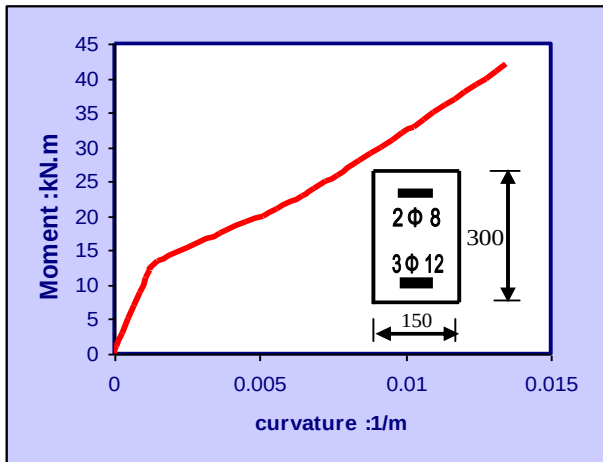


Figure (17) Theoretical moment-curvature diagram for Thandamoorthy beam

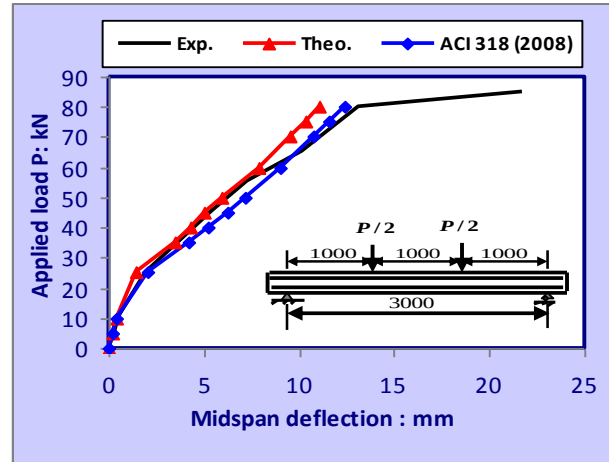


Figure (18) Load-deflection diagram (Thandamoorthy, 1999)

GB1 control beam is tested by Alsayed, et al., (2002). The typical beam is 150*200 mm in cross-section. It is reinforced with three $\Phi 10$ mm steel bars for tension with an effective depth of 152 mm and one $\Phi 6$ mm for compression with depth of 46 mm and with E_s equal to 200000 MPa. The beam is simply supported over a span of 2050 mm and loaded by two concentrated loads, each placed at 100 mm from the beam centerline. The ultimate compressive strength for concrete is ($f'_c = 35.5$ MPa). Moment-curvature and load-deflection diagrams of this beam are shown in Figs. (19 and 20).

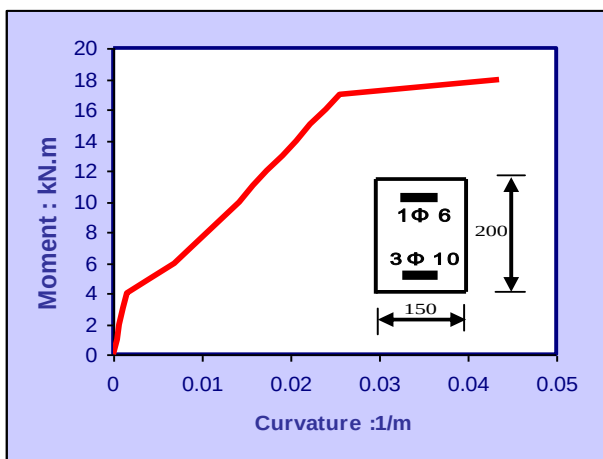


Figure (19) Theoretical moment-curvature diagram for Alsayed et al. beam

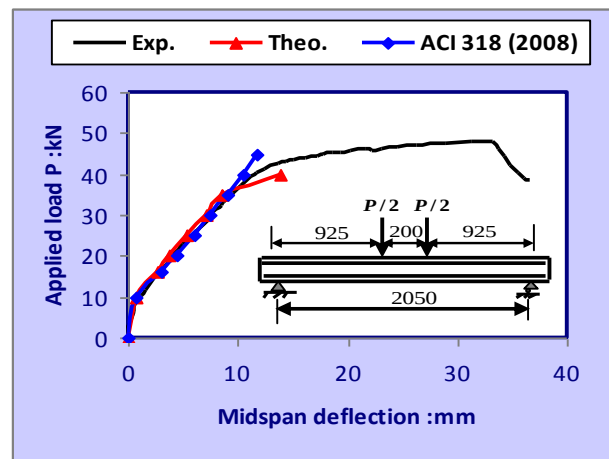


Figure (20) Load-deflection diagram (Alsayed et al., 2002)

Partially prestressed concrete beam

Beam SSP2 was tested by Harajli and Naaman (1985). The beam has 2743.2 mm span length. The ultimate compressive strength for concrete is ($f'_c = 36.55$ MPa). It was subjected to two-point loading. The cross-section was 114.3*228.6 mm in dimensions. It was with ordinary tensile reinforcement of area 96.774 mm² with an effective depth of 203.2 mm and a tensile prestressing strand of area 54.839 mm² with an effective depth of 158.75 mm. Moment-curvature and load-deflection diagrams of this beam are shown in Figs. (21 and 22).

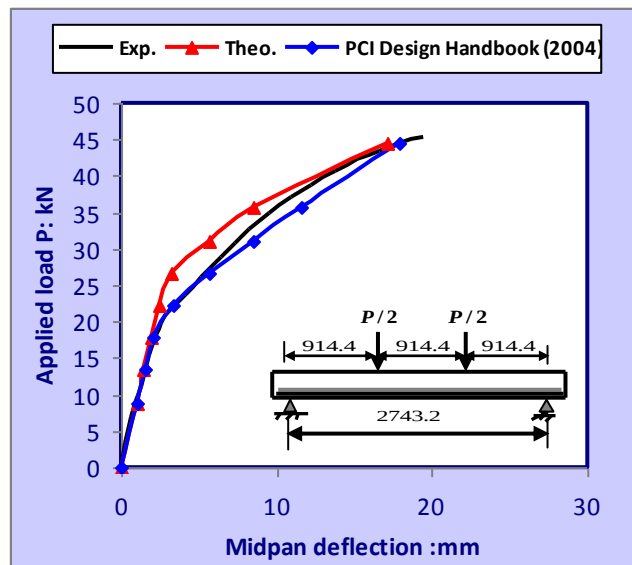
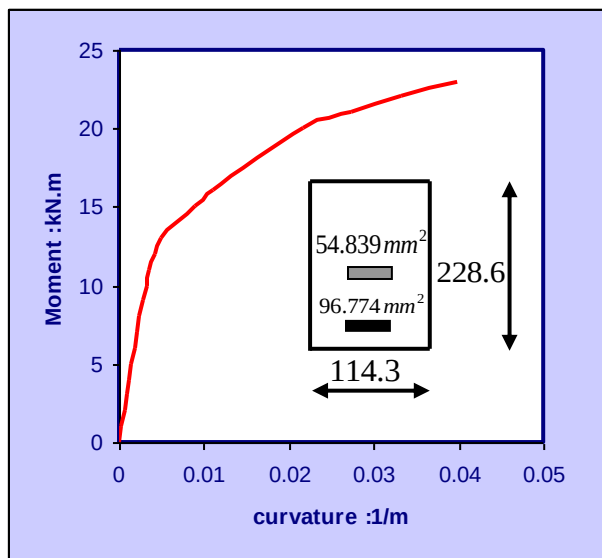


Figure (21) Theoretical moment-curvature diagram for Harajli and Naaman beam

Figure (22) Load-deflection diagram (Harajli and Naaman, 1985)

The beam (beam III-2) was tested by Oukaili (1991). The cross-section was $210 \times 305 \text{ mm}$. The beam was reinforced in tension with steel of area 907 mm^2 with an effective depth of 275 mm and prestressing strand of area 420.27 mm^2 at a depth of 235 mm . It is also reinforced in compression with steel area of 157 mm^2 and prestressing strand area of 96.535 mm^2 at a depth of 30 mm . The ultimate compressive strength for concrete is ($f'_c = 39.4 \text{ MPa}$). Moment-curvature and load-deflection diagrams of this beam are shown in Figs (23 and 24).

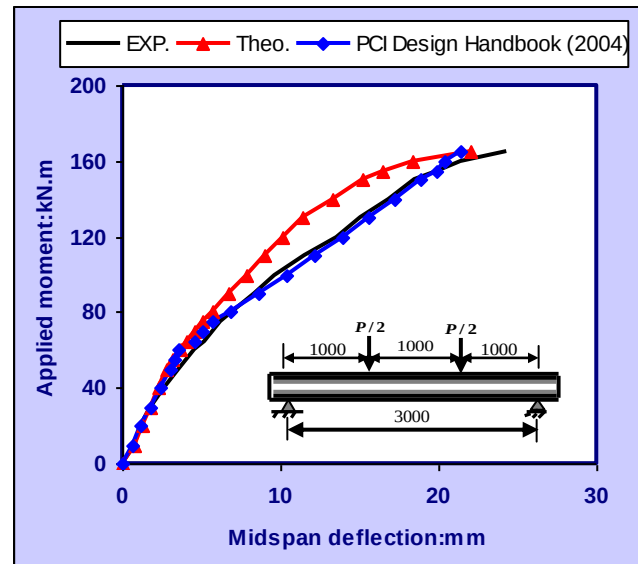
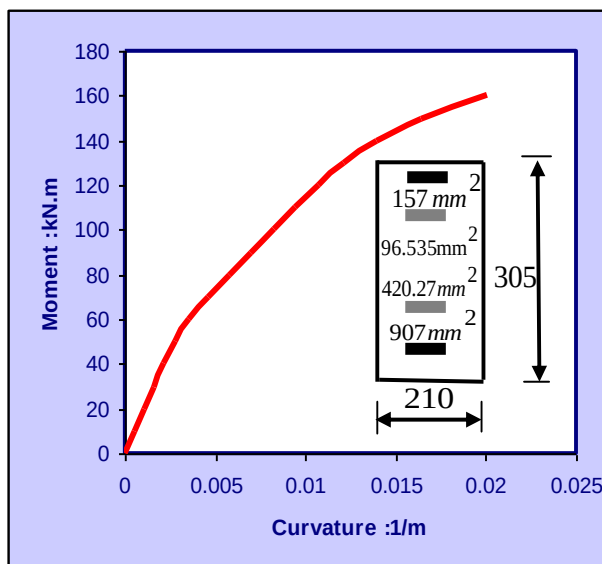


Figure (23) Theoretical moment-curvature diagram for Oukaily beam

Figure (24) Load-deflection diagram (Oukaily, 1991)

Beams Reinforced with GFRP

Benmokrane et al. (1996) built a series of 3300 mm long doubly reinforced concrete beams. Series 1 is taken for comparison. The beam tested had two $\Phi 19.1 \text{ mm}$ GFRP bars in tension and two $\Phi 6 \text{ mm}$ GFRP bars in compression. The beam section was $200 \times 300 \text{ mm}$. It had a clear span of 3000 mm and was loaded by two concentrated loads each at 500 mm from midspan. The ultimate

compressive strength for concrete was ($f'_c = 43 \text{ MPa}$). Moment-curvature and load deflection diagrams of this beam are shown in Figs (25 and 26).

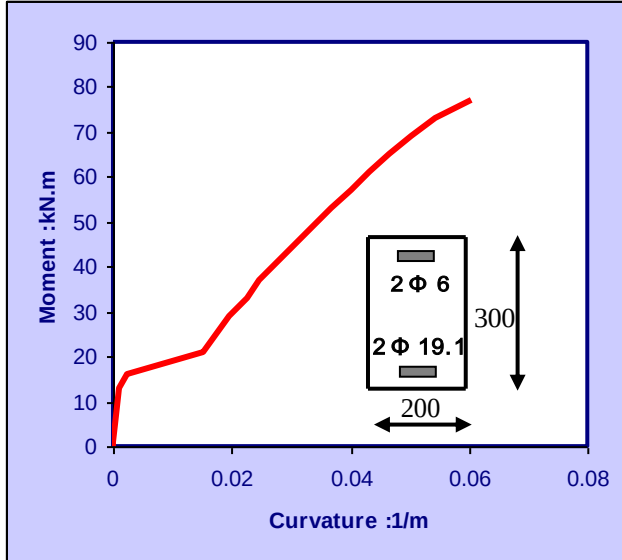


Figure (25) Theoretical moment-curvature diagram for Benmokrane et al. beam

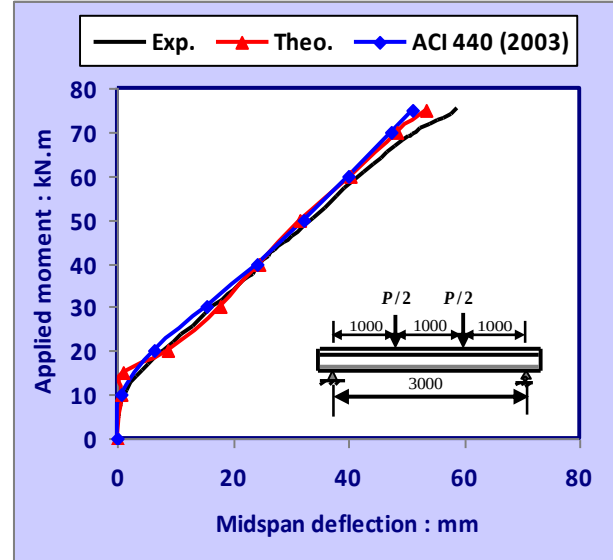


Figure (26) Load-deflection diagram (Benmokrane et al., 1996)

Beam F3 tested by Pecce et al., (1998) has 500*185 mm in cross section, reinforced with seven Φ 12.7 mm GFRP bars in tension at a depth of 145 mm and two Φ 12.7 mm GFRP bars in compression at a depth of 40 mm. The clear span of the beam is 3400 mm, and it is loaded by two concentrated loads at 1200 mm from the simple supports. The ultimate compressive strength for concrete is ($f'_c = 30 \text{ MPa}$). The theoretical moment-curvature and load-deflection diagrams are shown in Figs. (27 and 28).

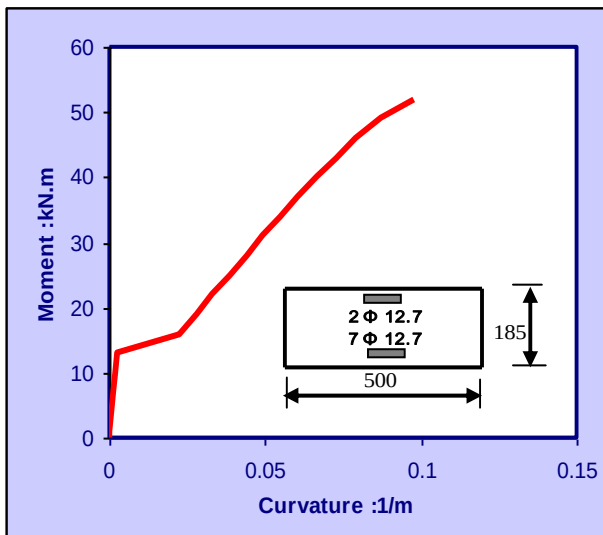


Figure (27) Theoretical moment-curvature diagram for Pecce et al. beam

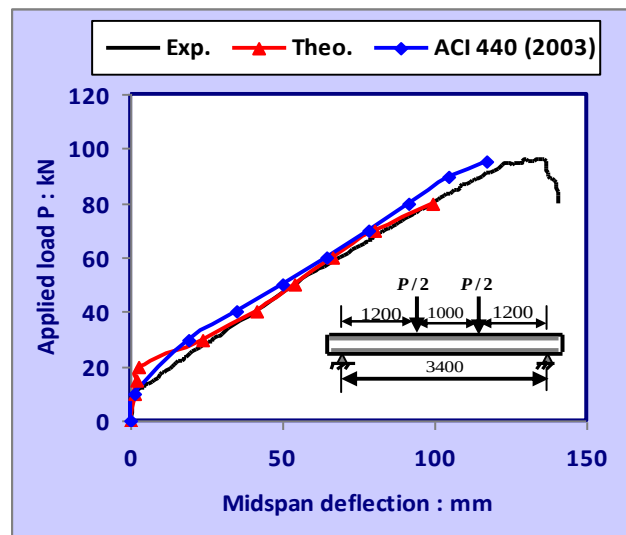


Figure (28) Load-deflection diagram (Pecce et al., 1998)

CONCLUSIONS

The following conclusions can be stated:

- The analytical stress-strain model used in the SECTION program which was developed by Korpenko et al., (1986) gave very good agreement in comparison with the experimental data and other analytical models for each of concrete, mild steel, high strength steel, and prestressing steel.
- SECTION program presented in this study has shown to be capable of predicting the full history for the structural concrete beams under short-term loading.
- The SECTION program has the ability of dealing with structural beams with different values of partial prestressing ratio (PPR).
- The SECTION program has shown to be capable of predicting the deflection state for each of ordinary reinforced concrete, partially prestressed concrete, and bar fiber reinforced concrete beams.
- In the pre-crack stages, there is very good agreement between the theoretical results and the experimental data of deflection for all the three types of beams used.
- In the loading stages corresponding to 20% of the failure load, the average discrepancy of the analytical deflections values with respect to experimental values reached 18.3% for ordinary reinforced concrete, 4.9% for partially prestressed concrete beams, and 24.92 % for beams reinforced with fiber bars. One problem that seems to be common to all deflection prediction methods is that of predicting the cracking moment. This is primarily due to the difficulty in accurately predicting the modulus of rupture f_r (standards tend to require the use of relatively low conservative values).
- In the loading stages corresponding to 50% from the failure load, the average discrepancy of the analytical deflections values with respect to experimental values reached 6.83% for ordinary reinforced concrete, 27.4% for partially prestressed concrete beams, and 8.73% for beams reinforced with fiber bars.
- In the loading stages corresponding to 70% of the failure load, the average discrepancy of the analytical deflections values with respect to experimental values reached 8.63% for ordinary reinforced concrete, 30.75% for partially prestressed concrete beams, and 7.45% for beams reinforced with fiber bars.

NOTATIONS:

The following symbols are used in this paper:

e_{1c}, e_{2c} = Factors expressing the type of the concrete.

e_{1s}, e_{2s} = Factors expressing the type of the steel.

$\bar{E}$ = secant modulus of elasticity of the material.

E_c = Modulus of elasticity of concrete.

E_s = Modulus of elasticity of reinforcing steel.

f'_c = Ultimate compressive strength of concrete.

HSC = High Strength Concrete.

HSS = High Strength Steel.

K = Curvature.

K_x = Curvature about x-axis.

K_y = Curvature about y-axis.

LSC = Low Strength Concrete.

M_x = Bending moment in OXZ level.

M_y =Bending moment in OYZ level.

N =Normal force.

NSC =Normal Strength Concrete.

U =Strain energy.

Δ =Deflection.

ϵ =Strain.

ϵ_c =Strain corresponding to σ_c .

$\tilde{\epsilon}_c$ =Concrete strain level.

$\hat{\epsilon}_c$ =The concrete strain corresponding to $\hat{\sigma}_c$.

$\epsilon_{c,el}$ =Strain corresponding to $\sigma_{c,el}$.

$\tilde{\epsilon}_{c,el}$ =Strain corresponding to $\tilde{\sigma}_{c,el}$.

ϵ_{fu} =FRP ultimate strain.

ϵ_s =Strain in steel.

ν_c =Concrete elastic modulus factor that expresses the ratio of elastic strains to the total strains.

ν_o =Factor depending on stress level in the material.

ν_s = Steel elastic modulus factor that express the ratio of elastic strains to the total strains.

σ =Stress.

σ_c =Concrete compressive stress.

$\hat{\sigma}_c$ =Concrete ultimate compressive strength.

$\tilde{\sigma}_c$ =Concrete stress level.

$\sigma_{c,el}$ =Elastic concrete stress.

$\tilde{\sigma}_{c,el}$ = The level of elastic concrete stress.

σ_{fu} =FRP ultimate stress.

σ_s =Stress in steel.

$\tilde{\sigma}_s$ = Steel stress level.

$\sigma_{s,el}$ = Elastic steel stress.

$\tilde{\sigma}_{s,el}$ = The level of elastic steel stress.

Ω = Space occupied by the section.

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AN INVESTIGATION INTO THREE DIMENSIONAL TURBULENT FLOW OF NEWTONIAN LIQUID IN STIRRED TANKS MIXERS

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ABSTRACT:

The present work is concerned with the theoretical and experimental investigation of flow pattern of Newtonian fluid in liquid mixing process in stirred tank with flat blade impeller. A three-dimensional model for mixing process was simulated. The effected parameters are rotation speed and impeller diameter. Continuity, momentum, and turbulent equations were solved by ANSYS package software 5.4 code with FLOTRAN/CFD based on Finite Element method. In the experimental work, two visualization methods are used in this work, the first method is the acid-base reaction visualization method and the second is the particle distribution visualization method. Different chemical materials were used in the first method, $NaOH$ as a base, H_2SO_4 as acid and Methyl red as indicator, while polymer particles were used in the second method. The results of 3D model showed that the speed rotation directly affected the mixing zones, where the speed reduction by half decreasing the mixing zones approximately by half. Also the impeller diameter increasing clearly affected the mixing process where the mixing zones concentrated directly above and below the impeller. In the experimental work, the acid-base reaction visualization method showed that the mixing zones decreased due to the rotation speed reduction depend on the red and yellow colors, which describe the good mixing and poor mixing zones respectively. The mixing zones were concentrated directly above and below the impeller due to the impeller diameter increasing,. The particles distribution method showed that the mixing zones decreased due to the speed reduction, while the mixing zones concentrated directly above and below the impeller due to the impeller diameter increasing. The results showed a good agreement between the theoretical and experimental works in studying the effect of rotating speed, and impeller diameter .

هذا البحث يتعلق بالدراسة العملية والنظرية لجريان سائل نيوتوني أثناء عملية خلطه باستخدام تأثير عوامل مختلفة في خزان يدور فيه السائل بواسطة ريشة مسطحة. تصميم ثلاثي الأبعاد لعملية الخلط تمت محاكاته في هذا البحث. العوامل المؤثرة التي استخدمت في التصميم ثلاثي الأبعاد هي السرعة ألد و رانية، قطر الريشة. معادلة الاستمرارية، الزخم، والاضطراب تم حلها بواسطة Ansys package FLOTTRAN/CFD والتي استندت إلى طريقة العناصر المحددة F.E. method. في الجانب العملي من البحث ، طريقتان لتصوير جريان السائل استخدمت في هذا البحث الطريقة الأولى هي طريقة تصوير تفاعل الحامض مع القاعدة والثانية هي طريقة تصوير توزيع الجزيئات. مواد كيميائية مختلفة استخدمت في الطريقة الأولى هيدروكسيد الصوديوم NaOH كقاعدة، حامض الكبريتيك H_2SO_4 كحامض، والمثيل الأحمر Methely red ككاشف بينما جزيئات بلاستيكية استخدمت في الطريقة الثانية. النتائج للتصميم ثلاثي الأبعاد أظهرت إن السرعة ألد و رانية أثرت بشكل مباشر على مناطق الخلط حيث أن تقليل السرعة إلى النصف أدى إلى تقليل مناطق الخلط تقريبا إلى النصف وبشكل واضح زيادة القطر أثرت على عملية الخلط. في الجانب العملي طريقة تصوير تفاعل الحامض مع القاعدة أظهرت إن مناطق الخلط قلت بسبب نقصان السرعة ألد و رانية اعتمادا على توزيع الألوان الأصفر والأحمر والتي توصف مناطق الخلط الجيدة والغير جيدة على التوالي. مناطق الخلط تتركز مباشرة فوق وتحت الريشة بسبب زيادة القطر. طريقة توزيع الجزيئات أظهرت إن مناطق الخلط تقل نتيجة لتقليل السرعة الدورانية، بينما تتركز فوق وتحت الريشة بسبب زيادة القطر. النتائج أظهرت توافق جيد بين الجانب النظري و العملي في دراسة تأثير السرعة ألد و رانية و قطر الريشة.

KEYWORDS: Mixers, Newtonian liquid, Turbulent, Three Dimensional

INTRODUCTION:

Mixing is generally considered as a complex subject, but its essence is quit simple: related stretching and folding of fluid elements. Stirred tanks are widely used in mixing process for blending, liquid-liquid dispersion, suspension formation, heat transfer, mass transfer and chemical reactions. Efficient mixing is crucial to the outcomes of all of these processes. For these applications, poor mixing can have serious consequences such as excessive by product formation, inconsistent product quality in blended products, wide particle size distributions in crystallization processes, and slow mass transfer rates in bioreactors, (Ottino, 1989). (Verzico et al, 2000), studied the flow induced by an impeller in a cylindrical tank, and showed that the combination of the Immersed Boundary “ IB “ procedure with DNS and LES (Large Eddy Simulation), simulations can efficiently be used for the accurate prediction and analysis of many technologically relevant flows.(Kresta et al, 1991), showed that the three dimensional simulations allow a realistic treatment of the baffles, where details of the predicted behavior of turbulence Kinetic energy and dissipation rate are in quantitative agreement with the available data. (Szalai et al, 2002), stated that the ORCA uses Galerkin least-squares finite element technology, novel approach to computer aided modeling and optimizing mixing process. Computer aided mixing, modeling, and analysis involves Lagrangian and Eulerian analysis for relative fluid stretching, and energy dissipation concepts for

laminar and turbulent flows. High quality, conservative accurate, fluid velocity, and continuity solutions are required for determining mixing quality. The present work studied the flow patterns and mixing process in the turbulent flow of the liquid stirred mixer. The ANSYScode/FLOTRANE CFD that based on finite element method was used for theoretical work

NUMERICAL SIMULATION:

Continuity, momentum, and two turbulence equations were solved in the present work these equation are respectively as follows (Nizar 2006):

$$(1) \quad \frac{\partial(V_y)}{\partial y} + \frac{\partial(V_z)}{\partial z} = 0 \quad \frac{\partial(V_x)}{\partial x} +$$

$$(2) \quad = \rho\{g\} - \nabla P_{abs} + \mu \nabla^2 \{V\} - \rho \frac{D\{V\}}{Dt} + 2\rho\{\omega\} * \{V\} + \rho\{\omega\} * \{\omega\} * \{r\}$$

$$\begin{aligned} & \rho \frac{\partial \varepsilon}{\partial t} + \rho \frac{\partial(V_x \varepsilon)}{\partial x} + \rho \frac{\partial(V_y \varepsilon)}{\partial y} + \rho \frac{\partial(V_z \varepsilon)}{\partial z} = \\ & \frac{\partial}{\partial x} \left(\frac{\mu_t}{\sigma_\kappa} \frac{\partial \kappa}{\partial x} \right) + \frac{\partial}{\partial y} \left(\frac{\mu_t}{\sigma_\kappa} \frac{\partial \kappa}{\partial y} \right) + \frac{\partial}{\partial z} \left(\frac{\mu_t}{\sigma_\kappa} \frac{\partial \kappa}{\partial z} \right) + \mu_t \phi - \rho \varepsilon + \\ (3) \quad & \frac{C_4 \beta \mu_t}{\sigma_t} \left(g_x \frac{\partial T}{\partial x} + g_y \frac{\partial T}{\partial y} + g_z \frac{\partial T}{\partial z} \right) \end{aligned}$$

$$\rho \frac{\partial \varepsilon}{\partial t} + \rho \frac{\partial(V_x \varepsilon)}{\partial x} + \rho \frac{\partial(V_y \varepsilon)}{\partial y} + \rho \frac{\partial(V_z \varepsilon)}{\partial z} =$$

$$\frac{\partial}{\partial x} \left(\frac{\mu_t}{\sigma_\varepsilon} \frac{\partial \varepsilon}{\partial x} \right) + \frac{\partial}{\partial y} \left(\frac{\mu_t}{\sigma_\varepsilon} \frac{\partial \varepsilon}{\partial y} \right) + \frac{\partial}{\partial z} \left(\frac{\mu_t}{\sigma_\varepsilon} \frac{\partial \varepsilon}{\partial z} \right) + C_1 \mu_t \frac{\varepsilon}{\kappa} \phi - C_2 \rho \frac{\varepsilon^2}{\kappa}$$

$$\frac{C_1 C_\mu (1 - C_3) \beta \rho \kappa}{\sigma_t} \left(g_x \frac{\partial T}{\partial x} + g_y \frac{\partial T}{\partial y} + g_z \frac{\partial T}{\partial z} \right)$$

(4)

During the present work F.E method (Finite Element) was used and the numerical simulation was carried out by commercial software ANSYS 5.4 code, which is based on this method.

Tetrahedral grid and cylindrical coordinate of element FLUID142 is suggested for modeling present problem. The flow is assumed to be Newtonian, incompressible, single phase, and turbulent.

The boundary conditions applied for mixing process are as following:

1-No-slip condition at the bottom of the tank, $V_x = 0$, $V_z = 0$, and $V_y = 0$

2-No-slip condition at the wall of the tank, $V_x = 0$, $V_z = 0$, and $V_y = 0$).

3-Flat free slip conditions at the top of the tank.

4- $V_x = 0.157$ m/S., $V_z = 0$, $V_y = 0$, at the tip of the impeller, this velocity is changes to 0.0785 m/S. in the first case of study.

5- $\kappa = .5$, $\varepsilon = 1$, at the tip of the impeller.

The dimensions of the tank is 0.09 m in diameter, 0.12 m high, and has a liquid height of 0.105 m. its bottom has a flat plate shape, and the shaft is 0.005m in diameter. Six radial-pumping impellers with an outer diameter of 0.03 m, width .012m, and .002m thickness are positioned at 0.046m above the tank bottom, the impeller and shaft rotate at 100rpm. The fluid has a density of 1000 kg/m^3 , a viscosity of 0.001 kg/m-s, and the flow is turbulent. The property of the fluid used in the present work is for water.

A segregated, sequential solution algorithm is used. This means that element matrices are formed, assembled and the resulting system solved for each degree of freedom separately. Development of the matrices proceeds in two parts. In the first, the form of the equations is achieved and an approach take towards evaluating all the terms. Next, the segregated solution algorithm is outlined and the element matrices are developed from the equations.

EXPERIMENTAL WORK:

A visualization technique based on an acid-base reaction and on particle distribution is used in the present experimental work to investigate the flow pattern qualitatively. This is important to validate the theoretical work. The experimental apparatus consists of many components, mixer, rotor, vessel, regulator, cover of the vessel, needle, chemical material, polymer particle, digital camera, and analog speed meter. It is used to test the flow pattern depending on colors in acid-base visualization method and on particle distribution according to the flow trajectories in the particle visualization method. Acid- base reaction visualization method is a visualization technique based on an acid-base neutralization reaction, also exploits the size and shape of segregated regions in the mixing tank. A soluble, PH-sensitive indicator, that appears yellow in base media and red in acidic media is added to each of the fluids. When the mixture components come into contact during the mixing process, the neutralization reaction instantaneously proceeds at the interface and a color change occurs.

Particles distribution visualization method used ellipsoidal polymer particles with longitudinal port. The particles in this test illustrate the flow trajectories in stirred tank.

NUMERICAL RESULTS:

The effects of two parameters on flow pattern and mixing process in stirred tank were studied. These parameters are as follows:

1-Rotation speed, which is decreased from 100 rpm to 50 rpm

2-Impeller diameter, which is increased from 0.03m to .045m.

The effect of rotating speed results in **Fig.1** shows the same shapes of the radial velocity general and the vertical velocity reduced by half, due to the rotating speed reduction. **Fig.2** shows that the axial velocity is decreased from 0.458 to 0.216m/s or about 53 %, due to the same reason. The same general contour shapes in two pictures are occurred. These results closely follow the results of Verzico et al, 2000. **Fig. 3** illustrates the same behavior of azimuthal velocity contours in general, a small change in contours shapes of the second graph above and below the impeller is occurred. The azimuthal velocity decreased from 0.186 to 0.089m/s or about 50 %, due to the speed reduction from 0.157 to 0.0785m/s. **Fig. 4** illustrates the two recirculation flow in the regions above and below the impeller in each pictures. The recirculations in **Fig.4, b** above the impeller is shifted up and towards the tank wall, due to the speed reduction. Agreement of these results with that Verzico et al, 2000,. The centers of loops below the impeller are closer to the rotating shaft than the loops above the impeller in two pictures. The effect of impeller diameter in **Figs. 5, a, b** and **6, a, b** show that the meridional plan is roughly divided into two halves by the radial jet flow from the impeller. It can be noted that the two recirculations are not symmetric owing to the different boundary conditions on the upper and lower horizontal surfaces. An important effect of lower no-slip wall is the strongly positive vertical velocity in the lower half of the domain in the region close to the shaft, see **Fig. 6, a, b**. This effect is characteristic of wall-bounded rotating flows. It causes the fluid to be pushed radially inward at the plate, see **Fig.5, a, b** and axially upward at the axis of rotation as shown in **Fig.6, a, b**. Because of mass conservation, a vertical ascending fluid column at the axis induces a descending current at the external radial wall, thus reinforcing the lower-half recirculation with respect to the upper one. This is also well evidenced by the radial jet that dose not point exactly in the radial direction, but rather has a position vertical velocity close to the blade region and then a weakly negative vertical velocity. The radial velocity is increased by 133 %, while the axial velocity is increased by 57 % in general and particularly above the impeller near the surface and directly below the impeller. **Fig.7, a, b** indicates the effect of impeller diameter increasing on the shapes of contours. The maximum azimuthal velocity is increased from 0.186 to 0.296m/s or about

59 % and the first and second graphs are closely follow the results of Verzico et al, 2000. **Fig. 8** indicates the recirculations scale in the second graph are increased due to the impeller diameter increasing. The mixing flow is concentrated in front of blade directly below the impeller and above the impeller near the liquid surface also the recirculations above and below the impeller is shifted toward the tank wall

. The effect of rotating speed in **Fig. 9** at $y = 0.03\text{m}$ shows that the regions near the shaft above and below the impeller a peak is observed. This is due to the large-scale recirculation that drives the fluid from the external radial region towards the axis, thus increasing the azimuthal velocity owing to the conservation of angular momentum. The maximum negative magnitude of radial velocity is reduced from -0.085 to -0.037m/s or about 53 %. Also the modes of axial velocity is similar to that in two dimensional model, and the maximum positive velocity magnitude is reduced from 0.255 to 0.13m/s or about 49 %, while the azimuthal velocity is decreasing from 0.04 to 0.012m/s or about 70 %, due to the speed reduction. The positions of the maximum magnitude of radial and azimuthal velocities in the second graph are shifted towards the tank wall, due to the same reason. **Fig. 9, b** indicates zero velocity for all components at 0.035m distance from the rotating shaft, which illustrates poor mixing zone. **Fig.10** shows the behavior of radial, axial, and azimuthal velocities at centerline of the impeller. The decay of radial velocity in the second graph is slower than that in the first figure. The decay of azimuthal velocity is approximately occurred in the same profiles in the two graphs, and the peak of this velocity always in the limit of impeller radius end. The axial velocity is reduced and then increased in the two graphs. **Fig.11, a, b** shows that the decay of κ in the second picture is slower than that in the first one, due to the speed reduction. **Fig. 12, a, b** indicates that the decay of ε consist of two stages, the first one before 0.04m radial distance and the second one after 0.04m in the two Figs. Also the decay in the second picture is slower than that in the first one due to the speed reduction. Agreement is very good with the results of Kresta et al 1991. The effect of impeller diameter in **Fig.13** at $y = 0.03\text{m}$ illustrates the radial profile of azimuthal, radial, axial velocity components at $DT/3$ and $DT/2$ respectively. The maximum magnitude of radial, axial, and azimuthal velocity is shifted towards the tank wall due to the impeller diameter increasing. The maximum negative magnitude of radial velocity is increased by 194 %, the maximum positive magnitude of axial velocity is increased by 250 %, and the maximum positive magnitude of azimuthal velocity is increased by 72 %, due to the impeller diameter increasing. **Fig. 14** at $y = 0.052\text{m}$ indicates the decay of radial velocity and the behavior of axial and azimuthal velocities on the centerline of impeller due to the impeller diameter increasing. The maximum magnitude of these velocities is shifted towards tank wall, and the axial velocity increased and then decreased toward the tank wall. In the second graph the curves behavior of

velocities is changed, and poor mixing zone is observed. **Fig. 15, a, b** shows the decay of κ on the impeller centerline in both impeller diameter, where the decay in the second graph consists of two stages. The first stage occurs before 0.035m radial distance and the second one occurs after 0.035m radial distance. **Fig. 16, a, b** indicates the decay of ε on the centerline of the impeller. The decay in the first and second graphs consists of two stages. The first stage in the first graph is ended at $\varepsilon = 0.2$, where the first stage in the second graph is ended at $\varepsilon = 0.35$, due to the impeller diameter increasing. It is useful to define zones in the stirred tank where average values of the turbulence quantities may be applied. Based on the results of these simulations, two zones have been defined. The first is the impeller discharge zone. The value of ε for this zone is virtually independent on D/D_T . The second zone comprises the remaining free volume of the tank, and reflects the influence of changing D/D_T . These results have a good agreement with that of Kresta et al, 1997

EXPERIMENTAL RESULTS:

Experimental results consist of two parts, the first one is acid-base reaction visualization and the second one is particle distribution visualization method. Acid-base Reaction Visualization Method in **Fig. 17, a, b** shows the effect of speed reduction on color change from yellow to red, and on the red color zones. In the second picture the changing from yellow to red color is slower than that in the first picture due to the speed reduction, and the color red zones in the second picture is smaller than that in the first one due to the same reason, which make the recirculation flow above and below the impeller shifted toward the rotating shaft.. The red color indicates the mixing zones and the yellow color indicates the poor mixing zones. The rotation speed reduction decreases the mixing zones and the mixing time, this also relates with the volume of the cylinder. **Fig.18, a, b** indicates the effect of impeller diameter increasing on the colors zones. The recirculation flow above and below the impeller associated with the impeller tips, and weak mixing zones near the bottom of the tank and near the top surface of the liquid are observed in the second picture. The major different between these two pictures is that the strongly mixing occurs directly above and below the impeller, and the flow directed vertically above the impeller near the rotating shaft, due to the impeller diameter increasing in the second picture. **Figs. 17 and 18** show a good agreement with the results of Verzico et al, 1991 . Particles distribution visualization method in **Fig. 19, a, b** shows the effect of speed reduction on the particles distribution in the vessel, which indicates the same general behavior with reduction in the speed of the particles by half. Poor mixing zones above and below the impeller near the surface of liquid and near the bottom of the vessel are observed. Also the centers of circulation above and below the impeller are shifted toward the rotating shaft, due to the speed reduction. The mixing zones in the second picture are decrease according to the particles

distribution in the vessel. **Fig. 20, a, b** shows the effect of impeller diameter increasing on the particles distribution in the vessel. The centers of circulation are shifted with the impeller tip towards the vessel wall, due to the diameter increasing. The mixing zones are reduced in the second picture, due to the flow movement concentrated directly above and below the impeller. Comparison between numerical and acid-base reaction results in **Figs. 4 and 17** show the effect of speed reduction on the vectors distribution and the red and yellow color zones distribution respectively. The general behavior of vectors distribution and red color zones in these two figures is approximately the same, which indicates a good agreement between the numerical and experimental results. The mixing zones are decreasing in the second picture of each figure according to the vectors distribution and red color zones, respectively due to the rotation speed reduction. **Figs. 8 and 18** indicate the effect of the impeller diameter on the vectors distribution and red and yellow color zones distribution respectively. The general behavior of the vectors distribution and red color zones in these two figures is approximately the same, so the results of numerical simulation are closely following the results of experimental work. The mixing zones in the second picture of each figures are strongly concentrated above and bellow the impeller, and above the impeller near the rotating shaft. Comparison between numerical and particles distribution results in **Figs. 4 and 19** show the effect of the rotation speed reduction on the vectors and particles distribution respectively. The general behavior of vectors and particles in these two figures is approximately the same, which make a good agreement between the numerical and experimental results. According to the vectors distribution the mixing zones in the second picture of the first figure are decreased due to the velocity reduction, also the recirculation above and below the impeller are shifted toward the rotating shaft due to the same reason. The same behavior occurred in the second figure where the mixing zones are decreasing in the second picture as indicated from the particles distribution, also the recirculation flow above and below the impeller are shifted towards the rotating shaft due to the rotation speed reduction.

Figs. 8 and 20 show the effect of impeller diameter on the vectors and particles distribution respectively. The general behavior of the vectors and particles in these two figures is approximately the same, which makes the numerical results closely follow the experimental results. Depending on the vectors distribution the mixing zones in the two pictures of the first figure is approximately the same results in 3D model indicated that the negative radial velocity is decreased by 53 %, 54 %, and 35 % at 0.03m, 0.07m, and 0.09m heights respectively. The positive axial velocity is decreased by 49 %, 52 %, 45% at 0.03m, 0.07m, and 0.09m heights respectively. The azimuthal velocity is decreased by 50 %, keeps the same magnitude, and decreased by 60 % at 0.03m, 0.07m, and 0.09mheights respectively. Also the effect in axial velocity profiles indicated that the radial



velocity decreased by 50 % at the centerline of impeller, and the negative axial velocity is decreased 30%, while the azimuthal velocity is decreased by 35 %.

CONCLUSIONS:

The Ansys/ FLOTRAN CFD, which uses Galerkin finite element technology, is a new approach to computer aided modeling and optimizing mixing processes. The Galerkin technique provides the basis of the confidence, accuracy, convergence, and stability of FLOTRAN. This method ensures extremely accurate solutions for the mixing process. The effect of speed rotation reduction in radial velocity profiles

The effect of impeller diameter increasing from 0.03m to 0.045m in the radial velocity results of 3D model indicated that the radial velocity is increased by 194 %, 180 %, and 100 % at 0.03m, 0.07m, and 0.09m heights respectively. The positive axial velocity is increased by 250 % at 0.03m height, and its negative magnitude is increased by 100 % at height 0,07m, while its negative magnitude is increased by 260 % at height 0.09m. The positive azimuthal velocity is increased by 59% at 0.03m height, and its positive magnitude is increased by 600 % at 0.09m height. Also the effect in axial velocity profiles indicated that the radial velocity is increased by 100 % at the centerline of impeller, and the negative axial velocity is increased by 166 %, while the positive azimuthal velocity is increased by 89 %. The qualitative results of the particle distribution and acid-base reaction visualization methods have a good agreement with the velocity vectors field in 3D-model simulation.

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NOMENCLATUR:

Symboles	Definition	Units
N	Rotation Speed	rpm
V _x	Radial Velocity	m/s
V _z	Axial Velocity	m/s
V _y	Azimuthal Velocity	m/s
ε	Kinetic Energy Dissipation Rate	W
κ	Kinetic Energy	W

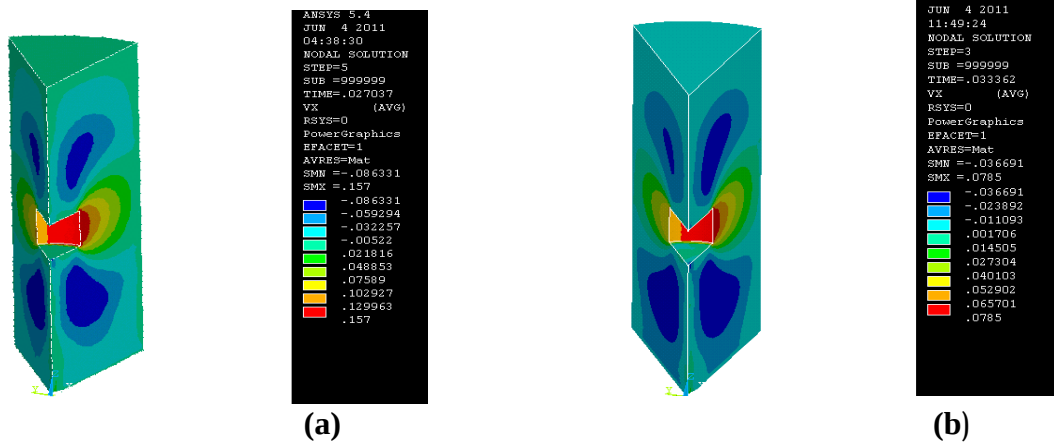


Fig. 1. Effect of Rotating Speed (N) on Radial Velocity (V_x) Contours at, (a) $N=100$ rpm, (b) $N=50$ rpm..

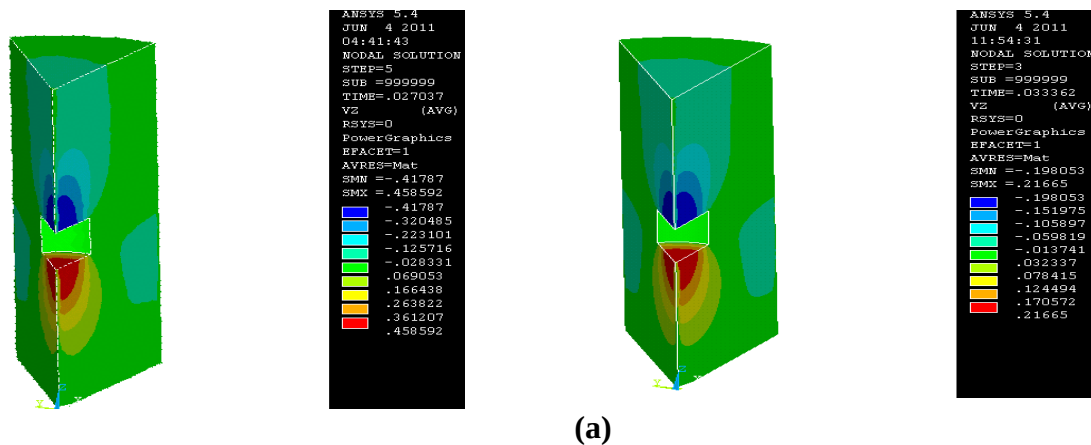


Fig. 2. Effect of Rotating Speed (N) on Axial Velocity (V_z) Contours at, (a) $N=100$ rpm, (b) $N=50$ rpm.

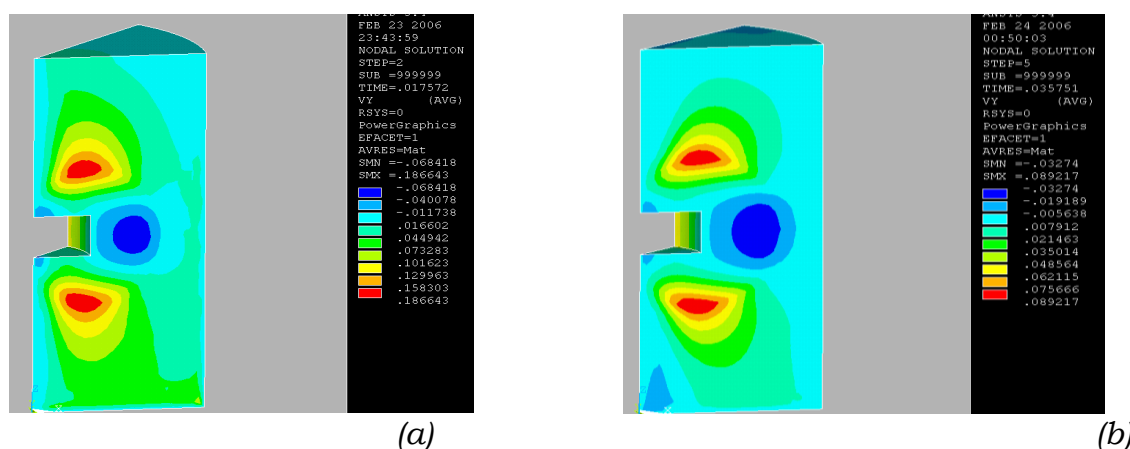


Fig. 3. Effect of Rotating Speed (N) on Azimuthal Velocity (V_y) Contours at (a) $N=100$ rpm, (b) $N=50$ rpm .

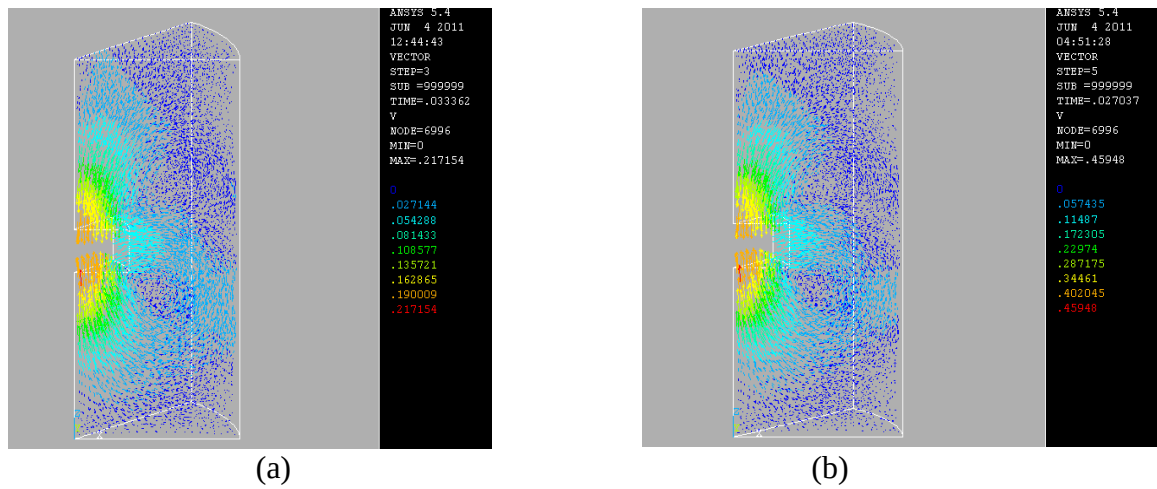


Fig. 4. Effect of Rotating Speed (N) on Averaged Velocity Vectors Fields at (a) N=100 rpm, (b) N=50 rpm

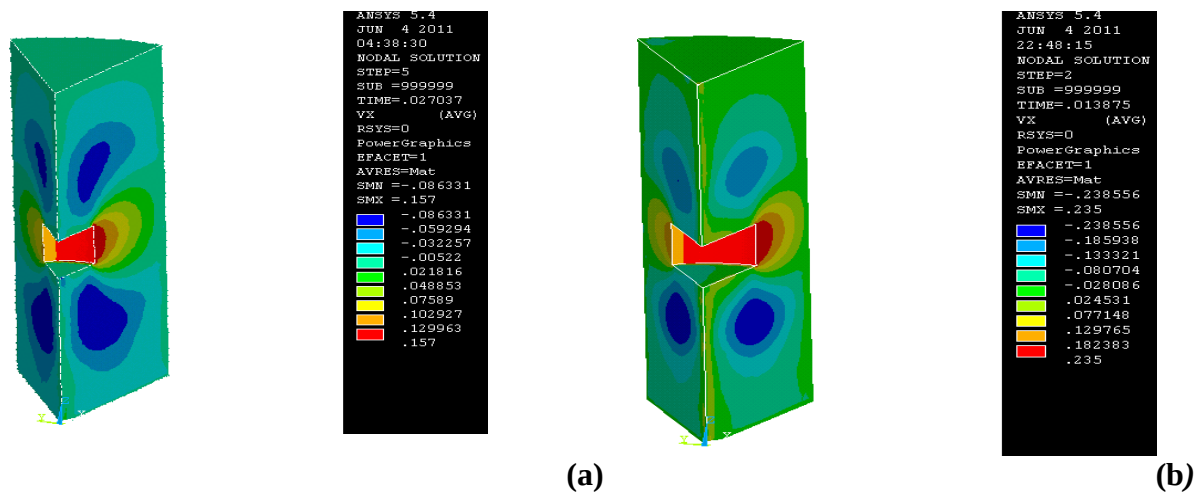


Fig. 5. Effect of Impeller Diameter (D) on Radial Velocity Contours at ,(a) D= D / 3 (b)D=D/ 2

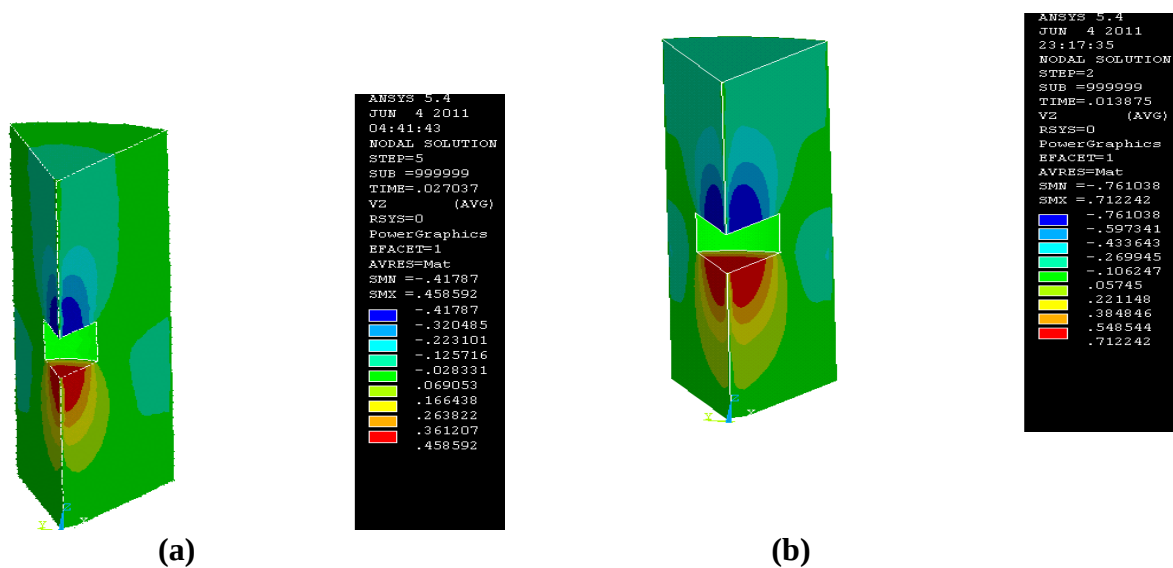


Fig. 6. Effect of Impeller Diameter (D) on Axial Velocity Contours at , (a) $D = D/3$ (b) $D = D/2$.

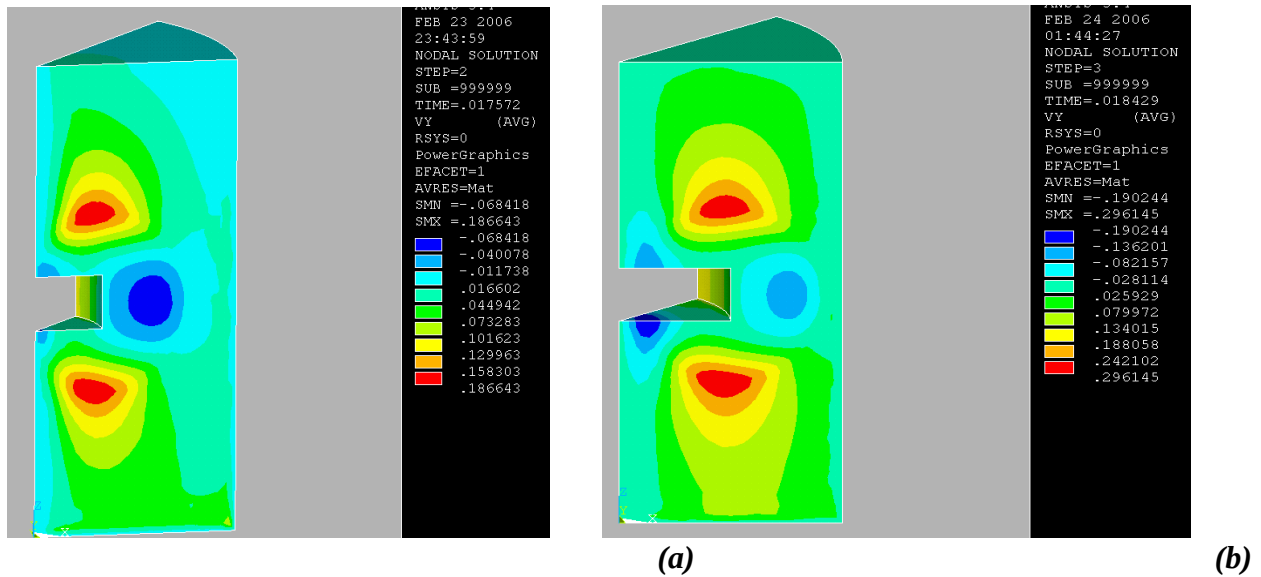


Fig. 7. Effect of Impeller Diameter D on Azimuthal Velocity Contours at ,(a) $D = D/3$, (b) $D = D/2$

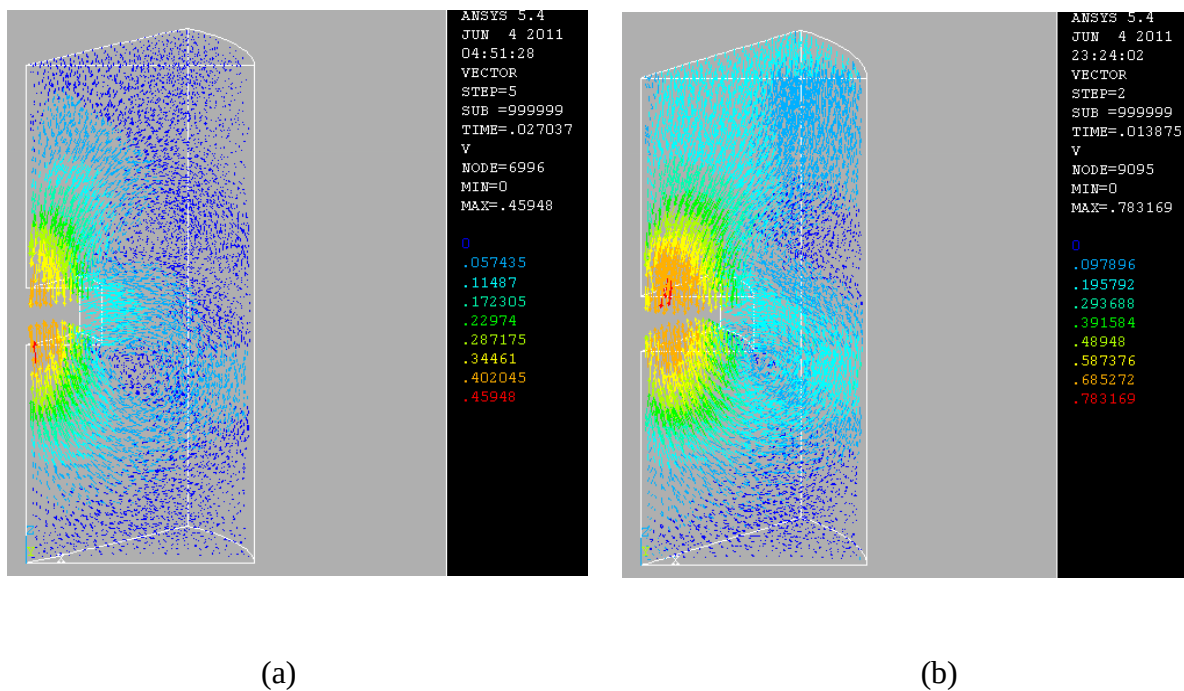
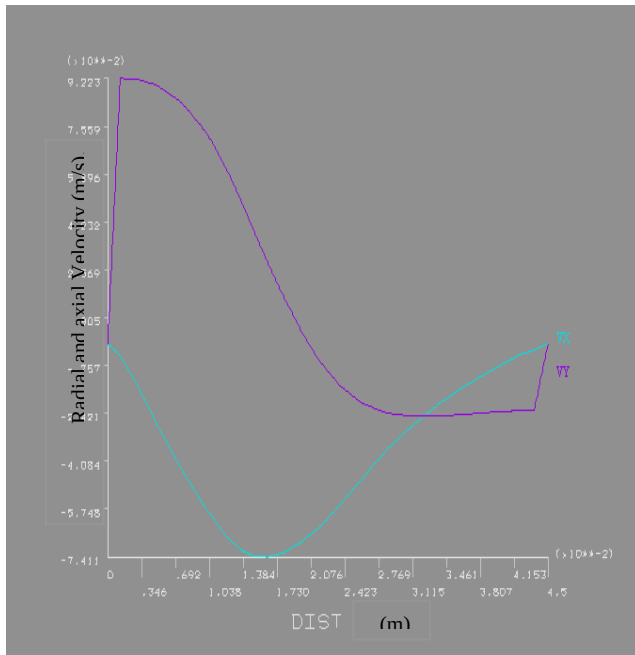
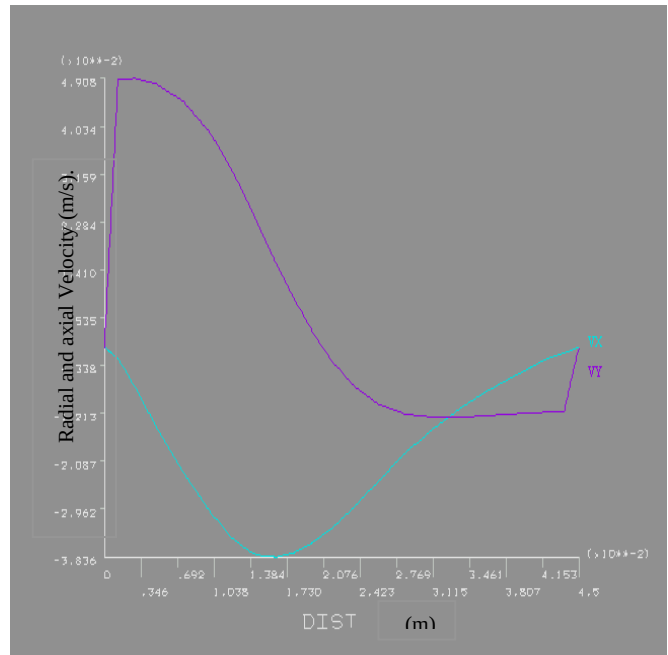


Fig. 8. Effect of Impeller Diameter (D) on Velocity Vectors Fields at , (a) $D = D/3$, (b) $D = D/2$

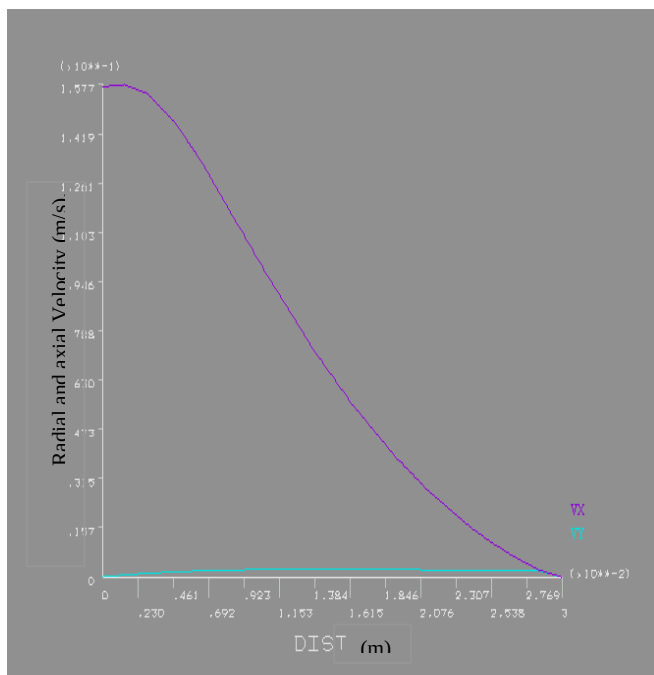


(a)

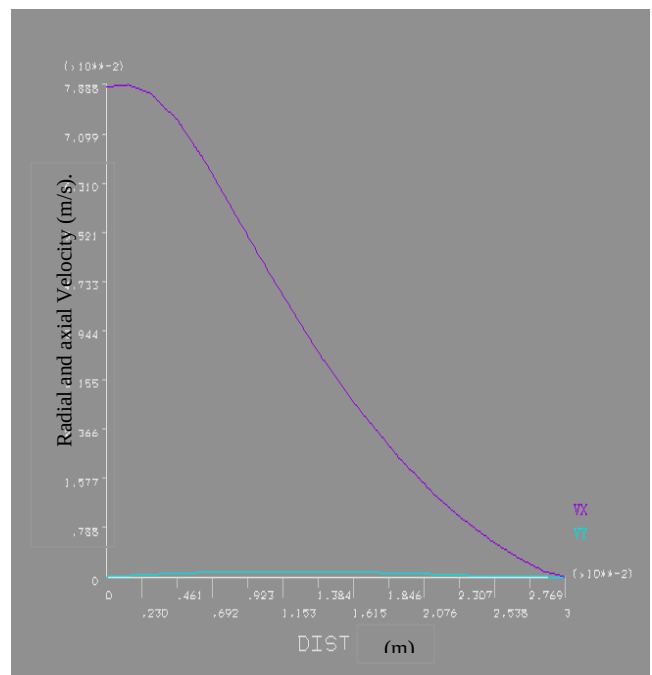


(b)

Fig. (9): Effect of Rotating Speed (N) on Averaged Radial Velocity Profiles at Height 0.03m from the bottom of the tank, (a) N=100 rpm, (b) N=50 rpm.

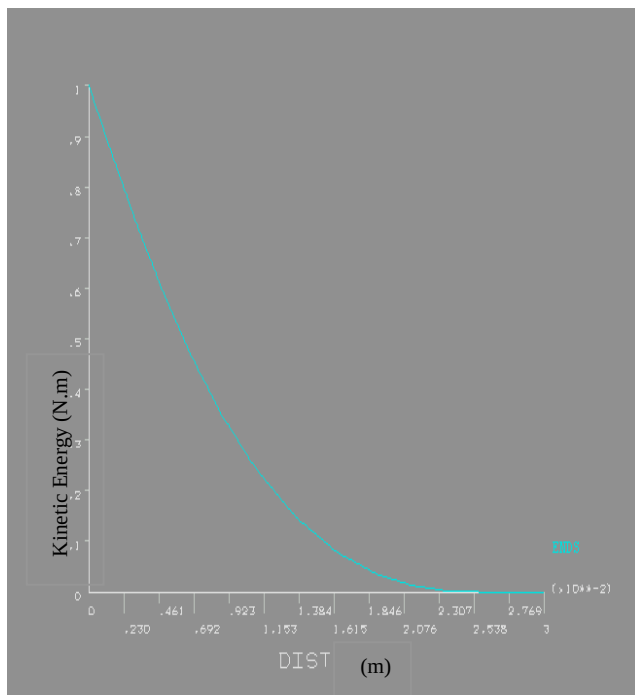


(a)

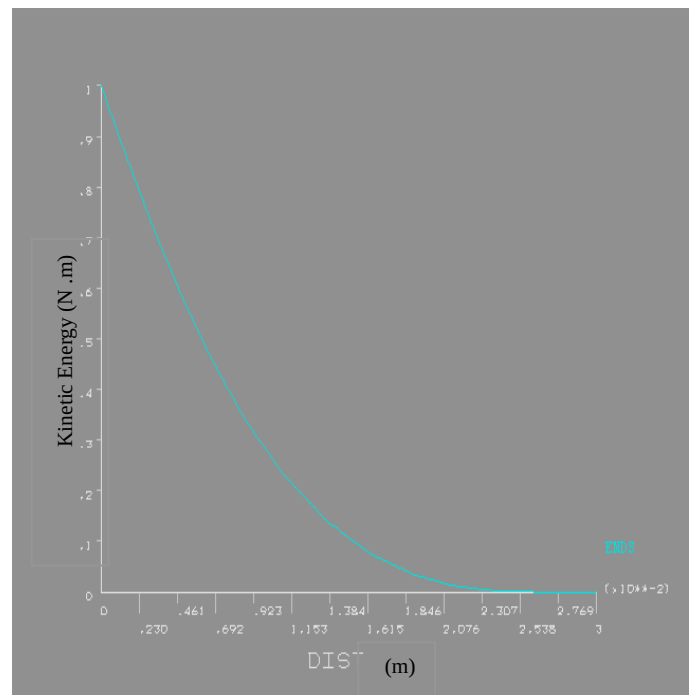


(b)

Fig. (10): Effect of Rotating Speed (N) on Averaged Radial Velocity Profiles at Height y=0.052m From the Bottom of the Tank, (a) N=100 rpm, (b) N=50 rpm.

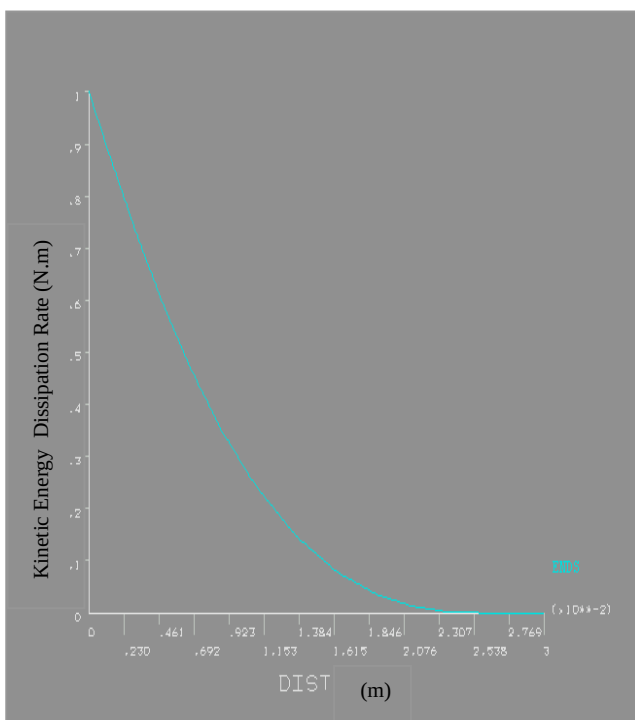


(a)

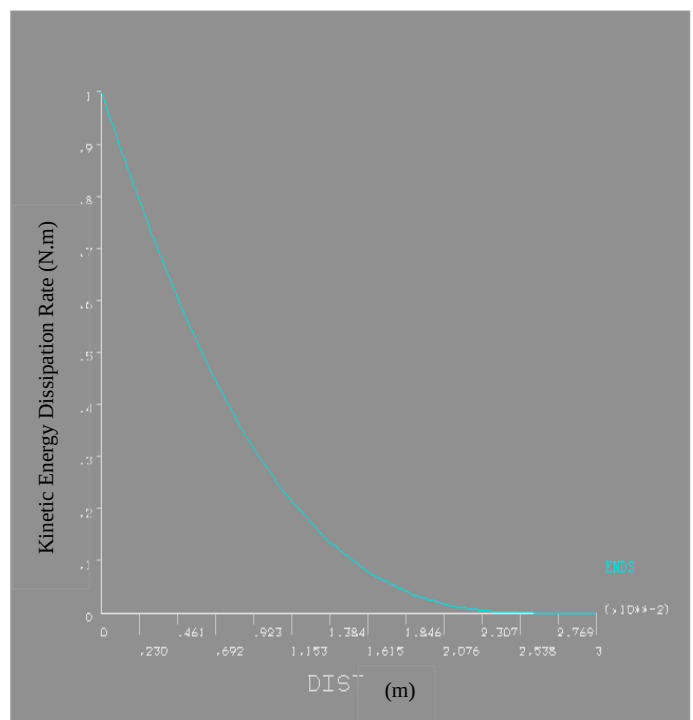


(b)

Fig. (11) : Effect of Rotating Speed on Decay of Turbulence Kinetic Energy on Impeller Centerline at (a) N=100 rpm, (b) N=50 rpm.

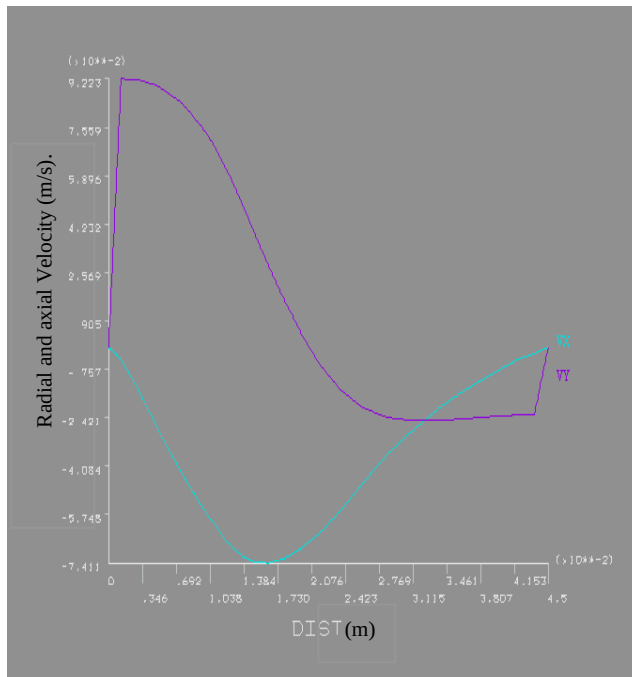


(a)

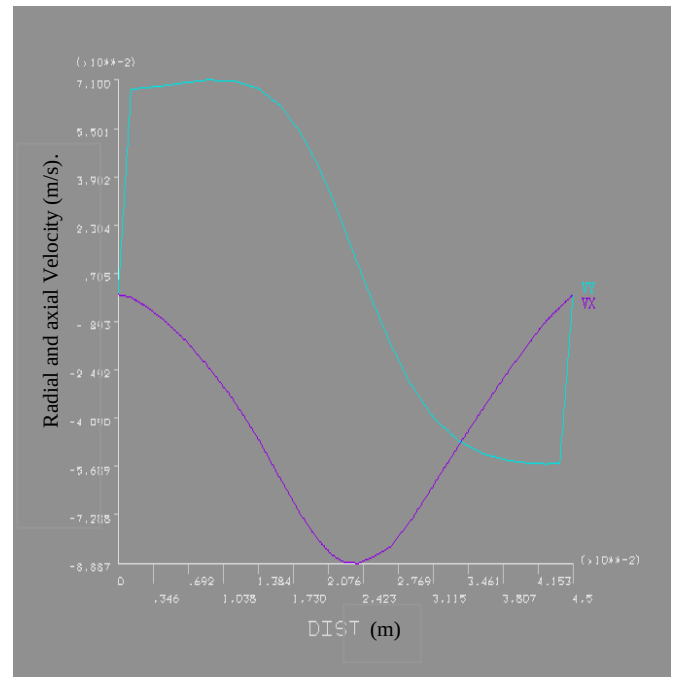


(b)

Fig. (12): Effect of Rotating Speed on Decay of Turbulence Kinetic Energy Dissipation Rate on Impeller Centerline at ,(a) N=100 rpm, (b) N=50 rpm.

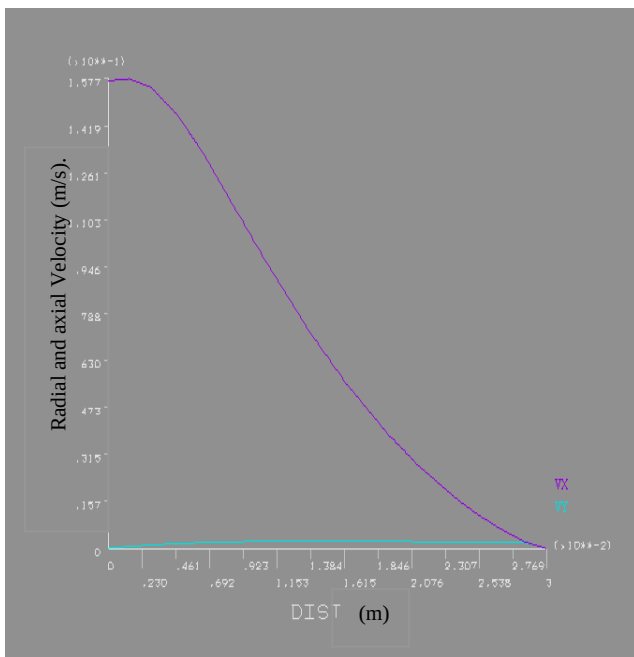


(a)

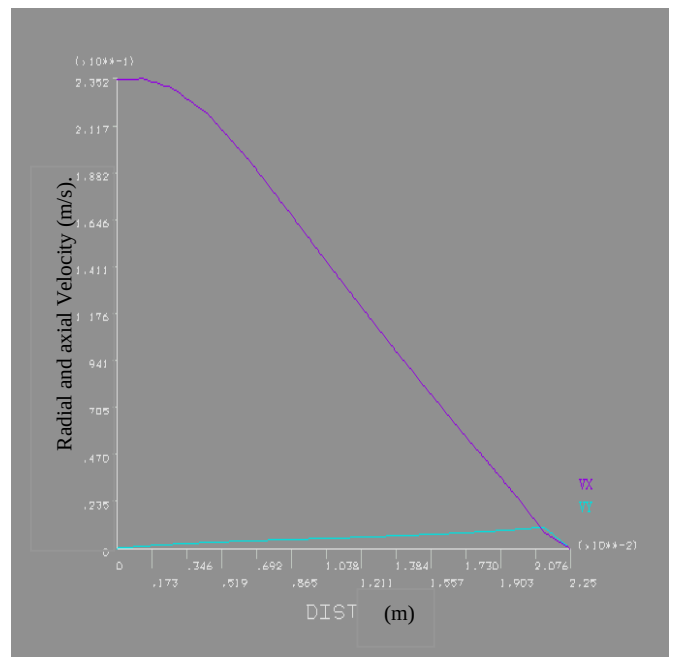


(b)

Fig. (13) : Effect of Impeller Diameter (D) on Averaged Radial Velocity Profiles at Height $y=0.03m_T$, (b) $D=D/3_T$ (a) $D=D/2$

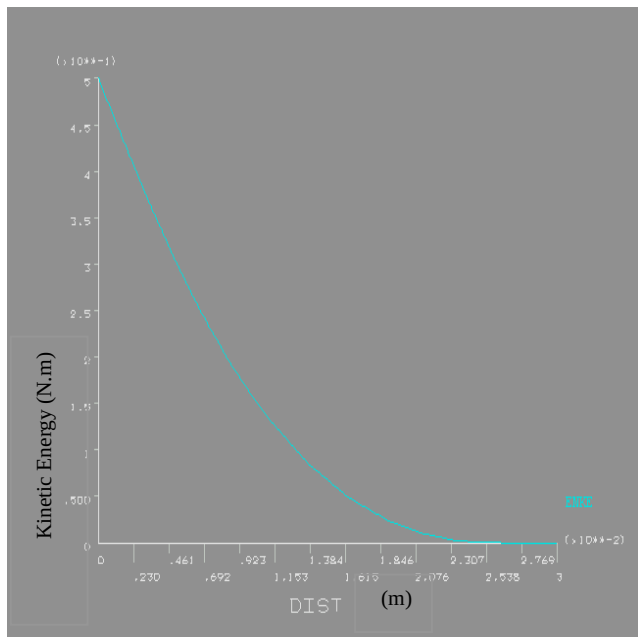


(a)

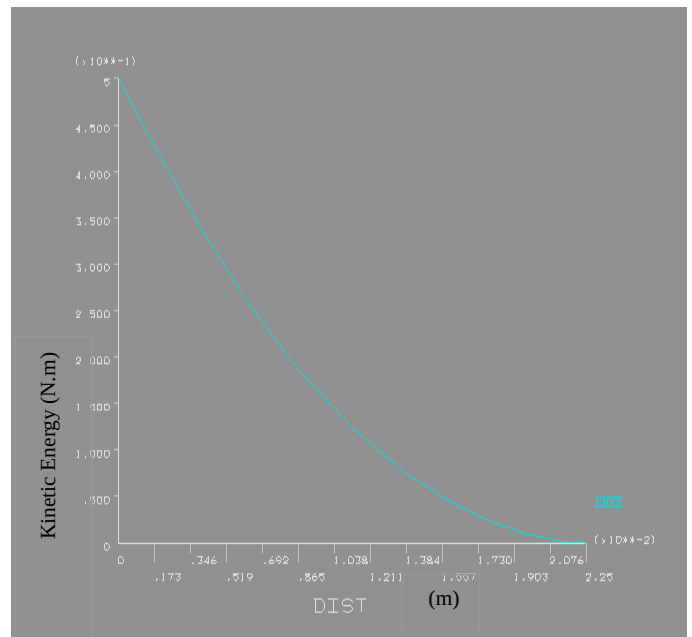


(b)

Fig. (14) : Effect of Impeller Diameter (D) on Averaged Radial Velocity Profiles at Height $y=0.52m$ From the Bottom of the Tank, T , (b) $D=D/3_T$ (a) $D=D/2$

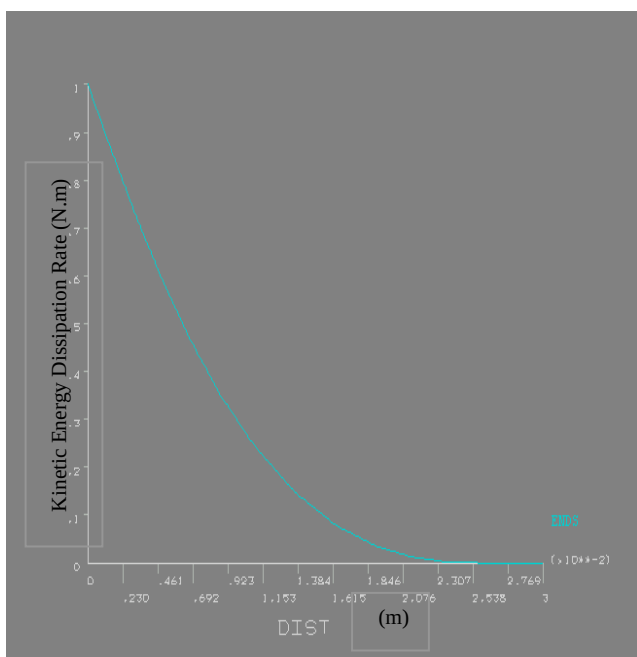


(a)

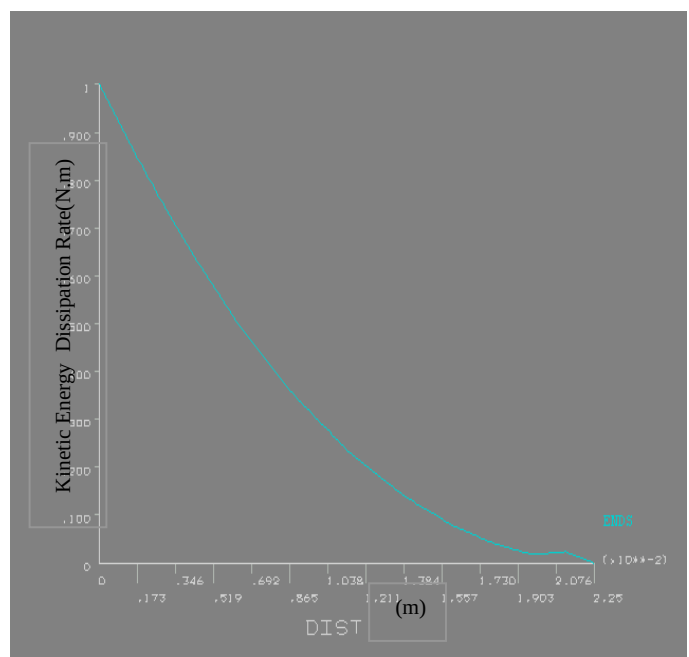


(b)

Fig. (15): Effect of Impeller Diameter on Decay of Turbulence Kinetic Energy (a) $D = D/2$ (b) $D = D/3$

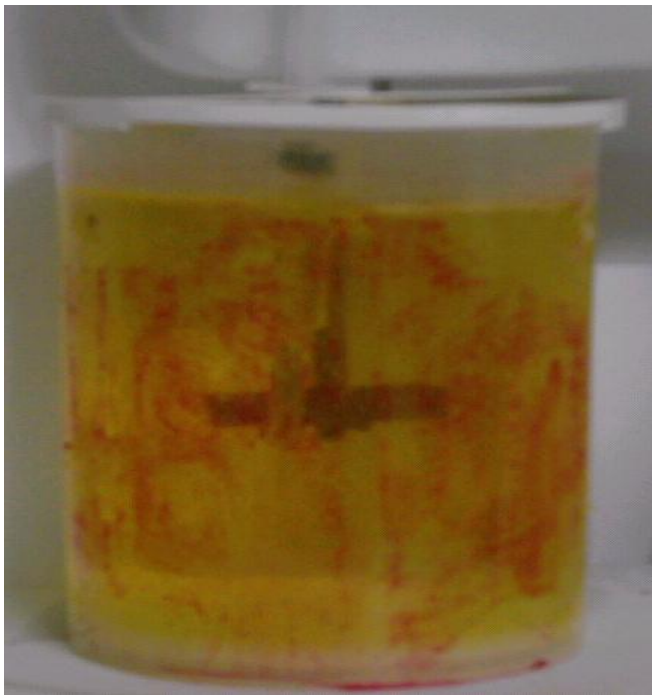


(a)



(b)

Fig. (16) : Effect of Impeller Diameter on Decay of Turbulence Kinetic Energy Dissipation Rate (a) $D = D/2$ (b) $D = D/3$.



(a)



(b)

Fig. (17): Effect of the Speed Reduction on the Colors Zones of the Acid-Base Visualization Method Test, (a) 100rpm and 0.04m Impeller Diameter, (b) 50rpm and 0.04m Impeller Diameter.

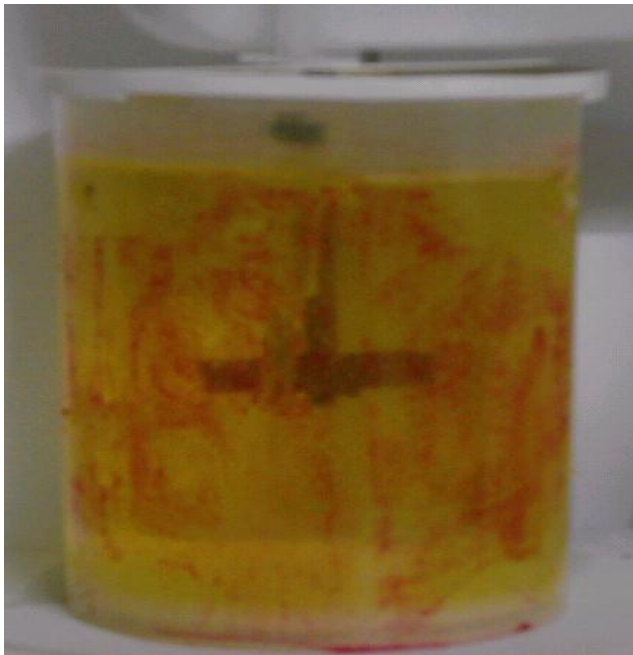
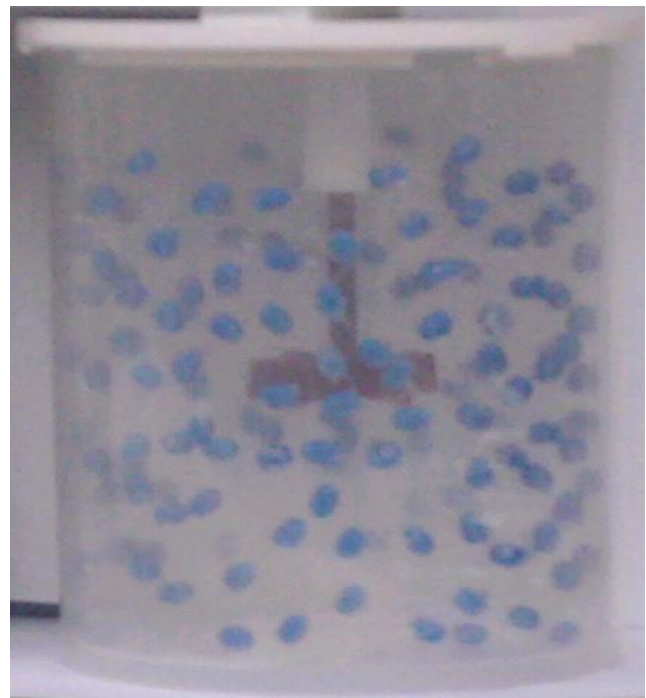


Fig. (18): Effect of the Impeller Diameter Increasing on the Colors Zones of the Acid-Base Visualization Method Test, (a) 100rpm and 0.04m Impeller Diameter, (b) 100rpm and 0.06m Impeller Diameter.



(a)

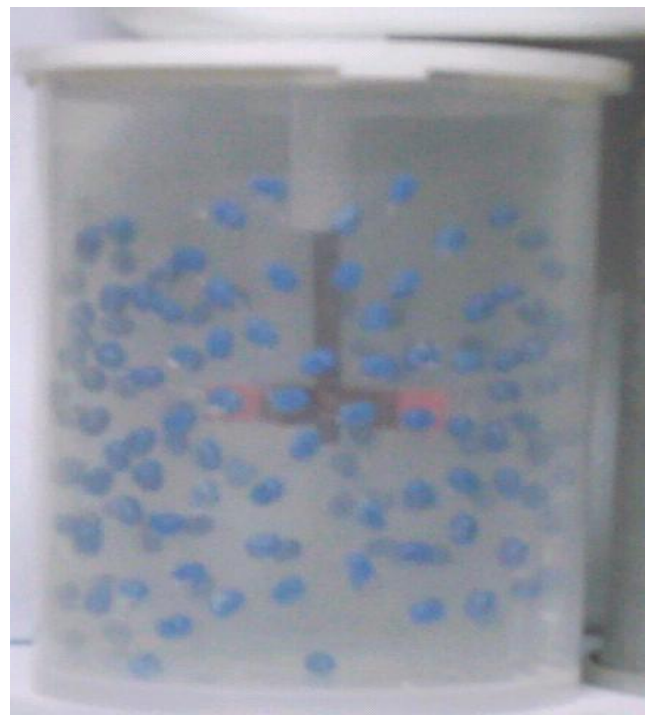


(b)

Fig. (19): Effect of Speed Reduction on the Particles Distribution Visualization Test, (a) 100rpm and 0.04m Impeller Diameter, (b) 50rpm and 0.04m Impeller diameter.



(a)



(b)

Fig. (20): Effect of Impeller Diameter Increasing on the Particles Distribution Visualization Test, (a) 100rpm and 0.04m Impeller Diameter, (b) 100rpm and 0.06m Impeller Diameter

CORRECTION PROCEDURE FOR THE DETERMINATION OF SOIL SPECIFIC SURFACE

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ABSTRACT:

Specific surface has a very important role in geotacnic especially with that home dell with gypseous soils or other types of salty soils. Because its calculation need for high accuracy, a procedure is presented to calculate a correction factor for Specific surface determination.

In a previous work, grain size distribution curves of many soil samples are collected. A value for the specific surface of each soil is determined summing the surface area of subintervals in the distribution curve.

In this work, the values of specific surface are obtained from these gradation curves and compared to those calculated using the values of the equivalent diameter for each soil. Fitting has been made and gets the best equation representing these points. From this equation, new values for specific surface are obtained by interning the specific surface calculated from the equivalent diameter and again the point is draw with the origin point (specific surface obtained from these gradation curves). Fitting is made again and the new equation is obtained. Finally, the equation of the calculated corrected specific surface is written. The results showed a very good agreement when using the corrected procedure.

الخلاصة

ان المساحة السطحية النوعية لها اهمية كبيرة في مجال ميكانيك التربة و بخاصة لأولئك الذين يتعاملون مع الترب الجبسية او الترب الحاوية على الاملاح بانواعها. ولان حسابها يتطلب دقة عالية اقترح في هذا البحث منهج عملي لحساب معامل تصحيح لحساب مساحة سطحية نوعية دقيقة .

في بحث سابق تم جمع بيانات لمنحني التوزيع الحبيبي للعديد من النماذج وتم تعيين قيمة المساحة السطحية النوعية لكل عينة بحساب المساحة السطحية للمسافات الثانوية في منحني التوزيع .

في هذا البحث اجريت مقارنة لقيم المساحة السطحية النوعية التي تم الحصول عليها من منحنيات التوزيع الحبيبي مع تلك المحسوبة باستخدام القطر المكافئ لكل عينة. تم ايجاد افضل معادلة تمثل هذه النقاط ومن هذه المعادلة تم حساب قيم جديدة للمساحة السطحية النوعية من تلك المحسوبة من القطر المكافئ ومرة ثانية رسمت هذه

النقاط كعلاقة بين المساحة السطحية الاصلية التي وجدت باستخدام منحني التوزيع الحبيبي مع هذه المساحة السطحية الجديدة ومن هذه العلاقة تم ايجاد افضل معادلة تمثل هذه النقاط . اخيراً اعيد كتابة معادلة المساحة السطحية المصححة وقد اظهرت نتائج جيدة جداً يمكن استخدامها لاجاد مساحة سطحية دقيقة بمقدار كبير.

KEY WORDS:

Specific surface, grain size distribution, correction

INTRODUCTION

The usual method to calculate the specific surface of a soil is the summation of the surface area of several sub divisions of the soil grains according to corresponding intervals on the gradation curve. There are various techniques to measure the specific surface of solids. Gas adsorption (i.e., the condensation of molecules on the mineral surface) determines surface area from the relationship between applied pressure and volume of gas forced into the specimen (water vapor is included in this group). Another technique is the absorption of molecules from solution onto a solid surface, in particular, dyes such as methylene blue. Additionally, specific surface values can be inferred from known thermodynamic properties (e.g., heat of immersion of a powder in a liquid), the rate of dissolution of soluble materials, microscopy, and the diffusiveness of X-ray diffraction patterns. Details of these measurement techniques can be found in Adamson (1990).

The potential use of specific surface in various geotechnical engineering applications and in the characterization of mineral resources.

A few examples are as follows: (i) assessing the extent of internal and interconnected micro porosity; (ii) characterizing the average slenderness of fine particles; (iii) computing the charge density on particle surfaces ,knowing the specific surface and the cation exchange capacity ; (iv) identifying the extent of fines coating coarse particles; n petroleum production, fines coating coarser particles may detach when the pore fluid is changed ("water shock"), migrate, and clog pore throats, thereby causing a dramatic decrease in permeability ("formation damage "); and (v) quality control and process monitoring, including natural and industrial situations such as the evolution of residual soils ,cement hydration, pyro-etamorphosis of minerals (e.g., ochre, bentonite),and the effectiveness of mineral separation processes, (Santamaria et al, 2002).

DEFINITION OF THE EQUIVALENT DIAMETER AND THE SPECIFIC SURFACE

The usual method to calculate the specific surface of a soil is the summation of the surface area of several sub divisions of the soil grains according to corresponding intervals on the gradation curve. If a grain size distribution curve such as the one shown in **Fig.1** is divided into n intervals, the specific surface of the soil, assuming spherical particles, is calculated according to the following. The average surface area of particles in an interval i of this gradation curve is

$$S_{piav} = \pi D_{iav}^2 \quad (1)$$

Where D_{iav} is the average diameter in this interval, while the average volume of a particle in this interval is

$$V_{piav} = \frac{\pi}{6} D_{iav}^3 \quad (2)$$

Hence, the total surface area of particles of this interval will be: -

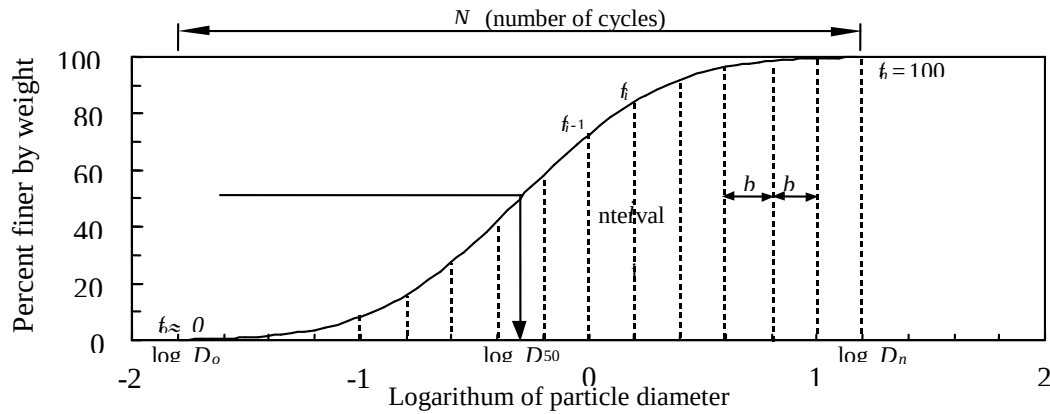


Fig. 1. A typical gradation curve of a soil divided into n equal intervals, Al-Muftly and Al-Hadidi, (2005)

$$S_i = \frac{(f_i - f_{i-1})W}{V_{piav}G\rho_w} S_{piav} = \frac{6(f_i - f_{i-1})W}{D_{iav}G\rho_w} \quad (3)$$

where W is the total weight of soil particles in grams, f_i and f_{i-1} are the cumulative percentages by weight of the particles finer in diameter than those at the beginning and the end of the interval i respectively, substituted in decimals, G is the average specific gravity of soil particles and ρ_w is the density of water = 1gm/cm^3 . To unify the units, diameters are substituted in centimeters and the surface areas are obtained in cm^2 . The specific surface of the soil, in cm^2 per 100gm of soil, may then be computed as: -

$$S_s = \left(\sum_{i=1}^n S_i \right) * \frac{100}{W} = \frac{6}{G\rho_w} \sum_{i=1}^n \frac{f_i - f_{i-1}}{D_{iav}} * 100 \quad (4)$$

In 2005 Al-Muftly and Al-Hadidi, presented a procedure to predict the effective diameter. The equivalent diameter is defined as the diameter that may substitute the whole soil grains for calculating the specific surface. The specific surface in cm^2 per 100gm of a soil may be calculated from the equivalent diameter as: -

$$S_s = \frac{100S_{pe}}{G\rho_w V_{pe}} = \frac{600}{G\rho_w D_e} \quad (5)$$

where S_{pe} and V_{pe} are the surface area in cm^2 and the volume in cm^3 respectively, of a particle having a diameter equal to the equivalent diameter, D_e in cm.

Equating the specific surface from Eq. (5) and Eq. (4), the following is obtained: -

$$\frac{1}{D_e} = \sum_{i=1}^n \frac{(f_i - f_{i-1})}{D_{iav}} \quad (6)$$

From which the equivalent diameter may be obtained for a specific grain size distribution curve. It is obvious that the equivalent diameter represents the harmonic mean of the particle diameters available, cf. Kezdi (1974).

Al-Muftly and Al-Hadidi (2005) reformed Eq.(4) to get this equation

$$S_s = \frac{600}{G\rho_w} \frac{10^b - 1}{b \ln(10)} \sum_{i=1}^n \frac{f_i - f_{i-1}}{D_i} \quad (7)$$

THE EQUIVALENT DIAMETER EQUATIONS

In 2005 Al-Muftly and Al-Hadidi presented the equivalent diameter which could be used to calculating the specific surface.

The aforementioned steps which were presented by Al-Muftly and Al-Hadidi, (2005) were devoted to determine an average diameter for a specific interval of a small width within the grain size distribution curve. Next, it is required to assess the value of the percentage finer corresponding to the diameter closest to the effective equivalent diameter, the latter being adopted to calculate the average specific surface of the soil as a whole. It is plausible to assume that the required value of the percentage finer is dependent on the number of logarithmic cycles and on the properties of the cumulative distribution of the grains.

The cumulative distribution which assumed following the well-known cumulative normal probability distribution. This enables the calculation of the cumulative function corresponding to a certain diameter and vice versa. The most significant range of the probability distribution assumed as from $\mu - 3\sigma$ to $\mu + 3\sigma$, μ and σ being the mean and the standard deviation of the distribution, giving a confidence level of 99.73%. This is called the “3 σ rule” advised by Duncan (2000) for reliability problems in geotechnical engineering. Thus, the N cycles will correspond to 6σ of the by weight distribution of the logarithms of diameters of particles. Then, it is possible to determine the standard deviation of the distribution.

$$\sigma = N / 6 \quad (8)$$

The standard random variable of the standard normal probability distribution will be

$$z = \frac{\log D - \mu}{\sigma} \quad (9)$$

Substituting Eq.(9) in Eq.(5) and Eq. (7) and equating the latter equations as in Eq. (6), the following is obtained: -

$$\frac{1}{10^{z_e \sigma + \mu}} = \frac{10^b - 1}{b \ln(10)} \sum_{i=1}^n \frac{f_i - f_{i-1}}{10^{z_i \sigma + \mu}} \quad (10)$$

The mean μ is the logarithm of D_{50} which may be easily determined. Nevertheless, its value is cancelled out from both sides if the equation is multiplied by (10^μ) . The variables z_e and z_i represent the standard normal variables that correspond to the effective diameter in question and the diameter at the end of the interval i in the gradation curve.

If a standard cumulative normal distribution curve is divided into n intervals within the range $z = -3$ to $z = +3$, z_e may be easily found as; -

$$z_e = \frac{1}{\sigma} \log \left\{ \frac{b \ln(10)}{10^b - 1} \left(\sum_{i=1}^n \frac{f_i - f_{i-1}}{10^{z_i \sigma}} \right)^{-1} \right\} \quad (11)$$

For a specified number of intervals, n , and a known value of the number of cycles N , the values of the standard deviation σ and the interval width b are determined. For each interval i , the value of z_i is determined from the inverse of the cumulative standard normal distribution function as the random

variable corresponding to f_i , the cumulative frequency.

After z_e is found, the corresponding cumulative frequency f_e may be found from the cumulative standard normal distribution function as being the percentage finer that corresponds to the required effective diameter D_e . The specific surface of the soil may be determined through Eq. 5 using a single diameter obtained from the gradation curve.

To put a single equation for simple assessment of f_e , several trials to solve Eq. 11 are performed using different number of intervals and logarithmic cycles. The results of these trials are given in Table 1. Of course, the range of N for natural soils is from about one cycle for uniform soils to about five or six cycles for widely sorted soils (very well graded). The results have shown that 200 intervals would be enough to assess properly accurate values for f_e .

Table 1. The percentage finer f_e corresponding to the equivalent diameter

n	N					
	1	2	3	4	5	6
10	42.446	34.868	28.118	22.346	17.615	13.870
20	42.774	35.480	28.937	23.281	18.584	14.810
40	42.856	35.634	29.144	23.520	18.834	15.056
100	42.879	35.677	29.202	23.587	18.905	15.125
200	42.883	35.683	29.211	23.597	18.915	15.135

The values for the effective percentage of finer particles for the case of 200 intervals are plotted against the number of logarithmic cycles of the gradation curve in **Fig. 3**.

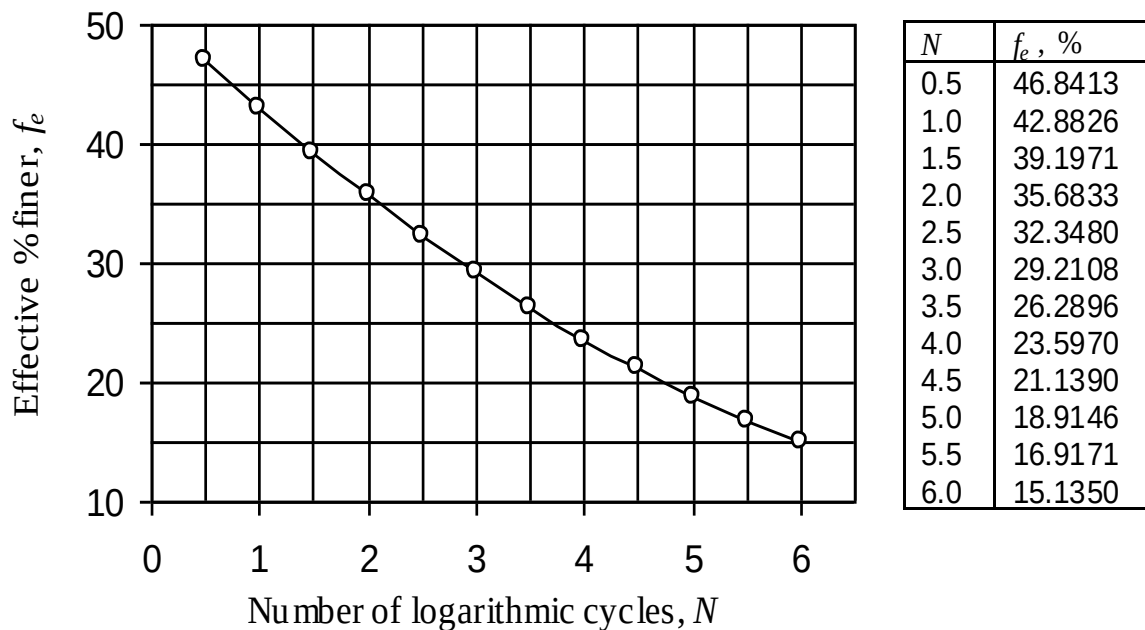


Fig. 3. The percent finer corresponding to the equivalent diameter for the case of 200 intervals for different N values

The plotted values in the figure are tabulated to the right of the plot in the same figure. A regression analysis has been performed and a best-fit curve is found to be the following: -

$$f_e = 0.43N^2 - 8.6N + 51.12 \quad (12)$$

with f_e in percent. The coefficient of correlation is found to be 0.999994, which is very high indeed. The equation is limited to the range $N \in [0.5, 6]$ where the trend of the relation with f_e is completely different for N values lower than 0.5, while for $N > 6$, the fitting equation should be changed (particle diameters in natural soils yield no values out of this range practically).

It is obvious now that for a certain soil, the equivalent diameter can be easily determined from the grain size distribution curve of that soil. It will be the diameter corresponding to the effective percentage finer determined from the table or from the graph given in **Fig. 3** or using Eq.(12) directly. As the equivalent diameter is determined, the specific surface of the soil can be calculated using Eq. (5).

The target equivalent diameter may be calculated by using equation derived in 2005 by Al-Muftly and Al-Hadidi .

THE TEST RESULTS

Grain size distribution curves for 154 different soil samples have been analyzed. The particle diameter values are taken in centimeters and plotted on the usual logarithmic axis against which the percentage finer is plotted. The curves are subdivided into intervals each of width $b=0.2$. The tails of the curves in the direction of small diameters are extended to determine an approximate value for the D_0 to start calculation.



Dmm	0.0001	0.00016	0.00025	0.0004	0.00063	0.001	0.0016	0.0025	0.004	0.0063	0.01	0.016	0.025	0.04	0.063	0.1	0.16	0.25	0.4	0.63	1	1.6	2.5	4	6.3	10	
Log D	-5	-4.8	-4.6	-4.4	-4.2	-4	-3.8	-3.6	-3.4	-3.2	-3	-2.8	-2.6	-2.4	-2.2												
Soil No.																P%											
1															0	5.2	11	35	72.6	82.6	87.8	93.5	95.2	97.7	98.6	99.1	100
2												0	0.8	2.6	4.3	8.6	40	74.3	83.4	90	93.4	96.5	98.6	99.1	100		
3														0	5.2	11	45	76.9	86	92.1	95.2	97.8	99.5				
4												0	1.7	4.3	6.9	12	50	86	93	98	99.5						
5												0	1.7	4.3	7.8	13.4	74.3	90.8	96.9	100							
6													0	3	7	10	20	36	70	83.9	90.8	95.2	98.6	99.1	100		
7														0	4.3	11.3	33.9	86	93.4	97.8	100						
8													0	3	6.9	13.4	47.8	90.8	96.9	100							
9													0	4.3	8.6	16	75.2	93.4	100								
10														0	2.5	10.6	20	30	48.1	53.7	63.7	73.7	76.2	78.1	81.2	88.8	
11															0	2.5	10	20	33.7	40	41.2	45	50	55	61.2	72.5	
12															0	1.2	1.3	2.5	5	10	15	25	34	43	66.2	70	
13																	0	1.8	2.5	6.2	12	20	25	35	50	60	
14																	0	1.2	1.8	3.7	5.6	13.7	25	45	72	83.7	
15															0	1.2	2.5	3.7	7.5	13.7	28.7	40	52	70	80	90	
16																		0	2.5	7.5	15	25	40	67.5	80	90	
17																0	1.2	1.8	5.6	10	15	23	30	37	48	62	
18													0	0.8	3.4	8.6	17.3	31.7	51.7	71.3	83.5	91.7	96	98.6	100		
19											0	0.8	5.2	8.6	13	20.8	36	57.8	74.7	84.4	91.3	94.4	96.9	100			
20													0	0.8	3.4	8.6	22.6	64.3	81.7	91.7	97.8	100					
21													0	2.1	5.2	10.8	26.9	82.6	94.3	100							
22														0	5.2	12.6	60	85.2	93.4	97.8	100						
23															0	1.7	14.3	70	90	96.9	100	</					

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132									0	7.5	15	26.3	32.5	35	38.8	45	51.3	52.5	57.5	65	66.3	70	72.5	83.8	95	98.8	99	99.5						
133																				0	3.75	8.75	15	47.5	83.8	96.3	97.5	97	98	99	99.5			
134												0	47.5	51.3	53.8	62.5	65	67.5	72.5	78.8	79	83.8	90	93.8	97.5	98.8	99	99.8						
135																				0	7.5	12.5	20	51.3	85	93.8	95.5	96.3	97.5	98	100			
136																				0	4.5	10	17.5	47.5	82.5	96.3	98	98	98.2	98.5	99	100		
137												0	57.5	58	61.3	68.8	73.8	76.3	80	88.8	90	93.8	97.5	98	98.5	99	99.5							
138												0	72.5	76.3	82.5	92.5	93	94	94.5	95	95	97.5	98	98.5	99	99.5								
139											0	27.5	55	60	67.5	81.3	90	95	96	97	97.5	98	98.5	99	99	99	99	99.8						
140											0	28.8	54.5	60	68.8	82	91.3	98.8	98.8	98.8	98.8	98.8	98.8	98.8	98.8	99	99	99.8						
141												0	18.8	20	22.5	26.3	28.8	30	30.5	31.3	33.8	38.8	47.5	70	92.5	98	99.5							
142												0	10	18	20	22.5	26.3	27.5	28.8	31.3	32.5	36.3	50	68.8	80	93.8	98	99.5						
143									0	8.75	16.3	23.8	28.8	40	48	52.5	57.5	61.3	65	71.3	76.3	85	92.5	95	97.5	98	98.5	99	99.9					
144												0	50	53.8	58.8	65	67.5	70	70	72.5	80	87.5	93.8	96.3	97.5	99.5								
145												0	20	42.5	44.5	50	60	67.5	72.5	81.3	92.5	96.3	97.5	98	99	99.5								
146												0	16.3	35	37.5	40	48.8	58.8	60	72.5	85	97.5	98	98.5	99	99.5								
147												0	40	43.8	47.5	61.3	66.3	71.3	78.8	92.5	98	98	99	99.8	100									
148												0	5	15	18.8	23.8	31.3	40	47.5	55	62.5	66.3	70	71.3	73.8	76.3	78.8	82.5	85	88.8	93.8	100		
149												0	18.8	20	23.8	28.8	33.8	35	42.5	50	57.5	70	80	82.5	85	85.1	87.5	90	91	93	95	100		
150												0	12.5	22.5	23.8	27.5	32.5	40	43.8	57.5	78.8	92.5	96.3	98	99	100								
151												0	7.5	14	15	17.5	22.5	25	28.8	32.5	40	50	71.3	97.8	98	98.8	99	99.5						
152												0	60	62.5	68.8	80	85	88.8	90	91.3	92.5	93.8	96.3	97.5	98.8	99	100							
153												0	62.5	66.3	73.8	80	87.5	90	90	90	90	92.5	95	96.3	97.5	98.8	100							
154												0	3.5	5	8.75	23.8	33.8	38.8	45	50	57.5	61.3	63.8	65	67.5	72.5	75	78.8	82.5	86.3	91.3	100		

Al-Muftly and Al-Hadidi (2005) draw the relation between the ratio of the specific surface calculated using the equivalent diameter to the specific surface calculated through summing the interval surface area of particles (S_{pe}/S_{PT}) and the coefficient of curvature (C_C which is equal to $(D_{30}^2/(D_{60} * D_{10}))$) as show in Figure 4.

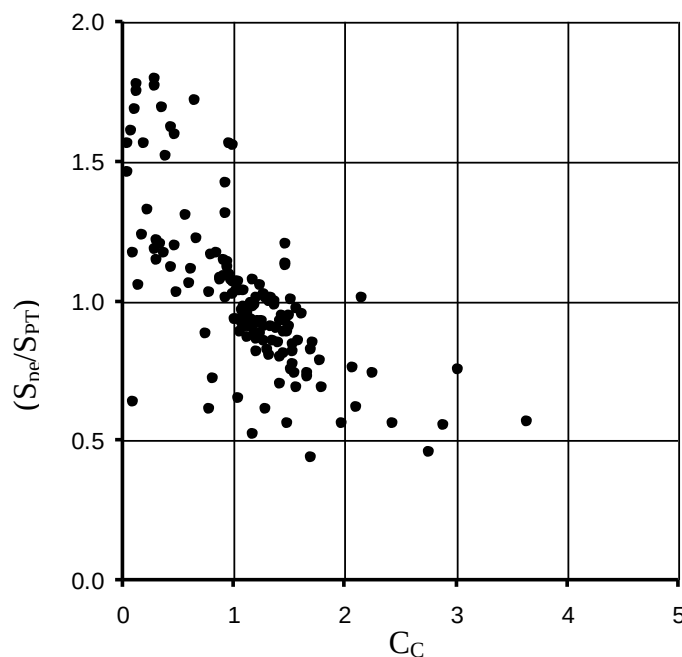


Fig. 4. Comparison between (S_{pe}/S_{PT}) values and coefficient of curvature (C_C) for uniformly graded samples

Al-Muftly and Al-Hadidi (2005) found that the ratio (S_{pe}/S_{PT}) decreases with the increase in the coefficient of curvature (C_C). Ratios closer to 1.0 are found for values of the coefficient of curvature in the range 1.0 to 3.0.

Considering the soil type and gradation, it is found that the results are less accurate in clayey soils than in sandy soils.

THE COMPUTER PROGRAM

Simple computer program has been written for this research in order to find C_C , C_u the f_e and D_e for the 154 samples as shown in Table (3).

Table 3. The results of the program for all the

Sample no.	Cu	C _c	N	f _e	D _e	S _{pe}	S _{PT}	Gradation Type
1	2.33	1.04273	2.4	39.689	0.01679	14582	13634	UNIFORM
2	2.03	0.88527	2.6	41.428	0.01616	15844	14718	GAP
3	2.13	0.92038	2	40.8167	0.01498	15916	14677	GAP
4	2.16	1.02884	2	40.6574	0.01415	16687	17939	UNIFORM
5	1.88	1.19515	1.6	42.4153	0.01245	18386	20170	UNIFORM
6	4.60	1.69923	2.4	31.7842	0.02225	9657	11693	WELL
7	2.17	1.1693	1.4	40.5599	0.01681	13294	14561	UNIFORM
8	2.30	1.09874	1.4	39.8645	0.01425	15581	17235	UNIFORM
9	2.05	1.28265	1.2	41.3364	0.01218	18235	20116	UNIFORM
10	8.73	0.15255	2.8	25.3741	0.0203	8755	8289	GAP
11	59.72	0.22156	2.8	12.1995	0.01754	6234	4705	GAP
12	57.73	7.77115	2.8	12.353	0.07836	1063	1529	GAP
13	6.54	2.10094	2.4	28.136	0.29021	613	992	WELL
14	4.00	1.20	2.4	33.3026	0.30411	737	902	WELL
15	6.43	0.75	2.6	28.3026	0.15657	1242	1406	GAP
16	4.77	1.32	2	31.3837	0.30557	638	792	WELL
17	8.03	0.79	2.6	26.1478	0.19496	793	1291	GAP
18	4.49	1.09	2.4	32.0358	0.02531	8594	9223	WELL
19	5.79	1.42	2.6	29.3687	0.01296	15988	20037	WELL
20	2.29	1.18	1.8	39.9216	0.01919	11955	12269	UNIFORM
21	2.23	1.36	1.4	40.267	0.0177	12590	14666	UNIFORM
22	2.45	0.79	1.4	39.0702	0.01293	17041	16527	GAP
23	1.71	1.04	1.2	43.6872	0.01275	17759	17111	UNIFORM
24	2.47	1.29	2.6	38.9822	0.01858	12948	12797	UNIFORM
25	2.72	1.47	2.6	37.7804	0.01756	13475	14436	UNIFORM
26	2.57	1.54	2.2	38.4596	0.01736	13266	16226	UNIFORM
27	2.72	1.55	1.8	37.7728	0.01667	13411	18136	UNIFORM
28	1.61	1.01	1.6	44.4564	0.01299	17920	19155	UNIFORM
29	2.73	1.27	3	37.7667	0.01866	13290	14317	UNIFORM
30	2.95	1.45	3	36.8324	0.01763	13794	15532	UNIFORM
31	3.19	1.66	2.4	35.914	0.01652	13849	19131	UNIFORM
32	2.71	1.80	1.6	37.8364	0.01703	12996	18925	UNIFORM
33	2.27	1.13	1	40.0144	0.01585	13669	15749	UNIFORM
34	2.49	1.30	2.4	38.87	0.01855	12769	12616	UNIFORM
35	2.77	1.49	3	37.5891	0.01753	13822	15534	UNIFORM
36	2.59	1.54	2.6	38.4026	0.01738	13558	16063	UNIFORM
37	2.77	1.52	1.6	37.588	0.01653	13341	17756	UNIFORM
38	2.02	1.23	1.6	41.5055	0.01252	18198	19589	UNIFORM
39	2.10	1.21	2.2	40.9816	0.00183	128919	127354	UNIFORM
40	1.50	0.92	2	45.3843	0.00135	178197	155676	GAP
41	2.45	1.16	2.2	39.0838	0.00167	140266	150460	UNIFORM
42	1.92	1.04	1.8	42.1567	0.00136	171269	160370	UNIFORM
43	16.93	10.19	1.6	19.8062	0.01036	18312	20600	GAP
44	2.34	1.45	1.8	39.6484	0.01198	18944	23418	UNIFORM
45	2.19	1.12	1.8	40.4693	0.0167	13753	14767	UNIFORM
46	2.37	1.33	2.2	39.4795	0.01788	13065	12966	UNIFORM
47	2.25	1.10	2	40.1396	0.01673	13927	14236	UNIFORM
48	2.32	1.15	2.2	39.7347	0.01663	14222	15681	UNIFORM
49	2.75	1.42	1.8	37.6754	0.01623	13769	19554	UNIFORM
50	1.87	1.10	1.6	42.4848	0.013	17704	19552	UNIFORM
51	2.24	1.39	1.8	40.161	0.01761	12939	14385	UNIFORM
52	3.84	1.54	3	33.7814	0.02435	10256	13237	UNIFORM
53	2.46	3.03	1.8	39.0104	0.01698	13284	17685	GAP
54	2.12	1.27	1.4	40.8563	0.01233	18165	21220	UNIFORM
55	3.47	0.96	2.4	34.9308	0.01903	12110	11057	GAP
56	3.32	1.18	2.2	35.4368	0.01757	12929	12018	UNIFORM



57	2.64	1.10	1.8	38.1582	0.01532	14815	15699	UNIFORM
58	2.49	1.10	1.8	38.8738	0.01472	15558	16429	UNIFORM
59	1.96	1.13	1.4	41.8641	0.0128	17681	18364	UNIFORM
60	2.16	1.28	2.4	40.6245	0.01857	12801	12481	UNIFORM
61	2.20	1.44	2	40.3897	0.01744	13312	14118	UNIFORM
62	2.28	1.34	2.6	39.9594	0.0181	13216	14587	UNIFORM
63	2.45	1.58	2	39.0921	0.01716	13346	15647	UNIFORM
64	2.51	1.66	2	38.7639	0.01705	13377	18146	UNIFORM
65	2.74	1.58	1.8	37.7143	0.01657	13482	19662	UNIFORM
66	2.02	0.99	2.4	41.5154	0.0178	13609	12651	GAP
67	1.99	1.00	2.4	41.6945	0.01774	13627	12737	UNIFORM
68	1.70	0.88	2	43.7528	0.01417	16992	15713	GAP
69	1.83	0.93	1.6	42.7604	0.01394	16671	16564	GAP
70	1.81	1.09	1.6	42.8946	0.01301	17741	19307	UNIFORM
71	2.15	1.30	1.8	40.6824	0.0124	18478	22475	UNIFORM
72	2.15	1.47	2	40.6824	0.01327	17548	15510	UNIFORM
73	2.15	1.47	2	40.6824	0.01327	17548	15585	UNIFORM
74	2.08	0.62	2.4	41.153	0.01793	13571	12221	GAP
75	1.92	0.86	2.4	42.1838	0.01531	16276	13909	GAP
76	1.67	1.00	1.8	43.942	0.01323	17822	17411	UNIFORM
77	1.75	1.08	1.4	43.3347	0.0128	17848	18523	UNIFORM
78	1.55	2.15	2.6	44.9464	0.02078	12636	12533	UNIFORM
79	2.98	1.62	2.6	36.6829	0.01728	13722	14405	UNIFORM
80	2.71	1.79	2.2	37.8402	0.0171	13450	17102	UNIFORM
81	2.85	2.07	1.6	37.2135	0.0168	13093	17219	UNIFORM
82	2.28	1.22	1	39.9512	0.01636	13261	15434	UNIFORM
83	2.27	1.12	1.8	40.0444	0.01667	13738	14981	UNIFORM
84	2.29	1.42	1.6	39.8898	0.01758	12787	13795	UNIFORM
85	2.37	1.38	2.6	39.5051	0.0174	13794	13858	UNIFORM
86	2.08	0.94	2.6	41.107	0.01423	17510	15643	GAP
87	1.85	1.13	1.4	42.6179	0.01264	17980	18946	UNIFORM
88	2.27	1.07	1.4	40.0245	0.01475	15084	17053	UNIFORM
89	2.68	1.53	2.2	37.9508	0.0179	12848	12795	UNIFORM
90	2.33	1.32	2.2	39.7039	0.01803	12971	13046	UNIFORM
91	2.42	1.38	2.2	39.2138	0.01778	13094	13321	UNIFORM
92	2.47	1.50	2	38.9542	0.01781	12826	13612	UNIFORM
93	2.50	1.71	1.2	38.7961	0.01697	12829	15083	UNIFORM
94	2.48	1.41	1.2	38.9427	0.01659	13144	15537	UNIFORM
95	10.00	0.48	2.4	24.1408	0.0252	7269	7056	GAP
96	3.92	1.24	2.2	33.5355	0.02696	8120	7685	UNIFORM
97	3.47	1.48	2	34.9334	0.02055	10695	11935	UNIFORM
98	3.25	1.24	1.8	35.6682	0.02084	10377	11745	UNIFORM
99	3.01	1.06	2.2	36.5738	0.01575	15024	14520	UNIFORM
100	5.05	1.70	2.6	30.792	0.36708	587	1338	WELL
101	2.28	0.95	2.4	39.9664	0.02335	10490	9210	GAP
102	2.29	1.15	2.2	39.9327	0.03106	7630	7727	UNIFORM
103	3.64	0.37	2.6	34.3807	0.04302	5420	4632	GAP
104	10.33	0.31	2.2	23.8572	0.03855	4198	3463	GAP
105	11.13	0.29	2.2	23.2006	0.04233	3853	3249	GAP
106	20.86	0.32	2.6	18.275	0.02778	5294	4614	GAP
107	2.65	1.03	2.8	38.1103	0.0321	7683	7411	UNIFORM
108	3.61	0.35	2	34.4782	0.04323	5031	4188	GAP
109	8.01	0.44	2.2	26.1736	0.04082	4576	4093	GAP
110	4.57	1.49	2.2	31.849	0.29837	706	1259	WELL
111	8.46	1.97	2.2	25.656	0.25976	555	992	WELL
112	2.54	1.09	2.2	38.6048	0.0263	8981	8668	UNIFORM
113	20.09	0.18	2.6	18.544	0.02165	6027	4880	GAP
114	9.10	2.76	2.4	24.9884	0.36837	457	994	WELL
115	825.40	0.08	5.2	8.91957	6.3E-05	1398620	869652	GAP
116	72.92	0.48	4.4	11.3533	5.4E-05	1617321	1355615	GAP

117	39.62	0.82	3	14.2455	0.00021	307105	425130	GAP
118	4.34	1.17	2.8	32.4078	0.00111	210221	404403	WELL
119	41.69	0.09	3	13.9696	0.00024	601038	513625	GAP
120	27.83	1.29	4	16.3403	0.00044	296826	484244	WELL
121	331.13	0.60	4.8	8.13421	6.4E-05	788814	741184	GAP
122	3.40	1.19	2.2	35.1544	0.01211	18685	21228	UNIFORM
123	11.75	0.68	3.2	22.7411	5.4E-05	3138395	2569744	GAP
124	24.55	0.39	4.2	17.1573	0.00014	1208252	795101	GAP
125	14.45	0.66	4.8	21.0355	0.00015	1666790	970095	GAP
126	593.38	0.00	4	8.39877	3.7E-05	2862777	1834184	GAP
127	23.07	1.47	4.8	17.5756	0.00076	228785	190241	WELL
128	3.30	1.46	2.4	35.4893	0.21188	1087	1170	UNIFORM
129	5.30	2.25	2.4	30.2827	0.17386	1231	1659	WELL
130	11.48	2.88	2.8	22.9371	0.06658	1635	2964	WELL
131	241.11	79.84	3.8	8.34206	0.00089	29844	50690	GAP
132	63.10	0.13	4	11.9566	0.00052	247684	141378	GAP
133	2.69	1.19	2.4	37.948	0.21939	1087	1103	UNIFORM
134	5.02	0.29	3.4	30.8455	0.00135	171290	96978	GAP
135	3.56	1.50	2.2	34.6172	0.19658	1136	1249	UNIFORM
136	3.73	1.57	2.4	34.1048	0.2045	1106	1143	UNIFORM
137	3.08	0.45	3.6	36.3153	0.00134	180835	111758	GAP
138	1.37	0.94	3.4	46.6226	0.00134	187377	142730	GAP
139	1.96	1.00	3.6	41.8692	0.00127	228897	147270	GAP
140	1.98	0.96	3.6	41.7754	0.00126	233226	149259	GAP
141	160.12	0.01	3.2	8.97641	0.00125	25500	40133	GAP
142	100.00	2.44	3.4	10.216	0.00101	28227	50250	WELL
143	31.62	0.48	4.2	15.5466	0.0006	238698	149579	GAP
144	3.98	0.36	3.2	33.3659	0.00136	171702	101628	GAP
145	21.70	0.11	3.2	17.9999	0.00095	188646	112153	GAP
146	20.57	0.14	3.2	18.3741	0.00105	166502	93679	GAP
147	5.39	0.29	3	30.0951	0.00141	158795	88648	GAP
148	27.12	0.79	4	16.5039	0.00302	35710	30659	GAP
149	54.12	0.57	4	12.6528	0.00136	56857	43627	GAP
150	29.08	1.04	2.8	16.0631	0.00118	42691	65994	WELL
151	65.64	3.65	3.8	11.7864	0.00135	23706	41733	GAP
152	32.92	0.04	3	15.3047	0.00112	177618	121592	GAP
153	1.45	0.93	3	45.9261	0.0014	179217	126336	GAP
154	20.73	0.20	4	18.3188	0.00534	35382	22621	GAP

CORRECTION PROCEDURE

By using Eq. (7), the specific surface of soil particles is obtained. Meanwhile, the number of logarithmic cycles, N , for each soil is determined and the percent finer corresponding to the equivalent diameter is found using Eq. (12). Accordingly, the equivalent diameter is determined and the corresponding specific surface is calculated using Eq. (5). The results from the latter equation are

compared with those obtained from Eq. (7) and plotted in Fig. 5.

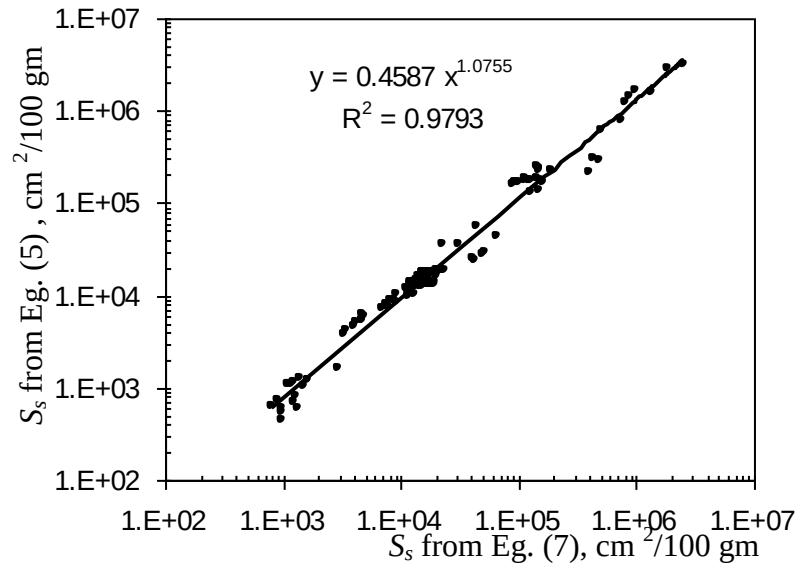


Fig. 5. Comparison between values of specific surface obtained from Eq. (7) and Eq. (5) for the analyzed soils

Fitting has been made for specific surface obtained from eq.(7) and that obtained from eq.(5) and from this fitting it is found that the best equation representing this relationship is:

$$Y = (0.4587) * X^{(1.0755)} \quad (13)$$

by using this equation new S_{pe} is found as follows:

$$S_{pe(new)} = (1/0.4587) * S_{pe}^{(1/1.0755)} \quad (14)$$

And this $S_{pe(new)}$ is re drawn with original S_{PT} obtained from equation no. (7), as shown in Fig. 6

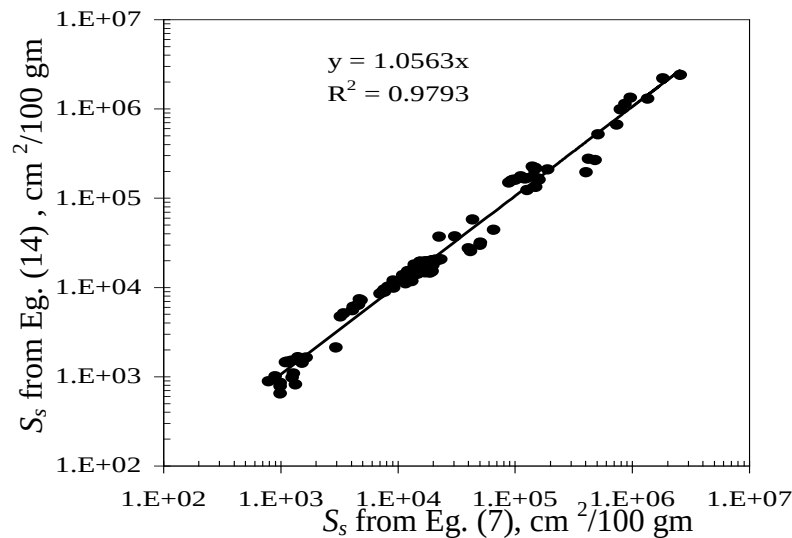


Fig. 6. Comparison between values of specific surface obtained from Eq. (7) and Eq. (14) for the analyzed soils

Fitting has been made for specific surface obtained from eq.(7) and that obtained from eq.(14) and from this fitting it is found that the best equation representing this relationship is:

$$Y = (1.0563) * X \quad (15)$$

By using this equation another new S_{pe} is found as follows:

$$S_{pe(final)} = (1/1.0563) * S_{pe(new)} \quad (16)$$

And this $S_{pe(final)}$ is re drawn with original S_{PT} obtained from equation no. (7), as shown in **Fig. 7**

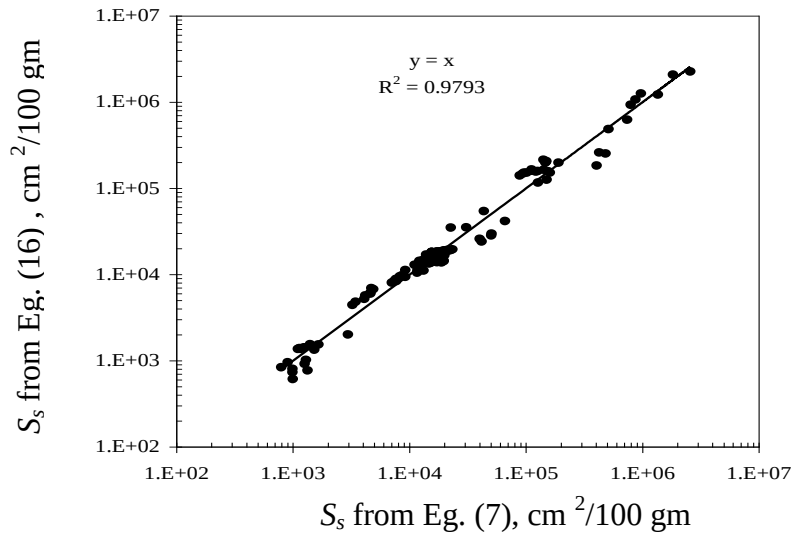


Fig. 7. Comparison between values of specific surface obtained from Eq. (7) and Eq. (16) for the analyzed soils

Fitting has been made for specific surface obtained from eq.(7) and that obtained from eq.(16) and from this fitting it is found that the best equation representing this relationship is:

$$Y=X \quad (17)$$

The comparison has proved better agreement and the coefficient of correlation between the results of the two equations is found to be 0.982921. The values obtained for the ratio of the specific surface calculated using the equivalent diameter to the specific surface calculated through summing the interval surface area of particles ($S_{pe(new)}/S_{PT}$) varied from 1.594972 to 0.453831 with an average of 1.025342, which is more close to 1.0. The standard deviation of the ratio distribution is found to be 0.225367.

SEPARATING THE SAMPLES

In order to find the best correction equation, the samples are separated to gap, well graded and uniformly graded samples.

Well Graded Samples:

Fitting has been made for specific surface obtained from eq.(7) and that obtained from eq.(5) for well graded samples as shown in **Fig.(8)**

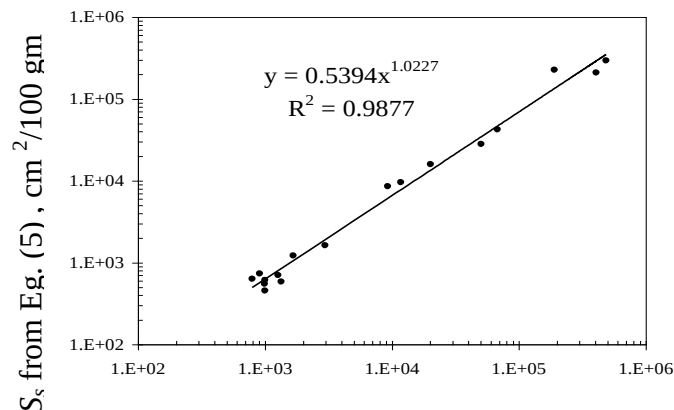


Fig. 8. Comparison between values of specific surface obtained from Eq. (7) and Eq. (5) for the well graded analyzed samples.

from this fitting it's found that the best equation could represented this relationship is:

$$S_{pe(final)} = (S_{pe}/0.59394)^{(1/1.0227)} \quad (18)$$

And this $S_{pe(final)}$ re draw with original S_{PT} that obtained from equation no. (7), as shown in **Fig. 9**

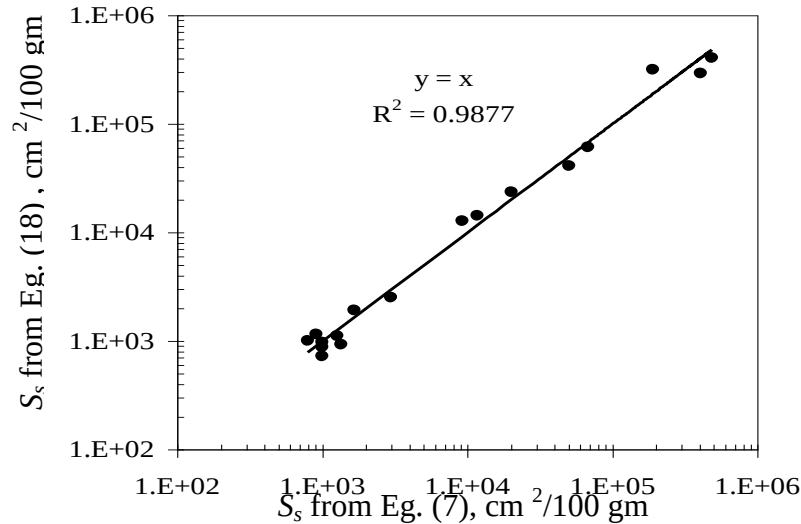


Fig. 9. Comparison between values of specific surface obtained from Eq. (7) and Eq. (18) for the well graded analyzed samples.

The comparison has proved better agreement and the coefficient of correlation between the results of the two equations is found to be 0.985730. The values obtained for the ratio of the specific surface calculated using the equivalent diameter to the specific surface calculated through summing the interval surface area of particles ($S_{pe(new)}/S_{PT}$) varied from 1.67 to 0.5031 with an average of 0.9438, which is more close to 1.0. The standard deviation of the ratio distribution is found to be 0.2008.

Gap Graded Samples:

Fitting has been made for specific surface obtained from eq.(7) and that obtained from eq.(5) for gap graded samples as shown in **Fig.(10)**

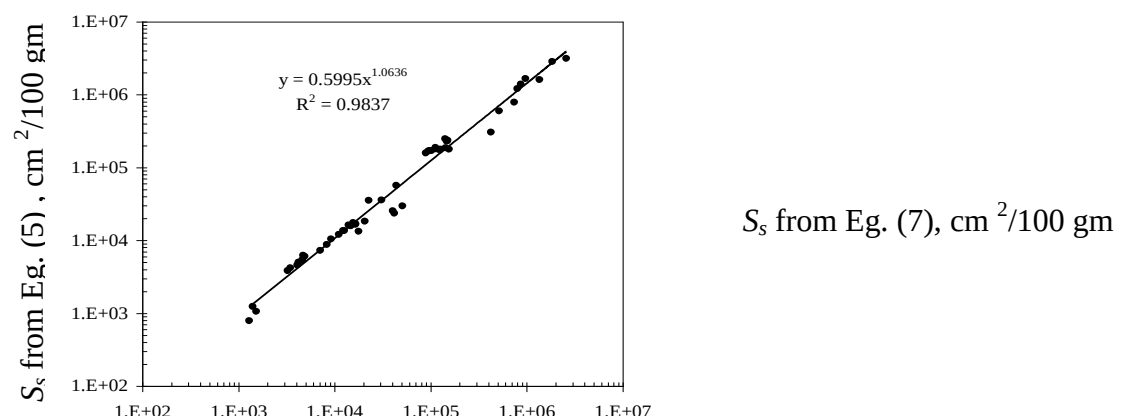


Fig. 10. Comparison between values of specific surface obtained from Eq. (7) and Eq. (5) for the gap graded analyzed samples.

from this fitting it's found that the best equation could represented this relationship is:

$$S_{pe(\text{final})} = (S_{pe}/0.5995)^{(1/1.0636)} \quad (19)$$

And this $S_{pe(\text{final})}$ re draw with original S_{PT} that obtained from equation no. (7), as shown in **Fig. 11**

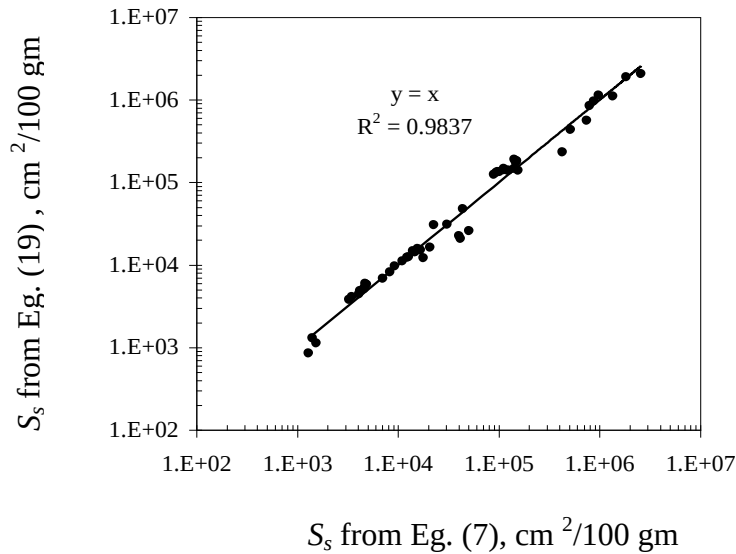


Fig. 11 Comparison between values of specific surface obtained from Eq. (7) and Eq. (19) for the gap graded analyzed samples.

The comparison has proved better agreement and the coefficient of correlation between the results of the two equations is found to be 0.985421. The values obtained for the ratio of the specific surface calculated using the equivalent diameter to the specific surface calculated through summing the interval surface area of particles ($S_{pe(\text{new})}/S_{PT}$) varied from 1.420 to 0.3256 with an average of 0.8975, which is more close to 1.0. The standard deviation of the ratio distribution is found to be 0.2166.

Uniform Graded Samples

Fitting has been made for specific surface obtained from eq.(7) and that obtained from eq.(5) for uniform graded samples as shown in **Fig.(12)**

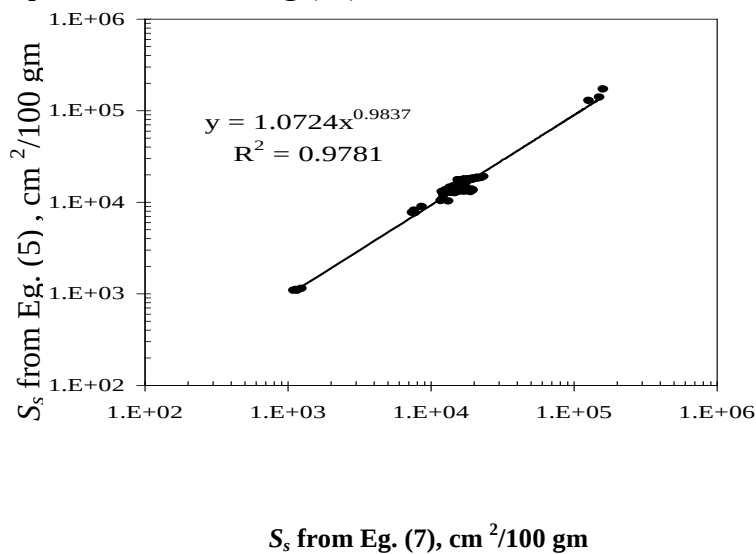


Fig. 12 Comparison between values of specific surface obtained from Eq. (7) and Eq. (5) for the uniform graded from this fitting it's found that the best equation representing this relationship is:

$$S_{pe(final)} = (S_{pe}/1.0724)^{(1/0.9837)} \quad (20)$$

And this $S_{pe(final)}$ re draw with original S_{PT} that's obtained from equation no. (7), as shown in **Fig. 13**

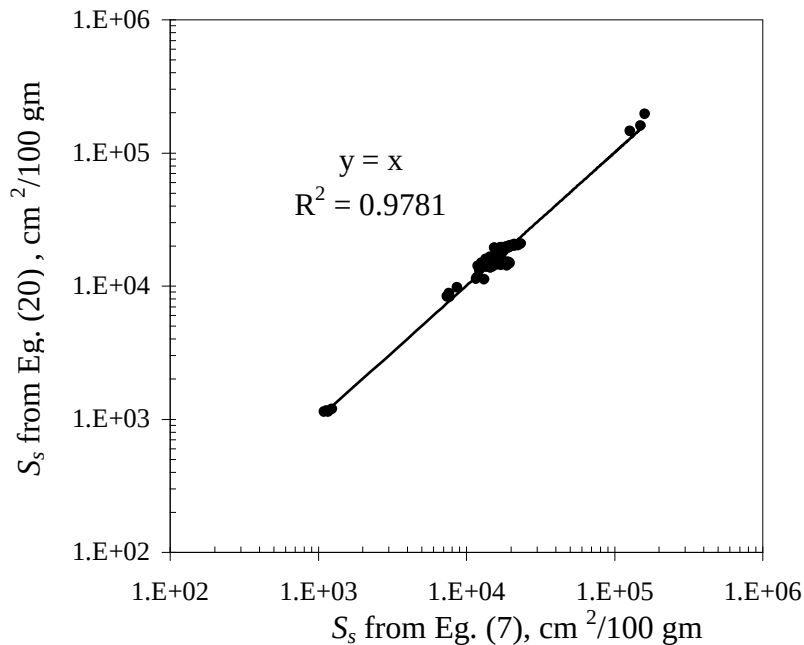


Fig. 13 Comparison between values of specific surface obtained from Eq. (7) and Eq. (5) for the uniform graded analyzed samples.

The comparison has proved better agreement and the coefficient of correlation between the results of the two equations is found to be 0.98545. The values obtained for the ratio of the specific surface calculated using the equivalent diameter to the specific surface calculated through summing the interval surface area of particles ($S_{pe(new)}/S_{PT}$) varied from 1.4161 to 0.3256 with an average of 0.9712, which is more close to 1.0. The standard deviation of the ratio distribution is found to be 0.2170.

CONCLUSIONS

Al-Mufti and Al-Hadidi proposed procedure for calculating the equivalent diameter by which the equivalent specific surface could be calculated. In this paper the equivalent specific surface could be corrected by a proposed procedure.

Analysis of 154 soil gradation curves has shown a very good agreement between the surface area values cumulated from gradation curves and the corrected specific surface which was obtained from the proposed equation.

NOTATIONS

- D_{iav} The average diameter
- S_{piav} The average surface area of a particle
- V_{piav} the average volume of a particle
- S_i the total surface area of particles of each interval
- W The weight of the whole soil in grams.

- f The values in percents representing the percentage of soil grains by weight passing the corresponding sieve size (diameter) on the gradation curve.
- G The average specific gravity of the soil particles.
- ρ_w The density of water = 1 gm/cm³
- S_s The specific surface of the soil
- S_{pe} The specific surface of the particle having the equivalent diameter
- V_{pe} The volume of the particle having the equivalent diameter
- D_e The equivalent diameter
- S_{pt} The specific surface calculated through summing the interval surface area of particles
- N Number of logarithmic cycles
- n Number of classes
- b The width of each interval
- f_e The % finer on the gradation curve that yields a diameter which is the equivalent diameter required
- z The standard normal distribution variable
- σ The standard deviation
- μ The mean
- π The constant ratio
- C_C The coefficient of curvature

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NUMERICAL ANALYSIS OF THIN BEAMS RESTING ON NONLINEAR ELASTIC FOUNDATIONS

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ABSTRACT

The finite difference method is used for solving the basic differential equation for the elastic deformation of a thin beam supported on a nonlinear elastic foundation. A tangent approach is used to determine the modulus of subgrade reaction after constructing a second degree equation for load-deflection diagram. Results of plate loading test of soil obtained in Iraq were used in the analysis. An iterative approach is used for solving the nonlinear problem until the convergence of the solution. The method of analysis, as programmed for a computer solution, considers the continuous elastic, nonlinear foundation to be active only when the beam is pressing against the foundation. Two examples of with simply supported beams are presented to illustrate the application of the method of analysis.

التحليل العددي للعتبات النحيفة المسندة على اساس غير خطي مرن

الخلاصة

إنَّ طريقةَ الفروقِ المحدودةِ تمسَّعُ لحلَّ المعادلةِ التفاضليةِ الأساسيةِ للتشوهِ المرنِ للعتباتِ النحيفةِ المسندةِ على اساسٍ مرنةٍ لاختطيةٍ. المعامل المماسي يُستعملُ لتحديد معامل ردِّ فعل التربة باستعمال معادلة من الدرجة الثانية من مخطط الحمل مع الإزاحة. تم الحصول على نتائج إختبار تحميل الصفيحة لتربة في العراق والتي تم استخدامها في التحليل. تم اعتماد طريقة الحل المتكرر لحل مسألة الاسس للاختطية حتى يتقارب الحل. ان طريقة التحليل، تم برمجتها باستخدام الحاسوب، حيث يعتبر الاسس للاختطية المرنة المستمرة التي ستكون فعالة فقط عندما الحمل يضغط الاسس. تم انتخاب إثنان من أمثلة العتبات المسند اسناد بسيط لكي تُقدَّم تصور لكيفية تطبيق طريقة التحليل.

KEYWORDS

Beams, finite differences, Winkler foundation, nonlinear analysis, tangent modulus.

INTRODUCTION

The analysis of a linear elastic thin beam supported on a linear elastic foundation and subjected to lateral loads has been accomplished by many different techniques. The beam may have different support types such as fixed, simply supported and a load bearing media. Elastic support provided for beams is referred to foundation. The basic assumption is that the reaction forces of the foundation are proportional at every point to the deflection of the beam at that point. Winkler first introduces that assumption in 1871. Many researches were carried out this works such as Heteny (1946); Vlasov and Leontiev (1960); Selvadurai (1979); Chen (1999); Yin (2000) and Guo and Y. Jack Weitsman (2002).

Modulus of subgrade reaction is a conceptual relationship between soil pressure and deflection. It can be measured by using plate-loading test. Using this test, a load-deflection curve is adapted. The modulus of subgrade reaction K_s can be calculated using:

$$K_z = \frac{p}{w} \quad (1)$$

where :

K_z is the modulus of subgrade reaction,
 p is the applied pressure and
 w is the deflection.

The value of K_z is obtained from the concept of secant or tangent approach as shown in **Fig. (1)**.

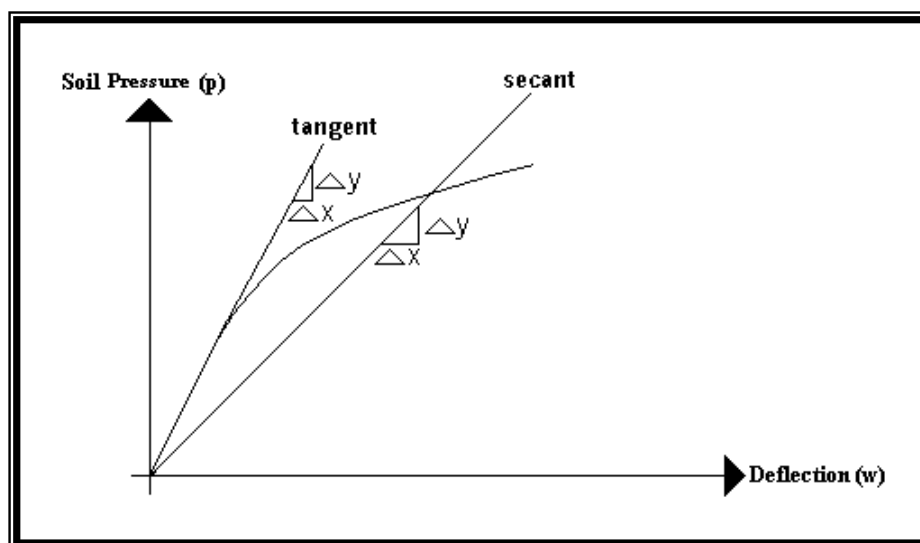


Fig. (1): Typical load-deflection curve.

There are a wide range of K_z values for different types of soils. In the present study a quasi linearization method or iteration procedure to get the value of K_z was used. This lineariazation by method iteration was developed using tangent method as a basic approach.

THEORY

The basic or differential equation for beams resting on Winkler foundation is [Fig. (2)]:

$$\frac{d^4 w}{dx^4} + \frac{K_z}{EI} w = \frac{q}{EI} \quad (2)$$

where:

- w is the deflection of the beam,
- E is the modulus of elasticity of the beam,
- I is the moment of inertia of beam section and
- q is the distributed load per unit length.

There are many methods used to solve this equation depending on type of support and applied loading:

- ❑ Exact solutions.
- ❑ Finite difference method.
- ❑ Finite element method.
- ❑ Fourier series method.

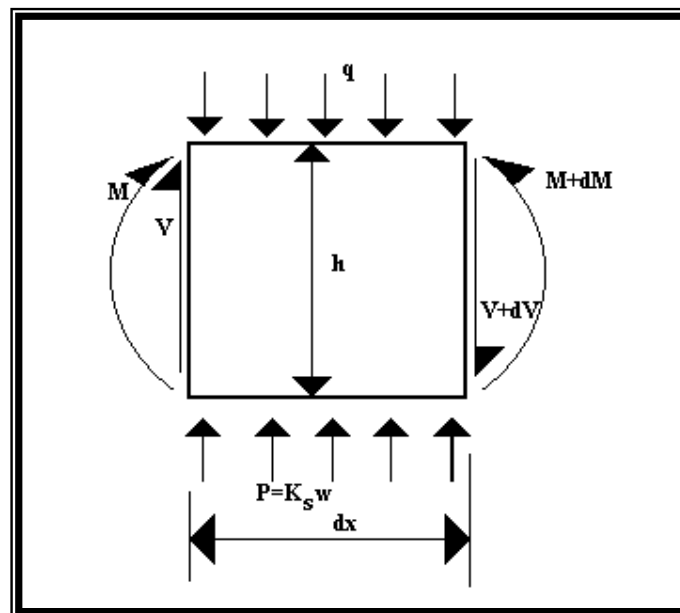


Fig. (2): Beam element supported by load bearing media.

FINITE DIFFERENCE METHOD

The method of finite difference was used in the present study to solve the differential eq. (2). The basic concept of this method is to replace the derivatives by ratio of infinite small quantities or difference at selected points [Fig. (3)].

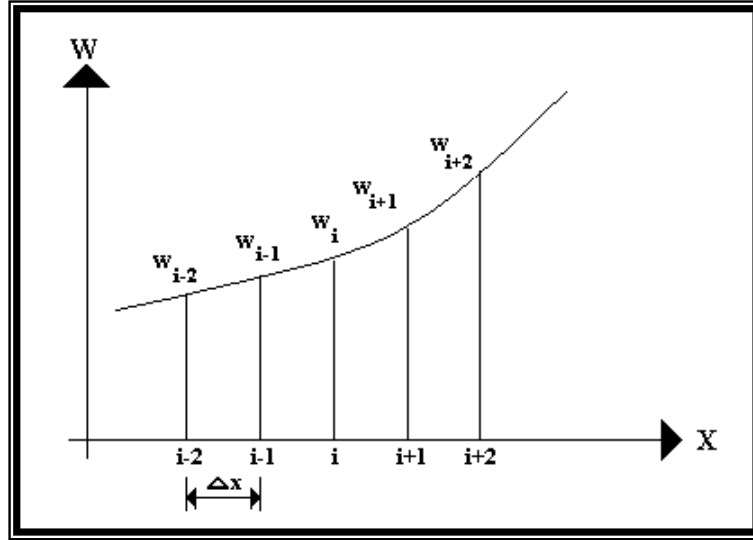


Fig. (3): Finite difference at selected points.

In this method the derivatives $\frac{dw}{dx}$, $\frac{d^2w}{dx^2}$, $\frac{d^3w}{dx^3}$, $\frac{d^4w}{dx^4}$ are converted into equivalent finite difference representations as follows:

$$\frac{dw}{dx} = \frac{w_{i+1} - w_{i-1}}{2\Delta x} \quad (3)$$

$$\frac{d^2w}{dx^2} = \frac{w_{i+1} - 2w_i + w_{i-1}}{\Delta x^2} \quad (4)$$

$$\frac{d^3w}{dx^3} = \frac{w_{i+2} - 2w_{i+1} + 2w_{i-1} - w_{i-2}}{2\Delta x^3} \quad (5)$$

$$\frac{d^4w}{dx^4} = \frac{w_{i+2} - 4w_{i+1} + 6w_i - 4w_{i-1} + w_{i-2}}{\Delta x^4} \quad (6)$$

The beam is divided into small elements of length Δx . Depending on boundary condition (support conditions) the differential equation can be solved as shown in **Fig. (4)**.

$$\frac{w_{i+2} - 4w_{i+1} + 6w_i - 4w_{i-1} + w_{i-2}}{\Delta x^4} + \frac{K_z}{EI} w_i = \frac{q_i}{EI}$$

(7)

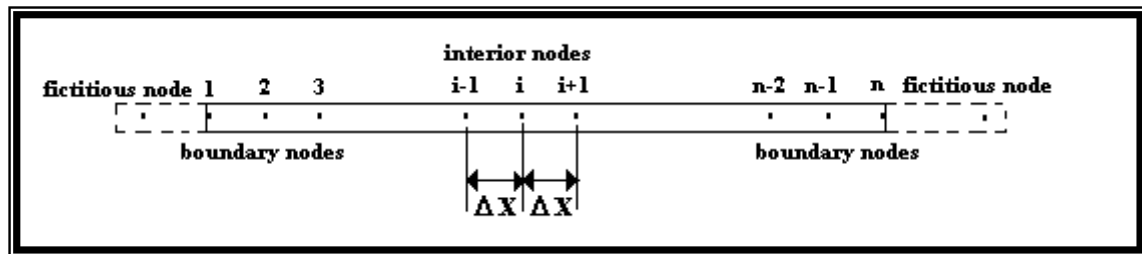


Fig. (4): Finite difference mesh.

In this study, the nonlinear behavior is adapted using iterative values of K_z . A typical p-w diagram was taken from a plate loading test was carried out on a soil in Baghdad. The reading of this test is shown in **Fig. (5)**. The consultant Bureau in the University of Baghdad carried out this test.

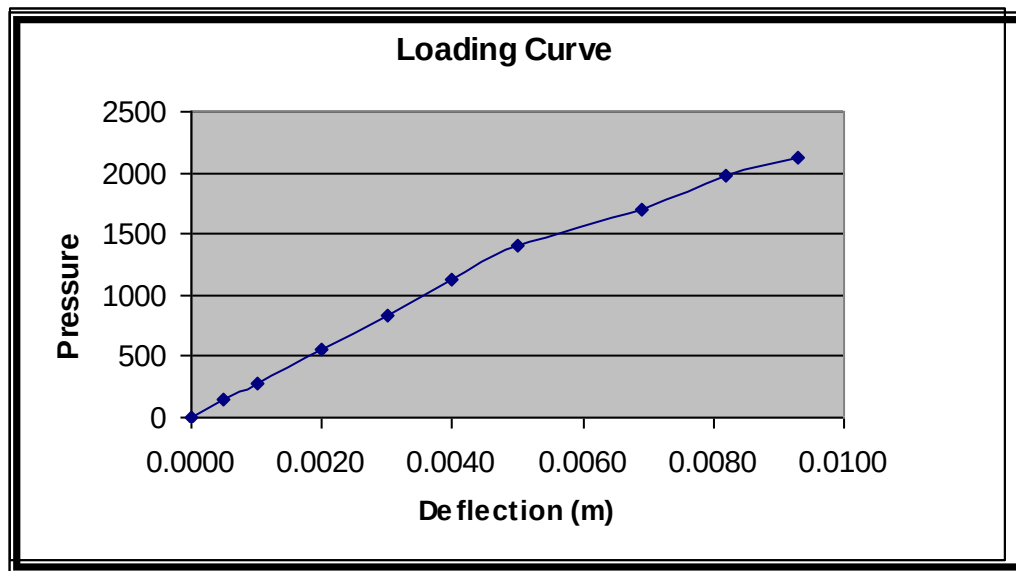


Fig. (5): Plate test data.

The data shown in the load-deflection curve is used to obtain the following second degree polynomial equation:

$$K_z(w) = 280000 + 1.962 * 10^7 w - 8.021 * 10^9 w^2$$

(8)

which gives, the initial modulus of subgrade reaction= 280000 kN/m^3 and the final modulus of subgrade reaction= 171429 kN/m^3 for $w \geq 0.0051$

APPLICATIONS

Two cases were considered in this study for a simply supported beam (concentrated load and uniform distributed load) as shown in **Fig. (6)** and **Fig. (7)**.

Case 1

Beam depth = 0.25m

Beam height = 0.25m

Concentrated load $P = 500 \text{ kN}$

Length = 5m

$E = 25 \times 10^5 \text{ kN/m}^2$

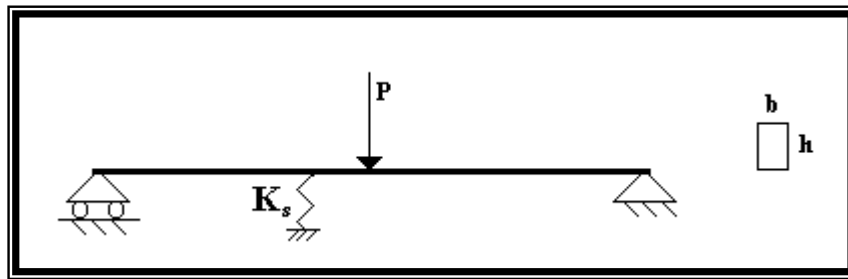


Fig. (6): Beam characteristics in case 1.

Case 2

Beam depth = 0.25m

Beam height = 0.25m

Uniform load $q = 250 \text{ kN/m}^2$

Length = 5m

$E = 25 \times 10^5 \text{ kN/m}^2$

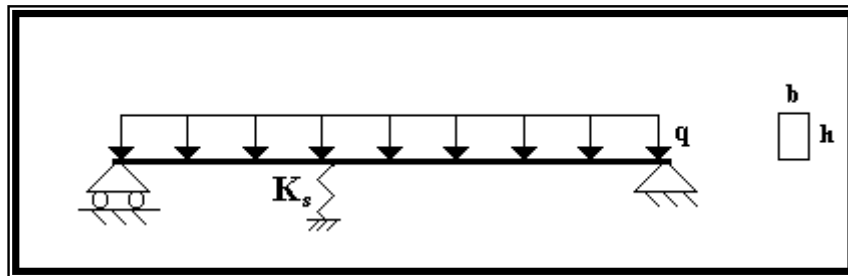


Fig. (7): Beam characteristics in case 2.

Here, the boundary conditions used to solve case 1 and 2 are:

- At $x = 0$, deflection = bending moment = 0.
- At $x = L$, deflection = bending moment = 0.

RESULTS

For the simply supported beam, figure (8) shows the deflection profile along x-direction for the linear elastic and non-linear elastic Winkler foundation while figures (9) and (10) show the bending moment and shearing force along x-direction. The results show nonlinear effect of K_z in the two solutions. For the beam under a concentrated load, figures (11), (12) and (13) show the deflection profile, bending moment diagram and shearing force diagram. The results show nonlinear effect of K_z in the two solutions. Figure (14) shows that the mid-span deflection for the linear and nonlinear modulus decreases as the depth of the beam increases because the section flexural rigidity EI of the beam increases. Figures (15) and (16) show that the mid-span moment and maximum shear force increase as the depth of the beam increases because also the section flexural rigidity EI of the beam increases for the two approaches (linear and nonlinear).

CONCLUSIONS

The obtained results show different values for both deflection and bending moment but rather close values for shearing force for high values of applied loads on the beam, which is resting on linear or nonlinear elastic Winkler foundation. The nonlinear behavior of soil was obtained by using high-applied loads (to make the difference in results much obvious). This study shows that the elastic method for analyzing beam resting on Winkler foundation is still valid for ordinary applied loading on beams. The effect of beam depth on maximum beam deflection and bending moment is found to be significant but not much on shearing force.

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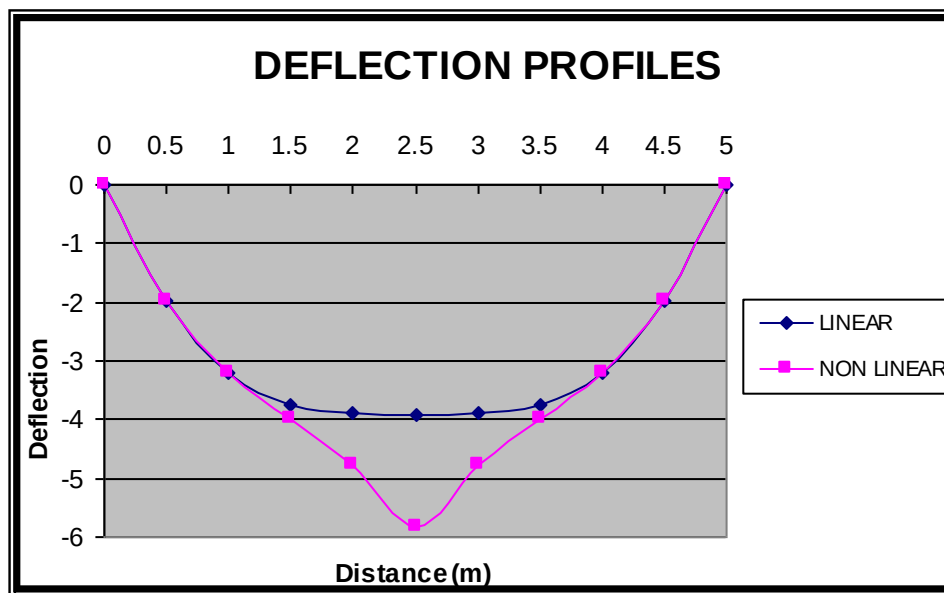


Fig. (8): Deflection profile of beam in case 1.

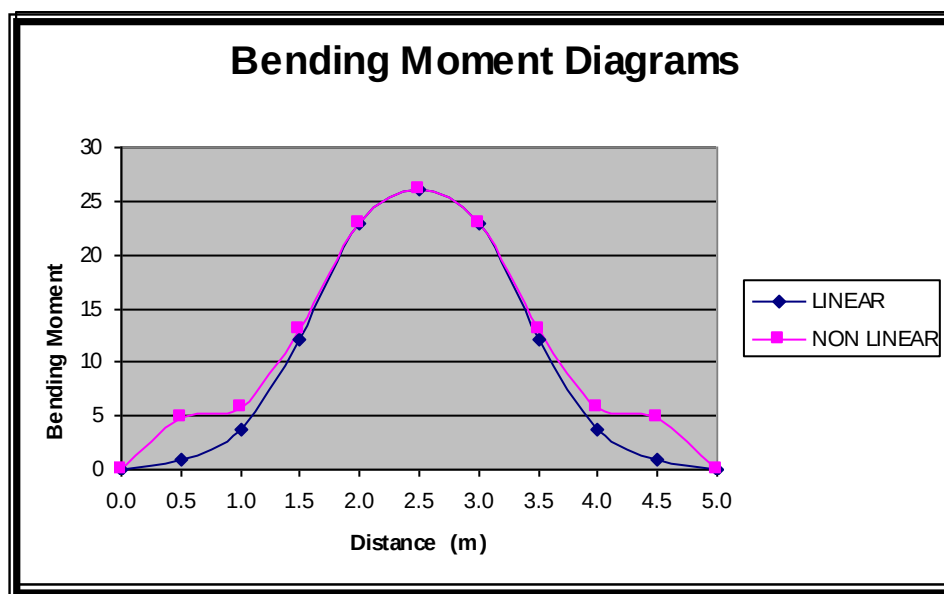


Fig. (9): Bending moment diagram of beam in case 1.

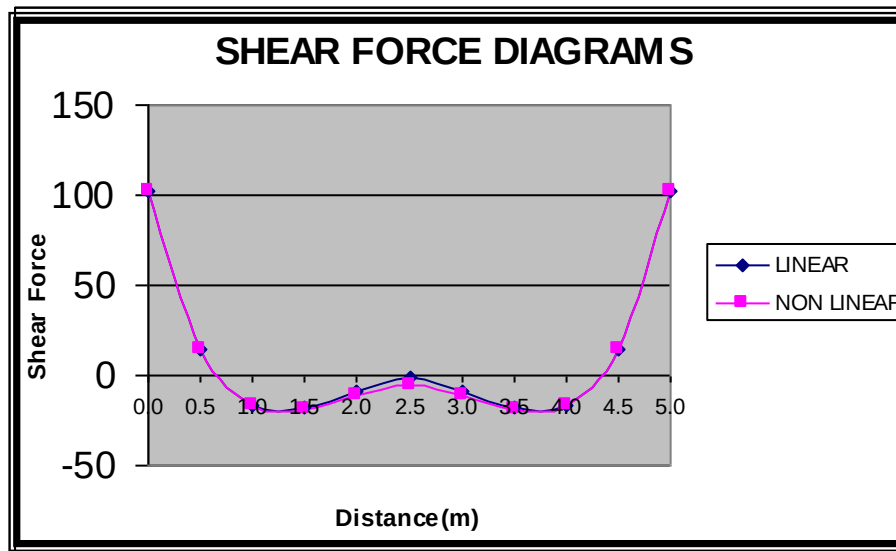


Fig. (10): Shearing force diagram of beam in case 1.

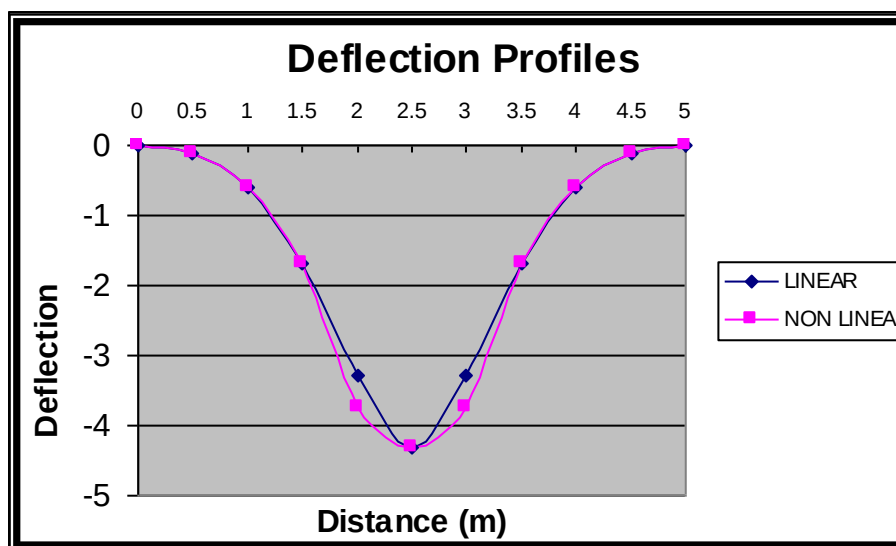


Fig. (11): Deflection profile of beam in case 2.

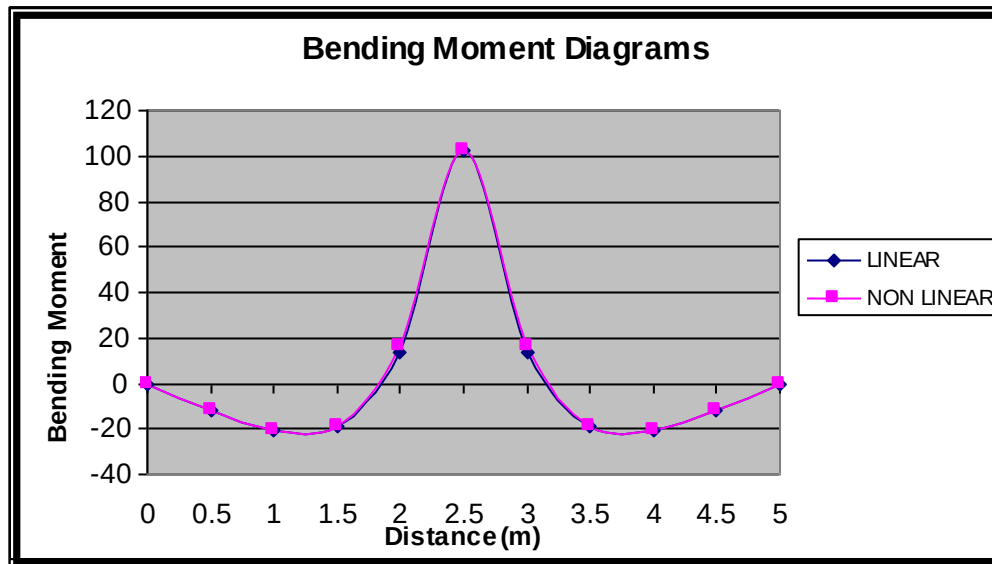


Fig. (12): Bending moment diagram of beam in case 2.

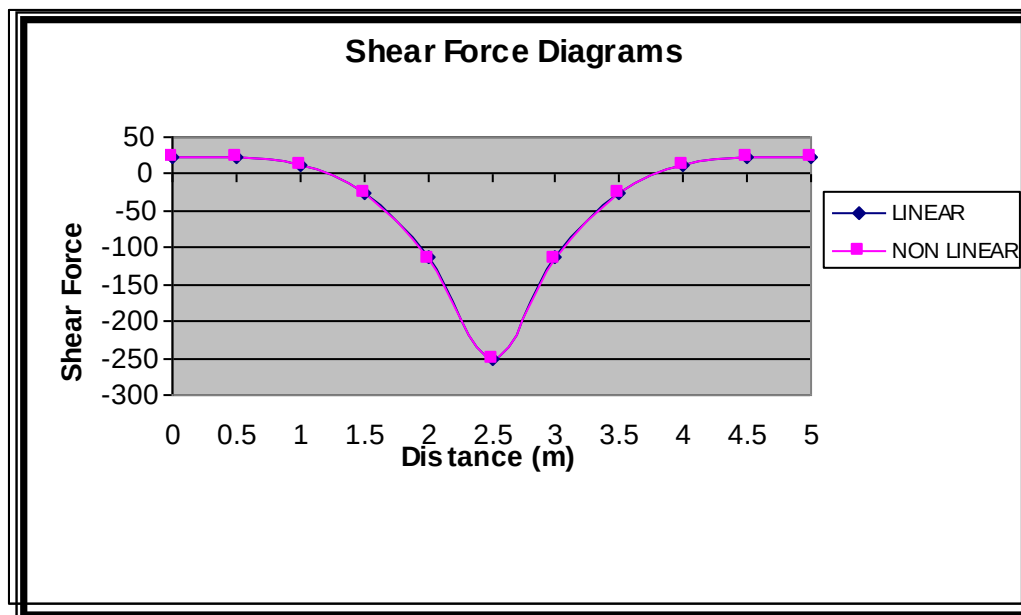


Fig. (13): Shearing force diagram of beam in case 2.

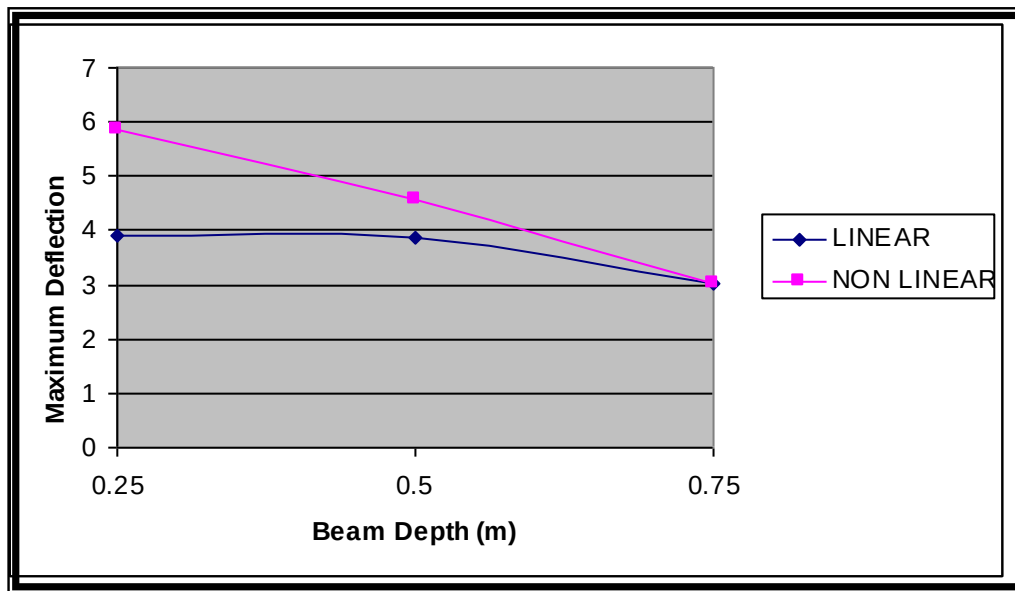


Fig. (14): Effect of beam depth on maximum deflection (case1).

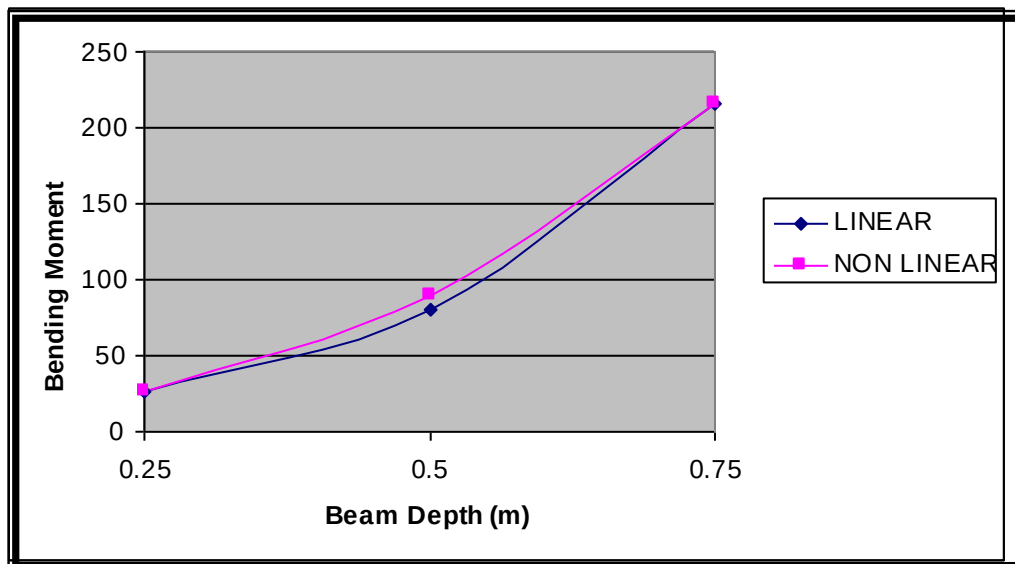


Fig. (15): Effect of beam depth on maximum bending moment (case1).

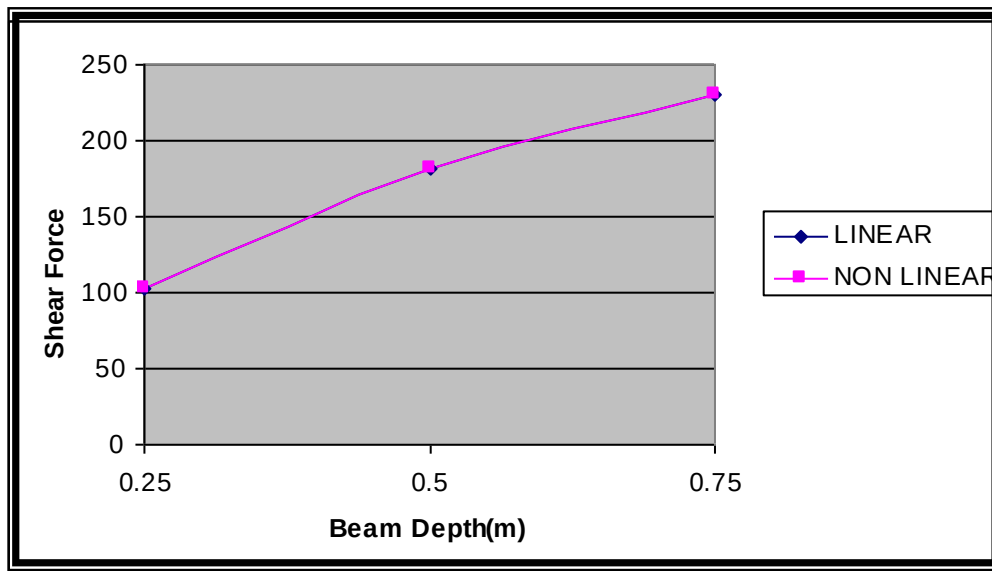


Fig. (16): Effect of beam depth on maximum shearing force (case1).

CALCULATION OF VOLUMETRIC AND THERMODYNAMIC PROPERTIES FOR PURE HYDROCARBONS AND THEIR MIXTURES USING CUBIC EQUATIONS OF STATE

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ABSTRACT

The objective of this study was to develop a complete package for prediction of volumetric and thermodynamic properties of pure hydrocarbons fluids and their mixtures in one and two phase regions. Two cubic equations of state that are Peng-Robinson and Soave-Redlich-Kwong were used with volatile and black oils respectively to calculate the desired properties in addition to bubble point and dew point pressures and temperatures. Different values of binary interaction parameter were used for each equation and effects of this parameter values on the prediction are examined. Also values of this parameter between the plus-fraction and other component have been evaluated for first time. In calculation of heat capacity, four different mixing rules have been proposed to evaluate the temperature derivatives in case of the mixtures. Wide comparisons with the literature experimental data were made which indicated that both equations of state predict accurately different properties and marked improvements are achieved by use binary interaction parameter other than zero. Also both equations predict bubble point pressure of a certain mixture approximately with same accuracies using the recommended values of binary interaction parameter. Among the proposed mixing rules, Kay's one appeared the best one to determine temperature derivatives.

الخلاصة

كان الهدف من هذه الدراسة هو تطوير برنامج متكامل لتنبؤ بالخواص الفيزيائية والثرموديناميكية للمركبات الهيدروكربونية وخلائطها في طور الغاز والسائل. تم استخدام معادلتين من معادلات الحالة وهما بنك-روبينسون وسواف-ريدلك-ونك لنفوط الخفيفة والثقيلة على التوالي لحساب الخواص المطلوبة وكذلك ضغوط ودرجات الحرارة لنقطة الفقاعة ونقطة الندى. لدراسة تأثير معامل التداخل الثنائي على الحسابات استخدمت مع PR Eos اربعة مجاميع مختلفة من معامل التداخل الثنائي و مجموعتين مع SRK Eos. ولأول مرة تم في هذه الدراسة حساب قيم هذا المعامل بين Plus Fraction وبقية المركبات كما اقترح ايضا استخدام المجموعة الرابعة المستخدمة مع PR Eos مع معادلة SRK. لحساب السعة الحرارية النوعية، تم اقتراح اربعة قواعد للمزج لتقييم مشتقات الحرارة في حالة الخلائط. مقارنات واسعة مع القيم التجريبية المنشورة في الادبيات تمت واعطت مؤشرا ان هاتين المعادلتين تنبأ بمختلف الخواص بدقة عالية وتحسينات ملحوظة تحققت باستخدام قيم لمعامل التداخل الثنائي غير الصفر. كذلك كلا المعادلتين وجدتا ضغط الفقاعة لمزيج معين تقريبا بنفس الدقة عند استخدام قيم معامل التداخل الموصى بها. من بين قواعد المزج المقترحة، قواعد Kay كانت هي الافضل في تقييم مشتقات الحرارة.

INTRODUCTION

Thermodynamic and physical properties of hydrocarbon fluids needed for process design and operation in petroleum industries are usually calculated through various thermodynamic models and equations available in process simulators. Generally there are four categories of thermodynamic models, which are: -

- Equations of state model.
- 2- Empirical equations and generalized correlations.
- 3- Activity coefficient models.
- 4- Specific models.

Among many equations of state proposed for predicting phase behavior of hydrocarbon (non-polar) systems, cubic equations of state have been widely used in the reservoir simulation because of their simplicity and accuracy. Soave-Redlich-Kwong (1972) and the Peng-Robinson (1976) cubic equations of state have enjoyed widespread acceptance in the petroleum industries. The purpose of this work is to report the results of simultaneous PVT, thermodynamic properties and vapor-liquid equilibrium prediction for pure hydrocarbons and their mixtures. Also transport properties calculated from empirical functions in temperature and density. The two equations of state mentioned above were used to perform vapor-liquid equilibrium calculation first and then to calculate thermodynamic and transport properties. Also bubble point and dew point pressures and temperatures were predicted using four sets of binary interaction parameter for PR Eos and two sets for SRK Eos. Values of this parameter between C_{7+} and other component have been computationally evaluated and a suggestion to used the last set of PR Eos with SRK Eos.

Thermodynamic properties such as enthalpy, entropy, heat capacity at constant pressure and volume, isothermal and adiabatic Joule-Thomson coefficients, isentropic pressure-temperature coefficient, and adiabatic temperature exponent were calculated analytically from the equations of state. In calculation of heat capacity, four different mixing rules have been proposed to evaluate the temperature derivatives in case of mixtures. Also transport properties such as viscosity, thermal conductivity, and sonic velocity were estimated using different methods and correlations. All calculated properties were compared with corresponding available experimental data.

EQUATIONS OF STATE

The Soave-Redlich-Kwong equation (1972) has the following form:

$$p = \frac{RT}{V_m - b} - \frac{a_T}{V_m(V_m + b)} \quad (1)$$

$$\text{with; } m = 0.48 + 1.574\omega - 0.176\omega^2 \quad (2)$$

$$\alpha = \left(1 + m(1 - T_r^{0.5})\right)^2 \quad (3)$$

$$a_T = a_c \cdot \alpha \quad (4)$$

$$a_c = 0.42747R^2 T_c^2 / P_c \quad (5)$$

$$b = 0.08664RT_c / P_c \quad (6)$$

SRK equation of state is a cubic equation in term of compressibility factor Z and this form is the most convenient form used in vapor-liquid equilibrium calculation. This form is:

$$Z^3 - Z^2 + (A - B - B^2)Z - AB = 0 \quad (7)$$

Where the dimensionless coefficient A and B are defined by the following expressions:



$$A = \frac{a\alpha P}{R^2 T^2} \quad (8)$$

$$B = \frac{bP}{RT} \quad (9)$$

For a mixture, Soave suggested the following mixing rule:

$$a_{Tm} = \sum_{i=1}^{NC} \sum_{j=1}^{NC} [x_i x_j (a_i a_j \alpha_i \alpha_j)^{0.5} (1 - k_{ij})] \quad (10)$$

$$b_m = \sum_{i=1}^{NC} x_i b_i \quad (11)$$

The term k_{ij} is the binary interaction coefficient and it will be discussed in the next section. The fugacity coefficient of component i in a mixture is calculated from the following equation:

$$\ln(\Phi_i) = -\ln(Z - B) + (Z - 1)B_i' - \left(\frac{A}{2^{1.5} B}\right)(A_i' - B_i') \ln\left(\frac{B}{Z} + 1\right) \quad (12)$$

Where $B_i' = \frac{b_i}{b_m}$ (13)

$$A_j' = \frac{1}{a_{Tm}^{0.5}} \left[2a_{Tj}^{0.5} \sum y_i a_{Ti}^{0.5} (1 - K_{ij}) \right] \quad (14)$$

Peng-Robinson Eos has the following form:

$$P = \frac{RT}{(V_m - b)} - \frac{a\alpha}{V_m(V_m + b) + b(V_m - b)} \quad (15)$$

where α is calculated from eq. (3). However, the parameter m is calculated according the following equation:

$$m = 0.3746 + 1.5423\omega - 0.2699\omega^2 \quad (16)$$

For PR EOS, the constants **a** and **b** are defined by the following equations:

$$a = 0.45724R^2 T_c^2 / P_c \quad (17)$$

$$b = 0.0778RT_c / P_c \quad (18)$$

In vapor-liquid calculation for mixture Peng–Robinson suggested the same mixing rule of Soave, i.e. eq. (10) and eq. (11). Compressibility factor are calculated from the following equation by employing Newton–Raphson method:-

$$Z^3 + (B - 1)Z^2 + (A - 3B^2 - 2B)Z - (AB - B^2 - B^3) = 0 \quad (19)$$

Where A and B are calculated from eq. (8) and eq. (9). The fugacity coefficient of component i in a mixture is calculated from the following equation:

$$\ln(\Phi_i) = -\ln(Z - B) + (Z - 1)B_i' - \left(\frac{A}{2^{1.5} B}\right)(A_i' - B_i') \ln\left(\frac{Z + 2.414B}{Z - 0.414B}\right) \quad (20)$$

Where A' and B' determine by eq. (13) and eq. (14) respectively.

The main causes which lead to select SRK and PR equations of state to predict the vapor –liquid equilibrium are:

- 1- Its parameters are known for many pure compounds.
- 2- Its interaction parameters are available for numerous binary mixtures.
- 3- Since its constants are fitted to vapor pressure data it is reliable for vapor-liquid equilibrium calculations.

BINARY INTERACTION PARAMETER

Typically all mixing rules used to determine equation of state parameters for multicomponent mixtures are utilized binary interaction parameter. This parameter is usually assumed to be independent of temperature, pressure, and composition. However, some authors introduced values for K_{ij} as a function of temperature.

Generally there are three different categories of binary interaction parameter that have been used by the investigators with Peng-Robinson and Soave-Redlich-Kwong equations of state. These categories are as following:

- In first category all binary interaction parameter values are set to be equal zero depending on the above assumption.
- In the second category K_{ij} for hydrocarbon pairs is taken as zero, while K_{ij} between CO_2 , N_2 , H_2S and hydrocarbons has been determined experimentally.
- In the third category K_{ij} between hydrocarbons themselves and non-hydrocarbons has been determined experimentally for each equation of state.

In this study, four different sets of binary interaction parameter were used with PR Eos. In the first set, values of binary interaction parameter are taken to be zeros. Table (1) and Table (2) show the values proposed by Brusilovsky and Prausitz (1968) which represented the second and third sets. The last set used with PR Eos is representing by equation proposed by Gao (1992) as a function of critical compressibility factor, which is:

$$(1 - K_{ij}^{PR}) = [2(T_{ci}T_{cj})^{1/2} / (T_{ci} + T_{cj})]^{Z_{cij}} \quad (21)$$

$$Z_{cij} = \frac{Z_{ci} + Z_{cj}}{2} \quad (22)$$

Where Z_{ci} is the critical compressibility factor for pure component i and it can be calculated form the following equation:

$$Z_c = \frac{P_c V_c}{RT_c} \quad (23)$$

Where these critical properties are available in the literatures (McCain, 1990) for any component except heptane-plus. Edmister (1984) show a simple relationship of Z_c with acentric factor ω , which obtained directly from the Pitzer-type Z-tables of Lee-Kesler (1975). This relationship illustrated by equation (24).

$$Z_c = 0.2901 - 0.0879\omega \quad (24)$$

By calculation of critical compressibility factor for heptane-plus, and then using eq. (22) and eq. (21), binary interaction parameters between heptane-plus and other components are calculated where



this study is the first one that considered this parameter between the plus fraction and other components.

Table (1) Binary Interaction Parameters for Peng-Robinson equation According to Brusilovsky

Comp -onent	C ₂	C ₃	i-C ₄	n-C ₄	i-C ₅	n-C ₅	C ₆	C ₇	C ₈	C ₉	C ₁₀	N ₂	CO ₂	H ₂ S
C ₁	0.005	0.01	0.035	0.025	0.050	0.030	0.030	0.035	0.040	0.040	0.045	0.025	0.105	0.070
C ₂		0.005	0.0	0.010	0.010	0.010	0.020	0.020	0.020	0.020	0.020	0.010	0.130	0.085
C ₃			0.0	0/0	0.015	0.002	0.010	0.005	0.005	0.005	0.005	0.090	0.125	0.090
i-C ₄				0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.095	0.115	0.075
n-C ₄					0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.095	0.115	0.075
i-C ₅						0.0	0.0	0.0	0.0	0.0	0.0	0.100	0.115	0.070
n-C ₅							0.0	0.0	0.0	0.005	0.0	0.100	0.115	0.070
C ₆								0.0	0.0	0.0	0.0	0.110	0.115	0.070
C ₇									0.0	0.0	0.0	0.115	0.115	0.060
C ₈										0.0	0.0	0.120	0.115	0.060
C ₉											0.0	0.120	0.115	0.060
C ₁₀												0.125	0.115	0.055
N ₂													0.0	0.130
CO ₂														0.135

Table (2) Binary Interaction Parameters for Peng-Robinson equation According to Prausnitz

Comp -onent	C ₂	C ₃	i-C ₄	n-C ₄	i-C ₅	n-C ₅	C ₆	C ₇	C ₈	C ₉	C ₁₀	N ₂	CO ₂	H ₂ S
C ₁	0.0	0.017	0.030	0.027	---	0.027	0.040	0.037	0.052	0.050	0.042	0.031	0.098	---
C ₂		0.0	-0.005	0.010	0.009	---	-0.040	0.007	0.018	---	0.014	0.042	---	---
C ₃			-0.008	0.003	0.012	0.028	-0.001	0.007	---	---	0.0	0.091	0.124	---
i-C ₄				-0.002	----	---	---	---	---	---	---	---	0.131	0.049
n-C ₄						0.017	-0.007	0.004	---	---	0.008	0.149	0.135	---
i-C ₅														
n-C ₅								0.010	---	---	---	---	0.127	---
C ₆													0.110	---
C ₇														
C ₈														
C ₉														
C ₁₀													0.113	---
N ₂													-0.012	0.176
CO ₂														0.096

With SRK Eos the first set of binary interaction was also representing by zeros, Table (3) shows the values of this parameter as proposed by Prausnitz (1968), which represented the second set. If one

examined PR and SRK equations of state he easily can recognize a large similarity between them, for example their parameters a_T and b are function for the same variables, their dimensionless parameters A , B have the same equation, and their parameters are evaluate for the case of a mixture using the same mixing rules. Therefore, we proposed that the same vales of binary interaction parameter could be used for SRK EOS as well as PR Eos. In this study, the Gao equation (1992) (set (4)), which used with PR Eos, has been used with SRK Eos.

Table (3) *Binary Interaction Parameters
for SRK Equation of State*

Compound	H₂S	CO₂	N₂
H₂S	---	0.102	0.140
CO₂	0.102	---	-0.022
N₂	0.140	-0.022	---
Methane	0.085	0.0973	0.0319
Ethane	0.0829	0.1346	0.0388
Propane	0.0831	0.1018	0.0807
n-Butane	0.0609	0.1474	0.1007
n-Pentane	0.0697	0.1278	---
Hexane	---	---	0.1444
Heptane	0.0737	0.1136	---
Octane	---	---	---
Nonane	0.0542	---	---
Decane	0.0464	0.1377	0.1293

TYPE OF RESERVOIR FLUIDS

Generally there are five types of reservoir fluids. The types are usually classified by the relationship of the reservoir temperature to the critical temperature and the cricondentherm of the mixtures, and by the surface conditions. The fluid types are; Dry Gas, Wet Gas, Retrograde Gas, Volatile Oil, and Black Oil

In this study, the classification of McGlashan and Peden (1981) for the natural hydrocarbons has been used to determine the type of fluid of interest. The suggested classification is shown in Table (4).

CHARACTERIZATION SCHEME FOR HYDROCARBON SYSTEMS

Vapor-liquid equilibrium and thermodynamic properties calculations generally require critical properties, molecular weight, and acentric factor as input data. Over the years, the critical properties have been measured and compiled for many hydrocarbons and other substances. For methane through decane and the impurities (nitrogen, carbon dioxide, and hydrogen sulfide), the critical pressure, critical temperature, and acentric factor are given in Table (5) (McCain, 1990).

**Table (4)** Typical Compositions of Hydrocarbon Fluids

Type of Fluid	Methane + Impurities (mol %)	Intermediates (mol %)	Heptane Plus (mol %)
Dry Gas	90	9	1
Retrograde Gas	70	22	8
Volatile Oil	55	30	15
Black Oil	30	35	35

Table (5) The Constant Physical Properties of Pure Hydrocarbon Substances

Compound	Critical Pressure Psia	Critical Temperature R°	Molecular Weight lbm/lb-mole	Acentric Factor w
Nitrogen	493.1	227.6	28.0134	0.0372
Carbon dioxide	1071	547.91	44.01	0.2667
Hydrogen sulfide	1300	672.45	34.08	0.0948
Methane	666.4	343.04	16.043	0.0104
Ethane	706.5	549.76	30.07	0.0986
Propane	616	665.68	44.097	0.1524
I-Butane	527.9	734.65	58.123	0.1848
N-Butane	550.6	765.3	58.123	0.1995
I-Pentane	490.4	828.7	72.150	0.2280
N-Pentane	488.6	845.4	72.150	0.2514
Hexane	436.9	913.4	86.177	0.2994
Heptane	396.8	972.4	100.204	0.3494
Octane	360.7	1024.5	114.231	0.3977
Nonane	331.8	1072.6	128.258	0.4445
Decane	305.2	1111.7	142.258	0.4898

As it well known that most laboratory analyses of produced fluids end with some residual or plus fraction. Typically this is C₇₊. So there is a need to obtain the physical properties of the plus fraction to perform equation of state calculations. In this study, Riazi and Daubert (1980) correlation has been used for estimate the physical properties of plus fraction with Peng-Robinson equation of state. Their equation has the form:

$$\theta = a(T_B)^b (\gamma_{c_7^+})^c \quad (25)$$

Where (θ) is a physical property to be predicted, $\gamma_{c_7^+}$ specific gravity of plus fraction, and (a, b, c) are correlation constants as shown in Table (6).

Mahdi (2002) modification of Riazi and Dubert correlation has been used to predicate the critical properties of the heavy fractions with Soave-Redlich-Kwong equation of state. The equation has the same form of equation (25) but with different values for the constants (a, b, c). The values of these constants are shown in Table (7). With both equations of state, the value of the boiling point has been estimated from Whitson relationship (15) which represented the following equation:-

$$T_B = \left[4.5579(M_{C_7^+})^{0.15178} \gamma_{C_7^+}^{0.15427} \right]^3 \quad (26)$$

where T_B is the boiling point in degree Rankine. Also the acentric factor has been estimated by Edmister approximation relationship, which has the following form (Mahdi (2002)):

$$\omega = \frac{3}{7} \left[\frac{\log P_c}{T_c / T_B - 1} \right] - 1 \quad (27)$$

where P_c in atmospheres.

Table (6) Constant for Riazi and Dubert Correlation

θ	a	b	c
M_w	$4.5673 \cdot 10^{-5}$	2.1962	-1.0164
T_c	24.2787	0.58848	0.3596
P_c	$3.12281 \cdot 10^9$	-2.3125	2.3201
V_c	$7.5214 \cdot 10^{-3}$	0.2896	-0.7666

Table (7) Constants for Mahdi Modification of Riazi and Dubert Correlation

θ	a	b	c
T_c	24.2787	0.58848	0.3596
P_c	$3.12281 \cdot 10^9$	-2.3125	2.3201

THERMODYNAMIC PROPERTIES FROM CUBIC EQUATION OF STATE

In the classical thermodynamic framework it is possible to obtain typical relationships for the calculation of enthalpy, entropy, fugacity and other thermodynamic properties. These properties can be related to operating variables of the processes, e.g. the temperature of a fluid in a heat exchanger. It is, therefore, important to establish relationships between the properties and independent variables like temperature or pressure. Such relationships for thermodynamic properties of fluids can be obtained using equations of states.

In this section, expressions for enthalpy, entropy, and heat capacity departures of a mixture are derived. The thermodynamic property expressions for a pure substance are not separately derived here, because the mixture expressions also apply to pure substances.

Enthalpy Departure

- For SRK Eos, isothermal enthalpy departure expression is given by:

$$\frac{H - H^*}{RT} = Z - 1 - \frac{A}{B} \left[1 - \frac{T}{a} \left(\frac{da}{dT} \right) \right] \ln \left(1 + \frac{B}{Z} \right) \quad (28)$$

where:

$$T \left(\frac{da}{dT} \right) = - \sum_i^N \sum_j^N X_i X_j m_j (a_i a_{cj} T_{ri})^{0.5} (1 - k_{ij}) \quad (29)$$

- For enthalpy departure is given by the following equation:

$$\frac{H - H^*}{RT} = Z - 1 - \frac{A}{2^{1.5} B} \left[1 - \frac{T}{a} \left(\frac{da}{dT} \right) \right] \ln \left(\frac{Z + (2^{0.5} + 1)B}{Z - (2^{0.5} - 1)B} \right) \quad (30)$$

where $T(da/dT)$ is given by eq. (29) too.

Entropy Departure

- For SRK Eos:

$$\frac{S - S^*}{R} + \ln \frac{P}{P^*} = \ln(Z - B) + \frac{A}{B} \left[\frac{T}{a} \frac{da}{dT} \right] \ln \left(1 + \frac{B}{Z} \right) \quad (31)$$

- For PR Eos:

$$\frac{S - S^*}{R} + \ln \frac{P}{P^*} = \ln(Z - B) + \frac{A}{B} \left[\frac{T}{a} \frac{da}{dT} \right] \ln \left(\frac{Z + (2^{0.5} + 1)B}{Z - (2^{0.5} - 1)B} \right) \quad (32)$$

Where P^* is equal to 14.7 psia.

HEAT CAPACITY DEPARTURE

The deviation of the isobaric specific heat values from ideal gas state can be expressed on the basis of the definition $C_p = \left(\frac{\partial H}{\partial T} \right)_p$ from classical thermodynamics. One can use eq. (28) to derive the expression of heat capacity departure; however, the above relationship is more convenient and widely used. Also, in all literatures, which have been surveyed in this study, we found only the expression of the isobaric heat capacity departure of a pure component derived from Peng-Robinson equations of state. Therefore, the expressions of isobaric heat capacity for a multicomponent mixture have been derived in this study by both selected equations of state, which are also applied to pure components with restrictions of $N = 1$, and $K_{ij} = 0$. For SRK Eos we got:

$$C_p - C_p^* = R \left[(Z - 1) + T \left(\frac{\partial Z}{\partial T} \right)_p - \frac{1}{Rb} \left(\ln(\beta) \left(\frac{\gamma}{T} - \eta \right) + \frac{\theta}{T} (\gamma - a_T) \right) \right] \quad (33)$$

$$\text{Where } \beta = 1 + \frac{B}{Z} \quad (34)$$

$$\gamma = T \left(\frac{da}{dT} \right) = - \sum_i^N \sum_j^N X_i X_j m_j (a_i a_{cj} T_{ri})^{0.5} (1 - k_{ij}) \quad (35)$$

$$\eta = \frac{\partial}{\partial T} T \left(\frac{da}{dT} \right) = -0.5 \sum_i^N \sum_j^N X_i X_j m_j a_{cj} (a_{Ti} T_{rj})^{-0.5} \left[\frac{a_{Ti}}{T_{cj}} - \frac{a_{ci} \alpha_i^{0.5} m_i T_{rj}}{(T_{ci} T)^{0.5}} \right] \quad (36)$$

$$\theta = \frac{\partial}{\partial T} \ln(\beta) = \frac{-1}{T} \frac{B}{Z + B} (1 + T/Z \left(\frac{\partial Z}{\partial T} \right)_p) \quad (37)$$

$$\left(\frac{\partial Z}{\partial T}\right)_P = \frac{\left[-2B^2 - B + 2A + \frac{AmT_r^{0.5}}{\alpha^{0.5}}\right]Z - 3AB - \frac{ABmT_r}{\alpha^{0.5}}}{T[3Z^2 - 2Z - B^2 - B + A]} \quad (38)$$

- For Peng-Robinson equation of state

$$C_p - C_p^* = R \left[(Z - 1) + T \left(\frac{\partial Z}{\partial T} \right)_P - \frac{1}{2^{1.5} Rb} \left(\ln(\beta) \left(\frac{\gamma}{T} - \eta \right) + \frac{\theta}{T} (\gamma - a_T) \right) \right] \quad (39)$$

Where $\beta = \frac{Z + 2.414B}{Z - 0.414B}$ (40)

$$\gamma = T \left(\frac{da}{dT} \right) = - \sum_i^N \sum_j^N X_i X_j m_j (a_i a_{cj} T_{ri})^{0.5} (1 - k_{ij}) \quad (41)$$

$$\eta = \frac{\partial}{\partial T} T \left(\frac{da}{dT} \right) = -0.5 \sum_i^N \sum_j^N X_i X_j m_j a_{cj} (a_{Ti} T_{rj})^{-0.5} \left[\frac{a_{Ti}}{T_{cj}} - \frac{a_{ci} \alpha_i^{0.5} m_i T_{rj}}{(T_{ci} T)^{0.5}} \right] \quad (42)$$

$$\theta = \frac{\partial}{\partial T} \ln(\beta) = \frac{-1}{T} \left[\frac{T \left(\frac{\partial Z}{\partial T} \right)_P + 0.414B}{Z - 0.414B} - \frac{T \left(\frac{\partial Z}{\partial T} \right)_P - 2.414B}{Z + 2.414B} \right] \quad (43)$$

$$\left(\frac{\partial Z}{\partial T}\right)_P = \frac{BZ^2 \left[6B^2 + 2B - 2A - \frac{AmT_r^{0.5}}{\alpha^{0.5}} \right] Z + 3B^3 + 2B^2 - 3Ab - \frac{ABmT_r}{\alpha^{0.5}}}{T[3Z^2 + 2(B-1)Z - 3B^2 - 2B + A]} \quad (44)$$

To applying the above two equations to predict the isobaric heat capacity of a multicomponent mixture, the term $\frac{mT_r^{0.5}}{\alpha^{0.5}}$ of mixture must be evaluated first. None of the surveyed literature illustrated how to evaluate this term even ones predict heat capacity by both equations of state. In this study, the following mixing rules have been proposed to evaluate the required term for a mixture:

1. Use of Kay's additive⁽⁵⁾ rules to calculate mixture w_m , T_{cm} , P_{cm} , then

$$T_r = T/T_{cm}$$

$$\alpha_m = \left(1 + m_m \left(1 - T_r^{0.5} \right) \right)^2$$

$$m_m = 0.48 + 1.574\omega - 0.176\omega^2 \text{ with SRK Eos and}$$

$$m_m = 0.3746 + 1.5423\omega - 0.2699\omega^2 \text{ with PR Eos.}$$

2. Molal average mixing rule which is given by:

$$\left(\frac{mT_r}{\alpha^{0.5}} \right)_m = \sum_{i=1}^N X_i \frac{m_i T_{ri}}{\alpha_i^{0.5}} \quad (45)$$

3. Van der Waal's mixing rule, which is given by:



$$\left(\frac{mT_r}{\alpha^{0.5}} \right)_m = \sum_{i=1}^N \sum_{j=1}^N X_i X_j \frac{m_i^{0.5} m_j^{0.5} T_{ri}}{(\alpha_i^{0.5} \alpha_j^{0.5})^{0.5}} (1 - k_{ij}) \quad (46)$$

4. Herning and Zipper mixing rule which is given by:

$$\left(\frac{mT_r}{\alpha^{0.5}} \right)_m = \frac{\sum_{i=1}^N X_i \frac{m_i T_{ri}}{\alpha_i^{0.5}} M_{wi}}{\sum_{i=1}^N X_i M_{wi}} \quad (46)$$

Other Thermodynamic Properties

- Heat capacity at constant volume: From the fundamental property relations, the following relationship between C_V and C_P has been used to calculate the isochoric heat capacity:

$$C_V = C_P - RT \left[\frac{Z}{T} + \left(\frac{\partial Z}{\partial T} \right)_P \right] \quad (47)$$

In this equation universal gas constant R must be in Btu/lb-mole-R.

- Joule-Thomson effects: where the adiabatic coefficient is given by the following expression:

$$\eta = \frac{RT^2}{C_P P} \left(\frac{\partial Z}{\partial T} \right)_P \quad (48)$$

and the isothermal coefficient is given by:

$$\xi = \left(\frac{\partial T}{\partial P} \right)_S = \frac{RT}{C_P P} \left[Z + T \left(\frac{\partial Z}{\partial T} \right)_P \right] \quad (49)$$

- Sonic velocity:

$$U_f = [(g_c / Mw)(kRT)(Z + \rho(\partial Z / \partial \rho)_T)]^{1/2} \quad (50)$$

For PR Eos:

$$(\partial Z / \partial \rho)_T = - \frac{(\partial P / \partial \rho)_T (Z^2 B + Z(A - 2B - 6B^2) + (2B^2 + 3B^3 - 2AB))}{P(3Z^2 + Z(2B - 2) + (A - 2B - 3B^3))} \quad (51)$$

For SRK Eos:

$$\left(\frac{\partial Z}{\partial \rho} \right)_T = \frac{- \left(\frac{\partial P}{\partial \rho} \right)_T (ZA - ZB - 2AB - 2ZB^2)}{P(3Z^2 - 2Z - B + A - B^2)} \quad (52)$$

IDEAL GAS STATE THERMAL PROPERTIES

The thermodynamic property calculation methods presented in the previous sections are for calculating the isothermal departure function of the properties from their ideal gas state values for pure fluids or mixtures. Therefore, it is imperative to know the ideal gas state properties for the calculation of the absolute values of thermodynamic properties of real fluids at a given temperature and pressure.

For pure components and defined composition mixture we utilize the Aly and Lee (1981) equations for calculating ideal gas state thermal properties. For all pure components except hydrogen sulfide, the following equations have been used:

$$C_p^* = B + C \left[\frac{(D/T)}{\sinh(D/T)} \right]^2 + E \left[\frac{(F/T)}{\cosh(F/T)} \right] \quad (53)$$

$$H^* = BT + CT \left(\frac{D}{T} \right) \coth \left(\frac{D}{T} \right) - ET \left(\frac{F}{T} \right) \tanh \left(\frac{F}{T} \right) + A \quad (54)$$

$$S^* = B \ln T + C \left[\frac{D}{T} \coth \left(\frac{D}{T} \right) - \ln \sinh \left(\frac{D}{T} \right) \right] - E \left[\frac{F}{T} \tanh \left(\frac{F}{T} \right) - \ln \cosh \left(\frac{F}{T} \right) \right] + G \quad (55)$$

Where temperature in °K, enthalpy in Cal/gm-mole, heat capacity and entropy in Cal/gm-mole °K. One of the prominent features of the above equations is that the parameters (A, B, C, D, E, F, and G) have physical meaning through their statistical mechanics derivation. For example, the constant B represents the contributions due to the translational and rotational motions of the molecules, and constant D characterizes vibrational temperature of the polyatomic molecules.

For hydrogen sulfide, the correlation of Passut and Danner (1972) has been used. This correlation represented by Eqs, 2.28, 2.29, and 2.30. Values of the equations constant are:

A = -0.61782, B = 0.238575, C = -0.024457 E-3, D = 0.044067 E-6, E = -0.130126 E-10, F = 0.144852 E-14, and G = -0.045932.

For undefined mixtures and petroleum fractions a method named “Equivalent Pure Component” has been used. This method is simple and generally involving only one parameter. It states that if there is an undefined substance (pure or mixture) has a value for certain variable equal to that of a pure component, then they will have the same properties (Sehgal, 1968). Since that the ideal gas thermal properties are a function of the molecular weight, so this variable can be adapted as correlated parameter. This method has two disadvantages, the first one that it restricted to mixtures of homogenous series. The second one is that for large molecular weight mixtures, ideal gas thermal properties must be available for heavy hydrocarbon components. In this study, this method restricted to molecular weight of 282 (of Eicosane) lbm/lb-mole.

RESULTS AND DISCUSSION

The objective of current study was to develop a complete package for calculating of physical and thermodynamic properties mainly for hydrocarbon and petroleum fluids by means of two equations of state in vapor and liquid phases. Peng-Robinson and Soave-Redlich-Kwong equations of state have been used for volatile and black oils respectively in this package, these equations used to perform the following calculation types: -

- Fluid properties prediction (P & T specified).
- Bubble point pressure calculation (T specified).
- Bubble point temperature calculation (P specified).
- Dew point pressure calculation (T specified).
- Dew point temperature calculation (P specified).
- Gas-oil separation calculations (isothermally and adiabatically).

In these calculation types the following properties are calculated:-

- Phase region and Phase envelope.
- Vapor and liquid mole fractions (V, L).
- Phase's compositions (y_i , x_i).
- Equilibrium ratios (K-values).
- Compressibility factor (Z).
- Density.
- Enthalpy (H).
- Entropy (S).
- Isobaric heat capacity (Cp).

- Isochoric heat capacity (C_v).
- Isothermal and adiabatic Joule – Thomson coefficients.
- Adiabatic temperature exponent.
- Surface tension.
- Viscosity.
- Thermal conductivity.
- Speed of sound.

Many correlations for viscosity, thermal conductivity, surface tension and sixty tables compare the computed values of phase region, vapor mole fraction, vapor and liquid phases compositions, bubble point pressure and temperature, enthalpy, entropy, heat capacity, adiabatic and isothermal Joule-Thomson coefficients and sonic velocity for pure component, binary mixtures, multicomponent mixtures, volatile and black oils samples (The mole composition and properties of plus fraction of hydrocarbon mixtures and oil samples are tabulated in Appendix A) in different phase regions not included in these few papers because little space available. So only the most important results and their discussions presented in this section

The validity of both equations of state is examined by using absolute relative deviation (RD) and absolute average percentage error (AAPE) according to the following equations:-

$$RD = Abs\left(\frac{Exp - Cal}{Exp}\right) \times 100.0 \quad (56)$$

$$AAPE = \frac{\sum RD}{N} \quad (57)$$

In addition to the comparisons with the corresponding available experimental data, the calculated properties from the present package are compared with those calculated by other internationally developed software, namely PhysPros and MixProps. A trial version for 14 days for these two software were gotten from G&P Engineering Software company (<http://www.gpengineeringsoft.com>) that specializes in delivering high quality chemical engineering software for chemical professionals. PhysPros is used for application of pure component, thermophysical property database and property estimating. MixProps is used to calculate a two-phase vapor-liquid equilibrium, thermodynamic, and transport property for technical professionals using five equations of state including SRK and PR.

Phase Region

In order to check the capability of equations of state to predict the phase region of a mixture, experimental data of simple hydrocarbon mixtures (binaries) have been used. Table (9) shows the experimental and predicted phase regions for Ethane-n-Butane mixtures (Wolfe, 1966) using PR and SRK Eos at 400 Psia pressure and temperature range from 50 to 250 ° F. This table illustrates the effect of the binary interaction parameter on estimation of phase region.

Regardless of the value of binary interaction parameter, PR Eos predicts the phase region with reasonable accuracy as shown in Table (9). It is clear that the 4th set of K_{ij} and MixProps software give the exact results, also 1st set give good agreement with experimental phase regions. While 2nd and 3rd sets give results with lower accuracy especially for mixtures B2, and B3. For SRK Eos both sets give good results and no improvement noted for one over another one. SRK results are better matched with experimental results than those obtained by MixProps software. The second set is eliminated from this comparison because it considers the values of binary interaction parameter only between non-hydrocarbon and hydrocarbon components and since the investigated binaries do not contain non-hydrocarbon component, it will make no difference in results from those of the first set.

**Table 9 - Comparison of Predicted and Experimental Phase Region
for Ethane-n-Butane Mixtures At 400 psia**

Sample No	Temp. (°F)	Exp.	PR					SRK		
			Cal (1)	Cal (2)	Cal (3)	Cal (4)	MixProps	Cal (1)	Cal (3)	MixProps
B1	246.2	V	V	V	V	V	V	V	V	V
B2	205.4	V	V	V	V	V	V	V	V	V
B3	166.0	V	V	V	V	V	V	V	V	V+L
B4	124.8	V	V	V	V	V	V	V	V	V
B5	75.0	V	V+L	V	V	V	V	V+L	V	V
B1	209.1	L	L	L	L	L	L	L	L	L
B2	129.0	L	L	V+L	V+L	L	L	L	L	L
B3	88.4	L	L	V+L	V+L	L	L	L	L	V+L
B4	63.8	L	L	L	L	L	L	L	V+L	V
B5	47.8	L	L	L	L	L	L	L	L	V

V = Vapor, L = Liquid

Bubble Point Pressure Prediction

Bubble point pressures of different hydrocarbon mixtures have been calculated by PR Eos with its four sets of binary interaction parameter and compared with experimental pressures and those calculated by MixProps software (Table (10)). It is obvious that PR Eos gives very good agreements with experimental data for these mixtures, which included binary, ternary, and multi component mixtures. The capability of the fourth set of K_{ij} to improve the results appear again specially over the first set, however, all sets gave results much more accurate than those calculated by MixProps software which gave AAPE of 14.37 while first set in the present program gave 5.031 (maximum). Also bubble point pressure has been calculated by SRK Eos with its three sets for binary interaction parameter for these hydrocarbon mixtures and presented in the same table. SRK Eos gives very good agreements with experimental data and the second set of K_{ij} gave the minimum error of 2.85 %, and all sets gave results much more accurate than those of MixProps software.

With respect to petroleum fluids, bubble point pressure has been calculated for five volatile oil samples and presented in Table (11). In general, agreement between predicted and experimental results is good. However, in some instances, significant disagreement was noted. While it is not possible to explain such disagreement with certainty, close scrutiny of the experimental data suggests that for some of the reported points there may be appreciable experimental error specially when these experimental data taken from one reference as the case of volatile oils.

Many studies have been used bubble point pressure as the **basis** to conclude that PR Eos is more suitable for predicting of volatile oils phase behavior. Most of these studies predicted Pb by PR and SRK Eos with zero binary interaction parameter, and found the PR give less AAPE for volatile systems than black ones.

Table (12) shows the predicted results of Pb for ten black oil samples by PR Eos. As in the other studies, PR Eos gives AAPE for black oils great than that of volatile oils with zero binary interaction parameter, also this is the case of the 2nd and 3rd sets of K_{ij} , but PR Eos give **very good** agreement with

**Table (10)** – Comparison of Experimental and Calculated Bubble Point Pressure by PR and SRK Eos for Binary, Ternary and Multicomponent Mixtures

Sample No	Temp °F	Bubble Point Pressure (Psia)									
		Exp.	SRK				PR				
			Cal (1)	Cal (2)	Cal (3)	MixProps	Cal (1)	Cal (2)	Cal (3)	Cal (4)	MixProps
B7	-130	483.56	488.261	488.261	488.373	488.732	485.649	485.73	485.806	485.787	486.079
T1	-179.8	488.5	444.973	489.225	450.410	447.5	441.42	548.5	472.32	447.27	447.5
T2	-50	400	396.364	396.364	408.183	341.974	388.751	395.283	395.669	401.179	335.631
M1	-144	100	109.366	112.704	121.097	113.938	104.575	114.596	119.639	115.845	108.782
M1	-100	200	196.876	200.165	213.674	183.378	188.683	202.408	209.930	205.443	176.095
M1	-81	250	240.969	244.141	259.618	221.778	231.604	246.705	255.197	250.543	213.646
M1	-62	300	287.9012	290.922	308.074	261.628	277.754	293.913	303.204	298.376	252.926
M1	-24	400	388.141	390.785	410.215	344.149	377.614	395.067	405.544	400.575	335.319
M1	12	500	488.759	490.998	511.152	423.057	479.347	497.019	507.809	503.065	415.368
M1	47	600	590.493	592.329	611.863	498.134	583.348	600.219	610.663	606.369	492.51
M1	76	700	676.84	678.347	696.464	557.38	672.094	687.641	697.380	693.441	553.872
M1	102	800	754.448	755.668	771.843	762.548	752.025	765.84	774.551	771.114	603.359
AAPE			3.76	2.85	4.675	11.8	5.03	3.41	3.4	2.9	14.37

B=Binary, T=ternary and M=Multicomponent

Table (11) – Comparison of Experimental and Calculated Bubble Point Pressure by SRK and PR Eos for Volatile Oil Samples

Sample No	Temperature °F	Bubble Point Pressure (Psia)							
		Exp ⁽⁶⁾	PR			SRK			
			Cal (1)	Cal (2)	Cal (3)	Cal (1)	Cal(2)	Cal(3)	Cal(4)
1	210	4452	4082.365	4135.293	4598.849	3958.64	4018.98	3977.95	4484.99
2	264	4900	3731.529	3735.498	4161.018	3643.717	3667.426	3660.7	4092.07
3	210	4300	3587.515	3589.398	3995.562	3505.4	3532.3	3525.31	3929.77
4	210	3982	3934.522	3978.944	4465.389	3828.87	3878.909	3843.83	4374.66
5	12	3556	3835.185	3873.514	4401.388	3739.002	3782.36	3751.32	4323.84
AAPE			11.55	11.28	12.27	12.83	12.33	12..58	11.45

experimental pressures for black oils using the fourth set and these results give AAPE (6.55), which is less than that of volatile oils (11.45) themselves. This behavior may be explained as a result for using the fourth set which is the single set that considered binary interaction parameter between C_{7+} and the other components and since black oils contain large amounts of C_{7+} , this will have large effect on any equation involved binary interaction parameter. From the above discussion, one can **conclude** that the selection of the suitable Eos for certain fluids should not be based only on one property, and PR Eos predicts bubble point pressure of black oils with very good accuracies.

Also Table (12) shows the calculated bubble point pressures for these ten black oil samples using SRK Eos which with Gao equation (set (3)) for binary interaction parameter gives very **good**

agreement with the experimental data as with PR Eos. First and second sets give results for Pb deviated substantially from experimental data where AAPE was 17.3 and 17.2 respectively as shown in Table (12), but these two sets give errors less than those of PR Eos with first three sets of K_{ij} .

From these entire comparisons one can **note** that for binary, ternary, and multicomponent mixtures PR Eos with Gao equation and SRK with second set approximately gave the same AAPE, which was 2.905 and 2.85 respectively. This point is also true for volatile oil samples (AAPE of 11.45 and 11.28). For black both equations of state with Gao equation also approximately gave the same error of 6.627 and 6.445 respectively. Therefore, a **conclusion** can be made which state that any equation of state utilizing in this study can be used for calculation of Pb for any hydrocarbon mixture (binary, ternary, multicomponent, volatile oil, and black oil) by considering the recommended binary interaction parameter sets. Table (13) shows the recommended binary interaction parameter set for each Eos.

Table (12) – Comparison of Experimental and Calculated Bubble Point Pressure by PR and SRK Eos for Black Oil Samples

Sample No	Temp °F	Exp	Bubble Point Pressure (Psia)						
			PR				SRK		
			Cal (1)	Cal (2)	Cal (3)	Cal (4)	Cal (1)	Cal (2)	Cal (3)
1	200	2890	2281.78	2339.95	2290.67	2857	2372.43	2372.43	2867.19
2	234	2623	1982.64	1987.41	1985.98	2370.13	2012.513	2011.907	2374.352
3	232	1970	1639.58	1643.88	1642.52	1926.01	1657.502	1657.797	1947.195
4	210	2010	1522.464	1528.889	1527.392	1781.386	1543.564	1543.679	1784.026
5	210	2800	2177.226	2188.741	2185.468	2549.884	2208.326	2208.409	2531.288
6	210	2340	1854.604	1862.647	1860.652	2171.845	1878.55	1878.643	2174.239
7	140	2247	1962.11	1977.51	1973.37	2432.11	2000.919	1991.83	2445.491
7	176	2403	2175.52	2188.56	2185.04	2627	2190.789	2210.352	2619.088
7	210	2643	2353.942	2364.788	2361.789	2797.797	2385.264	2384.676	2799.373
8	220	2620	2163.550	2180.62	2177.052	2495.311	2185.974	2186.631	2491.662
9	205	2420	1700.16	1708.69	1706.54	1995.07	1724.013	1724.237	1998.347
10	210	2375	1999.502	2011.625	2008.47	2312.75	1717.198	1720.13	2033.629
10	176	2218	1855.01	1868.71	1865.17	2181.33	1887.346	1889.512	2192.608
10	140	2062	1680.21	1695.51	1691.61	2015.46	2027.491	2029.087	2318.432
AAPE			18.601	18.030	18.262	6.627	17.307	17.254	6.445

Table (13) – Recommended Sets of K_{ij} for Calculation of Bubble Point Pressure By PR and SRK Eos.

Sample Type	PR	SRK
Binary, Ternary, and Multicomponent	Set (4)	Set (2)
Volatile Oil	Set (4)	Set (2)
Black Oil	Set (4)	Set (4)



CONCLUSIONS

Four sets of binary interaction parameter have been used with PR Eos and two with SRK Eos in this study, which indicated that the value of the binary interaction parameter has obvious effect on predicting of different properties especially P-V-T properties of the hydrocarbon mixtures. Also we proposed that the last set of binary interaction parameter, which represented by Gao equation, might be used with SRK Eos as a third set.

Peng- Robinson equation of state with the last three sets of the binary interaction parameter and Soave-Redlich-Kwong equation of state with the last set predict accurately different properties of interested fluids and the last set (Gao equation) for both equations is the better one and it give the minimum errors for large number of the calculated properties.

Using the fourth set of binary interaction parameter, Peng-Robinson equation of state predict bubble point pressure of black oils with very good accuracy, so it can be used with this type of reservoir fluids. Therefore, the selection of suitable equation of state for certain fluids should be not based only on one property. For certain hydrocarbon mixtures (may be binary, ternary, multicomponent, volatile oil, and black oil) both equations of state predict bubble point pressure approximately with the same accuracies using the recommended values for binary interaction parameter, so there are no limitations in use this equation only for certain fluids and other one for other fluids.

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Nomenclature

List of Symbols:

AAPE	Average absolute percentage error.
a, b	Equation of state constants.
C_p	Isobaric heat capacity Btu/lb-mole. $^{\circ}R$.
C_v	Isochoric heat capacity Btu/lb-mole. $^{\circ}R$.
Eos	Equation of state.
K	Equilibrium ratio.
K_{ij}	Binary interaction parameter.
m	Parameter in Eos .
M_w	Molecular weight lb/lb-mole.
N	Number of data points.
N_c	Number of components in the mixture.
P	Pressure, Psia
P_b	Bubble point pressure Psia.
P_d	Dew point pressure Psia.
P_r	Reduced pressure.
R	Universal gas constant 10.732 Psia.ft ³ /lb-mole. $^{\circ}R$.
Rd	Relative deviation.
S	Entropy Btu/lb-mole $^{\circ}R$.
Sp.gr	Specific gravity.
T	Temperature F
T_B	Boiling point temperature, $^{\circ}R$.
v	Vapor mole per 1 mole of feed.
V_m	Molar volume ft ³ /lb-mole.
Uf	Sonic velocity, ft/sec.
X	Liquid mole fraction.
Y	Vapor mole fraction.
Z	Compressibility factor.
Z_i	Mole fraction of component i in the feed.

Greek Letters:

ω	Acentric Factor
γ_g	Gas specific gravity, (air = 1.0)
Φ	Fugacity coefficient.
ρ	Density of the Fluids, lbm/ft ³ .
η	Adiabatic Joule-Thomson Coefficient, $^{\circ}R$ /psia.
ξ	Isothermal Joule-Thomson Coefficient, $^{\circ}R$ /psia.

Superscripts:

L	Liquid
V	Vapor
*	Ideal gas state property.

Subscripts:

c Critical Property.

r Reduced property.

APPENDIX (A): Hydrocarbon Samples Compositions**Table A.1-** Mole Compositions of Hydrocarbon Samples Binary, Ternary, and Multicomponent Mixtures Volatile Oils

Sample No	B1	B2	B3	B4	B5	B7	T1	T2	M1	V1	V2	V3	V4	V5
Mole Percent														
N ₂	-	-	-	-	-	-	26.347	-	0.20	0.122	0.135	0.2	-	0.149
CO ₂	-	-	-	-	-	-	-	-	0.05	2.955	2.991	0.45	1.6	3.092
H ₂ S	-	-	-	-	-	-	-	-	-	9.872	9.799	0.08	0.15	9.88
C ₁	-	-	-	-	-	94.8	71.358	27.70	23.16	55.236	58.28	55.48	54.87	60.75
C ₂	17.49	45.10	65.77	82.18	94.72	-	2.295	52.30	0.050	5.989	6.005	11.83	10.18	6.167
C ₃	-	-	-	-	-	5.02	-	20.00	76.53	2.139	2.091	5.77	5.23	2.201
i-C ₄	-	-	-	-	-	-	-	-	-	0.248	0.235	0.88	1.08	0.273
n-C ₄	82.51	54.90	34.23	17.82	5.28	-	-	-	0.110	0.673	0.688	3.65	3.06	0.744
i-C ₅	-	-	-	-	-	-	-	-	-	0.198	0.205	1.2	1.22	0.23
n-C ₅	-	-	-	-	-	-	-	-	-	0.237	0.25	138	1.42	0.283
C ₆	-	-	-	-	-	-	-	-	-	0.216	0.245	-	-	0.316
C ₇	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C ₈	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C ₉	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plus Fraction	-	-	-	-	-	-	-	-	-	22.12	19.06	18.88	21.03	15.92
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Sp.gr of C _n	-	-	-	-	-	-	-	-	-	0.8404	0.824	0.828	0.84	0.822
Mw of C _n	-	-	-	-	-	-	-	-	-	158	154	156	163	150

Table A.2- Mole Compositions and Properties of Plus Fraction of Black Oils Samples

Sample No	1	2	3	4	5	6	7	8	9	10	11
Mole Percent											
N ₂	-	0.47	0.01	0.70	1.32	1.22	1.66	0.91	0.67	1.66	1.31
CO ₂	-	0.35	0.79	0.39	0.42	0.71	1.29	0.16	0.44	1.29	1.31
H ₂ S	-	-	0.43	-	-	-	-	-	-	-	-
C ₁	42.41	29.99	25.89	25.61	34.64	30.55	36.53	36.47	28.77	36.53	31.62
C ₂	5.33	11.44	11.49	8.95	10.46	8.86	10.49	9.67	9.22	10.49	9.52
C ₃	4.67	6.36	6.98	7.65	6.16	7.22	7.15	6.95	7.47	7.15	7.76
i-C ₄	1.55	1.12	1.53	1.49	1.81	1.33	0.94	1.44	1.68	0.94	1.54
n-C ₄	2.02	4.07	4.07	4.48	4.56	4.22	5.36	3.93	4.36	5.36	2.74
i-C ₅	0.92	1.70	2.08	1.53	1.60	1.39	1.63	1.44	1.68	1.63	1.33
n-C ₅	0.86	1.93	2.55	2.42	1.83	2.30	2.26	1.41	2.59	2.26	2.79
C ₆	3.13	-	-	-	-	-	-	4.33	-	-	-
C ₇	-	-	-	-	-	-	-	-	-	-	-
C ₈	-	-	-	-	-	-	-	-	-	-	-
C ₉	-	-	-	-	-	-	-	-	-	-	-
Plus Fraction	39.11	42.60	44.03	46.78	37.54	42.20	32.69	33.29	43.10	32.69	40.07
Total	100	100	100	100	100	100	100	100	100	100	100
Sp.gr of C _n	0.895	0.9314	0.9304	0.8947	0.8730	0.8769	0.8739	0.8515	0.8890	0.8739	0.8655
Mw of C _n	267	266.2	286.16	227.64	210	225.4	250	218	222.48	250	191



BOUNDARY ELEMENTS MODELLING FOR SMALL/LARGE STRAIN ANALYSIS OF ELASTOMERIC MATERIALS

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ABSTRACT

In this paper the boundary elements method is used as numerical techniques for solving elastomeric materials (rubber or rubber-like materials) under small and large strains analysis. Under small deformations, the formulations are based on assuming that the elastomer is linear elastic isotropic incompressible solid. While for the large deformation, the formulation is based on decomposing the 1st Piola-Kirchhoff stresses into linear and nonlinear parts. Thereafter, the final derived equations are composed of both boundary integral and non-linear domain integrals. The non-linear analyses were performed using an incremental procedure with an iterative algorithm.

Solving some numerical examples and comparing the results with that obtained from some available results and ANSYS 10.0 showed that the boundary elements method is a good numerical technique for solving incompressible elastomeric materials. And the formulation used for the boundary elements derivations for large strain analysis gave satisfactory results as compared with that of ANSYS ver. 10.0.

الخلاصة

التحقيقات العددية اعتمدت على استخدام طريقة العناصر الحدودية. تم استخدام هذه الطريقة لحل مسائل المواد المطاطية عند التشوهات الصغيرة والتشوهات الكبيرة. اعتمد الاشتقاق الرياضي في التشوهات الصغيرة لهذا النوع من المواد بافتراض ان هذه المواد هي مواد ذات خواص متسقة الاتجاهات، خطية، مرنة، ولا انضغاطية. بينما اعتمد الاشتقاق الرياضي تحت التشوهات الكبيرة على اساس فصل الاجهادات الكلية او اجهادات بايلا-كرشوف الاولى الى جزء خطي وجزء لاخطي. بناء عليه، فان المعادلات النهائية احتوت على تكاملات محيطية وتكاملات ميدانية. تم الحصول على الحلول في الجزء اللاخطي بالاعتماد على اسلوب عددي يحوي على اجراءات تزايدية للحمل مع خوارزمية تكرارية، اثبتت المقارنات عند حل بعض المسائل العددية ان طريقة العناصر الحدودية اكثر ملائمة من الطرق الاخرى لحل المسائل الخاصة بالمواد اللانضغاطية. كذلك اثبت ان الاشتقاق الخاص بالتشوهات الكبيرة للعناصر الحدودية صحيح واعطى نتائج مرضية عند مقارنته مع طرائق العناصر المحددة مثل ال ANSYS.

KEYWORD: rubber or rubber-like, elastomers, BEM, incompressible materials, large strain, hyperelastic

INTRODUCTION

Successful analysis of elastomers (rubber or rubber-like materials) requires robust numerical methods and representative material models applicable to small/large strains and multiple deformation modes. Although the mathematical foundation of strain energy density function has been studied by many researchers, the application to engineering problems is not straightforward.

Two major challenges are encountered in the numerical analysis of rubber materials. The first is due to the material incompressibility of rubber. The material incompressibility leads to a locking difficulty when using the conventional finite element method. The finite element prediction is often much stiffer (locking) than analytical solution or experimental data resulting from the imposition of "constant volume constraint" in the numerical formulation. Locking usually accompanies with pressure oscillation that completely corrupts the numerical stress solution, Herrmann 1985. The second difficulty is the mesh distortion caused by the large deformation nature in many elastomeric applications. Therefore it is necessary to search for other numerical techniques that may help in getting improved numerical analysis. In this work the boundary elements method has been chosen as numerical technique for solving elastomeric problems.

The boundary elements method is relatively a new technique and successfully applied to many engineering problems. The most remarkable feature of these methods are that instead of attempting to find an approximate solution for the governing differential equations throughout the relevant solution domain, as in the domain methods, the equations are converted into an integral form, often involving only integrals over the boundary of the domain, consequently, only the boundary has to be discretised in order to carry out the integration. Although these methods successfully applied to many engineering problems have had limited application with elastomers, Polyzos 1998.

The lack of inaccurate results of the conventional finite element method is due to Poisson's ratio values in elastomers, which ranges between 0.499 and 0.5. The elements used in FEA need to be reformulated to accommodate this high value of Poisson's ratio. This is usually accomplished by utilizing an approach developed by Herrmann 1985, by introducing a new variational principle that includes another degree of freedom called the "mean pressure function." When using the boundary elements method there is no such restriction and the method can handle elastomeric materials or generally incompressible materials accurately.

When managing elastomeric components using the boundary elements method, or any numerical technique, two major decisions will present themselves:

- Is a nonlinear analysis required, or will a linear analysis suffice?
- What material properties will be used?

These two decisions are interrelated, and the answer depends on what application the elastomeric components are designed for.

Keeping this in mind, therefore, one has to adopt either linear or non-linear analyses. As a result, in the present work, the boundary elements method is applied to elastomers by considering both small and large deformations. For small deformation the formulation is considered by assuming that the elastomers are linear elastic isotropic axisymmetric solids. The derivations lead to

a fact that only the boundary of the region being investigated has to be discretised. In large, or finite, deformation elastomers are considered to be hyperelastic solids, and nonlinear boundary elements method has been used. The derivations of the boundary integral equations were done by splitting the first Piola-Kirchoff stresses or total stresses into linear and non-linear components. Thereafter, the final derived equations are composed of both boundary integral and non-linear domain integration terms, consequently, both the boundary and the domain of the problem are discretised.

SMALL DEFORMATION BEM

In this section rubber components are considered under small deformations or small strains. A good approximation for the corresponding stresses is given by conventional elastic analysis, assuming simple linear stress-strain relationships, because, like all solids, rubber behaves as a linearly elastic substance at relatively small strains, Gent 2001. When applying the boundary elements technique to an axisymmetric elastomeric solid under axisymmetric loading and by taking the advantage of symmetry, the original three-dimensional problem will be reduced to a two-dimensional one. Therefore, it is only required to discretise the boundary of the radial plane, as shown in Fig. 1.

The boundary integral equation, BIE, can be obtained using weighted residual technique. Now, consider that one desire to minimize the error involved in the numerical approximation of the governing equations of axisymmetric solid;

$$\frac{\partial \sigma_r}{\partial r} + \frac{\partial \tau_{rz}}{\partial z} + \frac{\sigma_r - \sigma_\theta}{r} + \beta_r = 0$$

$$\frac{\partial \tau_{rz}}{\partial r} + \frac{\partial \sigma_z}{\partial z} + \frac{\tau_{rz}}{r} + \beta_z = 0$$

Which usually have to satisfy the essential and the natural boundary conditions.

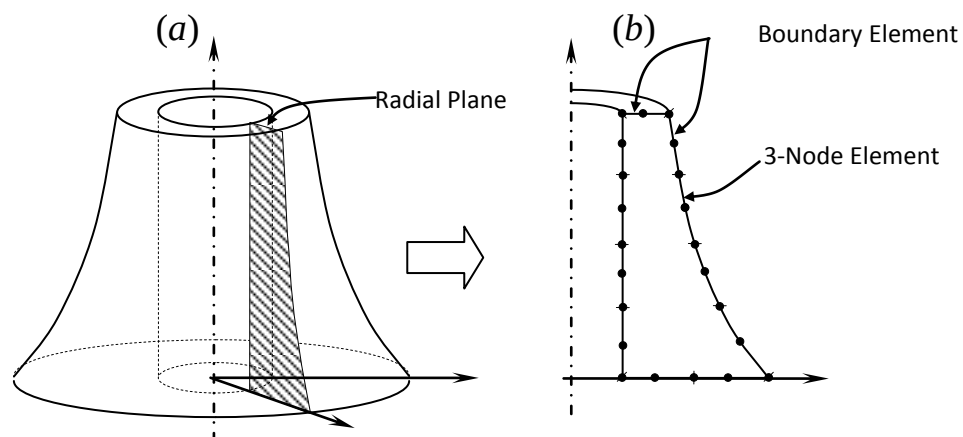


Figure 1: Discretisation of axisymmetric solid using BEM;
(a) original 3D problem, (b) radial plane BEM mesh

Minimizing the above equations by displacement type functions u^* and v^* using weighted residual technique as;

$$\iint_{\Omega} \left(\frac{\partial \sigma_r}{\partial r} + \frac{\partial \tau_{rz}}{\partial z} + \frac{\sigma_r - \sigma_{\theta}}{r} + \beta_r \right) u^* d\Omega + \iint_{\Omega} \left(\frac{\partial \tau_{rz}}{\partial r} + \frac{\partial \sigma_z}{\partial z} + \frac{\tau_{rz}}{r} + \beta_z \right) v^* d\Omega = 0 \quad (1)$$

where $d\Omega = 2\pi r dr dz$, carrying out the integration by parts for each term separately leads to

$$\begin{aligned} & \int_{\Gamma} \sigma_r u^* n_r r d\Gamma - \iint_{\Omega} \sigma_r \frac{\partial}{\partial r} (u^* r) dr dz + \int_{\Gamma} \tau_{rz} u^* n_z r d\Gamma - \int_{\Gamma} \sigma_r u^* n_r r d\Gamma - \iint_{\Omega} \sigma_r \frac{\partial}{\partial r} (u^* r) dr dz \\ & + \int_{\Gamma} \tau_{rz} v^* n_z r d\Gamma - \iint_{\Omega} \tau_{rz} \frac{\partial v^*}{\partial z} r dr dz + \iint_{\Omega} \frac{\sigma_r - \sigma_{\theta}}{r} u^* r dr dz + \int_{\Gamma} \tau_{rz} v^* n_r r d\Gamma - \iint_{\Omega} \tau_{rz} \frac{\partial}{\partial r} (r v^*) dr dz \\ & + \int_{\Gamma} \sigma_z v^* n_z r d\Gamma - \iint_{\Omega} \sigma_z \frac{\partial v^*}{\partial r} r dr dz + \iint_{\Omega} \frac{\tau_{rz}}{r} v^* r dr dz + \iint_{\Omega} (\beta_r u^* + \beta_z v^*) r dr dz = 0 \end{aligned} \quad (2)$$

Further simplifications and rearranging, gives

$$\begin{aligned} & \int_{\Gamma} (\sigma_r n_r + \tau_{rz} n_z) u^* r d\Gamma + \int_{\Gamma} (\tau_{rz} n_r + \sigma_z n_z) v^* r d\Gamma - \iint_{\Omega} \left(\sigma_r \frac{\partial u^*}{\partial r} + \sigma_z \frac{\partial v^*}{\partial z} \right) r dr dz \\ & - \iint_{\Omega} \tau_{rz} \left(\frac{\partial u^*}{\partial z} + \frac{\partial v^*}{\partial r} \right) r dr dz - \iint_{\Omega} \sigma_r \left(\frac{u^*}{r} + \frac{v^*}{r} \right) r dr dz + \iint_{\Omega} \frac{\sigma_r - \sigma_{\theta}}{r} u^* r dr dz \\ & + \iint_{\Omega} \frac{\tau_{rz}}{r} v^* r dr dz + \iint_{\Omega} (\beta_r u^* + \beta_z v^*) r dr dz = 0 \end{aligned} \quad (3)$$

Define

$$\boldsymbol{\varepsilon}^* = \{\varepsilon_r^*, \varepsilon_z^*, \varepsilon_{\theta}^*, \gamma_{rz}^*\} \quad \text{and} \quad \boldsymbol{\sigma} = \{\sigma_r, \sigma_z, \sigma_{\theta}, \tau_{rz}\} \quad (4)$$

This leads to

$$\int_{\Gamma} (t_r u^* + t_z v^*) r d\Gamma - \iint_{\Omega} (\sigma_r \varepsilon_r^* + \sigma_z \varepsilon_z^* + \sigma_{\theta} \varepsilon_{\theta}^* + \tau_{rz} \gamma_{rz}^*) r dr dz + \iint_{\Omega} (\beta_r u^* + \beta_z v^*) r dr dz = 0$$

or in a vectorial form

$$\int_{\Gamma} (t_r u^* + t_z v^*) r d\Gamma - \iint_{\Omega} \boldsymbol{\varepsilon}^{*T} \boldsymbol{\sigma} r dr dz + \iint_{\Omega} (\beta_r u^* + \beta_z v^*) r dr dz = 0 \quad (5)$$

For linear elastic solids, $\boldsymbol{\varepsilon}^{*T} \boldsymbol{\sigma} = \boldsymbol{\varepsilon}^{*T} \mathbf{D} \boldsymbol{\varepsilon}$, and since $\mathbf{D}$ is a symmetric matrix, therefore $\mathbf{D} = \mathbf{D}^T$, subsequently

$$\boldsymbol{\varepsilon}^{*T} \boldsymbol{\sigma} = \boldsymbol{\varepsilon}^{*T} \mathbf{D}^T \boldsymbol{\varepsilon} = \boldsymbol{\sigma}^{*T} \boldsymbol{\varepsilon}$$

Substitute above into equation (5), leads to

$$\int_{\Gamma} (t_r u^* + t_z v^*) r d\Gamma - \iint_{\Omega} (\sigma_r^* \varepsilon_r + \sigma_z^* \varepsilon_z + \sigma_{\theta}^* \varepsilon_{\theta} + \tau_{rz}^* \gamma_{rz}) r dr dz + \iint_{\Omega} (\beta_r u^* + \beta_z v^*) r dr dz = 0 \quad (6)$$



The first domain integral of the above equation can further be simplified by integrating by parts getting the following equation:

$$\begin{aligned} & \int_{\Gamma} (t_r u^* + t_z v^*) r d\Gamma - \int_{\Gamma} (t_r^* u + t_z^* v) r d\Gamma + \iint_{\Omega} \left(\frac{\partial \sigma_r^*}{\partial r} + \frac{\partial \tau_{rz}^*}{\partial z} + \frac{\sigma_r^* - \sigma_{\theta}^*}{r} \right) u r dr dz + \\ & \iint_{\Omega} \left(\frac{\partial \tau_{rz}^*}{\partial r} + \frac{\partial \sigma_z^*}{\partial z} + \frac{\tau_{rz}^*}{r} \right) v r dr dz + \iint_{\Omega} (\beta_r u^* + \beta_z v^*) r dr dz = 0 \end{aligned} \quad (7)$$

Eq. (7) represents the inverse weighted residual expression, which can be used to obtain the boundary integral equation. Considering now a ring source load $\beta_j = \Delta^i \mathbf{e}_j$ applied at a point $i(r_i, z_i)$ in an infinite domain, in the direction of the unit vector $\mathbf{e}_j$, where $j=r, z$, i.e.

$$\begin{aligned} \frac{\partial \sigma_r^*}{\partial r} + \frac{\partial \tau_{rz}^*}{\partial z} + \frac{\sigma_r^* - \sigma_{\theta}^*}{r} + \Delta^i \mathbf{e}_r &= 0 \\ \frac{\partial \tau_{rz}^*}{\partial r} + \frac{\partial \sigma_z^*}{\partial z} + \frac{\tau_{rz}^*}{r} + \Delta^i \mathbf{e}_z &= 0 \end{aligned} \quad (8)$$

where i refer to the point at which the load is applied, Δ^i is the Dirac delta function, which is define as, Kyuichiro Washizo 1975;

$$\Delta^i = \begin{cases} [\text{singular at point } i] \\ 0 [\text{at any other point}] \end{cases} \quad (9)$$

and Δ^i has the following property:

$$\iint_{\Omega} \Delta^i(p, Q) \mathbf{u}_i(Q) d\Omega = C_i u(p) \quad (10)$$

where

$$C_i = \begin{cases} 1 & \text{if } p \in \Omega \\ 0 & \text{if } p \notin \Omega + \Gamma \\ 0.5 & \text{if } p \text{ is on smooth continuous boundary } \Gamma \\ \frac{\alpha_i}{2\pi} & \text{if } p \text{ is on a corner of angle } \alpha_i \text{ on the boundary } \Gamma \end{cases}$$

Substiute eq. (8) into eq. (7) one get

$$\int_{\Gamma} (t_r u^* + t_z v^*) r d\Gamma - \int_{\Gamma} (t_r^* u + t_z^* v) r d\Gamma - \iint_{\Omega} \Delta^i \mathbf{e}_r u d\Omega - \iint_{\Omega} \Delta^i \mathbf{e}_z v d\Omega + \iint_{\Omega} (\beta_r u^* + \beta_z v^*) r dr dz = 0 \quad (11)$$

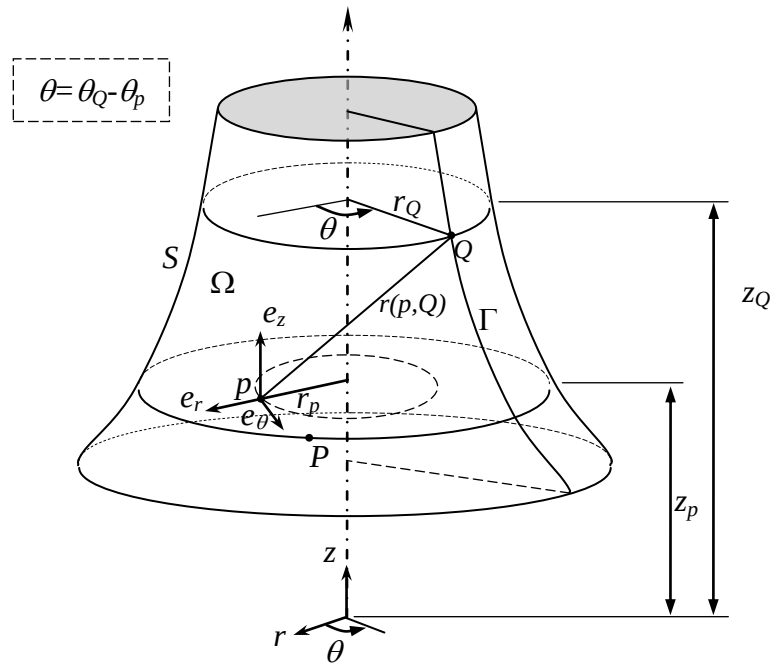


Figure 2: Domain of axisymmetric solid.

Consider each direction independently, the displacement at any point in the infinite domain is;

$$\begin{aligned} u^* &= U_{rr} \mathbf{e}_r + U_{zr} \mathbf{e}_z \\ v^* &= U_{rz} \mathbf{e}_r + U_{zz} \mathbf{e}_z \end{aligned} \quad (12)$$

$\mathbf{e}_r, \mathbf{e}_z$ is the components of the ring loads at point p in r and z direction, respectively, as shown in Fig. 2. U_{rr}, U_{rz}, U_{zr} and U_{zz} are displacement kernel functions. The first subscript refers to the direction of the displacement at the boundary point Q (field point), while the second refers to the direction of the ring load at point p (source point) causing the displacement at Q .

Similarly, the traction vector components at Q can be expressed as:

$$\begin{aligned} t_r^* &= T_{rr} \mathbf{e}_r + T_{zr} \mathbf{e}_z \\ t_z^* &= T_{rz} \mathbf{e}_r + T_{zz} \mathbf{e}_z \end{aligned} \quad (13)$$

where T_{rr}, T_{rz}, T_{zr} and T_{zz} are the traction kernels.

Substitute eq. (12) and eq. (13) into eq. (11), gives

$$\begin{aligned} &\int_{\Gamma} [t_r (U_{rr} \mathbf{e}_r + U_{zr} \mathbf{e}_z) + t_z (U_{rz} \mathbf{e}_r + U_{zz} \mathbf{e}_z)] r d\Gamma - \int_{\Gamma} [(T_{rr} \mathbf{e}_r + T_{zr} \mathbf{e}_z) u + (T_{rz} \mathbf{e}_r + T_{zz} \mathbf{e}_z) v] r d\Gamma \\ &- \iint_{\Omega} \Delta^i \mathbf{e}_r u d\Omega - \iint_{\Omega} \Delta^i \mathbf{e}_z v d\Omega + \iint_{\Omega} [\beta_r (U_{rr} \mathbf{e}_r + U_{zr} \mathbf{e}_z) + \beta_z (U_{rz} \mathbf{e}_r + U_{zz} \mathbf{e}_z)] r dr dz = 0 \end{aligned} \quad (14)$$

Since $\mathbf{e}_r$ and $\mathbf{e}_z$ are independent on each other, then eq. (14) can be split as:

$$\int_{\Gamma} (t_r U_{rr} + t_z U_{rz}) r d\Gamma - \int_{\Gamma} (T_{rr} u + T_{rz} v) r d\Gamma - \iint_{\Omega} \Delta^i u d\Omega + \iint_{\Omega} (\beta_r U_{rr} + \beta_z U_{rz}) d\Omega = 0 \quad (15)$$

and

$$\int_{\Gamma} (t_r U_{zr} + t_z U_{zz}) r d\Gamma - \int_{\Gamma} (T_{zr} u + T_{zz} v) r d\Gamma - \iint_{\Omega} \Delta^i v d\Omega + \iint_{\Omega} (\beta_r U_{zr} + \beta_z U_{zz}) d\Omega = 0 \quad (16)$$

When the source point is at an interior point ‘ p ’ then equations (15) and (16) lead to Somiglianna’s identity, Rizzo and Shippy 1986, defined as:

$$u(p) = \int_{\Gamma} (t_r(Q) U_{rr}(p, Q) + t_z(Q) U_{rz}(p, Q)) r_Q d\Gamma - \int_{\Gamma} (T_{rr}(p, Q) u(Q) + T_{rz}(p, Q) v(Q)) r_Q d\Gamma + \iint_{\Omega} (\beta_r U_{rr}(p, Q) + \beta_z U_{rz}(p, Q)) d\Omega \quad (17)$$

and

$$v(p) = \int_{\Gamma} (t_r(Q) U_{zr}(p, Q) + t_z(Q) U_{zz}(p, Q)) r_Q d\Gamma - \int_{\Gamma} (T_{zr}(p, Q) u(Q) + T_{zz}(p, Q) v(Q)) r_Q d\Gamma + \iint_{\Omega} (\beta_r U_{zr}(p, Q) + \beta_z U_{zz}(p, Q)) d\Omega \quad (18)$$

The above equations give the displacement components at an interior point p . To find the final boundary integral equation, each term in equations (17) and (18) is taken to the limits as the interior point p approach the boundary point P , i.e. $p \rightarrow P$. Therefore, these integral equations have now a singularity and the integral on Γ is defined only in the sense of the Cauchy principal value, Rizzo and Shippy 1986, and Brebbia 1989, resulting the following:

$$C_{rr} u^i + C_{rz} v^i + \int_{\Gamma} (T_{rr} u + T_{rz} v) r_Q d\Gamma = \int_{\Gamma} (t_r U_{rr} + t_z U_{rz}) r_Q d\Gamma + \iint_{\Omega} (\beta_r U_{rr} + \beta_z U_{rz}) d\Omega = 0 \quad (19)$$

and

$$C_{zr} u^i + C_{zz} v^i + \int_{\Gamma} (T_{zr} u + T_{zz} v) r_Q d\Gamma = \int_{\Gamma} (t_r U_{zr} + t_z U_{zz}) r_Q d\Gamma + \iint_{\Omega} (\beta_r U_{zr} + \beta_z U_{zz}) d\Omega = 0 \quad (20)$$

or in a matrix form

$$\begin{bmatrix} C_{rr} & C_{rz} \\ C_{zr} & C_{zz} \end{bmatrix} \begin{bmatrix} u^i \\ v^i \end{bmatrix} + \int_{\Gamma} \begin{bmatrix} T_{rr} & T_{rz} \\ T_{zr} & T_{zz} \end{bmatrix} \begin{bmatrix} u \\ v \end{bmatrix} r_Q d\Gamma = \int_{\Gamma} \begin{bmatrix} U_{rr} & U_{rz} \\ U_{zr} & U_{zz} \end{bmatrix} \begin{bmatrix} t_r \\ t_z \end{bmatrix} r_Q d\Gamma + \iint_{\Omega} \begin{bmatrix} U_{rr} & U_{rz} \\ U_{zr} & U_{zz} \end{bmatrix} \begin{bmatrix} \beta_r \\ \beta_z \end{bmatrix} r_Q d\Gamma \quad (21)$$

where C_{rr}, C_{rz}, C_{zr} and C_{zz} can be determined from the nature of the boundary geometry at “ P ”, and the value of C_{ij} ($i, j=r, z$) equal unity at interior point and $C_{ij} = \delta_{ij}/2$, (δ_{ij} is the Krönecker delta), when the boundary at P is smooth, i.e. have unique tangent at P , but can be expressed generally using rigid body motion, Nouri and Husain 2000.

LARGE DEFORMATION BEM

The large deformation BEM derivation, also, will starts from minimizing the error involved in the numerical approximation of the governing differential equations of axisymmetric solid;

$$\begin{aligned}\frac{\partial \sigma_r}{\partial r} + \frac{\partial \tau_{rz}}{\partial z} + \frac{\sigma_r - \sigma_\theta}{r} + \beta_r &= 0 \\ \frac{\partial \tau_{rz}}{\partial r} + \frac{\partial \sigma_z}{\partial z} + \frac{\tau_{rz}}{r} + \beta_z &= 0\end{aligned}\quad (22)$$

where β_r and β_z are the radial and axial body forces, the stresses in eq. (22) is the first Piola-Kirchoff stresses or total stresses and can be split into linear and non-linear components as follows:

$$\sigma_{ij} = \sigma_{ij}^{nl} + \sigma_{ij}^l \quad (23)$$

where the superscript nl refers to non-linear component and the superscript l refer to the linear one.

Therefore, equations (22) can now be rewritten as follows:

$$\begin{aligned}\frac{\partial \sigma_r^l}{\partial r} + \frac{\partial \tau_{rz}^l}{\partial z} + \frac{\sigma_r^l - \sigma_\theta^l}{r} + f_r^{nl} + \beta_r &= 0 \\ \frac{\partial \tau_{rz}^l}{\partial r} + \frac{\partial \sigma_z^l}{\partial z} + \frac{\tau_{rz}^l}{r} + f_z^{nl} + \beta_z &= 0\end{aligned}\quad (24)$$

where;

$$f_r^{nl} = \frac{\partial \sigma_r^{nl}}{\partial r} + \frac{\partial \tau_{rz}^{nl}}{\partial z} + \frac{\sigma_r^{nl} - \sigma_\theta^{nl}}{r}, \quad \text{and} \quad f_z^{nl} = \frac{\partial \tau_{rz}^{nl}}{\partial r} + \frac{\partial \sigma_z^{nl}}{\partial z} + \frac{\tau_{rz}^{nl}}{r}$$

Minimizing equations. (24) by displacement type functions u^* and v^* as:

$$\iint_{\Omega} \left(\frac{\partial \sigma_r^l}{\partial r} + \frac{\partial \tau_{rz}^l}{\partial z} + \frac{\sigma_r^l - \sigma_\theta^l}{r} + f_r^{nl} + \beta_r \right) u^* d\Omega + \iint_{\Omega} \left(\frac{\partial \tau_{rz}^l}{\partial r} + \frac{\partial \sigma_z^l}{\partial z} + \frac{\tau_{rz}^l}{r} + f_z^{nl} + \beta_z \right) v^* d\Omega = 0 \quad (25)$$

Using integration by parts and rearranging gives:

$$\begin{aligned}& \int_{\Gamma} (\sigma_r^l n_r + \tau_{rz}^l n_z) u^* r d\Gamma + \int_{\Gamma} (\tau_{rz}^l n_r + \sigma_z^l n_z) v^* r d\Gamma \\ & - \iint_{\Omega} \left(\sigma_r^l \frac{\partial u^*}{\partial r} + \sigma_z^l \frac{\partial v^*}{\partial z} + \sigma_\theta^l \frac{u^*}{r} + \tau_{rz}^l \left(\frac{\partial v^*}{\partial r} + \frac{\partial u^*}{\partial z} \right) \right) r dr dz \\ & + \iint_{\Omega} (f_r^{nl} u^* + f_z^{nl} v^*) r dr dz + \iint_{\Omega} (\beta_r u^* + \beta_z v^*) r dr dz = 0\end{aligned}\quad (26)$$

writing

$$\begin{aligned}t_r^l &= \sigma_r^l n_r + \tau_{rz}^l n_z, & t_z^l &= \tau_{rz}^l n_r + \sigma_z^l n_z, \\ \boldsymbol{\varepsilon}^* &= \{\varepsilon_r^*, \varepsilon_z^*, \varepsilon_\theta^*, \gamma_{rz}^*\}, & \boldsymbol{\sigma} &= \{\sigma_r^l, \sigma_z^l, \sigma_\theta^l, \tau_{rz}^l\},\end{aligned}$$

where:

$$\varepsilon_r^* = \frac{\partial u^*}{\partial r}; \quad \varepsilon_\theta^* = \frac{u^*}{r}; \quad \varepsilon_z^* = \frac{\partial v^*}{\partial z}; \quad \gamma_{rz}^* = \frac{\partial u^*}{\partial z} + \frac{\partial v^*}{\partial r}$$

Substitute the above expressions, into equation (26) gives;

$$\begin{aligned} \int_{\Gamma} (t_r^l u^* + t_z^l v^*) r d\Gamma - \iint_{\Omega} (\sigma_r^* \varepsilon_r^* + \sigma_z^* \varepsilon_z^* + \sigma_\theta^* \varepsilon_\theta^* + \tau_{rz}^* \gamma_{rz}^*) r dr dz \\ + \iint_{\Omega} (f_r^{nl} u^* + f_z^{nl} v^*) r dr dz + \iint_{\Omega} (\beta_r u^* + \beta_z v^*) r dr dz = 0 \end{aligned} \quad (27)$$

Neglecting the body forces, i.e. $\beta_r = \beta_z = 0$, eq. (27) can be written in vectorial form as:

$$\int_{\Gamma} (t_r^l u^* + t_z^l v^*) r d\Gamma - \iint_{\Omega} (\boldsymbol{\varepsilon}^{*T} \boldsymbol{\sigma}^l) r dr dz + \iint_{\Omega} (f_r^{nl} u^* + f_z^{nl} v^*) r dr dz = 0 \quad (28)$$

For the linear $\boldsymbol{\sigma}^l$:

$$\boldsymbol{\varepsilon}^{*T} \boldsymbol{\sigma} = \boldsymbol{\varepsilon}^{*T} \mathbf{D}^l \boldsymbol{\varepsilon} = \boldsymbol{\sigma}^{*T} \boldsymbol{\varepsilon}^l$$

where $\boldsymbol{\sigma}^* = \{\sigma_r^*, \sigma_z^*, \sigma_\theta^*, \tau_{rz}^*\} = \mathbf{D}^l \boldsymbol{\varepsilon}^*$

Therefore, eq. (28) can be written as:

$$\int_{\Gamma} (t_r^l u^* + t_z^l v^*) r d\Gamma - \iint_{\Omega} (\sigma_r^* \varepsilon_r^* + \sigma_z^* \varepsilon_z^* + \sigma_\theta^* \varepsilon_\theta^* + \tau_{rz}^* \gamma_{rz}^*) r dr dz + \iint_{\Omega} (f_r^{nl} u^* + f_z^{nl} v^*) r dr dz = 0 \quad (29)$$

The first domain integral of the above equation can further simplified by integrating by parts, and equation (29) will be as follows:

$$\begin{aligned} \int_{\Gamma} (t_r^l u^* + t_z^l v^*) r d\Gamma - \int_{\Gamma} (t_r^l u + t_z^l v) r d\Gamma + \iint_{\Omega} \left(\frac{\partial \sigma_r^*}{\partial r} + \frac{\partial \tau_{rz}^*}{\partial z} + \frac{\sigma_r^* - \sigma_\theta^*}{r} \right) u r dr dz \\ + \iint_{\Omega} \left(\frac{\partial \tau_{rz}^*}{\partial r} + \frac{\partial \sigma_z^*}{\partial z} + \frac{\tau_{rz}^*}{r} \right) v r dr dz \\ + \iint_{\Omega} (f_r^{nl} u^* + f_z^{nl} v^*) r dr dz = 0 \end{aligned} \quad (30)$$

Eq. (30) represents the inverse weighted residual expression. Considering a ring source load $\beta_m = \Delta^i \mathbf{e}_m$ applied at a point $i(r_i, z_i)$ in an infinite domain, in the direction of the unit vector $\mathbf{e}_m$, where $m=r, z$, i.e.

$$\begin{aligned} \frac{\partial \sigma_r^*}{\partial r} + \frac{\partial \tau_{rz}^*}{\partial z} + \frac{\sigma_r^* - \sigma_\theta^*}{r} + \Delta^i \mathbf{e}_r = 0 \\ \frac{\partial \tau_{rz}^*}{\partial r} + \frac{\partial \sigma_z^*}{\partial z} + \frac{\tau_{rz}^*}{r} + \Delta^i \mathbf{e}_z = 0 \end{aligned} \quad (31)$$

where i refers to the point at which the load is applied, Δ^i is the Dirac delta function.

Therefore eq. (30) will be

$$\begin{aligned} & \int_{\Gamma} (t_r^l u^* + t_z^l v^*) r d\Gamma - \int_{\Gamma} (t_r^* u + t_z^* v) r d\Gamma - \iint_{\Omega} \Delta^i \mathbf{e}_r u r dr dz - \iint_{\Omega} \Delta^i \mathbf{e}_z v r dr dz \\ & + \iint_{\Omega} (f_r^{nl} u^* + f_z^{nl} v^*) r dr dz = 0 \end{aligned} \quad (32)$$

From the property of Dirac delta function, eq. (10), eq. (32) gives the nonlinear boundary integral equations of axisymmetric elastomeric solids sustaining large or hyperelastic deformation:

$$C_i u_i \mathbf{e}_r + C_i u_i \mathbf{e}_r + \int_{\Gamma} (t_r^* u + t_z^* v) r d\Gamma = \int_{\Gamma} (t_r^l u^* + t_z^l v^*) r d\Gamma + \iint_{\Omega} (f_r^{nl} u^* + f_z^{nl} v^*) r dr dz \quad (33)$$

The domain integral of equation (33) represents the non-linear part of this equation. This domain integral is defined as:

$$\iint_{\Omega} (f_r^{nl} u^* + f_z^{nl} v^*) r dr dz = \iint_{\Omega} \left(\frac{\partial \sigma_r^{nl}}{\partial r} + \frac{\partial \tau_{rz}^{nl}}{\partial z} + \frac{\sigma_r^{nl} - \sigma_{\theta}^{nl}}{r} \right) u^* r dr dz + \iint_{\Omega} \left(\frac{\partial \tau_{rz}^{nl}}{\partial r} + \frac{\partial \sigma_z^{nl}}{\partial z} + \frac{\tau_{rz}^{nl}}{r} \right) v^* r dr dz$$

Integrating by parts and rearranging

$$\begin{aligned} \iint_{\Omega} (f_r^{nl} u^* + f_z^{nl} v^*) r dr dz &= \int_{\Gamma} (\sigma_r^{nl} n_r + \tau_{rz}^{nl} n_z) u^* r d\Gamma + \int_{\Gamma} (\tau_{rz}^{nl} n_r + \sigma_z^{nl} n_z) v^* r d\Gamma - \\ & \iint_{\Omega} \left(\sigma_r^{nl} \frac{\partial u^*}{\partial r} + \sigma_z^{nl} \frac{\partial v^*}{\partial z} + \sigma_{\theta}^{nl} \frac{u^*}{r} + \tau_{rz}^{nl} \left(\frac{\partial u^*}{\partial z} + \frac{\partial v^*}{\partial r} \right) \right) r dr dz \end{aligned}$$

since $t_r = \sigma_r n_r + \tau_{rz} n_z$, and $t_z = \tau_{rz} n_r + \sigma_z n_z$, therefore

$$\begin{aligned} \iint_{\Omega} (f_r^{nl} u^* + f_z^{nl} v^*) r dr dz &= \int_{\Gamma} (t_r^{nl} u^* + t_z^{nl} v^*) r d\Gamma - \\ & \iint_{\Omega} \left(\sigma_r^{nl} \frac{\partial u^*}{\partial r} + \sigma_z^{nl} \frac{\partial v^*}{\partial z} + \sigma_{\theta}^{nl} \frac{u^*}{r} + \tau_{rz}^{nl} \left(\frac{\partial u^*}{\partial z} + \frac{\partial v^*}{\partial r} \right) \right) r dr dz \end{aligned} \quad (34)$$

Substitute eq. (34) into eq. (33) gives:

$$\begin{aligned} C_i u_i \mathbf{e}_r + C_i u_i \mathbf{e}_r + \int_{\Gamma} (t_r^* u + t_z^* v) r d\Gamma &= \int_{\Gamma} (t_r^l u^* + t_z^l v^*) r d\Gamma + \int_{\Gamma} (t_r^{nl} u^* + t_z^{nl} v^*) r d\Gamma - \\ & \iint_{\Omega} \left(\sigma_r^{nl} \frac{\partial u^*}{\partial r} + \sigma_z^{nl} \frac{\partial v^*}{\partial z} + \sigma_{\theta}^{nl} \frac{u^*}{r} + \tau_{rz}^{nl} \left(\frac{\partial u^*}{\partial z} + \frac{\partial v^*}{\partial r} \right) \right) r dr dz \end{aligned} \quad (35)$$

Noting that:

$$\begin{aligned} t_r &= t_r^l + t_r^{nl} = \sigma_r n_r + \tau_{rz} n_z \\ t_z &= t_z^l + t_z^{nl} = \tau_{rz} n_r + \sigma_z n_z \end{aligned}$$

Then, eq. (35) gives:

$$C_i u_i \mathbf{e}_r + C_i u_i \mathbf{e}_r + \int_{\Gamma} (t_r^* u + t_z^* v) r d\Gamma = \int_{\Gamma} (t_r u^* + t_z v^*) r d\Gamma + \iint_{\Omega} \left(\sigma_r^{nl} \frac{\partial u^*}{\partial r} + \sigma_z^{nl} \frac{\partial v^*}{\partial z} + \sigma_{\theta}^{nl} \frac{u^*}{r} + \tau_{rz}^{nl} \left(\frac{\partial u^*}{\partial z} + \frac{\partial v^*}{\partial r} \right) \right) r dr dz \quad (36)$$

Similarly, as performed in the small deformation derivations, u^* and v^* , considering each direction independently, may be written as:

$$u^* = U_{rr} \mathbf{e}_r + U_{zr} \mathbf{e}_z, \text{ and } v^* = U_{rz} \mathbf{e}_r + U_{zz} \mathbf{e}_z.$$

similarly, the traction vector components at the field point Q can be expressed as;

$$t_r^* = T_{rr} \mathbf{e}_r + T_{zr} \mathbf{e}_z, \text{ and } t_z^* = T_{rz} \mathbf{e}_r + T_{zz} \mathbf{e}_z.$$

Substitute the above equations into eq. (36), and simplified the final boundary integral equation will be given in a matrix form as;

$$\begin{bmatrix} C_{rr} & C_{rz} \\ C_{zr} & C_{zz} \end{bmatrix} \begin{bmatrix} u^i \\ v^i \end{bmatrix} + \int_{\Gamma} \begin{bmatrix} T_{rr} & T_{rz} \\ T_{zr} & T_{zz} \end{bmatrix} \begin{bmatrix} u \\ v \end{bmatrix} r d\Gamma = \int_{\Gamma} \begin{bmatrix} U_{rr} & U_{rz} \\ U_{zr} & U_{zz} \end{bmatrix} \begin{bmatrix} t_r \\ t_z \end{bmatrix} r d\Gamma + \iint_{\Omega} \begin{bmatrix} \sigma_r^{nl} \frac{\partial U_{rr}}{\partial r} + \sigma_z^{nl} \frac{\partial U_{rz}}{\partial z} + \sigma_{\theta}^{nl} \frac{U_{rr}}{r} + \tau_{rz}^{nl} \left(\frac{\partial U_{rr}}{\partial z} + \frac{\partial U_{rz}}{\partial r} \right) \\ \sigma_r^{nl} \frac{\partial U_{zr}}{\partial r} + \sigma_z^{nl} \frac{\partial U_{zz}}{\partial z} + \sigma_{\theta}^{nl} \frac{U_{zr}}{r} + \tau_{rz}^{nl} \left(\frac{\partial U_{zr}}{\partial z} + \frac{\partial U_{zz}}{\partial r} \right) \end{bmatrix} r dr dz \quad (37)$$

Equation (37) represents the final boundary integral equation for the large strain elastomeric materials. The boundary integral terms can be evaluated numerically by discretising the boundary of the problem. Whereas, the domain integral terms required the domain to be discretised in similar manner as usually used in the finite element techniques.

BOUNDARY ELEMENT FORMULATION

Small Deformation BE Formulation

In small deformation analysis, the problem is considered to be for linear elastic axisymmetric solids. Therefore as stated previously only the boundary of the radial plane has to be discretised. In order to solve the integral equations numerically the boundary, Γ , of the domain, eq. (21) will be discretized into a number of boundary elements over which the displacements and traction are written in terms of nodal points, and the numerical integration performed over each elements and added together.

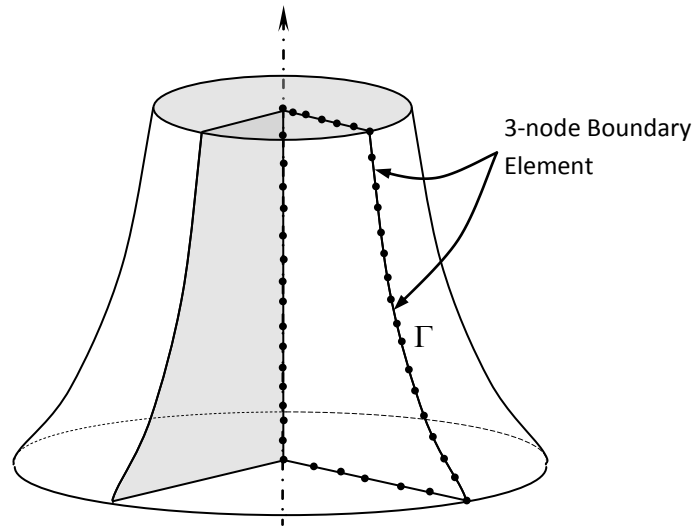


Figure 3: Discretisation of the boundary of linear axisymmetric solid into M_B quadratic element.

After discretising the boundary into M_B elements, eq. (21) may be rewritten, in the absence of body forces, as:

$$\begin{bmatrix} C_{rr} & C_{rz} \\ C_{zr} & C_{zz} \end{bmatrix} \begin{bmatrix} u^i \\ v^i \end{bmatrix} + \sum_{j=1}^M \int_{\Gamma_j} \begin{bmatrix} T_{rr} & T_{rz} \\ T_{zr} & T_{zz} \end{bmatrix} \begin{bmatrix} u \\ v \end{bmatrix} r_Q d\Gamma_j = \sum_{j=1}^M \int_{\Gamma_j} \begin{bmatrix} U_{rr} & U_{rz} \\ U_{zr} & U_{zz} \end{bmatrix} \begin{bmatrix} t_r \\ t_z \end{bmatrix} r_Q d\Gamma_j \quad (38)$$

In a matrix form

$$\mathbf{C}^i \mathbf{u}^i + \sum_{j=1}^{M_B} \int_{\Gamma_j} \mathbf{T} \mathbf{u} r_Q d\Gamma_j = \sum_{j=1}^{M_B} \int_{\Gamma_j} \mathbf{U} \mathbf{t} r_Q d\Gamma_j \quad (39)$$

or in terms of the shape functions as:

$$\mathbf{C}^i \mathbf{u}^i + \sum_{j=1}^{M_B} \left[\int_{\Gamma_j} \mathbf{T} \mathcal{F} r_Q d\Gamma_j \right] u_j = \sum_{j=1}^{M_B} \left[\int_{\Gamma_j} \mathbf{U} \mathcal{F} r_Q d\Gamma_j \right] t_j \quad (40)$$

where

$$\mathbf{T} = \begin{bmatrix} T_{rr} & T_{rz} \\ T_{zr} & T_{zz} \end{bmatrix}; \quad \mathbf{U} = \begin{bmatrix} U_{rr} & U_{rz} \\ U_{zr} & U_{zz} \end{bmatrix}$$

And $\mathcal{F}$ is the shape function matrix.

LARGE DEFORMATION BE FORMULATION

In this section elastomeric problem with large deformation is considered. It is noted that eq. (37) contains both boundary integral terms and domain integral terms. The boundary integral terms require the discretisation of the boundary in order to evaluate it. Thus, the boundary of the problem is discretised into boundary elements. The domain terms require the domain to be subdivided into cells or elements to evaluate the integrals. In this work the domain of the problem is discretised using 8-nodes isoparametric elements.

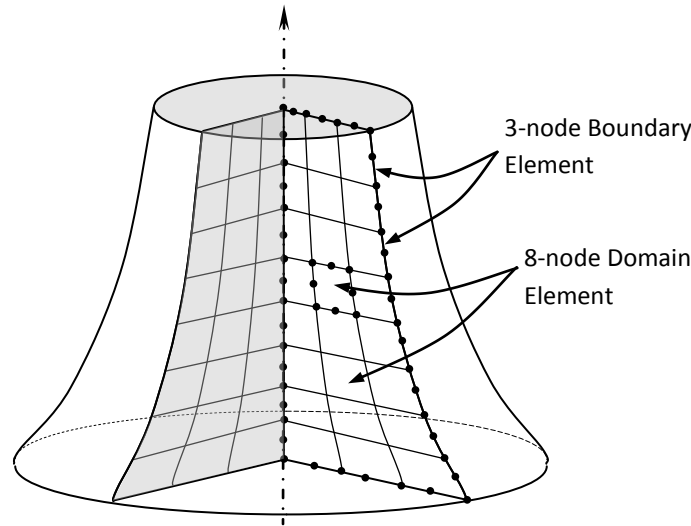


Figure 4: Discretisation of the boundary into M_B quadratic element, and the domain into M_D 8-node element.

To evaluate eq. (37) numerically, it is required that the boundary ‘ Γ ’ of the domain, and the domain of the problem to be discretised into boundary elements and domain cells, respectively. The boundary and the domain discretisation are shown in Fig. 4.

After discretising the boundary into M_B elements and the domain into M_D elements, equation (37) can be rewritten in a discretised form as:

$$\mathbf{C}^i \mathbf{u}^i + \sum_{j=1}^{M_B} \int_{\Gamma_j} \mathbf{T} \mathbf{u} r_Q d\Gamma_j = \sum_{j=1}^{M_B} \int_{\Gamma_j} \mathbf{U} \mathbf{t} r_Q d\Gamma_j + \sum_{j=1}^{M_D} \iint_{\Omega_j} \mathbf{D} r dr dz \quad (41)$$

where

$$\mathbf{D} = \begin{bmatrix} \sigma_r^{nl} \frac{\partial U_{rr}}{\partial r} + \sigma_z^{nl} \frac{\partial U_{rz}}{\partial z} + \sigma_\theta^{nl} \frac{U_{rr}}{r} + \tau_{rz}^{nl} \left(\frac{\partial U_{rr}}{\partial z} + \frac{\partial U_{rz}}{\partial r} \right) \\ \sigma_r^{nl} \frac{\partial U_{zr}}{\partial r} + \sigma_z^{nl} \frac{\partial U_{zz}}{\partial z} + \sigma_\theta^{nl} \frac{U_{zr}}{r} + \tau_{rz}^{nl} \left(\frac{\partial U_{zr}}{\partial z} + \frac{\partial U_{zz}}{\partial r} \right) \end{bmatrix}$$

or in terms of the shape function matrices as;

$$\mathbf{C}^i \mathbf{u}^i + \sum_{j=1}^{M_B} \left[\int_{\Gamma_j} \mathbf{T} \mathbf{F} r_Q d\Gamma_j \right] \mathbf{u}_j = \sum_{j=1}^{M_B} \left[\int_{\Gamma_j} \mathbf{U} \mathbf{F} r_Q d\Gamma_j \right] \mathbf{t}_j + \sum_{j=1}^{M_D} \iint_{\Omega_j} \mathbf{D} r dr dz \quad (42)$$

Solution Algorithm

Eq. (42) may be written as

$$\mathbf{C}^i \mathbf{u}_c^i + \sum_{j=1}^{M_B} \hat{\mathbf{H}}_{ij} \mathbf{u}_j = \sum_{j=1}^{M_B} \mathbf{G}_{ij} \mathbf{t}_j + \sum_{j=1}^{M_D} \mathbf{D}_{ij} \quad (43)$$

Define

$$\mathbf{H}_{ij} = \begin{cases} \hat{\mathbf{H}}_{ij} & \text{if } i \neq j \\ \hat{\mathbf{H}}_{ij} + \mathbf{C}^i & \text{if } i = j \end{cases}$$

Therefore, eq. (43) will be written as:

$$\sum_{j=1}^{M_B} \mathbf{H}_{ij} \mathbf{u}_j = \sum_{j=1}^{M_B} \mathbf{G}_{ij} \mathbf{t}_j + \sum_{j=1}^{M_D} \mathbf{D}_{ij} \quad (44)$$

And the global system of equations is written as,

$$\mathbf{H} \mathbf{u} = \mathbf{G} \mathbf{t} + \mathcal{D} \quad (45)$$

Applying the boundary condition and rearranging the columns in $\mathbf{H}$ and $\mathbf{G}$ matrix, eq. 45 can be rewritten as:

$$\mathbf{A} \mathbf{X} = \mathbf{Y} + \mathcal{D} \quad (46)$$

It can be seen that the boundary integral equations involves a non-linear term, which is a function of the displacement derivatives and the hydrostatic pressure. With the above equations it is possible to formulate the iterative solution procedure for non-linear boundary element analysis as follows. From eq. (45) it can be seen that non-linear terms are involved which are a function of the displacement derivatives and hydrostatic pressure. The dependence of this term on the hydrostatic pressure and the displacement derivatives stems from the term's involvement of the first Piola-Kirchhoff stress (total stress) in its derivative. These non-linear terms can be seen to augment the force/traction vector $\mathbf{Y}$ in eq. (46), the reduced system of equations after prescribed boundary conditions have been applied. Thus a solution to eq. (46) must involve an iterative solution procedure.

As with most iterative solution procedures the first step is to solve the equivalent linear problem to obtain an initial estimate of the solution. This involves solving eq. (46) but ignoring the domain term with the non-linear stresses i.e. $\mathcal{D} = \mathbf{0}$. The solution vector to this equation can then be used to evaluate the displacement derivatives and hydrostatic pressures to use in the full non-linear boundary integral equations including the non-linear term.

Evidently this first solution vector, and subsequent solution vectors before convergence, will not fully satisfy the full non-linear set of boundary integral equations and a residual or error value will result if the solution vector is substituted back into eq. (46). This residual can be reduced if a new

set of hydrostatic pressures and stresses are calculated based on the previous iteration results. These values can then be used to compute new non-linear domain terms to augment the standard linear BIE force vector. The solution to this set of equations will result in an improved vector of total nodal displacements and tractions. The difference between the new solution vector and the old one gives the iterative improvement in the solution vector. This process is repeated until the ratio of the square of the solution vector increment over the square of the total solution vector results in a value less than a given permissible, as depicted in Fig. 5a.

Incremental Modification to the Solution Algorithm

In the preceding section the basic iterative solution procedure was explained. It is the case that for non-linear problems the only way to achieve convergence of the iterative process for most load cases is to break the applied load down into load increments. This is certainly the only way to achieve convergence for the type of non-linear hyperelastic stress, Bayliss 2004. Therefore it is essential to develop an incremental version of the basic iterative solution algorithm. This can be achieved with the following algorithm shown in Fig. 5b.

As is usual for most non-linear numerical algorithms the first iteration of the first increment is the solution of the equivalent linear problem. The next part of the algorithm is as discussed in the preceding section where by the previous solution vector (tractions and displacements) is used to evaluate the displacement derivatives, and therefore, to enable the non-linear stresses to be found so as to compute the nonlinear domain terms in the system of boundary integral equations.

The significant difference however with the incremental algorithm is that for each iteration the 'old' and 'new' values of the solution vector and the non-linear stresses (at each domain Gauss point and at each source point) are stored. Therefore the total solution vector is formed from the total cumulative sum of the change in displacements and tractions at each iteration of each increment. The change in non-linear stress, or the difference between the current and previous iteration values, is used in the non-linear domain term. This means that for each increment the non-linear domain term reduces for each iteration until convergence occurs. Therefore this algorithm is pseudo incremental because at each iteration of every increment the system of boundary integral equations are still solved for the total displacements and tractions, Bayliss 2004 and Burn *et. al.* 2003.

Because the geometry is always changing as the displacements become large due increments of larger loads, therefore some additional steps are required. Because the boundary integral derivations are based on 1st Piola-Kirchhoff stress values the prescribed tractions (surface stresses) need to be converted to 1st Piola-Kirchhoff values, which will start to differ from nominal values as the strain increases.

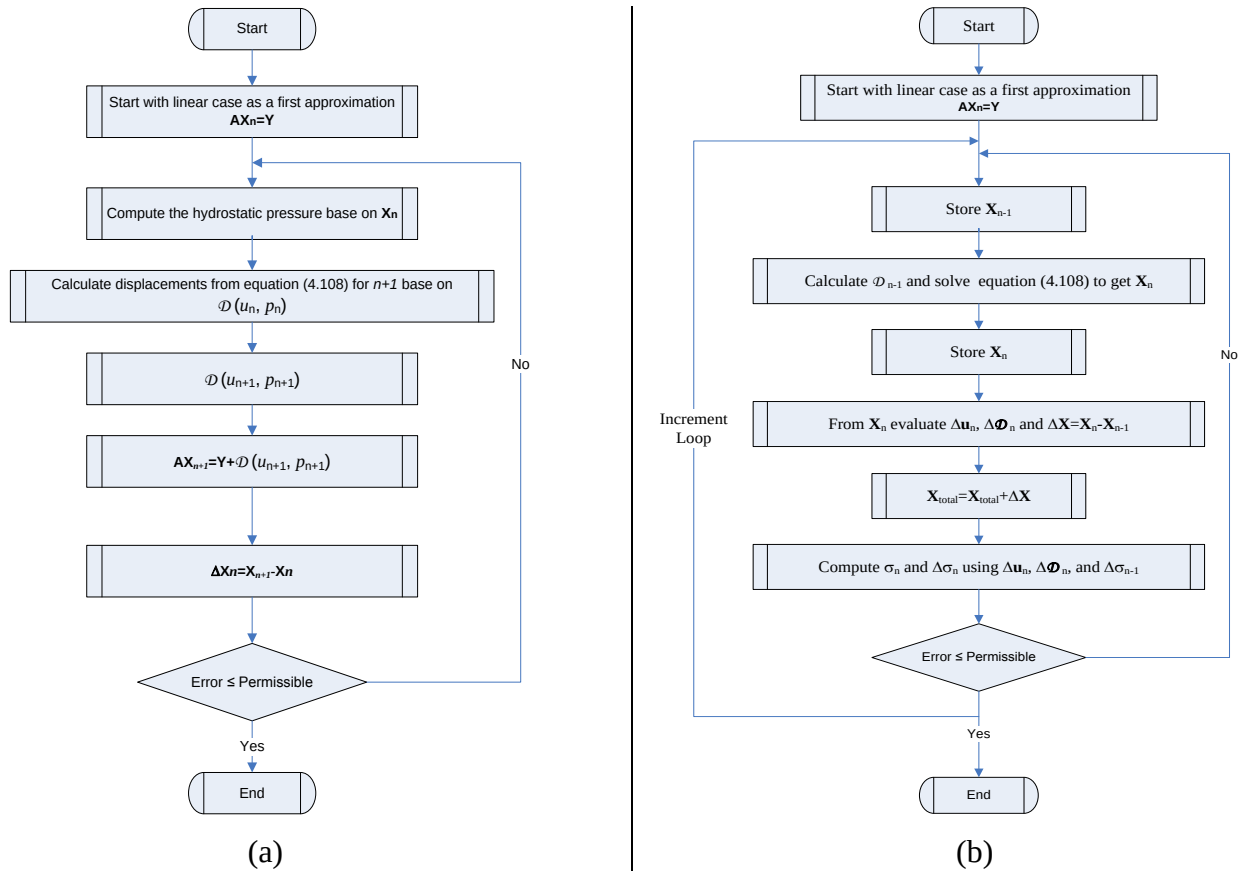


Figure 5: (a) Iterative solution procedure for non-linear boundary integral equations;
(b) Incremental modification to iterative solution procedure.

SMALL DEFORMATION OF INCOMPRESSIBLE MATERIALS

Compression of Bonded Rubber Block

In this example the deformation due to compression of bonded thin rubber block, which is widely used as spring, is studied. The rubber block, as shown in Fig. 6, is bonded on its major surfaces to rigid plates. Gent and Lindley, 1959, assumed that the deformation takes place in two stages: a pure homogeneous compression of amount e , requiring a uniform compressive stress $\sigma=3Ge$, i.e. $\nu=0.5$, and a shear deformation restoring points in the planes of the bonded surfaces to their original positions in these planes.

The material is completely incompressible with a Poisson's ratio of 0.5 exactly. The numerical values are chosen to be: $e=10\%h$, $(a/h)=4.5$, $\nu=0.5$, and $E=23 \text{ N/mm}^2$. The problem is solved by boundary element method of the present work and compared with the finite element software ANSYS Release 10.0. The boundary of the problem is discretised with 22 quadratic 3-node boundary elements with total number of nodes of 45. The Poisson's ratio is chosen of 0.5 exactly. While for the ANSYS the Poisson's ratio has to be approximated as close as 0.5. Firstly, the value is chosen as 0.49 and, secondly as 0.49999 with element type 183 of 8-node, the problem is solved as axisymmetric solid with mixed u/p (displacement/pressure). In ANSYS the Poisson's ratio has to be approximated as 0.49+, exact value of 0.5 is not allowed.

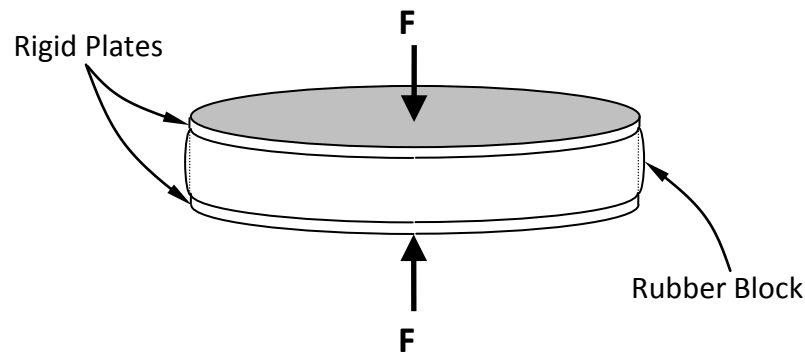


Figure 6: Compression of bonded rubber block

The results from the boundary element methods of the present work are compared with that of the analytical solution of Gent and Lindley 1959, as shown in Fig. 7. On the same graph the finite element results from ANSYS are plotted with Poisson's ratio of 0.49 and 0.49999. From this graph it is shown that the boundary element results are in good agreement with that of analytical solution. While for ANSYS the results are very sensitive to the chosen value of Poisson's ratio. For ANSYS selecting Poisson's ratio value close to 0.5 gives us better results.

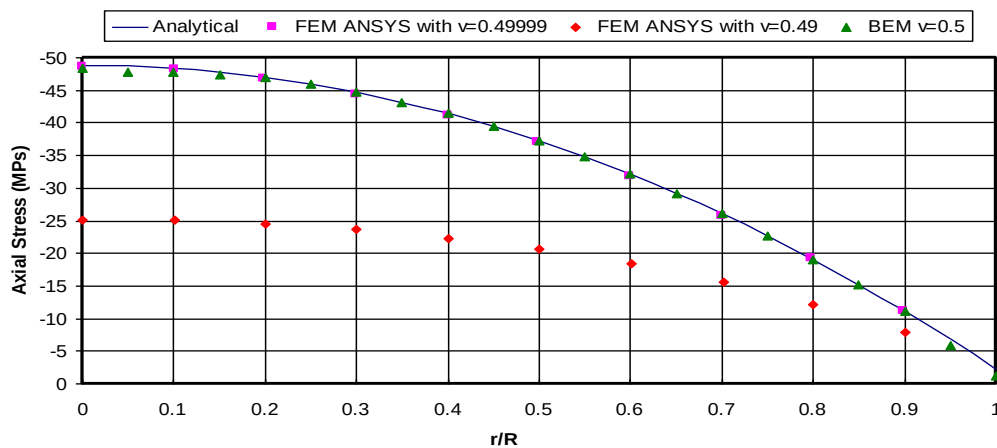


Figure 7: Axial stress for bonded rubber block

AXISYMMETRIC PRESSURE VESSEL

In this example an epoxy flat-headed pressure vessel subjected to internal pressure of 2.61 psi of a dimension shown in Fig. 8, is considered. Floyd, 1984, analyzed this vessel using experimental and theoretical analysis. The experimental Floyd's pressure vessel was made of epoxy resin, which is an almost incompressible material ($\nu=0.5$), the experimental analysis was performed using photo-elastic model and all the stresses are computed along the line BE, as shown in Fig. 8.

The problem is solved numerically using boundary elements method of the present work, and compared with finite element solution using ANSYS 10.0. The boundary elements mesh used is of 38 of 3-node quadratic elements. The boundary conditions are as follows: The material originally on the axis of rotation was constrained to remain on the center line (i.e. $u=0$) and the material of vessel along CD is constrained to move only in horizontal direction (i.e. $v=0$). These boundary conditions properly reflect the symmetry of the problem.

The stress results from boundary elements solution of the present work are compared with corresponding values obtained from and ANSYS 10.0, and these results are compared with Floyd's

experimental (photo-elastic) results obtained by at the inner and outer surface of a line of interest (BE), as shown in the following table.

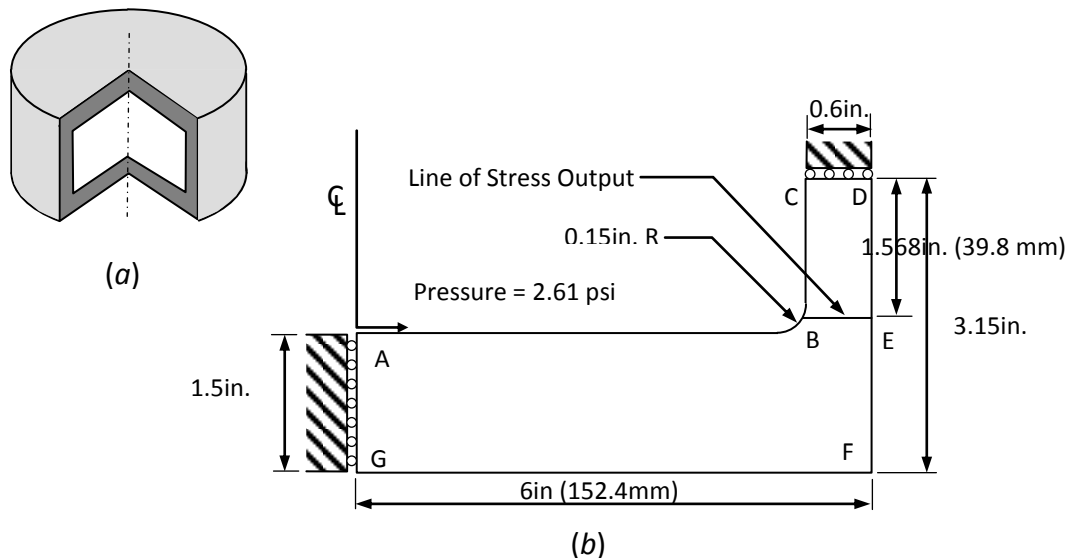


Figure 8: Axisymmetric pressure vessel geometry. (a) Schematic drawing. (b) Dimensions

Principal Stresses		Floyd 1984 Experimental	BEM Present Work	ANSYS 10.0 $\nu=0.49$	ANSYS 10.0 $\nu=0.49999$
σ_3	Inner surface	2130	2101	2344	2398
	Outer surface	-1000	-990	-1022	-1029
σ_2	Inner surface	-138	-203	299	291
	Outer surface	-1517	-1476	-1356	-1348
σ_1	Inner surface	5310	5320	5308	5291
	Outer surface	0	0	-15	-13

The analysis using ANSYS required refined mesh near the fillet to produce results of sufficient accuracy. While for the boundary elements method it is only requires very simple data input with small number of elements to attain accurate results. It is seen from the above table that the results from the boundary elements method of the present work gives accurate results compared with the experimental analysis. And these results are better than ANSYS results with comparatively very little total number of nodes. The Poisson's ratio used in the boundary element data input is 0.5 exactly, while in the finite element, i.e. ANSYS, it has to be approximated as 0.49+, in the same table the results is given for the finite element with 0.49 as a first case and 0.49999 as a second case. It is seen from these results that the chosen value of the approximated Poisson's ratio affect the results significantly and the results are not converged as increasing the value from 0.49 to as close value as near 0.5, and the question arises if there is a specific value of approximated Poisson's ratio that gives better results?

LARGE DEFORMATION ANALYSIS

Large Deformation of Rubber Cylinder

In this example a rubber thick cylinder of a finite length subjected to internal pressure is studied, the cylinder is considered as an axisymmetric hyperelastic solid and solved via finite and boundary element methods.

Shi Shouxia and Yang Jialing 1999 studied an infinite rubber cylinder subjected to internal pressure, the analyses type used was by considering two dimensional plane strain finite deformation. They solved the problem using Yeoh's hyperelastic constitutive model.

The dimensions and geometry of the rubber cylinder, shown in Fig. 9, are chosen to coincide with that of Shi Shouxia and Yang Jialing 1999. Therefore, the inner radius, R_i , is 70 mm; and $R_o=186$ mm and, contrarily, the length is chosen to be of finite length, viz. $L=500$ mm. The cylinder is subjected to internal pressure P .

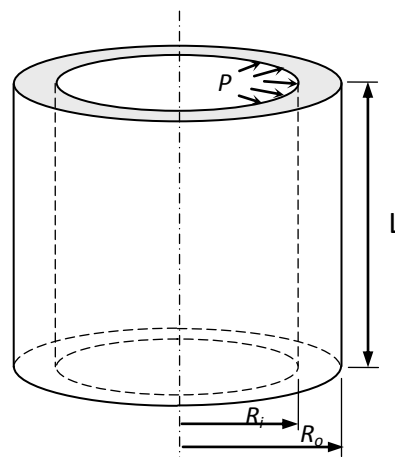


Figure 9: Dimensions and geometry of rubber cylinder

The problem was solved by using both the boundary elements method of the present work, which based on Mooney-Rivlin hyperelastic constitutive model. And using finite element methods via ANSYS 10.0. The material properties are assumed to be of Treloar, 1975, experimental data, and the stretch ratio is limited to 3. The material coefficients are calculated as: $c_{10}=1.37890$ and $c_{01}=0.324855$.

The results of the radial displacement is plotted against radial distance, as shown in Fig. 10, for both boundary elements and finite element using ANSYS. It is seen from the figure that the boundary element results is in good agreement with that of ANSYS especially when the pressure value is low, and as the value of the pressure increases the difference between the results of the boundary and finite element is slightly increases. And for internal pressure value of 3 MPa, the radial displacement is near 125 mm which gives a stretch ratio of approximately 2 in hoop, therefore the results of the constructed boundary elements program gives satisfactory values for both small and large deformations as compared with ANSYS.

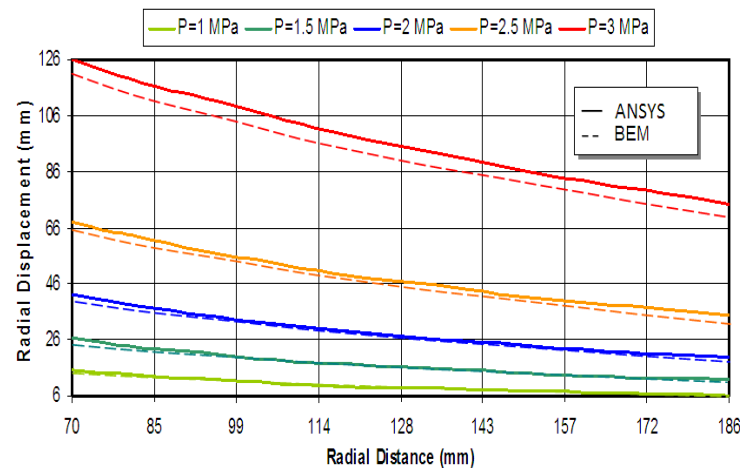


Figure 10: Radial displacement vs radial distance for rubber cylinder subjected to different values of internal pressure.

Figure 11 shows the results of the radial and hoop stresses along the radial distance for different values of internal pressure for both boundary elements and finite element using ANSYS. It is seen from the figure that results are in good agreement for both boundary and finite elements.

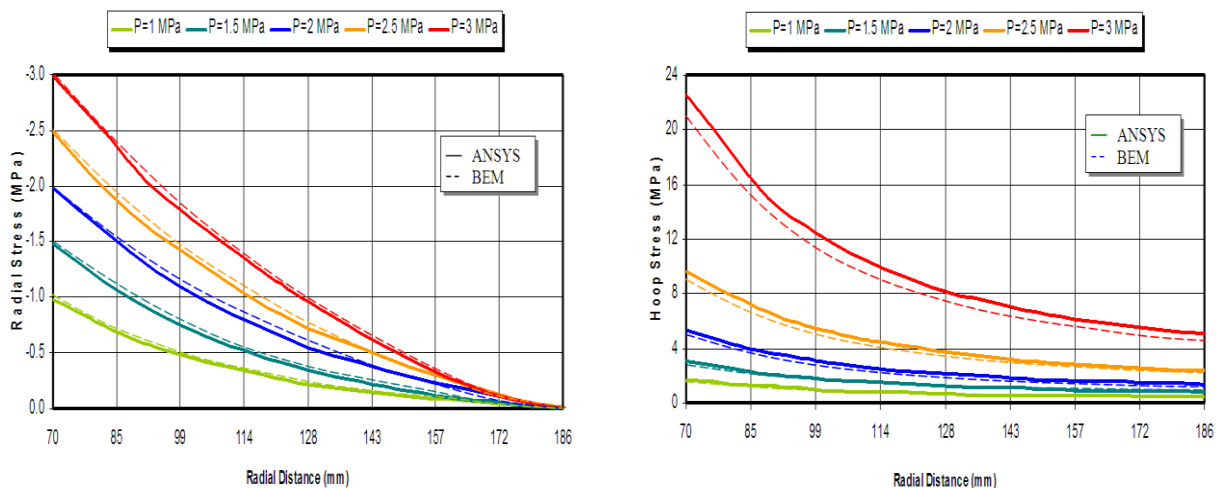


Figure 11: Radial and Hoop stresses versus radial distance for rubber cylinder subjected to different values of internal pressure.

Generally, for both FEM and BEM numerical results, it can be seen that good agreement of the results is obtained and that the expected shape of displacement and stress distribution is correct. Specifically, the radial stress is equal and opposite to the internal pressure on the internal radius and zero radial stress on the outer radius. And the absolute value of hoop stress at all radial position is greater than the absolute values of the radial stresses.



CONCLUSIONS

The following conclusions have been made regarding the use of the boundary elements method for solving elastomeric problems:

- The boundary element method is shown to be good and useful numerical technique for solving problems of incompressible elastomeric materials. The numerical results are improved by handling singularities using some sort of transformation or redistribution techniques for the Gauss integration points.
- In using this method there is no need to approximate the Poisson's ratio as required in the finite element techniques.
- The formulation for the large strain analysis is based on decomposing the 1st Piola-Kirchhoff stress into linear and nonlinear parts. For the non-linear analysis the incremental procedure is used with an iterative algorithm.
- Comparing the results with the available ones or with ANSYS 10.0 shows that this technique is satisfactory approximation and gives good results.

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NOMENCLATURE

C_{ij}	Cauchy principal value	
E	Modulus of elasticity	N/m^2
F	Shape function matrix	
G	Shear modulus	N/m^2
n_r, n_z	Direction cosines of the outward normal $\hat{n}$	
t	Traction components	N/m^2
T_{ij}	Traction kernel functions	
u	Displacements components	m
U_{ij}	Displacement kernel functions	
$\varepsilon_r, \varepsilon_\theta, \varepsilon_z$	Strains in r, θ, z direction	
$\sigma_r, \sigma_\theta, \sigma_z$	Stresses in r, θ, z direction	N/m^2
β_r	Radial components of the body force	
β_z	Axial components of the body force	
δ_{ij}	Kronecker delta	
ϕ_i	Interpolation (shape) function	
Γ	Boundary of the problem	
ν	Poisson's ratio	

THE APPLICATION OF A STEP BY STEP TECHNIQUE FOR THE PERFORMANCE PREDICTION OF THERMAL POWER PLANT SURFACE CONDENSERS

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ABSTRACT:

In the present work, the step by step technique is used to predict the performance of the power plant condenser. The procedure includes the calculation of pressure distribution, condensation temperature, water inlet and outlet temperature, condensation load distribution and single phase heat transfer sub-cooling. A quasi two dimensions model is applied, one in the tube water direction and the other in the vapor direction. It is applied with different operating conditions of the condenser such as operating pressure, air percentage mixed with steam, cooling water temperature and fouling factor on tube side for summer and winter seasons.

The present model revealed that the fouling resistance has a great effect and plays the major part of the decline in the condenser performance. This is because it decreases the overall heat transfer coefficient and condensation rate. The performance of the condenser when the cooling water enters at the lower pass is better than the upper pass, due to the balance in the distribution of the heat transfer and the condensation rate between tube passes. The model is verified with field operating conditions of Southern Baghdad thermal power station. It has revealed that there is a good agreement between the field data and the present technique. The accuracy fell within (98) % and (89) % for the cooling water temperature prediction for summer and winter respectively, while it showed accuracy of (98) % and (99) % for the condensate exit temperature prediction for summer and winter respectively.

استخدام تقنية الخطوة - خطوة للتنبؤ بأداء المكثفات المستخدمة في محطات الطاقة الحرارية

الخلاصة

يتضمن البحث الحالي تطبيق طريقة الخطوة-خطوة للتنبؤ بأداء المكثفات المستخدمة في المحطات الحرارية لإنتاج الطاقة الكهربائية. الطريقة المقترحة تتضمن حساب توزيع الضغط ، درجة حرارة التكثيف ، درجة حرارة الدخول والخروج لماء التبريد، توزيع معدل التكثيف بالإضافة إلى انتقال الحرارة للطور الواحد لدرجة أقل من درجة حرارة التشبع. تم تطبيق نموذج ذو بعدين ، أحدهما باتجاه جريان ماء التبريد والآخر باتجاه

انسياب البخار. ظروف عمل مختلفة للمكثف تم اعتمادها مثل ضغط التشغيل ، النسبة المئوية للهواء المتسرب مع البخار ، درجة حرارة ماء التبريد عند الدخول للمكثف بالإضافة لمعامل الاتساخ لجانب الأنابيب لفصلي الصيف والشتاء.

لقد بين النموذج الحالي بان مقاومة الاتساخ الحرارية لها تأثيراً كبيراً وتلعب دوراً أساسياً في تدهور أداء هذه المكثفات. إن هذه المقاومة الحرارية تؤدي إلى تقليل معامل انتقال الحرارة الكلي و معدل تكثيف البخار في المكثف. أداء المكثف يكون أفضل عندما يدخل ماء التبريد إلى المكثف في الممر السفلي لكونه يؤدي إلى توزيع متجانس لمعدل التكثيف والحمل الحراري على ممرات ماء التبريد للمكثف. لقد تم التحقق من صحة النموذج الحالي باستخدام الظروف التشغيلية لمحطة كهرباء جنوب بغداد الحرارية. لقد بينت الدراسة توافق جيد بين القراءات التشغيلية وتلك المحسوبة بالعمل الحالي ، وبدرجة دقة تتراوح بين (98%) و (89%) لدرجة ماء التبريد لكل من فصل الصيف والشتاء على التعاقب. في حين كانت النتائج لدرجة حرارة بخار الماء المتكثف المحسوبة بالنموذج الحالي تقع ضمن المدى (98%) و (99%) لكل من فصل الصيف والشتاء على التعاقب.

KEY WORDS: Iterative, Power Plants, Surface Condenser, Performance, Prediction

INTRODUCTION:

The condenser is a device in which the vapor is converted to liquid and latent heat is transferred to coolant. A common type of condensers is indirect contact condensers in which vapor does not mix with the cooling fluid, the shell and tube type is the common one and the most widely used.

(Jacob, 1959) introduced the mean heat transfer coefficient for a vertical column of (N) horizontal tubes with the same temperature difference. The influence of the drag extended by the vapor on the condensate film was considered by (Chen, 1961), and (Koh et al., 1961), from numerical solution of the governing equations. (Chisholm et al., 1965), developed a numerical method of evaluation heat and mass transfer coefficient and local heat fluxes in surface condensers. (Patankar and Spalding, 1974), introduced a more practical approach by considering the tube nest as porous medium allowing coarser computational grid to be used and hence economize on computer requirements. (Fujii, 1983), treated condensation phenomenon in small simple tube banks as a basic problem for research and development on turbine condensers.

(Zhang, 1994), proposed quasi-three dimension numerical model to predict performance of large power plant condensers. The prediction was achieved by solving the governing mass, momentum and air concentration by using semi implicit consistent control-volume for simulation with different conditions in work of condenser. A test facility was constructed by (McNeil, 1999), and used to generate data for filmwise and dropwise condensation from steam and steam-air mixtures flowing downward across a bundle of tubes. Pressure drops in a dropwise bundle are not noticeably different from a filmwise bundle.

(Karl and Hein, 1999) found that the non-condensable gas accumulates in the vapor phase boundary layer and causes a high heat transfer resistance, especially with high pressures and low water temperatures. (Seungmin, 2003), examined numerically the annular filmwise condensation

of vapors in a vertical tube with non-condensable gases. (Liang et al., 2004), presents accurate numerical solutions of the full two-dimensional governing equations for steady and unsteady laminar/laminar internal condensing flow. (Tarrad and Kamal, 2004), studied the performance prediction of Al-Daura steam power plant condensers, Fig. 1, in a quasi-two dimensional model. It revealed that cooling water resistance represents the greatest one among the whole resistances.

In the present work a step by step technique was used for the performance prediction of an existing power plant surface condenser. It provides a powerful tool for the performance assessment of the condenser working under various operation conditions at which the different measures that control the proper work of such equipments were investigated.

THEORETICAL TREATMENT MODEL:

The overall heat transfer coefficient that refers to the outside tube area may be expressed as, (Davidson,1987).:

$$U = \frac{1}{\frac{d_o}{d_i} \frac{1}{h_i} + \frac{d_o \ln\left(\frac{d_o}{d_i}\right)}{2 k_w} + R_f + \frac{1}{h_c} + \frac{1}{h_v}} \quad (1)$$

The heat flux at the condenser tube surface is calculated from:

$$Q = U \text{ LMTD} \quad (2)$$

FORCED CONVECTION IN TUBES:

Numerous relations have been proposed for predicting turbulent flow in tubes. The most popular correlation available for the prediction of the heat transfer coefficient is that of Petukhov cited in (Cengel, 1998) in the form:

$$Nu_i = \frac{Re_i Pr_i \left(\frac{\Gamma}{8}\right) \zeta}{1.07 + 12.7 (Pr_i^{1/4} - 1) \sqrt{\frac{\Gamma}{8}}} \quad (3.a)$$

$$Nu_i = \frac{h_i d_i}{k_i}$$

$$\zeta = \left(\frac{\mu_{ib}}{\mu_{iw}}\right)^{0.11}$$

$$\Gamma = (1.82 \log(Re_i) - 1.642)^{-2} \quad (3.b)$$

For the Reynolds and Prandtl number ranges:

$$10^4 \leq Re_i \leq 5 \times 10^6 \quad \text{and} \quad 0.5 \leq Pr_i \leq 2000$$

CONDENSATION HEAT TRANSFER COEFFICIENT:

The latent heat of condensation released as the vapor condenses must pass through a liquid film resistance before it reaches the solid surface and must be transferred to the medium on the other side.

NUSSELT EQUATION FOR A LAMINAR FILM:

The following relation for the heat transfer coefficient can be obtained from, (**Kreith and Boehm, 1999**) by the following expression:

$$h_{CN} = 0.925 \left(\frac{\rho_c (\rho_c - \rho_v) h_{fg} g k_c^3}{L_o \mu_c (T_{cs} - T_w)} \right)^{1/4} \quad (4)$$

With slight modification, the Nusselt analysis of laminar falling-film condensation over a flat plate can be adapted to film condensation isothermal horizontal cylinder. Doing so yields the following relation for the mean heat transfer coefficient as, (**Thome, 2004**):

$$h_{CN} = 0.728 \left(\frac{\rho_c (\rho_c - \rho_v) h_{fg} g k_c^3}{d_o \mu_c (T_{cs} - T_w)} \right)^{1/4} \quad (5)$$

Many investigators have made significant improvements to the original Nusselt theory to include the following effects to the condensation process:

Effect of Condensate Film Sub-cooling:

It has been shown that the cooling of the liquid below the saturation temperature during the condensation process can be accounted by using modified latent heat of condensation defined by (**Petukhov, 1998**) and (**Collier, 1972**) as:

$$h_{fg}^* = h_{fg} + 0.68 C p_c (T_{cs} - T_w) \quad (6)$$

EFFECT OF VAPOR VELOCITY:

When the vapor surrounding a horizontal tube is moving at a high velocity, the analysis of filmwise condensation is affected by the surface shear and the vapor separation and its influence upon the condensate flow, (**Thome, 2004**). In practice, shear stress will be increased and the film is thinned, due to momentum transferred to the condensing vapor.

(**Shekriladze and Gomelaui, 1966**) analyzed the case of downward vapor flow over an isolated tube. They obtained an expression for which the vapors shear dominated conditions:

$$h_c = 0.9 \text{Re}_{TP}^{1/2} \left(\frac{k_c}{d_o} \right) \quad (7.a)$$

$$\text{Re}_{TP} = \frac{\rho_c u_\infty d_o}{\mu_c} \quad (7.b)$$

When gravity and vapor shear dominated conditions, the expression will be as:

$$h_c = 0.64 \left[1 + (1 + 1.69 F)^{1/2} \right]^{1/2} \text{Re}_{TP}^{1/2} \left(\frac{k_c}{d_o} \right) \quad (8.a)$$

$$F = \frac{\mu_c h_{fg}^* d_o g}{u_\infty^2 k_c (T_{cs} - T_w)} \quad (8.b)$$

(Rose, 1984) resolved the (Shekrladze and Gomelaury, 1966) problem and obtained an improved equation (without taking the effect of separation and circumferential pressure gradient for condensate) as:

$$h_c = \frac{0.9 + 0.728 F^{1/2}}{(1 + 3.44 F^{1/2} + F)^{1/4}} \text{Re}_{TP}^{1/2} \left(\frac{k_c}{d_o} \right) \quad (9)$$

(Fujii and Kurata, 1972) modified eq. (9) to include a (generally small) correction for the fact that asymptotic shear stress expression has been used, thus:

$$h_c = \frac{0.9 (1 + G)^{1/3} + 0.728 F^{1/2}}{(1 + 3.44 F^{1/2} + F)^{1/4}} \text{Re}_{TP}^{1/2} \left(\frac{k_c}{d_o} \right) \quad (10.a)$$

$$G = \frac{\mu_c h_{fg}^*}{(T_{cs} - T_w) k_c} \left(\frac{\rho_v \mu_v}{\rho_c \mu_c} \right)^{1/2} \quad (10.b)$$

(Fujii, 1981) proposed the following experimental equations for the mean heat transfer coefficient for downward flow vapor as:

$$h_c = a F^b \text{Re}_{TP}^{1/2} \left(\frac{k_c}{d_o} \right) \quad (11)$$

$$a = 0.96 \quad b = 0.2 \quad 0.03 \leq F \leq 600$$

$$a = 0.7 \quad b = 0.25 \quad F \geq 600$$

(Berman and Tumanov, 1962) proposed from vertical down flow experimental data, corrective to Nusselt equation to take into account the effect of vapor shear as:

$$h_c = h_{CN} \left(1 + 0.0095 (\text{Re}_{\text{mix}})^{\frac{11.8}{\sqrt{Nu_{CN}}}} \right) \quad (12.a)$$

This equation is restricted for $\frac{h_c}{h_{CN}} \leq 1.5$

and

$$Nu_{CN} = \frac{h_{CN} d_o}{k_c} \quad (12.b)$$

$$Re_{mix} = \frac{\rho_{mix} u_{\infty} d_o}{\mu_{mix}} \quad (12.c)$$

EFFECT OF INUNDATION IN TUBE BANKS:

The average heat transfer coefficient at the lower tube rows is smaller than that experienced from the above tube rows, (Marto, 1988).

(Fuks, 1957) and (Kutateladze et al. ,1979) derived a non-dimensional equation which accounted for the predominant physical mechanism as:

$$\frac{h_{c,n}}{h_{c,1}} = \left(\frac{\sum_{i=1}^n m_{cr,i}}{m_{cr,n}} \right)^{-S} \quad (13)$$

(Fuks, 1957) showed that the index $S=0.07$, other authors as (Wilson, 1972) used $S=0.16$, (Grant and Osment, 1968) used $S=0.223$ and (Short and Brown, 1951) used $S=0.25$.

Effect of Non-condensable Gasses:

Since only the vapor is condensed, the concentration of the non-condensable gas at the interface is higher than its value in the far ambient. This, in turn, decreases the partial pressure of the vapor at the interface below its ambient value. The resulting depression of the interface temperature generally reduces the condensation heat transfer rate below that which would result for pure vapor alone under the same conditions, (Owen and Lee, 1983).

(Rose, 1980) used procedure, which relies on a heat mass transfer analogy to obtain solutions for the corresponding mass transfer problem. The coefficient of mass transfer is evaluated from (Rose, 1980) in the form:

$$Sh = a_2 Re_{mix}^{0.5} \Pi^{-1/3} E_v^{-b_2} \quad (14.a)$$

$$a_2 = 0.82 \quad b_2 = 0.6 \quad Re_{mix} \geq 350$$

$$a_2 = 0.52 \quad b_2 = 0.7 \quad Re_{mix} \leq 350$$

$$\Pi = \frac{P_v - P_{cs}}{P_{mix}} \quad (14.b)$$

$$E_v = \frac{P_a}{P_{mix}} \quad (14.c)$$

The partial pressure of vapor is evaluated by:

$$\frac{P_{mix}}{P_v} = 1 + 0.622 \frac{E_w}{1 - E_w} \quad (15.a)$$

$$E_w = \frac{m_a}{m_v + m_a} \quad (15.b)$$

By taking

$$Q = m_c h_{fg}^* \quad (16)$$

(Rose, 1980) showed that:

$$Q = h_{fg}^* \rho_{mix} \frac{D}{d_o} \left(\frac{w_{cs} - w_{\infty}}{w_{cs}} \right) Sh \quad (17)$$

And the heat transfer rate in eq. (16) may also be expressed as:

$$Q = h_{fg}^{*2} \rho_v \frac{D_p}{d_o} \left(\frac{T_v - T_{cs}}{T_v} \right) Sh \quad (18)$$

And the final expression for the heat transfer coefficient of the non-condensable gas, air, in the condenser has the form:

$$h_v = a_2 \frac{D_p}{d_o} Re_{mix}^{0.5} E_v^{-b_2} P_{mix}^{1/3} \left[\frac{\rho_v}{T_v} \right]^{2/3} h_{fg}^{*5/3} \frac{1}{(T_v - T_{cs})^{1/3}} \quad (19)$$

COMPUTATIONAL PROCEDURE:

The present work includes the prediction of the performance of the surface condenser used in the Southern Baghdad thermal power station. The object is to study the rating of an existing condenser and predict the total condensation load, condensation rate, pressure and temperature distribution on the steam side. The condenser is divided into a number of horizontal tube slices, rows, receive the steam and condensate from the above tube row. The first tube row is assumed to receive the steam directly from the exhaust turbine duct at its condition including mass flow rate, pressure and temperature. The condensation rate, vapor pressure, vapor temperature and overall heat transfer coefficient were calculated for each row.

The solution for the condenser rating was conducted a row by row, the exit condition from a tube row is assumed to be the entering condition to the next row and so on until the exit from the last tube slice. These calculations were based on an assumed arbitrary mass flow rate distribution

for the bays along the heat exchanger. An iterative procedure was followed to establish the rate of condensation for each bay depending on its ability for condensation which is a function of the tube side condition and position. A computer program is built to establish the performance of power plant condenser incorporating all different variables involved in the performance prediction. Detailed computer program structure and solution marching procedure for the suggested model is presented by (Majeed, 2007).

CASE STUDY:

The case study considered for verification of the present model is the condenser design and operating conditions of the unit number (1) of the Southern Baghdad thermal station. The geometrical design characteristics of this condenser are shown in **Table 1** and the condenser tubes layout is shown in **Fig. 2**. For the present work the following cases will be considered:

- Case (1):- The data of this case is shown in **Table 2** and is taken in summer.
- Case (2):- The data of this case is shown in **Table 2** and is taken in winter.
- Case (3):- all data of this case are the same as case (1) except mass flow rate of air which is as ($m_a=0.0092$) kg/s as obtained from the field data of the manufacturer company.
- Case (4):- all data of this case are the same as case (1) except that the temperature of vapor inlet to condenser which is as (316.2) K corresponding to saturation pressure of (8644) Pa in summer season.
- Case (5):- all data of this case are the same as case (1) except the temperature of water inlet to condenser which is as (290.2) K.
- Case (6):- all data of this case are the same as case (1) except the fouling resistance and roughness as ($R_f=0.00032$) $m^2.K/W$ and ($\varepsilon=0.000036$) m respectively as deduced from literatures.
- Case (7):- all data of this case are the same as case (1) except the water inlet to upper pass first.

RESULTS AND DISCUSSION:

Figure 3 shows the scheme of the longitudinal tube bundle arrangement for bay by bay condenser design. In all cases of performance prediction, Petukhov eq. (3) is used to calculate heat transfer coefficient inside tube, Fujii and Kurata eq. (10) to calculate condensate heat transfer coefficient and Rose eq. (19) to calculate air heat transfer coefficient.

Heat Load (Q):

As shown in **Figures 4** and **5**, the trend of the curves of heat transfer is the same for upper pass in case (1) and case (2), but the magnitude of reduction in heat transfer between rows is different according to pressure drop. For example, in case (1), the difference between rows in upper pass is (1163-1745) W and (2663-5003) W. For the lower pass, the trend of these curves is the same, but the magnitude of reduction between the first row in lower pass and the vent is different according to pressure drop. The extreme drop in curves for lower passes in the rows number (8) and (9). This is because that the number of tubes in these rows which are (19) and (20) are less than that of the other rows. This makes the quantity of cooling water less than in other rows, which explains the heat transfer decrease. As the pressure of vapor decreases towards the vent, the heat transfer rate of the tube rows and bays decreases. This can be explained by the decrease of temperature difference between vapor and cooling water which causes a decrease in heat transfer transmitted.

The variation of the condenser load with bay number for case (2) is shown in **Fig. 6**. The greatest heat transfer occurs in bay (11) for upper pass and bay (1) in lower pass because it has the lowest cooling water temperature, as compared with other bays, which leads to high temperature difference between vapor and cooling water and, hence, an increase in the heat transfer. The heat transfer rate in the lower pass is greater than that in the upper pass because of the coolest water temperature inlets to lower pass, except in three last bays in case (1) and four bays in case (2) since the temperature of cooling water is approximately equal, while the temperature of vapor in upper pass is greater than that in the lower pass.

As shown in **Fig. 7**, the trend of the curves of case (7) is opposite to those of case (1), because the cooling water enters the condenser at the upper pass which means high temperature difference between vapor and cooling water. This explains why the heat transfer rate in upper pass is higher than that in lower pass. On the other hand, the total heat transfer rate of case (7) is less than that in case (1) in all bays because the heat transfer rate in lower pass is lower than that in case (1). This can be explained by the small temperature difference between vapor and cooling water.

OVERALL HEAT TRANSFER COEFFICIENT (U):

As shown in **Figures 8, 9, and 10**, the trend of curves is the same for all cases. Although the heat transfer rate in the upper pass is less than in lower pass, but the overall heat transfer coefficient in upper pass is higher than that in the lower pass. That is for a specified surface area, the heat flux, $UA\Delta T_m$, for the upper pass is lower than that of the lower pass due to the decrease in temperature difference between vapor and cooling water. For case (7), the overall heat transfer coefficient, as shown in **Fig. 11**, increases from first bay to the last in upper and lower passes which is different

from other cases. This is because the increase in heat transfer is more pronounced than the increase in temperature difference between vapor and cooling water. For example, the difference in overall heat transfer coefficient between bays for upper and lower passes of case (1) is (11.1-17.3) W/m².K and for case (7) is (7.2-12.8) W/m².K.

The Rose correlation showed the highest overall heat transfer coefficient, whereas the (Shekriladze and Gomelaury, 1966) one expressed the lowest value, with a maximum corresponding deviation is about (5) %. The rest of correlations revealed a discrepancy in the range (2-5) % when compared to the minimum value given by the former correlation.

The results of the present work revealed that the cooling water resistance comprises the major part of the total resistance, it is within (50-65) %. The condensation resistance is ranged between (15-20) % which is followed by the fouling resistance with a percentage of (9-15) %. The mixture resistance showed the lower value among the various resistance types with a value fell within (0.01) %.

CONDENSATION RATE AND OTHER VARIABLES:

Condensation Rate (m_{cr}): For case (1) and for upper pass, the greatest condensation rate occurs in bay (11), as shown in **Fig. 12**, because it has the lowest cooling water inlet to the bay compared with other bays. This leads to high temperature difference between vapor and cooling water which increases heat transfer rate. The trend of curves shows the reduction from inlet to tube bundle towards the last row in upper pass. This reduction is because of pressure drop through the rows. For example, the difference in upper pass is in the range of (0.0005-0.0016) kg/s.

Vapor Pressure (P_v): The pressure drop in upper pass for all cases is greater than that of the lower pass. This is because the steam sustains the greatest velocity in the upper pass, whereas a sharp decrease in the steam velocity occurs in the lower pass. **Fig. 13** shows extreme slope for pressure drop between bays. This can be explained by the large difference in steam velocity between bays. For example, in case (1), the predicted pressure drop for the upper pass was between (8.7-6.8) Pa and for the lower pass was between (1.5-.8) Pa, while in case (2) the pressure drop for the upper pass was between (12.8-8.8) Pa and for the lower pass was between (1.5-0.4) Pa.

Inlet Temperature of Cooling Water (T_i)

As shown in **Fig. 14**, the rise in cooling water is different from case to another due to the operating conditions considered. These are temperature difference between vapor and cooling water or mass flow rate of vapor or fouling resistance. The rise in case (3) is approximately equal to that in case (1), due to the little effect of the presence of air mass flow rate. For example, the rises in inlet cooling water in cases (1,2,3,4,5 and 6) are (11.4,16.6,11.4,10.1,14.2 and 12.7) °C. The results

have also revealed that the rise of cooling water temperature in case (7) was (11.7) °C. This value was less than that of case (1) owing to its high decrease in temperature difference between vapor and cooling water.

COMPARISON WITH FIELD DATA:

The present model performance predictions was compared with the field data obtained from Southern Baghdad thermal power plant. It is suggested to consider the outlet cooling water temperature and condensate exit temperature as a measure for the accuracy of prediction. **Table 3** shows the predicted and measured temperature of the above two variables. It is obvious that there is a good agreement between the field data and the present work, with accuracy fell within **(98) %** and **(89) %** for the cooling water temperature prediction for summer and winter, while the accuracy fell within **(98) %** and **(99) %** for the condensate temperature prediction for summer and winter.

CONCLUSIONS:

The performance of power plant condensers is difficult and complicated art to be checked by single parameter, therefore a quasi two dimensional computer program has been built to depict the performance of this type of condensers. The principle findings of this investigation are listed below:-

- The procedure based on the step bay step method across tube bank of the condensers provides a powerful technique for the performance prediction of the condenser.
- The program is used to study different operating conditions, to analyze them and other parameters that affect the performance of Southern Baghdad power plant. From this study the followings are noticed:-
 - i. Best performance in winter owing to the large temperature difference between vapor and cooling water and the rise in the level of the river water which decreases the deposit inlet to the condenser tubes.
 - ii. Heat transfer, condensation rate, and overall heat transfer coefficient decrease towards the vent, because of vapor pressure drop. Heat transfer and condensation rate for the pass of condenser where river water enters first are higher than the other pass, while the overall heat transfer coefficient is lower. The increase of the heat transfer rate is mainly due to the increase in temperature difference between vapor and cooling water.
 - iii. The fouling resistance has an important effect on the condenser and plays a major part of decline of the condenser performance. This is due to the increase in the fouling resistance, leads to a decrease in the overall heat transfer coefficient and condensation rate.
 - iv. The performance of the condenser when the cooling water enters the condenser at the lower pass is better than that when it enters the condenser at the upper pass. This is because of the balance in the distribution of the heat transfer and condensation rate between passes.

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NOMENCLATURE:

- a_n : Constant defined in eqs. (11) & (14.a)
 b_n : Constant defined in eqs. (11) & (14.a)
 c_p : Specific heat (kJ/kg. K)
 d : Tube diameter (m)
 D : Molecular diffusion Coefficient (m^2/s)
 D_p : Coefficient of vapor diffusion in gas (kg/(s.m.Pa))
 E_v : Pressure ratio (air to mixture)
 E_w : Mass ratio (air to mixture)
 F : Parameter defined by eq.(8.b)
 g : Gravitational acceleration (m/s^2)
 h : Heat transfer coefficient ($W/m^2 K$)
 h_{fg} : Latent heat of vaporization (J/kg)
 h_{fg}^* : Modified latent heat of vaporization (J/kg)
 k : Thermal conductivity (W/m.K)
 L : Length of tube (m)
LMTD : Logarithmic mean temperature difference (K)
 m : Mass flow rate (kg/s)
 n : Number of certain row
Nu: Nusselt number
 P : Pressure (Pa)
Pr : Prandtl number
 Q : Heat flux (W/m^2)
 R : Gas constant (J/kg.K)
 R_f : Fouling resistance ($m^2 K/W$)



Re : Reynolds number

S : Index in eq. (13)

Sc : Schmidt number

Sh : Sherwood number

T : Temperature ($^{\circ}\text{C}$)

u : Fluid velocity (m/s)

U : Overall heat transfer coefficient ($\text{W/m}^2 \text{ K}$)

w : Mass fraction

Greek Symbols:

ρ : Density (kg/m^3)

μ : Viscosity (Pa.s)

β : Mass transfer coefficient (kg/s.m^2)

ν : Kinetic viscosity (m^2/s)

Π : Parameter defined by eq. (14.b)

Γ : parameter defined by eq. (3.b)

Subscript Symbols:

a : Air

c : Condensate

cs : Vapor/Condensate interface

i : Coolant inside tube

ib : Inside tube bulk

iw : Inside tube wall

mix: Mixture

o : Outside or outlet

TP : Two phase

v : Vapor

v_{∞} : Vapor at free stream

w : Tube wall

∞ : Free stream

Table (1.a): Geometrical Design Characteristics Data for the Test Condenser.

Input data	Value
Internal diameter of tube (m)	0.0197358
external diameter of tube (m)	0.022225
Tube pitch (m)	0.02778125
Number of bays	11
Length of bay (m)	0.72736
Width of tube sheet (m)	1.228
Number of tube passes	2
Number of tubes for all condenser	2430
Number of rows for all condenser	57
Number of rows before the vent	34
Tube numbers for upper pass of condenser	1201
Tube numbers for lower pass of condenser	1229
Row numbers for upper pass of condenser	27
Row numbers for lower pass condenser	30

Table (1.b): Number of Tubes for Each Row in the Condenser.

Number of row	Number of tubes
From(1-27) odd rows	44
From(1-27) even rows	45
28-29-30	42
31-33	35
32-34	36
35	19
36	20
37-38-39	38
40-42	44
41-43-44.....-57	45

Table (2): Shell Side and Water Side Input Data for Case (1) and Case (2).

Input data	Case(1)	Case(2)
Total mass flow rate of vapor (kg/s)	15.0926	17.26852
Mass flow rate of air (kg/s) *	0.00472	0.00472
Air mass percentage %	0.0313	0.0273
Inlet vapor temperature to condenser (K)	319.69	314.861
Air vent capacity (kg/s)	0.0275	0.0275
Total mass flow rate of water (kg/s)	791.34376	791.34376
Inlet water temperature to condenser (K)	296.2	283.2
Thermal conductivity of tube (W/m.K)	300	300
Tube side fouling resistance ($m^2.K/W$) *	0.0004	0.00032
Roughness of tube (m) *	0.000061	0.000036
Pressure of water inlet to condenser (bar)	3.5	3.5

All data labeled by (*) are assumed values.

Table (3): Comparison Between Field Data and Present Work.

Data	Field data		Present work	
	Case(1)	Case(2)	Case(1)	Case(2)
Temperature of condensate at outlet from condenser (K)	319.5	313.8	318.6	313.6
Temperature of cooling water at outlet from condenser (K)	307.2	297.2	307.6	299.8

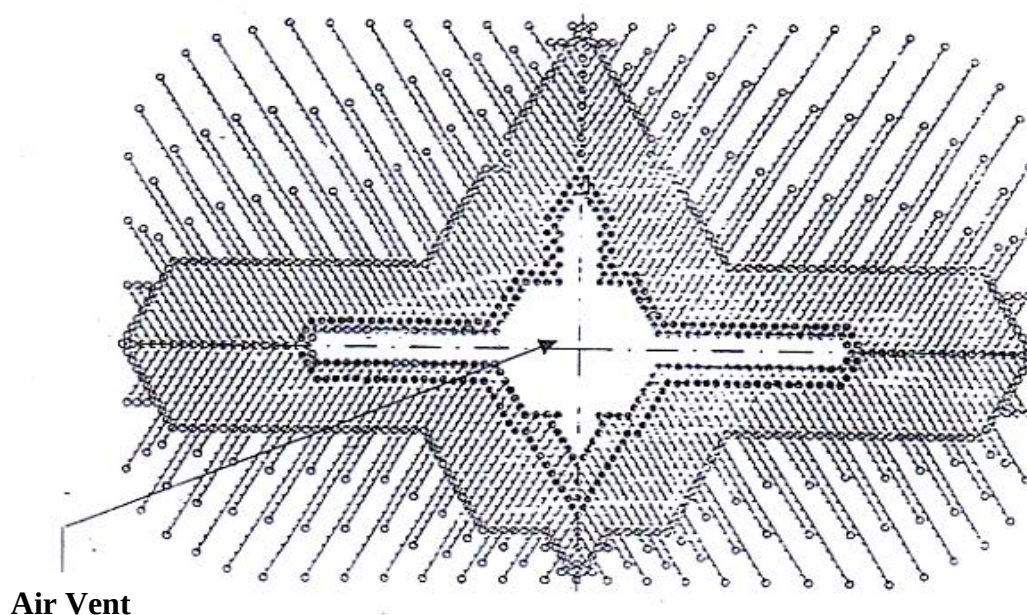


Figure (1): Arrangement of Tube Bundle in Al-Daura Thermal Power Station Condenser, (Tarrad and Kamal, 2004).

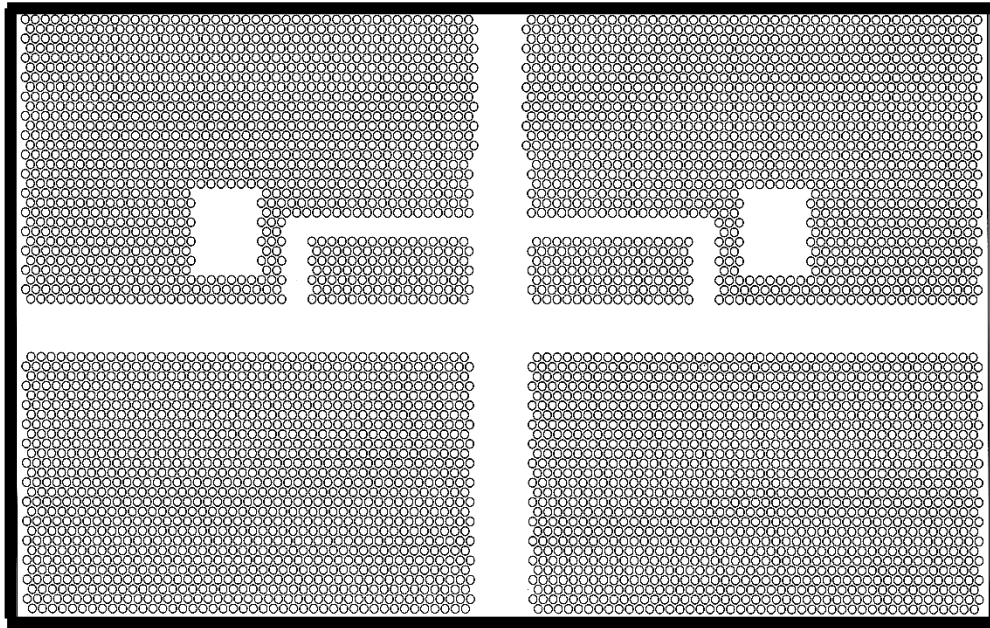


Figure (2): Geometrical Tube Arrangement of Southern Baghdad Power Plant Condenser.

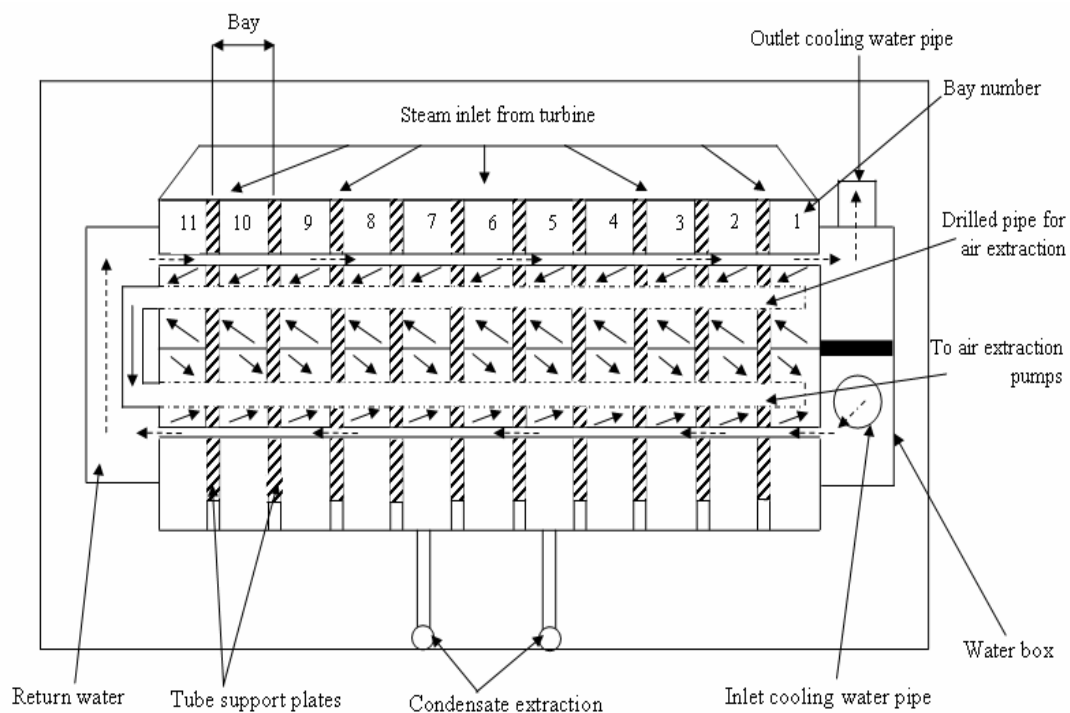


Figure (3): The Longitudinal Condenser Section for Bay and Tube Passes Arrangement.

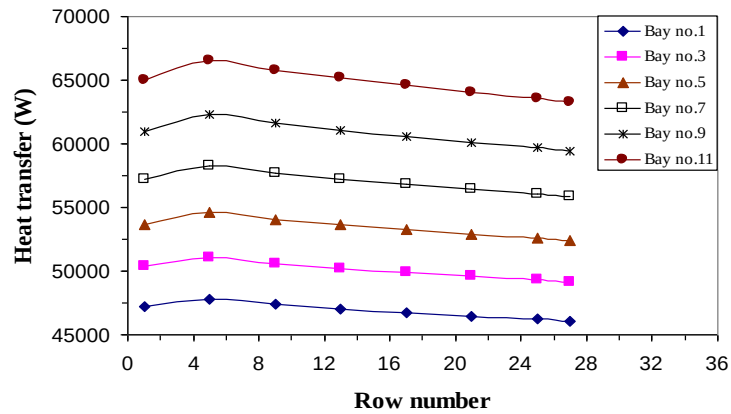


Figure (4.a):Heat Transfer Rate vs. Row Number for Upper Pass, Case (1).

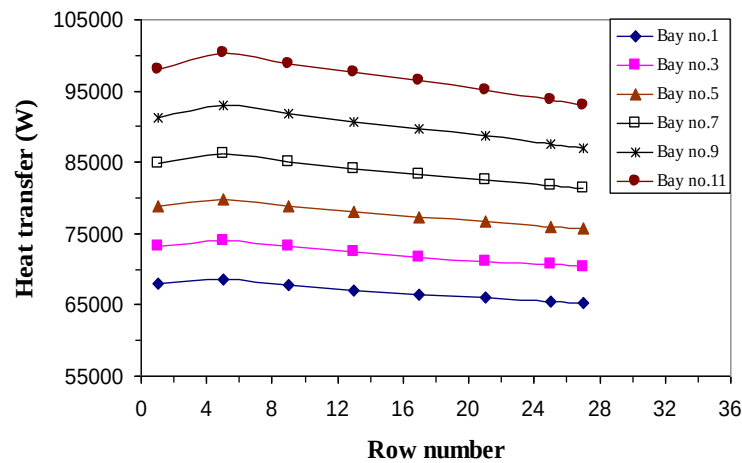


Figure (4.b):Heat Transfer Rate vs. Row Number for Upper Pass, Case (2).

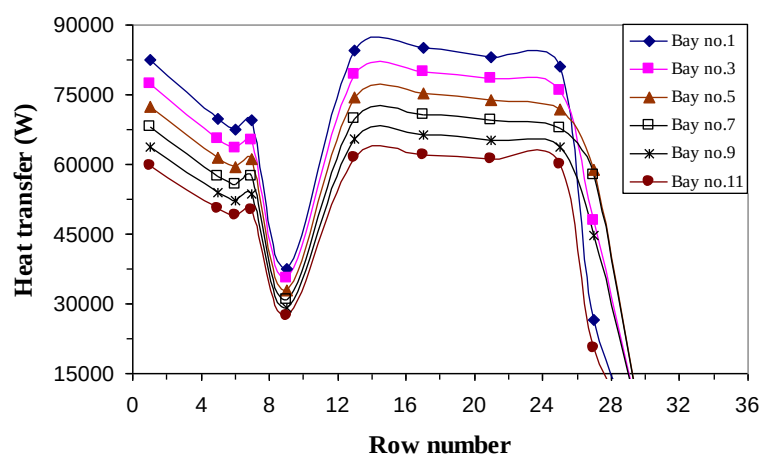


Figure (5.a):Heat Transfer Rate vs. Row Number for Lower Pass, Case (1).

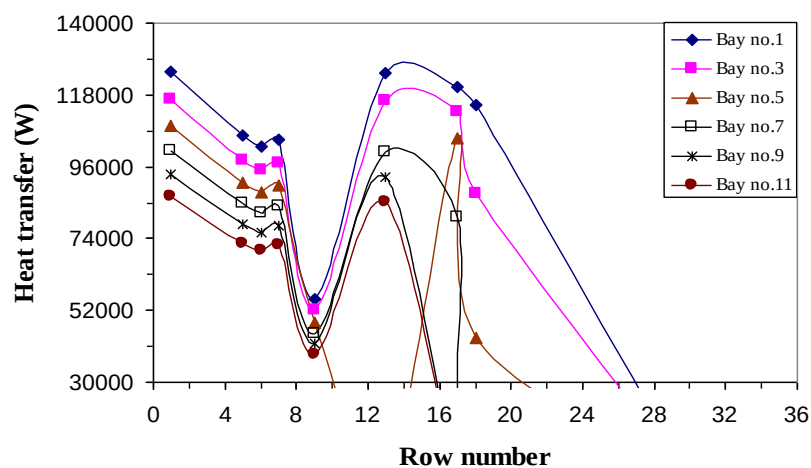


Figure (5.b):Heat Transfer Rate vs. Row Number for Lower Pass, Case (2).

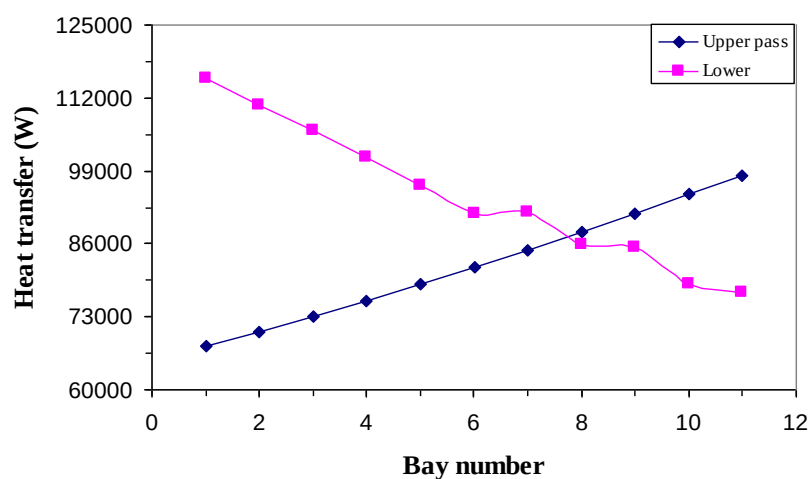


Figure (6): Heat Transfer Rate of Case (2) vs. Bay Number.

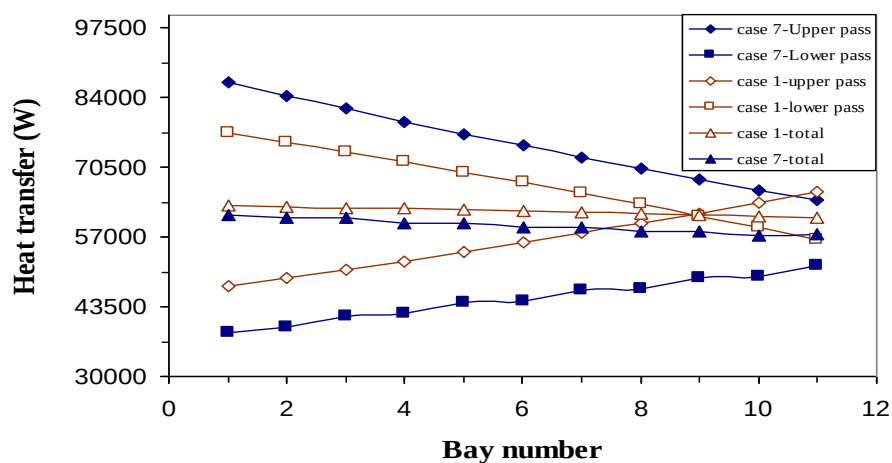


Figure (7): Heat Transfer Rate of Cases (1 & 7) vs. Bay Number.

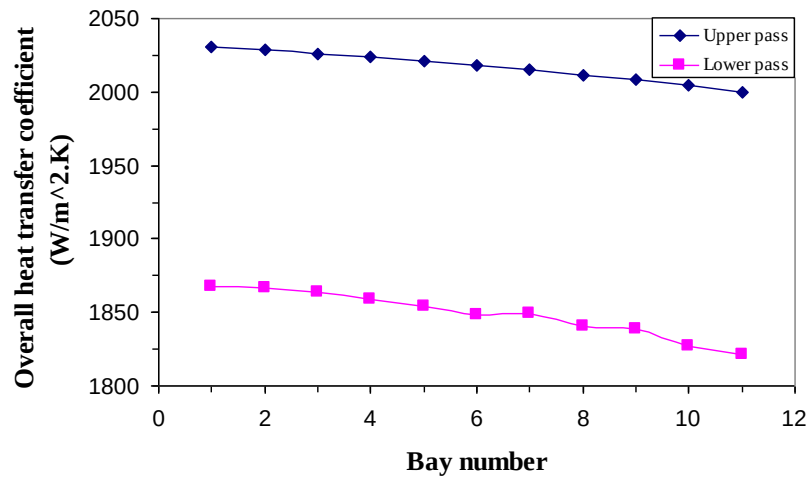


Figure (8): Overall Heat Transfer Coefficient of Case (2) vs. Bay Number.

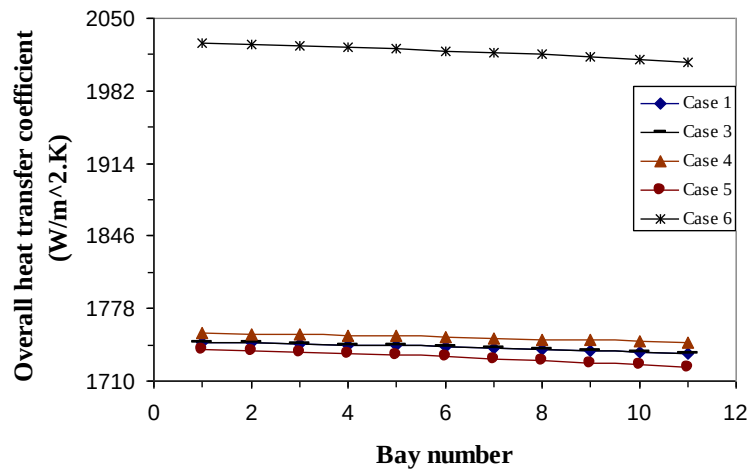


Figure (9): Overall Heat Transfer Coefficient of Various Cases vs. Bay Number for Upper Pass.

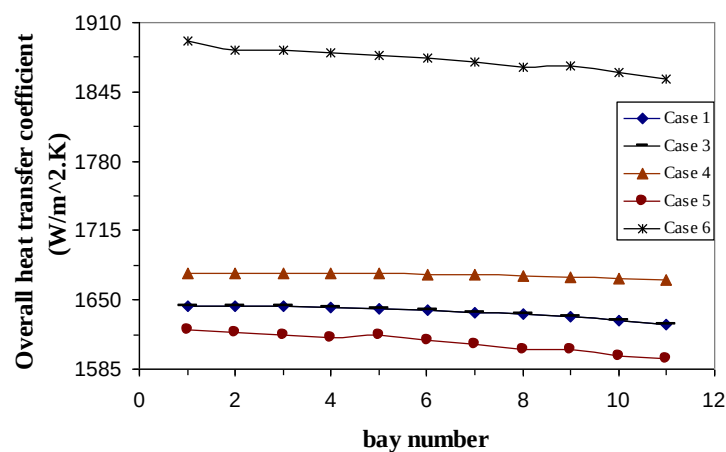


Figure (10): Overall Heat Transfer Coefficient of Various Cases vs. Bay Number for Lower Pass

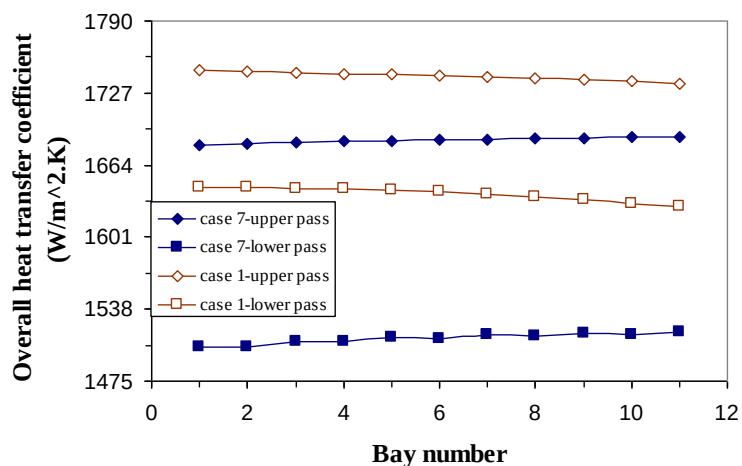


Figure (11): Overall Heat Transfer Coefficient of Cases (1 & 7) vs. Bay Number.

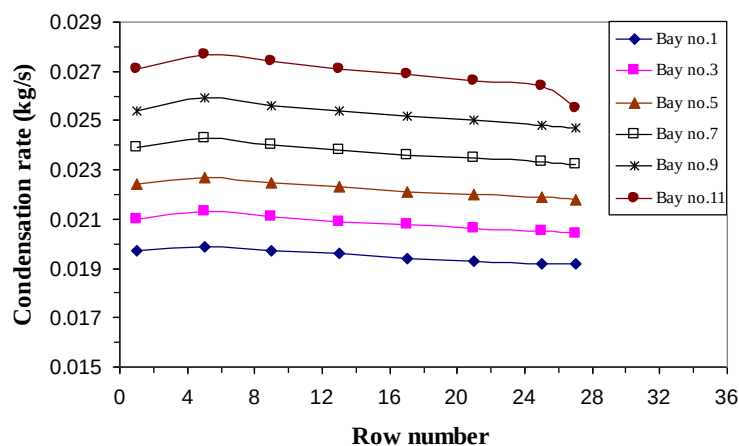


Figure (12): Condensation Rate Vs. Row Number of Case (1), Upper Pass.

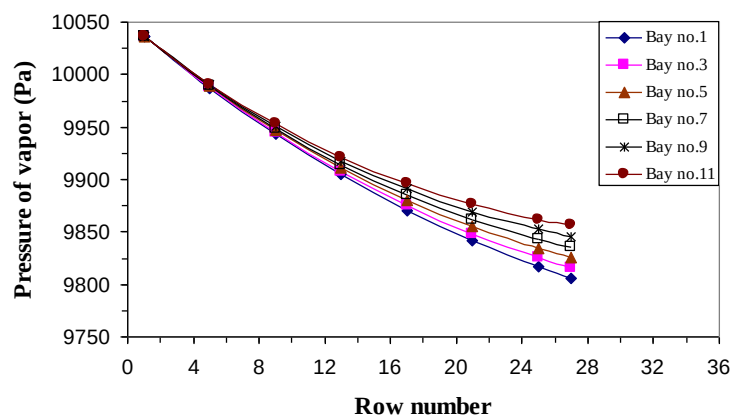


Figure (13.a): Pressure of Vapor vs. Row Number of Case (1) for Upper Pass.

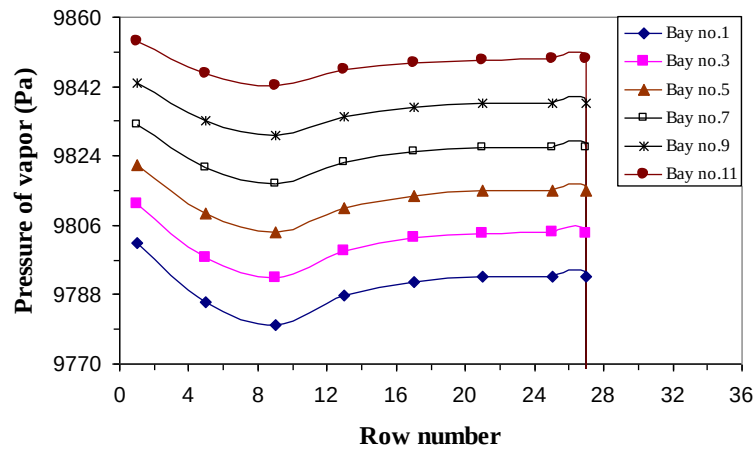


Figure (13.b): Pressure of Vapor vs. Row Number of Case (1) for Lower Pass.

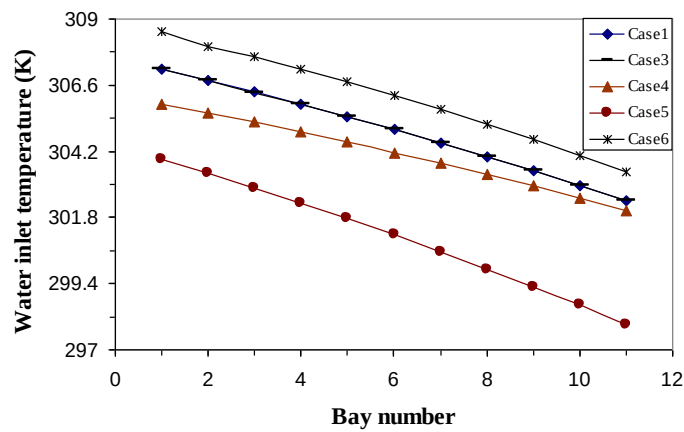


Figure (14.a): Water Inlet Temperature of Various Cases vs. Bay Number for Upper Pass.

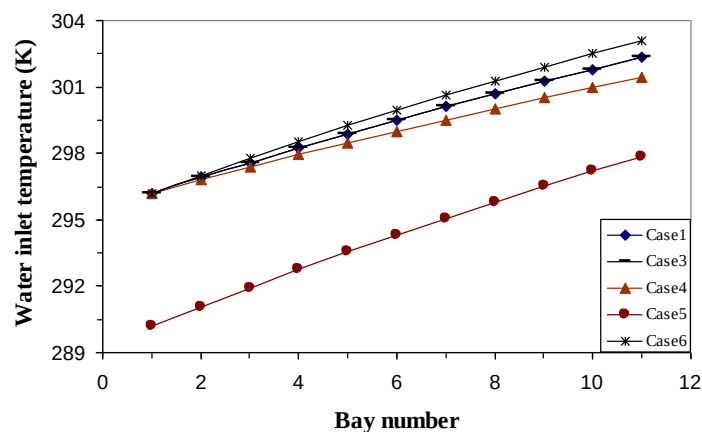


Figure (14.b): Water Inlet Temperature of Various Cases vs. Bay Number for Lower Pass.

نظرية الفوضى وتوليد الشكل المعماري

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الخلاصة

يتميز العصر الحديث بالإنتاج الهائل للمعرفة كماً ونوعاً يصاحبه تغير سريع في التخصصات والاهتمامات والمصطلحات وحتى وجهات النظر المعرفية، فقد ازدهرت في الأعوام الأخيرة طرق تفكير جديدة في حقل الرياضيات العائد لنظرية الفوضى هذا الحقل الذي استمر في النمو والتطور بسرعة في اتجاهات عديدة، بكل ما تحمله من امكانات للتطبيق على مدى واسع ومتنوع من الظواهر. وتمثل الأدوات والمفاهيم التي تزودنا بها هذه النظرية قطيعة جذرية مع الأساليب الرياضية السائدة التي أسست للعلم الحديث منذ غاليليو وديكارت ونيوتن وتمكّننا من رؤية العالم رؤية مختلفة جذرياً عن السابق ومن فهم أفضل لقواه المحركة وتنظيمه الذاتي وتطوره، وقادت إلى نتائج غير محسوبة التوقعات في مجالات عدة منها العمارة. ناقشت العديد من الطروحات المعمارية نظرية الفوضى وتركزت على تبيان تأثيراتها في حقل العمارة من خلال طرح نظري عام للنظرية ومفرداتها، ألا أن معظم هذه الطروحات لم تتطرق إلى أهمية النظرية واستثمار مفاهيمها في اطار التوليد الشكلي للنتائج المعمارية، وعليه جاءت أهمية البحث كونه يسعى للإجابة عن سؤال مهم بدأ منه البحث وهو: (مدى إمكانية تبني وسائل جديدة لتوليد الأشكال المعمارية؟). وعلى ضوء المعرفة العلمية المتأتية من نقد الدراسات المتخصصة (المعمارية والعلمية) تم صياغة مشكلة البحث المعرفية: (عدم وضوح القدرة التوليدية لنظرية الفوضى في العمارة لتوليد أشكال جديدة)، إذ استهدف البحث الكشف عن القدرة التوليدية لنظرية الفوضى في العمارة لتوليد أشكال جديدة. وفي سعيه إلى بناء أطار نظري لمفردات التوليد الشكلي على وفق نظرية الفوضى توصل البحث لصياغة ثلاث مفردات توليد رئيسة (الدynamية-التعقيد-المرونة)، ومفترضاً إنه (يمكن توليد أشكال جديدة في حقل العمارة من خلال توظيف مفاهيم نظرية الفوضى)، بدأ البحث بتحقيق هدفه من خلال الجانب العملي الذي توصل إلى صيغة برمجة خاصة للبرنامج الحاسوبي (Form) بهدف توظيف المفردات التي تخص التوليد الشكلي على وفق نظرية الفوضى لتوليد أشكال معمارية جديدة، وقد توصل البحث إلى مجموعة من الاستنتاجات التي تخص نظرية الفوضى ومفردات توليدها الشكلي لأشكال جديدة في العمارة.

Chaos theory and the Generation Of the Architectural form

ABSTRACT

The modern era features the incredible production knowledge by quantum and qualities and with quick changes in theories, interesting practices and even knowledge's view points. In the last years new thinking methods boomed in the mathematical field that refers to chaos theory, this field which continues in growth and evolution quickly in different directions, with all the practical potentiality that carried in large and variety phenomena's. The tools and the concepts of the theory is considered as a radical cutting with the known mathematical manners that based the modern science since Galileo, Descartes and Newton, and let us see the world in different and radical views, and with the best understanding for its movement powers, its self organization and its evolution. The different concepts of the chaos theory effected in all the knowledge fields and led to unpredictable results in many areas one of them is architecture. Many architectural studies discussed chaos theory and focused on its effects in architectural field through theoretical studying to the theory and its concepts, but the most of these studying didn't exploit the theory concepts in the formal Generation of the architectural deriving, therefore the research importance came from its trying to answer the important question that the research begins with: (How could new tools be adopted to the Generation of the Architectural forms?), and according to the scientific knowledge that came from the specialized study (architectural & scientific) formulating of the research's problem was: (the lack of knowledge concerning the generating ability of the chaos theory in architecture to generate new forms), therefore the research's aim was to expose the generation

ability for chaos theory in architecture to generate new forms. The research tried to build theoretical framework about the vocabularies of the formal Generation according to chaos theory the research reached to formulate three main Generation vocabularies (dynamics- complexity- flexibility), according to that the research hypothesis was: (could be generate new forms in architectural field through employing chaos theory concepts), the research started reaching its aim through the practical part which reached to formulate special programming with the computer program (Form) to employing the vocabularies of the formal Generation according to chaos theory to generate new architectural forms And finally reached to a group of conclusions that refer to chaos theory and its formal Generation to create new forms in architecture .

المقدمة :

تعد نظرية الفوضى من أحدث النظريات الرياضية الفيزيائية التي تتعامل مع الانظمة التي تبدي نوعاً من السلوك العشوائي، وتحاول النظرية أن تستشف النظام الخفي المضمّر في هذه العشوائية الظاهرة محاولة وضع قواعد لدراسة مثل هذه النظم مثل الموائع والتنبؤات الجوية والنظام الشمسي واقتصاد السوق وحركة الأسهم المالية والتزايد السكاني. ولأن العلم هو سبيل من المعارف المتتالية، يستند إلى معيار التطور والتقدم للوصول للحقيقة. لذا فإن العلم الحديث أصبح وفقاً لنظرية الفوضى يرفض مبدأ الحقيقة المطلقة، ويجد أن الحقيقة نسبية يتعين النظر إليها بعين الشك دائماً وتسليط الضوء على كافة أوجهها، وأصبحت مفردات الجزم والإطلاق والثبات والحتمية والضرورة، مفردات مرفوضة الاستعمال في السياق العلمي. وتستبدل بمفردات: الاحتمال والحقائق غير الثابتة، والشك من أجل فتح الأبواب على مصراعيها للمناقشة والتساؤل والشك والبحث للوصول إلى الحقيقة.

وبالتالي كان لابد أن تؤثر هذه النظرة العلمية الجديدة في حقل العمارة، وتستثمر في توليد الشكل المعماري، ومن هنا جاءت أهمية البحث كونه يسعى لتبني وسائل جديدة لتوليد الأشكال المعمارية، فالبحث يرى إن العملية التصميمية للتوليد الشكلي هي موهبة فنية-إبداعية باعتبارها خلقاً جديداً لمكونات معرفية عائمة ومنفصلة تجبل مع بعضها لبناء شكل جديد، وتحتاج لبذل جهد مضني من المصمم ليكون قادراً على إنتاج معرفة جديدة هدفها الارتقاء بالعمارة لمراتب أعلى وهو الهدف الاسمي، كونها مرآة المجتمع وتعكس تقدمه رفاهية وتسهم في رفد الحضارة الإنسانية، وعدّ البحث نظرية الفوضى إحدى هذه الوسائل الممكن تبنيها في إطار التوليد الشكلي.

- المحور الأول : ماهية نظرية الفوضى ؟

الفوضى في اللغة والاصطلاح

إن مفردة الفوضى متأتية من فوض، وفوض إليه الامر أي رده إليه. وقوم فوضى، أي متساوون لا رئيس لهم. ونعالم فوضى أي مختلط بعضه ببعض .

والفوضى: هي أختلال في أداء الوظائف العضوية أو الاجتماعية لفقد الرياسة والتوجيه، أو تعارض الميول والرغبات أو نقص التنظيم.

والفوضوية: هي مذهب ينادي بإلغاء الرتبة والسياسة داخل المجتمع مقررأ أن الدولة أكبر أعداء الفرد وأن في ألغائها قضاء على الافات والشرور الانسانية. (المعجم الفلسفي 1979 /ص141).

والفوضوية مذهب يقول بإلغاء الملكية والدولة وأن يصبح العلم والعقل هما المعول عليهما في إرشاد الناس. (العلالي 1974/ص265) .

والفوضى لها مرادفات عديدة في اللغة الانكليزية (chaos - disorder - disarray - clutter - confusion - madness - anarchy - lawlessness - mess - muddle). (الوافي الذهبي 2002 ، انطوان 1972) .

وما يهمننا في البحث تبيان مفهوم "chaos" لتعريف وتحديد مصطلح (chaos theory) تبعاً. لقد وردت تعريفات قاموسية متعددة لمفهوم chaos وكما يأتي:

- Chaos تعني الفوضى والتشويش والاختلال الكلي. (معجم المصطلحات العلمية والفنية الهندسية 1974) .
 - Chaos حالة التشويش المطلق، والتي منها بدأت الاشكال كحالة أساسية في الكون وفقاً للاسطير الاغريقية وهو يمثل حالة اللانظام في الفراغ ومنها أنبعثت كل الاشياء. (oxford dictionary 2000)
 - Chaos (العماء) مصطلح لاهوتي وهو على ما جاء في (سفر التكوين) خليط مضطرب من العناصر الكونية التي منها تشكل العالم ويطلق على كل ما هو ليس مرتباً ولا منسقاً. (المعجم الفلسفي 1979 /ص128) .
- لقد تم تعريب "Chaos" الى مفردات عديدة (الفوضى - الاضطراب - الشواش - اللانظام - الكيوسية - العماء...) وسيعتمد البحث مفردة الفوضى لكونها أقرب معناً ومضموناً ولورودها في معظم الادبيات العربية .

لقد كان مصطلح اللانظام disorder هو أول ما يرادف مصطلح الفوضى chaos وجذور ذلك يرجع الى قانون الترموديناميك الثاني الذي يشير الى إنتقال المواد من الحالة النظامية orderly بازدياد حالة اللانظام لتنتهي بحالة لانظامية تامة. حيث يعد مفهوم النظام هو هيكل أو بنية تنظيمية. هذه البنية عند تحطمها تدريجياً فإنها تتحول الى حالة لاشكلية, (Arnheim1996/p157). ويرى البحث أنه لابد من التمييز بين المفهومين، فاللانظام هو مستوى من النسق ذو أجزاء قابلة للتعريف والتعيين ويمكن إعطاء مقترحات حول امكانيات اصلاح أو تغيير هذا المستوى. على سبيل المثال، قد يظهر اللانظام في بعض الافعال الانسانية المختلة وغير الكاملة. أما الفوضى فهي فعل نظامي، يحدث من خلال تفاعل وتأثير متبادل بين قوى متضادة، هذا التعارض لا يدرك طالما كان ادراك الفرد يتم من خلال فهم التركيب الكلي لمجموع هذه العناصر. (Arnheim1996/p156-159) .

يوضح العلم المعاصر أن جميع الانتظامات هي حالات خاصة من الفوضى، نسبة إلى نظرية الفوضى في الرياضيات، وتؤكد النظرية على تفعيل الخيال والقدرة على ترتيب روابط بين سلاسل (علوم) مختلفة ، وبالتالي ابتكار نقلة جديدة في العلم الحديث. (يونس 2002/ص5) . - مما سبق يتبين أن مصطلح الفوضى لايعني اللانظام، بل على العكس فهو يمثل خصيصة من خصائص النظام والتي تسعى الى اختراع لغة جديدة للنظام، لذا فإن نظرية الفوضى أصبحت مفيدة علمياً ليس بقدر مساهمتها في دعم النظام، ولكن بقدر قدرتها على توليد أفكار جديدة أيضاً.

رياضيات نظرية الفوضى

إن بدايات مفهوم نظرية الفوضى ظهرت عندما قدم هنري بوانكاريه عالم الرياضيات بحثه في العام 1890م وبين أن قوانين نيوتن لا تقدّم أيّ حلٍّ لـ"مشكلة الأجسام الثلاثة"، أي كيفية التنبؤ بحركات الشمس والأرض والقمر، ووجد أن تباينات طفيفة في الشروط الابتدائية تُحدثُ تباينات هائلة في الظواهر النهائية وتتحدى الحالة التنبؤات. وهكذا صرفتُ اكتشافاتُ

بوانكاريه النظر عن الأتمودج الخطّي النيوتوني الذي كان يهمل التغيرات الطفيفة التي تبرز بروؤ غير متوقع. وقد أحدث البحث الذي توصّل إليه بوانكاريه عواقب إيجابية على إبداع نظرية الفوضى. وقد وضع العالمان لي Li ويورك Yorke في العام 1975م مصطلح "الفوضى" في سياق علمي للإشارة إلى مشكلة رياضية فحواها وصف التطور الزمني الذي يعتمد اعتماداً حساساً على الشروط الابتدائية. وقد استخدم البيولوجي والرياضي روبرت ماني Robert Many المصطلح ونشره في الأوساط العلمية حتى اشتهر. (رومية 2003/ص1-2) .

ومن دراسة منظومات التكيف المعقدة التي استخدمها بوانكاريه وبريغوجين اقترح الرياضي رونييه توم René Thom ما يُعرف حالياً باسم "نظرية الكارثة" catastrophe theory، أو الوصف الرياضي لكيفية تشعّب أو تقوُّع المنظومة الفوضوية، وطوّر نورمان باكارد وكريس لانغتون نظريات "حافة الفوضى": إذ تسبب الطاقة المتدفقة وتقلباتها عبر المنظومة تغيرات لانهائية، إما أن تضخّم الآثار الناتجة أو تُضائلها. يحدث هذا عند "التحول الطوري" لتيار الفوضى (يصف التحول الطوري المنظومة عندما تتغير من حالة إلى أخرى)، وقد يؤدي إلى إعادة تنظيم كاملة للمنظومة كلّها بأسلوب غير متوقّع أبداً.

الفوضى وحوار الطبيعة الجديد

ثمة مشاهد كثيرة في الطبيعة تُعدّ مثلاً للحركة الفوضوية. ونعدد منها مساقط المياه، وتشكّل الغيوم وحركاتها، وتبخّر المحيطات، وانفجار البراكين، وتشكّل السواحل والجبال، ونمو الأشجار، وتقلّب المناخ، والدوامات النهرية، وتوزع الإلكترونات الحرة في المواد الصلبة، وانطلاق غاز ما، وانتشار حريق أو وباء (الخوري 2003/ص2).

تنحو الطبيعة باستمرار إلى خلق المزيد من النماذج المعقدة؛ لكنها تحافظ، في الوقت نفسه، على نسق أساس. فبلورات الثلج السداسية المنمّقة يتجمع مثلاً بعضها إلى بعض لتشكل ندفة ثلجية لها من التعقيد ما لا يجرؤ أي رياضي أن يطلق عليه اسماً! وهذا ما يدعى في الرياضيات بتضاعف القصيمات . فأعقد البنى الطبيعية يمكن إرجاعها إلى تضاعف وتراكب قُصِيَمَات fractals* (أنماط هندسية متكررة) أساسية مكونة ما يدعى الهندسة الكسرية وهي من صور وتكوينات الأشكال الفوضوية . وهكذا فإننا نجد في خضمّ الفوضى التي تجنح الطبيعة إليها إشعاعاً ناظماً من قوانين التناسب، ولعل هذه الثنائية بين ظاهر الفوضى وباطن النظام هي التي أدّت إلى تفتح الوعي والطبيعة، وإن لم تكن لتقنّع أبداً بالأشكال البسيطة، إلا أنها لم تعدل أبداً قوانينها الأساسية البسيطة التي تقوم على مفهومي الوحدة والاتساق. (الخوري 2005/ص2).

ومن هذا نستنتج أن قانون الفوضى، كما وجدنا، يؤدي إلى أشكال ناظمة غاية في الإشراق. وهذا الصراع بين الميل إلى الفوضى والبحث عن حلٍّ أمثل للحركة باتجاه الانتظام والوعي هو جوهر الجمال الذي نشعر به في الطبيعة .

المحور الثاني : نظرية الفوضى وفكر العمارة :

* fractal :- أن التسمية مشتقة من الجذر اللاتيني franger الذي يعني "كسر" أو "شرح"، ومن الصفة fractus التي تحمل معنى اللانظام والتكسر. وأراد ماندلبورت B. Mandelbort جمع هذين المعنيين في كلمة "فراكتال". وهكذا فإن هذا المعنى بالنسبة لماندلبرت يشتمل على الشكل والصدفة والبعد. ومن خلالها وضع هندسة جديدة تختلف اختلافاً جذرياً عن الهندسة الإقليدية ودعاها بهندسة الفراكتالات (الهندسة الكسرية). (الخوري 2003/ص8).

نظرية الفوضى وحوار الشكل في العمارة

تتبلور الأفكار في العمارة من خلال الشكل الذي يحل محل الصور الإدراكية ، فخير وسيلة للمرور إلى التعبير يكون من خلاله. فالاهتمام بالشكل المعماري وفق نظرية الفوضى هو حصيلة من الاهتمامات بجوانب متعددة، في التوليد والإجراءات وكيفية التجسيد التي تتم على الشكل، والتي يهدف البحث الى تبينها من خلال الاهتمام بما يجري على الشكل من تغييرات والطريقة التي تتم بها وكيفية استثمارها في عملية التصميم الأمر الذي تطلب متابعة خاصة للموضوع بالاطلاع في البدء على ماهية الشكل ومصادره وموقف نظرية الفوضى منه

- يبين د.محمد إن العالم يشهد منذ نشأته حواراً حول الشكل وتوليده ، ومعه جرى التطوير ليكون أكثر تماشياً وملاءمة، وهو كل شيء ولا حدود له الا عندما يحاط أو يستوعب. فكل شيء جرى بالتطور، اذ بدأ الانسان مصمماً، ومطوراً لمفرداته (الاشكال) وهكذا نشأ التحضر ونمت المعرفة.

- إن الشكل الاول لاشك هو الاساس .

- إن الشكل التالي والتالي هو المستحدث المتوالد الذي أرتقى بفعل قدرة وجهد التكوين المجتمعي الذي كان امام الحاجة وصار موطاً لها. (محمد ب 2005/ص76) .

أن ما يحدث لخلق الشكل بأختصار هو تذويب النظام وتنظيم الفوضى أي عملية تفكيك وبناء. فخلق الشكل هو أكثر بكثير من مجرد عناصر شكلية، فالشكل يعطي إشارة Sign تنعكس من خلال ثلاثة جوانب الأول هو العناصر ذاتها، والثاني يرتبط بترتيب العناصر وتركيبها مع بعضها والجانب الثالث هو المعنى ومدى تأثير الشكل في الناس. (المالكي 2002/ص163) .

وهذه الجوانب الثلاث مهمة في عملية التوليد الشكلي لنظرية الفوضى، وبالتالي على أدراك المتلقي للشكل الفوضوي، فالافراد يمكن أن يختلفوا على الشكل الأساس المتوالد الذي ينتج عن محاولات التوظيف أو اعادة التصميم وبهذا المعنى فأن آلية التحليل يمكن أن تتغير تبعاً لبصيرة المتلقي، وإن حدث أختلاف فهو ناتج عن سوء فهم لبنية الشكل واستيعابه الظاهري أو الداخلي. إن الاشكال القابلة على التطويع الذهني هي الأكثر فهماً للمتلقي، فالبصر وهو مؤد لوظيفة النقل لايمكن أن يشتغل أو يُفعل قنواته لولا سببية تحريضية ، فالشكل هو الذي يعطي الاسباب سواء أكانت متعلقة بمكنون داخلي أو تظهر ظاهري للنقل ويُفعل البصرآلياته بفعل ذلك ، من هنا فالكثير من العناصر التصميمية يمكن أن تؤدي دوراً تحريضياً لكي تكون في ذاكرة المتلقي. إن عملية التوليد الشكلي وفقاً لنظرية الفوضى تستند على تأمل أولاً وعلى قناعة المتلقي ثانياً. (محمد 2005/ص78).

لذا جاءت أهمية نظرية الفوضى في العمارة كونها تعزو الى اعتمادها كاستراتيجية خلق للتكوينات المعمارية المعاصرة، واستثمار اشكالها ومعانيها لتحقيق التواصل مع عالم اليوم. فالحاجة الى استراتيجيات خلق جديدة لتوليد الاشكال دعت الى انتهاز تطبيقات هذا المفهوم في الفن كبدائية، ثم انتقلها الى ميدان العمارة كنتيجة للتطور التقني وتطور وسائل الاتصالات وتقنيات الحاسوب الحديثة وفقاً للنظرة الجديدة للعالم بأخذ علم نشوء الكون وتأثير الطبيعة بنظر الاهتمام. (Greene 1980/p186)

في التسعينات من القرن العشرين برز اهتمام واسع بعلم الكون وظهرت نتيجة لذلك العمارة الكونية وعمارة التعقيد العلمي وبضمنها نظرية الفوضى والتي سميت العمارة اللاخطية حيث تم استخدام الاشكال المطوية Folding والملتوية Twists والموجية Wave والتي تعكس الظاهرة الموجية التي تمثل انتقال الطاقة في الفضاء. وهذا الادراك الجديد للواقع ادى الى قلب المفاهيم التي اعتمدت الحداثة والمتمثلة بمفهوم الحتمية ، الميكانيكية ، الاختزالية والمادية، وتم استبدالها بمفاهيم جديدة والمتمثلة بالنشوء والتنظيم الذاتي والتطور بالموازنة الرقمية ونشوء الكون. (Jencks 1997/125).

استعراض الدراسات المتخصصة (المعمارية والعلمية) :

من مجمل ماتم طرحه من خلال المحورين السابقين يتبين اهمية نظرية الفوضى وتأثيراتها المختلفة في العلوم الحديثه ، فضلا عن فكر العمارة المعاصر . ويتضح عمومية الطرح فيما يخص تأثيرها في الشكل المعماري وتوليده على وجه التحديد ولاسيما فيما يخص طرائق التوليد الشكلي . وعليه تبرز اهمية بناء اطار مفاهيمي نظري للمشكلة المعرفية للبحث لاستكشاف الجوانب الأخرى المرتبطة بها حول توظيف مفاهيم نظرية الفوضى للتوليد الشكلي ضمن العملية التصميمية في العمارة. ونحو غاية تحقيق الهدف السابق تم تقسيمها إلى محورين، هما:

- **طروحات معمارية** تتعلق بنظرية الفوضى وعلاقتها بالتوليد الشكلي في حقل العمارة.

- **طروحات علمية** لحقول معرفية أخرى تتعلق بنظرية الفوضى لاستخلاص المفردات المرتبطة بها.

من مجمل ماورد في **الدراسات المعمارية** التي تناولت نظرية الفوضى في حقل العمارة، نستخلص أهم الجوانب التي تناولتها الدراسات ونستنتج ما يأتي :-

- فيما يخص ماهية النظرية فقد أشار كل من Arnheim, Grove, Johnson الى كونها من نظريات العلم الحديث التي تتعامل مع النظام بعيداً عن حالات اللانظام والتشويه، من خلال دراسة أشكال الطبيعة وأنماطها المختلفة. وأكد كل من Gilley, Jencks, وثابت الى كونها استراتيجية خلق للنواتج التصميمي خروجاً من دائرة المباشرة في المستويين الفكري والشكلي .
- أن أهداف نظرية الفوضى أشار إليها Grove كونها تهدف الى وصف الطبيعة بهندسياتها واشكالها، وطروحات Jencks, Arnheim التي بينت أنها تهدف الى خرق دائرة المباشرة بالتعبير باتجاه اللامباشرة والتعقيد والتضمين. وبين Ostwald انها تسعى الى مواكبة روح العصر نتاجاتها خير مثال على ذلك، كما أشار كل من ثابت و Gilley الى أنها تهدف الى زيادة الانفعال بين العمارة والانسانية عن طريق تحقيق الشد والتوتر التشويقي.
- فيما يخص طبيعة الشكل الفوضوي والتي بينت دراسات Salingaros, Johnson , March & Edg كونها أشكالاً هندسية ذات أنماط منظمة، كما بينت دراسات Grove, Jencks, Arnheim وثابت الى كونها أشكالاً (طبيعية، كوني، عضوية، تكوينات فنية).
- أن طبيعة معاني الشكل الفوضوي المراد التعبير عنها تمثلت بأبراز جمالية المعاني الايحائية للطبيعة، وبالتالي فإن اشكالها تعطي معاني متعددة (كالتعقيد، الانتظام، الغموض..) .

- أن خصائص الشكل الفوضوي ركزت عليها معظم الدراسات متطرفة الى بعض جوانبها مباشرة (كاللاخطية، عدم القدرة على التنبؤ، الحساسية للشروط الأولية...)، وأحياناً ضمناً (كالتكيف الذاتي، الدينامية، المرونة، التنظيم الذاتي...).
- أشارت الدراسات الى تأثير الشكل الفوضوي بضوء مفاهيم النظرية من حقول أخرى (كالرياضيات، الفيزياء، علم الكون، الطبيعيات....)، ويعد الرياضيات من أكثر الحقول المعرفية التي اعتمدتها النظرية في العمارة، من خلال قواعدها وقوانينها.
- أهمية نظرية الفوضى كمصدر للتوليد الشكلي وهو ما تناولته دراسات Jencks, Ostwald, Gilley.
- تناولت معظم الدراسات مفردتي التشابه الذاتي وتغير المقياس كآليات مستثمرة في توليد الاشكال على وفق نظرية الفوضى، واكتفت بالاطار النظري العام كدراسات Salingeros, Gilley, Ostwald, Jencks.
- اتصفت الدراسات العلمية المرتبطة بالمفهوم بالشمولية في الطرح وتناولت معظم الجوانب المتعلقة بنظرية الفوضى وبأسلوب علمي (كاللاخطية، التعقيد، التكيف الذاتي، الدينامية، المرونة، التنظيم الذاتي، عدم القدرة على التنبؤ، الحساسية للشروط الأولية...)، وارتباط المفهوم بالهندسة الكسرية وتطبيقاتها المختلفة.
- وبصورة عامة فإن الدراسات خلصت الى ما يأتي :-
- التركيز على جوانب مختلفة للنظرية بعضها تركز حول مفاهيم علمية وأخرى يمكن عكسها كجوانب ذات علاقة بالشكل وبالتوليد الشكلي في العمارة .
- جاءت المفاهيم العلمية مرتبطة بجوانب عامة تخص الكون والطبيعة .
- نظرية الفوضى تستند على رياضيات الديناميكية اللاخطية وكذلك التعقيد لتحقيق رؤيا وصور جديدة من خلال انتقال من التجزئة الى التكامل، وتطور من خلال اكتشاف (المبدأ الكوني للجاذبية)، فالفوضى هي تعقيد دينامي لاخطي.
- ترتبط الأجزاء المختلفة ضمن المنظومات الفوضوية المعقدة بشكل متأثر وتفاعلي.
- الفوضى ليست عشوائية بصورة كلية بل هي تحوي نظاماً ضمناً ضمن طبيعتها.
- الحتمية والحساسية للشروط الأولية وعدم ثبوت المقياس أو الشك تعطي في النتيجة عدم الاستقرار الدينامي والذي يمثل الفوضى .
- لا تكون المنظومة الفوضوية محددة حتمياً بشكل كامل ولا عشوائية بشكل كامل، بل تُبدي كلا الخاصيتين.
- هناك تغذية عكسية سالبة وموجبة في المنظومة الفوضوية، ويعتمد مستوى التعقيد على خصائص المنظومة وبيئتها وطبيعة التفاعل بين عناصرها.
- الانتروبي مقياس للمنظومة الفوضوية .
- أن حافة الفوضى تمثل مرحلة الانتقال من الفوضى الى النظام وتكوين شكل معقد جديد من خلال ظاهرة التشعيب.

استخلاص أبرز ما جاء في الدراسات المتخصصة :

- أهمية نظرية الفوضى في حقل العمارة كوسيلة لتوليد أشكال معمارية جديدة وتلبي حاجة العمارة المستمرة لنظريات تدعم الشكل .

- أن تأثيرات التداخل الجديد بين العمارة ونظرية الفوضى سيجقق تغييراً في البعد التعريفي للعمارة وتغيير العديد من المفاهيم المرتبطة بالعمارة كالبعد الانشائي والوظيفي والجمالي والفضائي والشكلي وكذلك توليد انماط جديدة تحقق الابداع والتواصل ويهدف الى تحقيق أنماط جديدة تسعى من خلالها الى تحقيق الابداع .
- تطبيقات نظرية الفوضى في العمارة تعتمد على قواعد رياضية في التوليد الشكلي من خلال التشابه الذاتي الذي يؤدي الى اشكال هندسية متكررة (كسرية) على وفق قواعد معينة وباستخدام عامل القياس .
- تأكيد مفهوم نظرية الفوضى في حقل العمارة كونها تمثل أقصى حالات النظام الكوني وبعيداً عن اللانظام والتشويه الذي أرتبط بالمفهوم على وفق النظرة القديمة .
- الهندسة الكسرية إحدى تطبيقات نظرية الفوضى في حقل العمارة .
- تتميز الاشكال الفوضوية بانها تحوي كمّاً معلوماتياً قد يتسم بالاستقرار والتغيير، ولكن تتجسد فيه حالات النظام الضمنية والخفية .
- الشكل على وفق نظرية الفوضى لا يتسم بالعشوائية والنشئت، بل هو ذو سمة طبيعية ومنظمة وتعطي نوعاً من التعقيد، وهي بذلك تحت قدرة العقل للمتلقي لمعالجة وفهم للشكل .
- أثر مفهوم تأثير الفراشة في الشكل على وفق نظرية الفوضى من خلال الحساسية للشروط الاولية
- الاشكال على وفق نظرية الفوضى تتسم بالتغير المستمر وبالدينامية من خلال سلسلة التحولات التي تمر بها، لذا فإنه يصعب التنبؤ بصورها أو خصائصها في المستقبل .
- الشكل الفوضوي يتميز بطاقة متدفقة تدفع بالشكل الى عدم الاستقرار الذي يكون مصاحباً لانظام مفاجئ وبدرجة عالية ويكون سبباً من اسباب حالات الابداع للشكل الفوضوي .
- يتمثل التعقيد في النظام الشكلي للفوضى من خلال الكسرية والدينامية اللاخطية، ويتولد التعقيد ذاتياً من خلال الية التكرار التي تحول المعلومات المحتواة للشروط الاولية نحو الحتمية .
- إن الانظمة الفوضوية تعمل ضمن تشكيلة واسعة من الشروط، لذا فالاشكال الفوضوية متكيفة وتتصف بالمرونة وهذه المرونة تسمح للانظمة تحمل المتطلبات المتقلبة والمتغيرة.
- تطبيقات نظرية الفوضى في حقل العمارة تمثلت بتوظيفها في أنواع التصميم المختلفة سواء على صعيد التصميم الداخلي، التصميم للفضاءات الخارجية، التصميم الحضري..... الخ .

وعلى ضوء المعرفة العلمية المتأتية من نقد الدراسات المتخصصة ، تتشكل مشكلة البحث المعرفية المتمثلة بـ:

(عدم توفر المعرفة الكافية حول القدرة التوليدية لنظرية الفوضى في العمارة لتوليد أشكال جديدة).

اما هدف البحث فانه يصاغ في حدود المشكلة المعرفية للبحث بالشكل الاتي:

هدف البحث : الكشف عن القدرة التوليدية لنظرية الفوضى في العمارة لتوليد أشكال جديدة.

المحور الثالث : مفردات الاطار النظري (مفردات توليد الشكل الفوضوي) : من مجمل ماوردته الدراسات المختلفة

التي تناولت مفهوم نظرية الفوضى سواء على صعيد التوليد الشكلي او على الصعيد النظري، فان البحث توصل الى صياغة

ثلاث مفردات رئيسية تتعلق بالشكل الفوضوي (الشكل وفق نظرية الفوضى)، تتداخل ضمن الناتج الشكلي الواحد، ويمكن اعتمادها في التوليد الشكلي للاشكال الفوضوية، وهي :

(الدينامية ، التعقيد ، المرونة)، والبحث لغرض التوضيح سيناقتش كل مفردة على حدة.

الدينامية :-

الدينامية، تعرّف بأنها "حالات البعد عن التوازن". إن حالة السكون أو الاسترخاء هي إحدى تعريفات التوازن، لكنه يتطلب أيضاً فكرة "الانزاح". يُعدُّ التوازن نادراً في المنظومات الدينامية المعقدة أو نوعاً من "مرحلة رجحان مؤقتة". وكي تبدأ الصيرورات الدينامية لا بدّ أن تتحرف المنظومة عن حالة التوازن. يرى بريغوجين أنه كلما كانت المنظومة أعقد كانت الفوضى والاضطرابات والتقلبات التي تهدد استقرار المنظومة أوفر عدداً. وعندما تصبح المنظومة عرضة للتأثر بهذه الاضطرابات فإن متطلباتها من الطاقة تتعاضد كي تحافظ على تماسكها. وتحدث التغيرات بشكل متعاقب في المنظومات المعقدة البعيدة عن التوازن، وتؤدي إلى تفكيك الرباط بين القوى الداخلية التي تعطي المنظومة تماسكها والقوى الخارجية التي تمثل بيئة المنظومة. ويتيح الرباط للمنظومة، في أغلب الأحيان، أن تعمل بسلاسة؛ ولكن عندما تتصاعد حدّة الاضطرابات، وتخضع المنظومة لـ"ضغوط" تتجاوز عتبات محددة، تبرز دلائل حادة على الفوضى، وقد تحدث فوضى لاختطية مفاجئة، فتبدأ الأشكال الحادة للفوضى بسلوك زائغ. ويسبب الانتقال أو الانزياح من جاذب إلى آخر تضارباً في سلوك المنظومة. (رومية 2004/ص5-9) .

أن دراسة ديناميكية الفوضى ترتبط بنظرية المعلومات، فالمقاييس الكمية للفوضى طورت واستعملت من خلال علاقتها بنظرية المعلومات وتطبيقاتها. فعلى صعيد الانظمة المغلقة فقد وجد ان المعلومات تبقى محصورة داخل النظام ولا تستطيع الانتقال او الهروب ولكنها تؤثر بالمجمل في ديناميكية النظام لان الانظمة المغلقة تتفاعل مع نفسها في جميع الاقطاب. ان اللأستقرار الاساس في هذه الانظمة مطلق والديناميكية محددة بمكان واحد لذا فان اغلب التجارب اثبتت ان الفوضى في هذه الانظمة لها مدى مكاني محدد، اما الانظمة المفتوحة فالمعلومات تدخل وتتدفق من خلال النظام بسهولة والديناميكية للنظام لا ترتبط بمكان محدد فاللأستقرار يمتد خلال النظام واي خلل في نقطة ما في النظام تسبب صخباً يؤدي الى الفوضى بمرور الزمن . (Miller&Swinney2001/ p5-6).

في النظم المفتوحة فان ما يدخل في النظام قد يولد تراتيباً مفاجئاً، كما تظهر حالة التحفيز الذاتي، والتي تعني ان احد انواع التفاعل يدخل دوره في انتاج ذاته. ودور التحفيز الذاتي يثبت البنية ويبقى على استمرارية شكلها وتدفقها، من خلال مفهوم الحلقات الاستراتيجية الموجبة والسالبة، مما يحقق صفة التوازن الديناميكي فيها. ومثال على ذلك الظواهر العضوية فهي تعتمد على التوازن الديناميكي في استمرارها، فالخلايا الحية محفزة ذاتياً، بمعنى انها تستطيع انتاج مزيد من نفسها بينما تصون ذاتها في محيط متغير . (Ho 2001/p118-120) .

- مما سبق نستنتج توازن ديناميكي يحصل في الانظمة المفتوحة وبدون تحكم خارجي وهو يعمل ضمن مبادئ الاتصال المتبادل و الاستجابة المشتركة معتمدا على اجزاء النظام التي تتشارك فيما بينها للبقاء على الكل. ويرى البحث أن دراسة ديناميكية الفوضى ترتبط بمفردتين (التحولات، كسر التناظر)، فمن خلال هاتين المفردتين يتحقق مفهوم الدينامية للشكل الفوضوي .

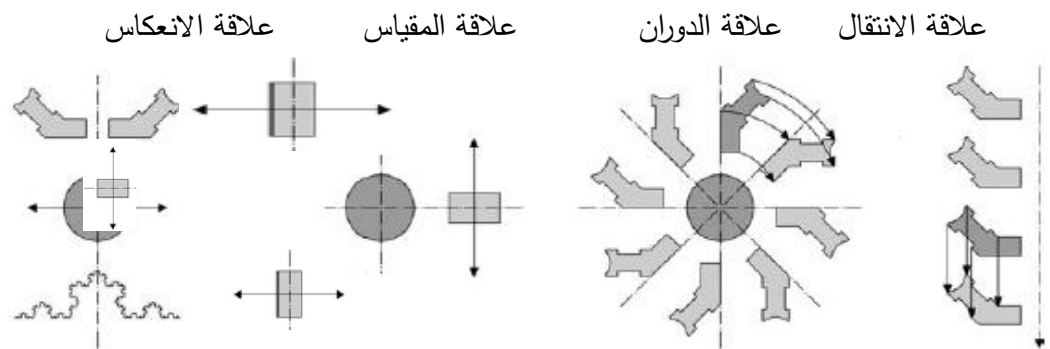
أ الدينامية والتحويلات :

أن التقلبات الخارجية أو الداخلية تسبب تحولاً في المنظومة الفوضوية من الاستقرار إلى اللااستقرار (الدينامية)؛ لكن هذا لا يحدث بالضرورة بسبب أي تحول عادي يقع، بل إنه يعتمد على نمط وقدر التحول أو الاضطراب، فضلاً عن درجة حساسية المنظومة للتأثر، هذا الأمر يجب أن يؤخذ بالحسبان قبل أن تُعد المنظومة غير مستقرة. وفي بعض الأحيان قد تحتاج المنظومة إلى أكثر من نوع من الاضطراب كي تتحول إلى حالة غير مستقرة. ويتوضح هذا من خلال "التنافس بين الاستقرار من خلال الاستمرارية، والاستقرار من خلال التحول"، حصيلة هذا التنافس تحدّد "عتبة الاستقرار" (الخوري 2003).

أن العناصر الأساسية ترتبط في أي تكوين بعلاقات معينة في توليد أشكال جديدة من الأشكال الأصلية. وأن هذه العلاقات هي مؤشر وجود الدينامية في هذا الشكل مما يعطيه إمكانية القدرة التوليدية. فالدينامية تقع ضمن أي عملية تطور ونمو سواء كان ذلك التطور شكلياً أو مفاهيمياً ، وتظهر الدينامية أثناء مراحل التطور هذه بصيغة المفاهيم الثانوية لتؤكد وجودها المستمر. وأكتسب الشكل بفضل هذا المفهوم إمكانية الاستمرار في تكوينه وتطوره، فالشكل يعتمد بفضل الطاقة الكامنة فيه على الاستمرار في كونه مما يعطي القراءات المتعددة من جهة أو الانتقال من البنية السطحية إلى العميقة من جهة ثانية وتساهم الدينامية في إبراز المعرفة المخزونة بفضل فعل المطابقة وعمليات المقارنة لتوليد التصميم الجديدة (العبودي 2004/ص13).

والدينامية تمثل التحول والانتقال من حال إلى حال في خطية أو دورية أو انكسار مع الحاجة لفضاء للتحرك وزمناً لانجازه. ولا تقود هذه التحويلات إلى تغيير الظواهر تغييراً كاملاً بل يحافظ على بعض منها. (د. مفتاح 1990/ص39). هناك أنواع عديدة للتحويلات حسب قواعد توليدها إلا أن علاقات التحول المقيسة تمثل القواعد الأساسية لتكوين الشكل الفوضوي المجرد والتي ظهرت واضحة من خلال ما تم ذكره سابقاً في أنواع الكسريات، وكما في الشكل (1) والتي تتجسد بالعلاقات المنطقية الآتية :

- علاقة الانتقال : وتعتمد على تكرار شكل معين على خط واحد.
- علاقة الانحراف الدوراني : وهو تكرار حول نقطة معينة محوراً.
- علاقة المقياس : وهو تكرار مع تغيير بالحجم على وفق معامل ثابت.
- علاقة الانعكاس : وهو عملية تناظر حول محور معين.



الشكل (1) يبين انواع التحويلات المقيسة . (المصدر :- Lorenz 2002/ P90).

- مما سبق يتبين ان العامل الاساس لحدوث الفوضى هو اللاخطية، فكلما ابتعدت المنظومة الديناميكية عن اتزانها لسبب ما زادت اللاخطية، وبمرور الزمن سوف تتعدى نقطة او لحظة حرجة وتبدأ عندئذ الفوضى ويبدأ وضع المنظومة على مفترق من الطرق، تختار احدى السلوكيات التي تحتاج الى اقل جهد ممكن وتدخل عندئذ مرحلة الفوضى الحتمية وتخلق فيها تراكيب منتظمة من خلال سلسلة من التحولات يزداد رقي تلك التراكيب كلما ازدادت الفوضى

ب الدينامية وكسر التناظر (اللاتناظر) :

أن خصائص التوازن الديناميكي في النظام الشكلي تقابل مفهوم التوازن غير المتناظر، اما التوازن الستاتيكي فانه يقابل التوازن المتناظر. ان التوازن في صفته العامة يقرب البنية من البساطة ويجعلها اسهل، لانه يقدم العناصر بشكل وقائع واضحة، الا ان ذلك قد يضعف القيمة الجمالية للشكل لذا، جاء مفهوم كسر التناظر (اللاتناظر) كمحاولة للخروج من عملية الادراك المباشر للنظام الشكلي المغلق من خلال اضافة صفات ديناميكية متأتية من تناسبية العلاقات بين الاجزاء، أي هو محاولة للاقترب من التوازن الديناميكي في النظام الشكلي. (العاني 2001/ص65).

مما سبق يتبين أن ظاهرة كسر التناظر رافقتها زيادة في تعقيد الشكل فكلما قل التناظر كلما تزداد التعقيد. أن ما يحدث في المنظومات الفوضوية يماثل هذه الحالة فالنظام يتعرض الى ضغط او ظرف معين ويحدث تغيير داخلي وحالة فوضى تنتج في النهاية شكلاً ونمطاً جديداً من خلال فقدان التناظر وبالتالي زيادة التعقيد، وبذلك يتضح اهمية توظيف مفهوم اللاتناظر في توليد الانماط الشكلية .

التعقيد :-

أن التعقيد يكمن في الفوضى وكذلك تكمن العشوائية والنظام داخل الشكل الهندسي. الفوضى تضع القيود حول عملية التنبؤ فكل شيء غير متوقع ممكن الحصول، وفي الانظمة الفوضوية لاعلاقة واضحة بين السبب والتأثير وهذا يعطيها سمة من العشوائية الانظمة الحتمية البسيطة مع بضعة مقومات وعناصر يمكن ان تولد سلوكا عشوائيا اساسياً لها وهذه العشوائية تدعى بالفوضى. أن النظام الفوضوي يتحول من نمط الى اخر بشكل مستمر وهذا يولد العشوائية الظاهرية للنظام الفوضوي والتي تمثل السطح الخارجي للنظام ويختفي تحت هذا القلب الفوضوي تركيب منظم ومعقد يحوي عدداً لا نهائياً من الحركات الدورية او المدرات غير مستقرة التي يمكن ان تنتقل من وضعية الصفر لحركة مدار ما الى نوع حركة جديد ومتغير وبسرعة كبيرة ولغرض السيطرة على الفوضى يغلق النظام على نوع معين ومتكرر من حركة واحدة . الفوضى تبين ان النظام ممكن ان يتحول الى سلوك معقد من خلال التفاعل اللاخطي البسيط لبعض مكوناته. فتفاعل المكونات على مقياس واحد ممكن ان يؤدي الى سلوك معقد جداً على مقياس كبير، فالفوضى تزود امكانية وضع التغييرات السريعة والمتطورة تحت السيطرة (Miller&Swinney 2001 p/10-11).

أن مفهوم حافة الفوضى وعلاقتها بتعقيد الطبيعة يُرى في العديد من الانظمة التي تطور تكوينات معقدة ناشئة في منطقة الانتقال بين النظام والفوضى والتي تدعى (حالة الفوضى) والتي تمثل منطقة التناقض بين الفوضى والنظام حيث يكون التعقيد ظاهراً. أن التشعبات او التفرعات تسعى الى تقديم تركيب جديد وتعقيد متزايد وخصوصاً عند الانتقال من الفوضى الى النظام وفي الديناميكية تسمى هذه الظاهرة حافة الفوضى. (fielder & king 2004 /p 88-496).

تدخل المنظومة في مرحلة التشعب إلى منطقة افتراضية (مجال افتراضي)، حيث تُصنع الخيارات أو الممكنات. قد تختار المنظومة هنا الجاذب الأكثر تأثيراً، أو يمكن أن تقفز من جاذب إلى آخر. في هذه المرحلة تُصنع الخيارات المستقبلية للمنظومة؛ وتسمى المرحلة بالفوضى العميقة: فإما أن تعيد المنظومة تنظيم ذاتها في مستوى أعلى من التعقيد أو تنحل وتتلاشى. تدعى مرحلة التحول الطوري بـ transient، وهي الموضع حيث تحصل الأحداث التحولية. وهو مصطلح يعني نظرياً أن هناك مؤثراً في المنظومة بأكملها ينتج عن داخلها وله آثار تحويلية؛ أمّا عملياً فإنه يعني إشارة إلى تذبذب أو اندفاع مفاجئ، قد تستقر المنظومة بعد التشعب في نسق دينامي جديد يحوي مجموعة من الجواذب الأكثر تعقيداً و فوضوية ؛ لذلك فهي تصبح أكثر تعقيداً من حالتها الابتدائية، هناك ثلاثة ضروب من التشعب:

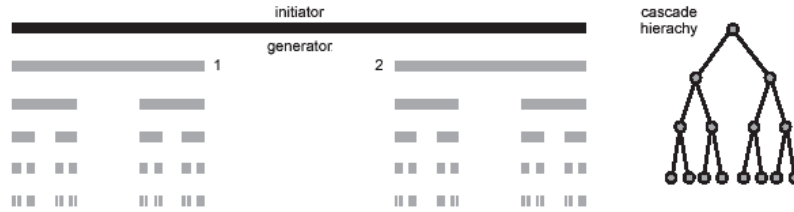
1. هادئ: يكون التحول فيه سلساً .

2. كارثي: يكون التحول حاداً، والنتيجة مزيد من الاضطراب . (رومية 2004/ص6).

3. انفجاري: يكون التحول مفاجئاً، وتتحكم فيه عوامل متقطعة تقلب المنظومة وتدفعها من نظام إلى آخر .

وتتمثل فكرة التشعبات من خلال مبدأ Cantor* في التوليد الشكلي المعتمد من توليد العديد من الاشكال الكسرية، فالاشكال المتولدة على وفق (IFS) تتبع مبدأ (Cantor) في التوليد والذي يبدأ بخط مستقيم بطول معين، ثم يستبدل بخطين جديدين طول كل منهما يمثل 3/1 من الخط الاول، ثم يستبدل كل من الخطين الآخرين جديدين وهكذا. وكما مبين في الشكل (2). (Bovil 1996/ p9).

يعتمد مبدأ (Cantor) في توليد العديد من الكسريات ويتمثل من الطبيعة كتوزيع النجوم وتجمعاتها في المجرات الفلكية وفي العديد من الظواهر الطبيعية. ويسمى الشكل الاصلي الداخل في التوليد "الشكل البادئ المولد".



الشكل (2) يوضح مبدأ (Cantor) في التوليد الشكلي. (المصدر: - Bovil 1996/ p9).

- مما سبق نستنتج ان عملية التوليد على وفق Cantor تتميز :-

- التشابه الذاتي من المقياس الكبير الى الصغير.
 - ان تجمع النقاط على وفق Cantor يشبه تجمعات الانظمة الطبيعية مع اضافة عامل العشوائية.
- وبذلك تقود التشعبات في الشكل الفوضوي الى توليد ما يسمى (بالتشابه الذاتي) والذي يمثل بالتالي مقياساً لتعقيد الشكل الفوضوي. ويرى البحث ان تعقيد الشكل الفوضوي اثناء عملية التوليد الشكلي تعزى الى ظاهرتين رئيسيتين هما:

1- ظاهرة التشعب والتي تدفع بالشكل الى التشابه الذاتي من خلال آلية التكرار.

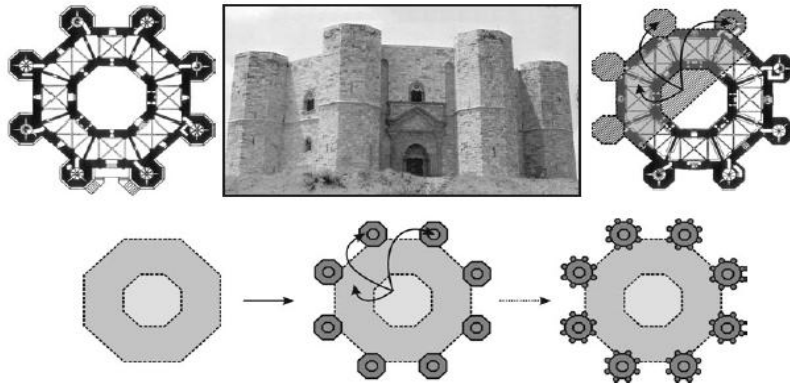
2- ظاهرة الامتداد والطي.

أ التعقيد والتشابه الذاتي :

ان التشابه الذاتي يعني انه عند توليد شكل ما على وفق مجموعة تحولات تخضع لنسب معينة وفقاً لمعامل مقياس معين، فان الشكل الجديد سواء كان اصغر ام اكبر ام مدور ستبقى خصائصه كما هي من حيث النسب والزوايا. فهذه التحولات تظهر وكأنها قد تم استنساخها بتكرارات معينة حتى يتولد الشكل النهائي. أن Fractal الناتجة من هذه التحولات تكون حقيقية وتبقى خوارزمية تكوينها هي ذاتها بتغير مقاييس الشكل نفسه. (Lorenz 2002 /p 10) .

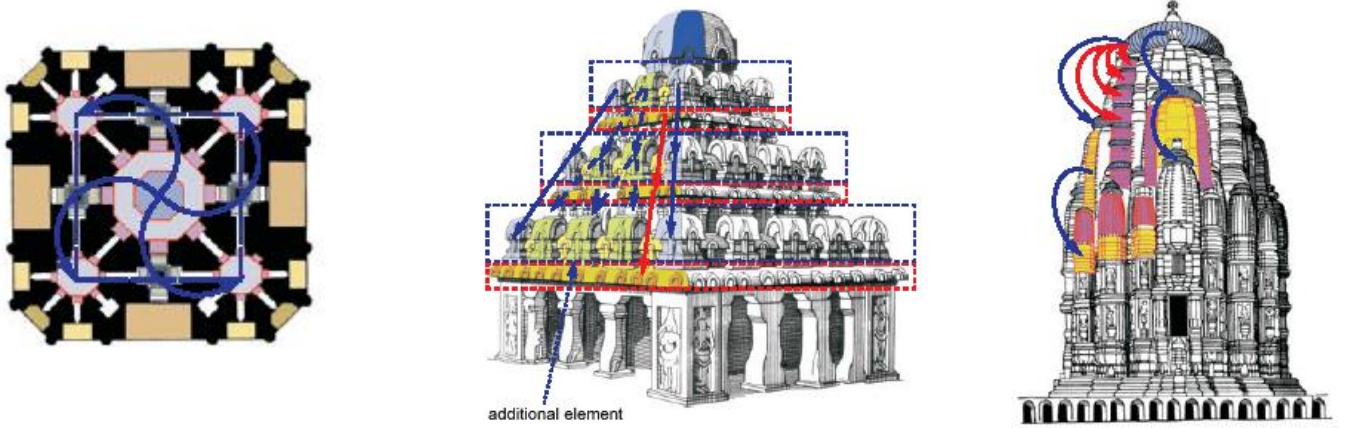
اكتشف ماندلبروت ومن خلال معادلته ان عملية التكرار المستمرة ستولد نتيجة فوضوية، وقد عمد الى توظيف هذه المعادلة لتوليد اشكال جديدة من خلال استعمال تقنيات الحاسوب فتوصل الى توليد مجموعة من الاشكال التي اتسمت بالتعقيد الشديد نتيجة التشابه الذاتي وفقاً لمختلف المقاييس، فعند تكبير أي جزء من الشكل فان النتيجة ستكون نفس الخصائص الشكلية للشكل الكلي، أي بتعبير آخر فانه عند التكبير جزء ما تكون التفاصيل ذاتها لاي جزء اخر، (Lorenz2002 /p 13) .

العديد من المباني في حقل العمارة تعكس في تصاميمها التشابه الذاتي كقلعة ديل مونت فهي مكونة من شكل مثنى رئيس في الوسط والابراج ذات الشكل المثنى الاضلاع على الحافات، وهو بذلك اعتمد التكرار للشكل مع اختزال المقياس. كما مبين في الشكل (3-أ).



الشكل (3-أ) يوضح التشابه الذاتي في قلعة ديل مونت

العديد من الكاتدرائيات للعمارة الغوطية تعكس مفهوم التشابه الذاتي، العمارة الهندية ايضاً اعتمدت هذا المبدأ سواء على صعيد المخططات كمخطط تاج محل او على الواجهات كما في معبد (rajarani) وكما موضح من خلال الشكل (3-ب).



الشكل (3-ب) يبين التشابه الذاتي في الكاتدرائيات الغوطية. (المصدر: - Lorenz 2002/ P69)

مما سبق نستنتج ان التشابه الذاتي يتولد من خلال التكرار وهذا يعني ان اعتماد بعض الصيغ او المبادئ الهندسية وبصورة تكرارية سيولد نتائج لحسابات واشكال جديدة. ومن الامثلة على تلك القوانين الهندسية معادلة ماندلبروت والتي تنتج اشكال فوضوية من خلال التكرار للتحويلات، ويرى البحث انه بالامكان عكس هذا المفهوم في حقل العمارة لتوليد اشكال جديدة، وهذا هو هدف البحث .

2.6. ب. التعقيد وظاهرة الامتداد والطي

إن المفتاح لفهم سلوك التعقيد الفوضوي يكمن في فهم عمليات الامتداد والطي البسيطة التي تحدث في الفضاء، فالمدارات في الفوضى الجاذبة تختلط ببعضها البعض من خلال هذه العمليات، وبالتالي تنتج هذه المدارات الفوضوية العشوائية، وعمليات المد و الطي هذه تحدث مرارا وتكرارا، فتخلق طية ضمن الطية وبشكل مستمر الى ما لا نهاية، وبذلك فإن الشكل الفوضوي يعطي تفاصيل اكثر بينما هو يكبر على نحو متزايد.

أن عمليات الامتداد والطي الفوضوية تزيل المعلومات الاولية بشكل منظم وتستبدلها بمعلومات جديدة فالامتداد يزيد اللاتبات والاستقرار على نطاق واسع، والطي يجمع المدارات البعيدة والمنفصلة عن بعضها ويزيل المعلومات المتعلقة بها، وبذلك ينتج كل جديد ومعقد وبمصطلحات جديدة. أن الانظمة الدينامية اللاخطية تنتج انماط التعقيد من خلال امتداد وطي الاشكال على نحو تكراري، لذا فالديناميكيا تعرف بانها تسلسل المسار الحتمي للاشكال التي تبدو وكأنها عشوائية بمرور الزمن، وتعطي احتمالات انتقالية متعددة. (Miller&Swinney 2001 p/5-8) .

ويعزي البحث التشكيلات العضوية والجاذب الغريبة للاشكال الفوضوية الى ظاهرة الامتداد والطي للانظمة الفوضوية.

أن الظواهر العضوية هي ظواهر نامية والنمو يحمل صفة التجديد والتغيير المستمر والدينامي، فالعضوية هي فكرة النظام المفتوح ذي خصائص تعقيدية وتوازن دينامي ولا تتمثل في علاقات شكلية ثابتة، وتُظهر أهمية العنصر الجزئي (الجزء) في التشكيل المعماري، مما يؤدي الى التمايز الفردي للأجزاء تشابك العلاقات بينها وظهور خصائص التنوع والتعقيد والتغير. (العاني 2001/ص77) .

والجاذب الطارئ هو أنموذج للمسار الذي يرسمه سلوك المنظومة عندما نعبر عنه تخطيطياً. ويميل سلوك المنظومات اللاخطية إلى التقصص أو الانقباض ضمن مناطق محددة من فضاء الحالة. يسمى هذا الانقباض بـ"الجاذب"؛ وهو يعبر، من الناحية الفعلية، عن "مجموعة من النقاط التي تتقارب جميع المسارات متجهة نحوها". (رومية 2004/ص9).

- مما سبق نستنتج ظاهرة الامتداد والطي تمثل مجموعة من التحولات التي تنقل الشكل من حالة الانتظام المتمثلة في التشكيلات الهندسية الى حالة غير منتظمة المتمثلة في التشكيلات العضوية والجاذب الغريبة. وأن الانظمة الفوضوية تخلق عشوائيتها الخاصة ذاتيا وبدون أي مساهمة او عشوائية خارجية عن النظام، أن العشوائية هذه تحدث بسبب التعقيد المتولد نتيجة لعمليات الامتداد والطي للنظام.

المرونة :-

هي صفة مدركة حسيّاً او ذهنياً في الناتج الشكلي وهي متأتية من طاقة التشكيل وتعبيرته الديناميكية. ان صفة المرونة في الشكل تظهر من خلال الطاقة الكامنة التي يحملها الشكل والتي تمكنه من التقولب ضمن اخر تشكيلة جديدة هذه التشكيلات المتكونة تكتسب تميزها من خلال مقارنتها بالشكل المرجعي الذي تم اشتقاقها منه، فالتشكيلات العضوية مثلاً تمثل تشكيلات ذات قيمة ومرونة عالية انطلاقاً من خصائصها الشكلية وتنوع تجلياتها. (العاني 2001/ص91).

والمرونة هي صفة واقعة في النظام الكلي للظاهرة، وهي التي تجعل النظام يتصف بصفات التغيير، التجديد، الديناميكية والتحرك. وهي تقسم على نوعين:-

1- المرونة النظامية البسيطة: وهي المرونة النظامية المتحققة بعد تكون النظام وتظهر عادةً في النظم البسيطة التعقيد.

2- المرونة النظامية المعقدة :- وهي المرونة النظامية المتحققة خلال عملية تكون النظام. هذه المرونة تتجلى من خلال كثرة المتغيرات الداخلة في عملية تكون النظام وسير هذه العملية بطرائق لاختية مع ظهور صفات النمو والتجدد. ونتحقق هذه المرونة في النظم المتطورة، كالنظم العضوية والظواهر الطبيعية. (العاني 2001/ص38).

ويرى البحث أن مرونة الشكل على وفق نظرية الفوضى هي مرونة نظامية معقدة، تتحقق من خلال :-

أ- التنظيم والتكيف الذاتي . ب- الحساسية للشروط الاولى .

أ المرونة و التنظيم الذاتي

يرتبط التنظيم الذاتي بالظواهر اللاخطية الأكثر تعقيداً بدلاً من العمليات البسيطة، والظواهر اللاخطية يمكن ان تكون مفهومة ببساطة خلال تفاعل ايجابي سلبي لدورة التغذية العكسية، ويحصل تغيير داخلي بين اجزاء النظام، وقد يخلق انماطاً معقدة "فوضى"، والتي تتطور بسرعة الى ان تصل الى تراتيب مستقرة، وبذلك فحالة الفوضى التي تصل اليها الانظمة تعد وقتية وتعود الى نظام اعلى عند عمليات تعويض الحالة من خارج نفس النظام. (Miller&Swinney2001/p4).

أن التنظيم الذاتي هي واحدة من أهم مفاهيم نظرية الفوضى، وهي تتجلى من خلال مفردتين (الانفتاح، المرجعية الذاتية)، فالانفتاح يعني أن النظام لا بد أن يكون مفتوحاً مع بيئته، وأن عملية تلقي المعلومات تصبح متزايدة لمواكبة حالة التغيير ومحاولة الوصول قدر الامكان الى نوع من التوازن الخاص بالنظام، فسمّة التنظيم الذاتي تعزز من تطور النظام وتدفعه نحو شكل جديد، بشرط أن يكون النظام مفتوحاً، فتكون امكانية التغيير عندئذ كبيرة، والمرجعية الذاتية هي من خصائص التنظيم الذاتي التي تسمح للشكل أن يحافظ على تركيبه وهويته، بالرغم من التحولات والتغييرات التي يمر بها، وهو بهذا يحافظ على

خاصية الانتظام للنظام، فالتغيير لا يعني أن يكون الشكل عشوائياً ولا يؤدي الى حالة جديدة غريبة، بل لابد أن تشير الى النظام الأصلي وتكون نابعة منه. (Reigeluth 2004/p10) .

ان الاعتماد على التنظيم والتكيف الذاتي بعيدا عن التخطيط المنظم الكلي، يدفع بالشكل المعماري ان يكون في حالة اللاتوازن بعيدا عن الاستقرار مما يدفع بالنظام الشكلي المعماري لصعوبة التنبؤ به في المستقبل. (March 2000/p65). مما سبق نستنتج أن ظاهرة التنظيم الذاتي هي سمة الانظمة الفوضوية المتكيفة، ومقدار تكيف النظام للتغيرات الداخلية الحاصلة هو إشارة الى مرونته.

ب. المرونة والحساسية للشروط الاولية

أن أكثر العلماء او المهندسين و المصممين في الماضي عدوا حساسية النظام الفوضوي للشروط الاولية شيئا لابد ان يتقادوه وانه لانجاز تفاعل كيميائي او تصميم وبناء جسر لا بد ان تكون العملية موثوقة ومتوقعة لذا حاولوا تصميم الانظمة التي تتجنب الفوضى . اما اليوم فبات واضحا ان نظرية الفوضى لها فائدة عظيمة فهي تسمح لمرونة التصميم بالنسبة لمصممي الانظمة وتعطي النظام احتمالات للتكيف بسرعة اكبر للحاجات المتغيرة، فالعلماء اليوم يؤكدون ان الحالة المستقبلية للنظام الفوضوي ممكن ان تعدل جوهريا بتغيير صغير جدا وبذلك نستطيع ان نغير حالة النظام ونوجهه الى ما نرغب بتحقيقه. (Miller&Swinney2001/P10-11) .

أن سلوك النظام الذي يحل من التكرار لنفس شروط البدء وتحت نفس الظروف، فيقود بالتالي الى نفس النتائج، هذا المبدأ يعرف بالسببية الضعيفة، ولكن من المحتمل أن البدء بشروط متقاربة وليس متطابقة نفسا قد يؤدي الى اختلافات في النتائج كبيرة، هذا المبدأ يعرف بالسببية القوية وهو ما يتمثل في أنموذج معادلة الطقس التي وضعها لورينز والذي اطلق عليها فيما بعد بتأثير الفراشة. وقد وجد علماء الفيزياء والرياضيات اليوم أن مفهوم تأثير الفراشة قد اعطى مفهوماً جديداً للعالم كونه متوازناً بين النظام الكلي على وفق القوانين البسيطة والفوضى الكلية، فالظاهرة متواجدة في كل مكان (Lorenz 2002/ P14) .

ويرى البحث أنه لابد من توظيف هذا المفهوم لنظرية الفوضى في العمارة والتي هي مرآة العصر والمجتمع، لذا فترجمة هذه المعرفة الجديدة تتحقق من خلال تعزيز المرونة في تخطيط المباني والمدن.

استنتاجات المحور الثالث :

- ان الشكل على وفق منظور نظرية الفوضى يتصف بالتوازن الدينامي وذلك من خلال كسر التناظر (اللاتناظر)، والتي تجعل الشكل نظاما مفتوحا قابلا للتقارب ضمن علاقات وتشكيلات متغيرة وجديدة، ويعد التحول المفتاح لذلك فهو يمثل عملية تغير الشكل ويصل بوساطته الى مرحلة القصوى او النهائية مستجيبا لذلك لعدد من الديناميكيات الداخلية والخارجية للشكل نفسه، من خلال اعتماد علاقات التحول المقيسة، وعليه فان الشكل الفوضوي هو شكل دينامي.
- ان التعقيد يعزز النظام في النتاج الشكلي الفوضوي، ويعتمد مستوى التعقيد الشكلي على العلاقة بين العناصر المكونة والهندسيات المعتمدة في النظام الشكلي.

- أهمية نقطة التشعيب في الشكل الفوضوي كونها تمثل نقطة التحول الطوري، فتنشعب المنظومة وتدفع بالشكل أما الى حالة من النظام الجديد عبر التنظيم الذاتي وهو ما يهمننا في هذا البحث فيما يتعلق بالتوليد الشكلي، او الى الانحلال والتلاشي، فهي تؤدي الى تغيير غير متوقع للشكل تحت تأثير التحولات المستمرة.
- الاشكال العضوية والجوانب الغريبة تمثل أنماطاً ذات بنية هندسية متشابكة ومعقدة، معتمدة في عملية التوليد الشكلي على فكرة الامتداد والطي لنظرية الفوضى .
- خصائص الشكل الفوضوي اللاخطية تدفع بالشكل الى أن يكون في حالة عدم التوازن المصاحبة لمرونة عالية من خلال القدرة على التكيف الذاتي مع المتغيرات الجديد، وبالتالي يحصل التنظيم الذاتي .
- أن مرونة الشكل الفوضوي تعزى الى مقدار تكيفه الذاتي (التنظيم الذاتي) وكذلك الحساسية للشروط الاولية، لذا فان مرونة الشكل والتشكيل تعزز من عدم القدرة للتنبؤ للاشكال الفوضوية، وهذه المرونة تسمح للشكل بتحمل المتطلبات المتقلبة والمتغيرة .
- من كل ما تم ذكره مسبقاً استطاع البحث تكوين رؤية واضحة عن كيفية التعامل لنظرية الفوضى ضمن العملية التصميمية لتوليد الاشكال المعمارية بشكل نظري، ويبقى الجانب التطبيقي والذي سيبحثه الفصل الرابع هو الفيلص للأجابة عن السؤال والذي منه بدأ البحث وهو: مدى إمكانية تبني وسائل جديدة لتوليد الأشكال المعمارية ؟ .

المحور الرابع : الدراسة التطبيقية :

ولغرض أجراء الدراسة العملية، لابد من صياغة مجموعة تصورات أفتراضية، لاستكشاف خصوصية التعامل لنظرية الفوضى في حقل العمارة . وعليه تم صياغة فرضية البحث الرئيسة :- (يمكن توليد أشكال جديدة في حقل العمارة من خلال توظيف مفاهيم نظرية الفوضى) .

ويتطلب اختبار الفرضية الرئيسة للجزء الثاني من المشكلة البحثية الى تجزئتها لعدد من التصورات الافتراضية الثانوية ذات العلاقة بالشكل وتوليده وفق نظرية الفوضى وكما يأتي :-

يمكن توظيف المفاهيم العلمية لنظرية الفوضى لتوليد اشكال معمارية جديدة بالاستعانة بالبرامج الحاسوبية .

التطبيق العملي

سيتعرض التطبيق العملي الى توظيف المفاهيم العلمية لنظرية الفوضى من خلال مفردات التوليد الشكلي للنظرية لتوليد أشكال معمارية جديدة، وذلك بالتوصل لصيغة برمجة خاصة لبرنامج حاسوبي توظف تلك المفردات والبرنامج المنتخب لتحقيق هذا الهدف برنامج (Form) *، تعتمد فكرة البرنامج على مفهوم التحولات في التوليد الشكلي وهو ما يتبناه البحث في أطار التوليد الشكلي على وفق نظرية الفوضى، فالبحث يفترض إن التحولات تنشئ حالة أختلال التوازن والحركة للنظام، لذا فلها تعزى دينامية الشكل الفوضوي، وتدفع هذه التحولات النظام الى أعلى مستويات التعقيد، فتتحقق بذلك تعقيد الشكل، ومن

* برنامج Form : وهو برنامج متخصص للرسم وتوليد أشكال العضوية، ويستعمل في مجال الفن، وهو يعمل على نظام التشغيل DOS، فبعد إن تتم برمجة الشكل على وفق برنامج Visual Basic يتم تطبيق البرمجة في شاشة البرنامج وبالتالي يتولد الشكل، صُمم البرنامج من قبل Andrew Rowbottom (rummy@snafile.demon.co.uk)، الاصدار الموظف في البحث هو 6 ، الموقع في الشبكة الدولية للمعلومات <http://www.netlink.co.uk/~snafile/form/form.html> .

خلال أحداث تغيير داخلي واستبدال أجزاء للنظام بأخرى جديدة، تعزز من مرونة الشكل. وفيما يختص بالتوليد الشكلي سيستعرض البحث في الجدول (1) أهم الايعازات التي ستوظف وطرق برمجتها .

الجدول (1) يبين ايعازات برمجة الاشكال لبرنامج Form . (المصدر: أعداد الباحثة).

طريقة البرمجة	الايعازات
STACK number_in _ number %	وهو يعني كومة أو متكوم، وهو يمثل مقدار Stack : - ايعاز التكرار للشكل، ويعبر عن حالة الانتقال في التحولات.
GROW size	ويمثل تغير المقياس للشكل، أي بمعنى آخر grow : - ايعاز تعبر عن حالة التدرج في المقياس للتحولات.
TWIST angle [, displacement]	وهو يشير إلى مقدار اللّي أو اللف للشكل حول twist : - ايعاز نفسه بزاوية معينة، وهو يعبر عن حالة الدوران للشكل في التحولات.
BEND angle	ويمثل مقدار إنحناء وطيه للشكل حول محوره bend : - ايعاز العمودي وفق زاوية معينة.
▪ box(vector)(vector gives x, y, z size) ▪ sphere(radius) ▪ ellipse(radius)- - ellipse(widht,height) ▪ torus(minradius , maxradius) ▪ cone(baseradius, height)	- أوامر تخص توليد مجموعة من التكوينات الشكلية وهي كما يأتي: ▪ Box: ويشير إلى توليد المكعب . ▪ Sphere: ويشير إلى توليد الكرة . ▪ Ellipse: ويشير إلى توليد الشكل البيضوي . ▪ Torus: ويشير إلى توليد الاشكال المستديرة الحلقية. ▪ Cone: ويشير إلى توليد المخروط .

والجدول (2) يبين منهج البحث التطبيقي بتوظيف مفردات التوليد الشكلي لنظرية الفوضى وأسلوب ترجمتها إلى اشكال جديدة وفق ايعازات البرنامج .

الجدول (2) يوضح أسلوب تجسيد مفردات التوليد الشكلي لنظرية الفوضى. (المصدر: أعداد الباحثة).

مفردات التوليد الشكلي الرئيسية	مفردات التوليد الشكلي الثانوية	أسلوب تجسيد مفردات التوليد الشكلي في البرمجة
الدينامية	- التحولات - كسر التناظر	- وتتحقق من خلال توظيف الابعازات (Stack، grow، twist) في التوليد الشكلي . - وتتحقق باللاخطية باستعمال معادلات لاخطية في التوليد الشكلي كمعادلة ماندلبروت والتي تمثل قيم (x,y) للشكل.
التعقيد	- التشعب - الامتداد والطي	- ويتحقق بالتشابه الذاتي من خلال التكرار وتدرج المقياس للشكل النهائي باستعمال الابعازات (Stack، grow، twist) . - وتحقق العضوية للشكل من خلال ألانحناء وألانبعاج لطي الشكل ومبدئياً يوظف إيعاز bend لتحقيق هذا الهدف، و يرى البحث إن التحولات التكرارية نفسها تحقق ذات الهدف.
المرونة	- الحساسية للشروط الأولية - التنظيم الذاتي	- وتحقق عدم القدرة للتنبؤ للشكل، وسيختبر البحث هذه المفردة من خلال تغير الاشتراطات الأولية البسيطة للتوليد الشكلي والتي يفترض البحث إنها ستدفع إلى نتائج مختلفة، من خلال توليد أشكال مختلفة . - ويتحقق من خلال مقدرة الشكل للتكيف الذاتي تبعاً للتغيرات الداخلية الناتجة من التحولات التكرارية على وفق الاشتراطات الأولية المتغيرة، وعليه فالبحث يفترض إنها تتحقق ضمناً في التوليد الشكلي في حال تحقق الحساسية للشروط الأولية للشكل، وبذلك فهي تعزز مرونة الشكل .

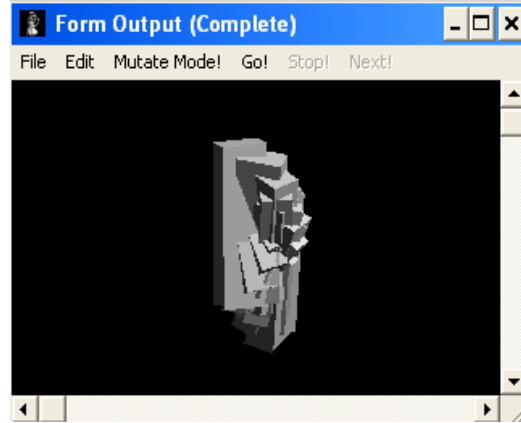
الخطوة الاولى تتم من خلال برمجة الشكل على وفق برنامج Visual Basic وتوظيف مفردات التوليد الشكلي وكما تم توضيحه آنفاً في الجدول (2) ، ثم يتم تطبيق البرمجة في شاشة تطبيق البرنامج و التي تعمل على نظام التشغيل DOS، ويتولد الشكل تبعاً لتلك البرمجة، والبرنامج يعطي امكانية احداث التغييرات الداخلية للشكل المتولد، من خلال ادخال عامل العشوائية وبقيمة معينة مناسبة لابعاد الشكل وصيغة توليده، فيتم من خلالها تغيير الاشتراطات الأولية لذات الصيغة، وبذلك تتولد الاشكال الجديدة، والشكل (4/4-أ) يبين عملية البرمجة والتوليد الشكلي على وفق برنامج Form.

```

c = 0.286691;
x = 1.46848 ;
z = 0.294029 ;
y = x^ 2*c ;
form1=box < x ,y , z> stack 5.00659 in 12.9099%
grow 0.26021 twist 70.2012 bend -11.9502 ;
form2 = sphere ( 0.00979873 ) stack 0.720956 ;
form2 & [form1] stack -10.4662 in 31.8975%
twist -178.993 grow 1.5 bend 31.8788 ;
end ;

```

برمجة الشكل (1)

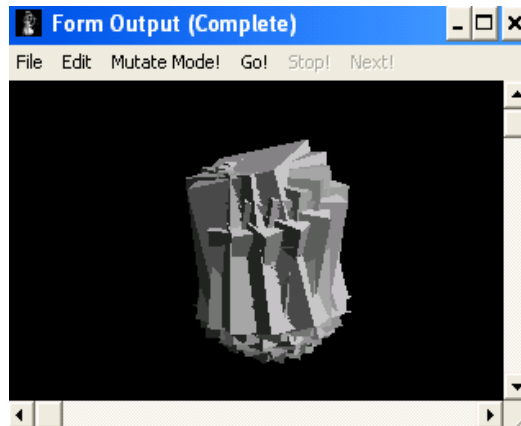


```

c = 0.12347;
x = 5.519;
z = 3.305
y = x^ 2*c;
form1 =box < x ,y , z> stack -3.35 in -18.18%
grow -0.062122 twist 51.02 bend -0.24;
form2 = sphere ( -0.217 ) stack 11.55;
form2 & [ form1] stack -45.37 in 9.86%
twist -604.6 grow 1.5 bend 3.856;
end;

```

برمجة الشكل (2)

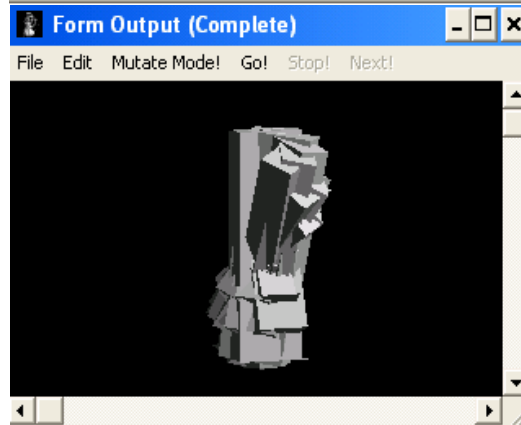


```

c = 0.255522;
x = 1.96637;
z = 0.312559;
y = x^ 2*c;
form1 =box < x ,y , z> stack 4.0876in -0.3374%
grow 0.308059 twist 68.0462 bend -0.186065;
form2 = sphere ( 0.165158 ) stack 0.0632649;
form2 & [form1] stack -10.6327 in 2.75727%
twist -184.708 bend 8.28481;
end;

```

برمجة الشكل (3)

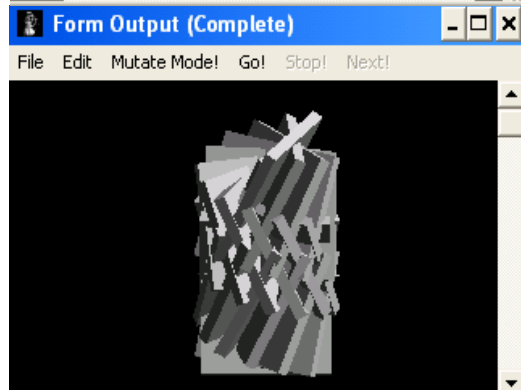


```

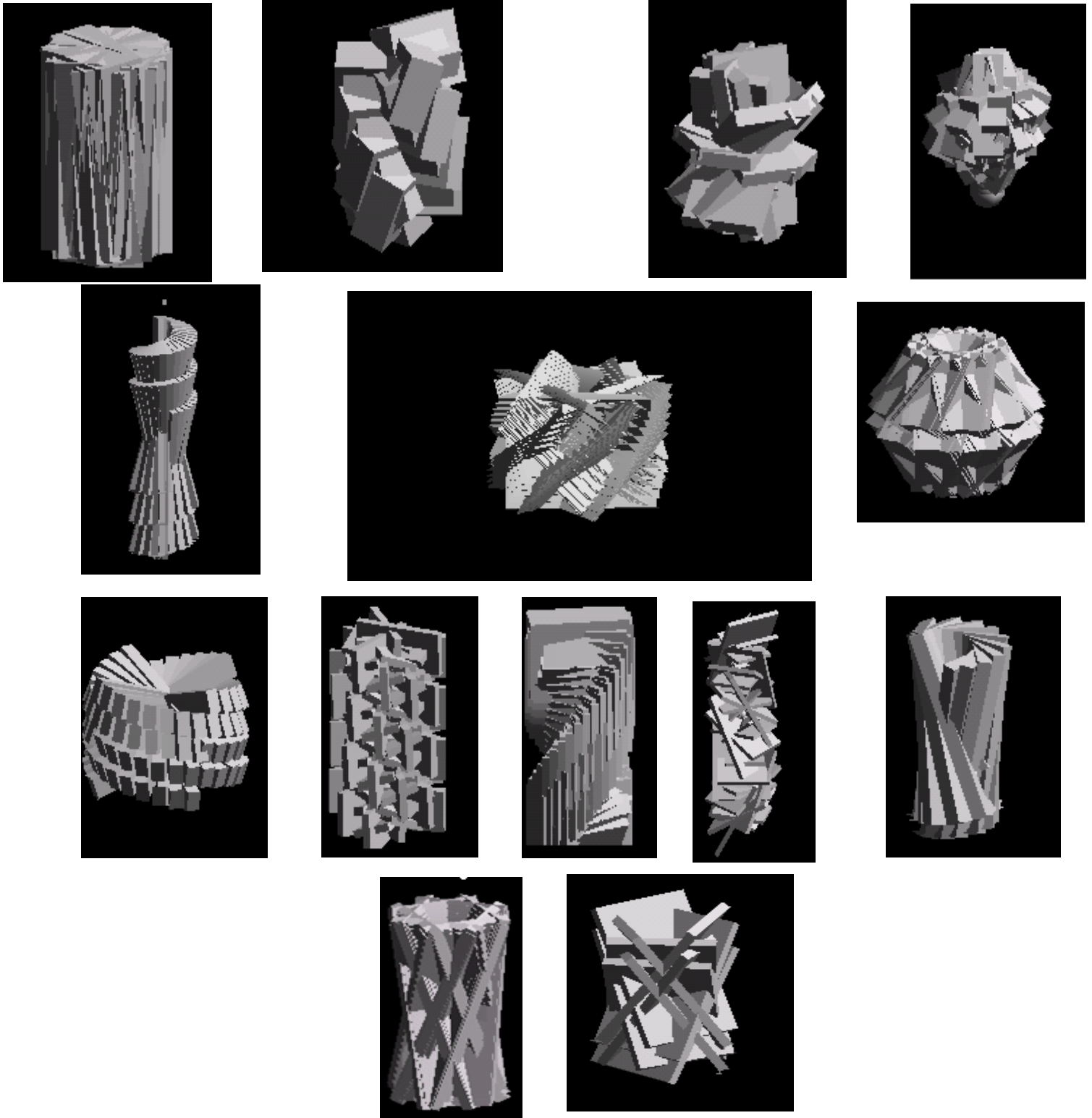
c = 1.04062;
x = 0.971115;
z = 0.08913;
y = x^ 2*c;
form1=box < x ,y , z> stack 0.58313in -4.6836%
grow -1.31832 twist -27.4293 bend 0.192949;
form2 = sphere ( 0.106549 ) stack 0.976013;
form2 & [form1] stack -39.4069 in 4.81083%
twist 515.032 bend -0.352846;
end;

```

برمجة الشكل (4)



الشكل (4) يبين عملية البرمجة والتوليد الشكلي لمجموعة أشكال وفقاً لبرنامج Form . (أعداد الباحثة).



الشكل (4-أ) مجموعة أشكال تجسد مفردات التوليد الشكلي لنظرية الفوضى على وفق برنامج Form .

(المصدر: تم التوليد الشكلي باستعمال البرنامج من قبل الباحثة).

النتائج المرتبطة بالمرحلة الثانية للتطبيق العملي

تعرض البحث إلى الاستعانة ببرنامج Form، واستعارته من حقل الفن وتطبيقه في حقل العمارة كوسيلة توليد للأشكال المعمارية من خلال توظيف مفردات التوليد الشكلي لنظرية الفوضى في برمجة صيغة التوليد ، وهذا بالتالي يحقق فرضية البحث الثانوية.

- وفيما يأتي سيتم استخلاص نتائج البرمجة والتي توصل إليها البحث من خلال توليد الأشكال وفق برنامج Form :-
- ايعاز Stack: وهو يمثل مقدار التكرار للشكل، فكلما ازدادت قيمة Stack زادت الكتل المتكومة وصَغُرَ حجم الشكل وقلت تفاصيله وقل ترابط الأجزاء بعضها ببعض (طريقة التكوم)، وكلما كانت القيمة أقل يظهر الشكل أكبر وتتداخل العلاقات أكثر، فالتكوم يظهر واضحاً والشكل يأخذ أبعاداً أكبر بحسب القيمة .
- ايعاز grow: وتمثل مقدار التغير بحجم الشكل، فكلما كَبُرَت قيمة grow كَبُرَ الشكل المتولد وقلت تفاصيله أي بمعنى يزداد حجم الشكل، وظهرت نتائج البرمجة إنه يفضل أن تكون القيمة صغيرة جداً وبمراتب عشرية فتعطي تفاصيل أكثر، ويمكن أن تكون القيمة موجبة (+) أو سالبة (-) فيحصل عندها نوع من الاستقطاع وانفصال التكوينات في الشكل عن بعضها البعض .
- ايعاز twist: و يشير إلى زاوية دوران الشكل والتفافه وأجزائه حول نفسه بمقدار قيمة الزاوية، وظهرت النتائج إنه يفضل أن تكون أقرب إلى أو أكبر من (360 درجة)، ويمكن أن تكون القيمة سالبة فيدور باتجاه عقرب الساعة أو موجبة فيدور عكس اتجاه عقرب الساعة .

الاستنتاجات الخاصة بالجانب النظري :

- تمثل التبصُّرات والمفاهيم التي تزوّدنا بها نظرية الفوضى قطيعة جذرية مع الأساليب الرياضية السائدة التي أسست للعلم الحديث منذ غاليليو وديكارت ونيوتن، وجاءت لتدحض النظرة العدمية Nihilism التي تطورت بسبب أفكار الحتمية والمادية وكون الموجودات جاءت نتيجة لعامل الصدفة، وتؤكد بالمقابل على مفاهيم (تعدد الاحتمالات، عدم القدرة للتنبؤ، النظام والانتظام ضمن العشوائية) والتي لاتخضع إلى مقاييس الإنسان الذاتية المبدئية، وتمكننا بالتالي من رؤية مختلفة للكون ومن فهم أفضل لقواه المحركة وتنظيمه الذاتي وتطوره، وبالتالي تفسير ظواهر الطبيعة وأشكالها المختلفة على وفق رؤية جديدة لهذه القوة المنظمة والمسيطرّة والتي تتجسد بالخالق جلّ وعلى. ويرى البحث إن نظرية الفوضى نفسها وإن جاءت من الفكر الغربي إلا إنها ناقضت بمفاهيمها رؤيته للخلق وعبثية التكوين والوجود لبعض نظرياته وأفكاره، وهذا بالتالي إن دلّ على شيء يدلّ على ملكوتية الله سبحانه وتعالى للكون، فهو الخالق المبدع الذي يسير كل الموجودات وينظم الكون وهو الحقيقة المطلقة والثابتة الوحيدة .
- لابد من التمييز بين الفوضى الديناميكية والعشوائية والتي تكون فيها أحداث النظام حرجة محددة ومحتملة، فالفوضى الديناميكية هي ليست ببساطة اللانظام او عشوائية بل هي تمثل حالة عدم استقرار داخلية مستمرة، فالانظمة الفوضوية لربما لها صياغات دينامية واضحة المعالم او حتى قد تكون حتمية كأنظمة كلاسيكية،

ولكن هذه الدينامية لا تستقر ولا تصل الى الموازنة ولكن تتقلب وتتغير الى سمات غير قابلة للتنبؤ والتي بمجملها تجعل النظام يبدو بشكل مخادع مشابه للعشوائية.

• إن استراتيجية خلق النتائج المعماري لا تبدأ من الصفر ، فعلى العكس لابد ان تحصل بتكامل مع العلوم الاخرى، فالعمارة تسعى وبتوجهاتها المستقبلية الى تكريس حالة تجسيد العلم في اطار من التخصص فيتوقع ان تحقق العمارة الانعكاس والتداخل المباشر مع العلوم الاخرى ولاسيما علم الرياضيات فهو منبع واصل كل العلوم، فهو يتعامل مع مجموعة قوانين وعلاقات منطقية يمكن أن تُستثمر في تفسير وتوليد الشكل المعماري بموجبها، ومن هنا برزت أهمية وتأثير نظرية الفوضى واستثمارها في التوليد الشكلي في حل العمارة كونها فرع من فروع علوم الرياضيات المعاصرة .

• التوصل إلى صياغة مفردات التوليد الشكلي الرئيسية (الدينامية، التعقيد، المرونة) في اطار البحث للكشف عن القدرة التوليدية لنظرية الفوضى في العمارة لتوليد أشكال معمارية جديدة، وهذا الجانب لم تنطرق له الدراسات المعمارية السابقة وبذلك فهو يمثل إضافة معرفية جديدة لم يتم بحثها من قبل .

• التوصل إلى صياغة تعريف عام للشكل الفوضوي (على وفق نظرية الفوضى) فهو :

• شكل لا يتولد من العشوائية واللانظام بل يتولد بمجموعة من القواعد النظامية التي تهدف الى شكل يحقق الابداع والتجديد وتتجسد فيه حالات النظام الضمنية والخفية، فهو يتصف بالدينامية التي تحقق الانفتاح للشكل وتتولد من خلال التحولات واللاخطية للشكل وتتولد من خلال كسر التناظر، ويتصف بالتعقيد الذي يحقق التشابه الذاتي للشكل ويتولد من خلال التشعب والخصائص العضوية للشكل وتتولد من خلال الامتداد والطي، ويتصف بالمرونة التي تحقق التكيف الذاتي للشكل وتتولد من خلال التنظيم الذاتي وتحقق عدم القدرة للتنبؤ بالشكل وتتولد من خلال الحساسية للشروط الأولية .

الاستنتاجات الخاصة بنتائج التطبيق العملي:

استنتجت هذه الاستنتاجات من الترابط بين مفردات الاطار النظري ونتائج التطبيق العملي وكما يأتي:

○ الاستنتاجات الخاصة بمفردات التوليد الشكلي لنظرية الفوضى

- مفردة الدينامية : تتحقق الدينامية في التوليد للأشكال على وفق نظرية الفوضى من خلال مفردتي توليد ثانويتين (التحولات- كسر التناظر (اللاتناظر)) .
- ب. مفردة التعقيد : يتحقق التعقيد في التوليد للأشكال على وفق نظرية الفوضى من خلال مفردتي توليد ثانويتين (التشعب- الامتداد والطي) .
- ج. مفردة المرونة : يتحقق التعقيد في التوليد للأشكال على وفق نظرية الفوضى من خلال مفردتي توليد ثانويتين (الحساسية للشروط الأولية- التنظيم الذاتي) .
- إن توظيف برامج حاسوبية كبرنامج (Form) في العمارة، يفتح آفاقاً جديدة للمصمم المعماري لتطوير مهاراته فيما يخص التعامل مع تقنيات الحاسوب ليست كونها تعطي اشكال جاهزة من خلال مجموعة من البرامج المعتمدة في

الرسم، بل تسعى إلى تطوير قدرات البرمجة لدى المصمم، وليتمكن من ادراك كيفية تنفيذ شكل معين على وفق ايعازات محددة، وذلك بالتالي يمكنه من توسيع مداه التخيلي في استنباط اشكال جديدة من خلال توظيف ذات الایعازات بصيغة برمجة مختلفة، وفهم اسلوب توليدها للاشكال وبالتالي سيطرته وقدرته في أحداث التغيير المناسب في صيغة البرمجة وبما يحقق ما يصبو إليه ويخدم كذلك العملية التصميمية .

- أظهرت نتائج توليد الاشكال على وفق مفردات التوليد الشكلي لنظرية الفوضى إنه على الرغم من توظيف علاقات ومعادلات رياضية منطقية تعتمد النظام في التوليد الشكلي، إلا إن هذه الاشكال قد اتصفت بالنهاية بخصائص قد تبدو لانظامية والتي تكررت هندسياً من خلال مقاييس مختلفة، وتحت هذا الانطباع الاول يقبع شكل ذو نسق نظامي ومتولد بتعقيد لا نهائي يتصف بالدينامية والمرونة في التشكيل، وهذا يدعو بالتالي إلى عدم التسرع في الحكم على بعض الاشكال كونها ذات خصائص لانظامية و متولدة بطرق عشوائية، فالنظام موجود ومتولد في كل شكل ويحكم العلاقات بين عناصره وإن كان خفياً، وعليه فهذا يثبت حقيقة كون العمارة مذ كانت ومازالت وستبقى تخضع لنظام يحكمها وحتى مع ظهور التيارات الفكرية التي تدعو إلى خلق التشويش والعشوائية والفوضى فحقيقة الامر هي تعتمد النظام الضمني في توليدها حتى وإن كانت غير قصدية .

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الفضاء في عصر المعلوماتية

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المستخلص

يتميز عصر المعلوماتية بأنه عقد لثلاث ثورات : ثورة المعلومات، و ثورة التكنولوجيا، وثورة الاعلام. وقد تزامنت هذه الثورات في التطور وتفاعلت مع بعضها بشكل مذهل، حتى باتت عنواناً لعمارتنا المعاصرة، و غيرت هذه الثلاثية من مفاهيم الناس وافكارهم و سلوكهم وعاداتهم وتقاليدهم. ان دخول التكنولوجيا الى البنية الحضرية عامة والفضاء الحضري خاصة، ادى الى تغيير في البنية الفيزيائية لهذه الفضاءات كنتيجة حتمية لتغير البنية الفكرية للمجتمع. و غيرت الثورة المعلوماتية الكثير من سمات ومفاهيم الفضاء الحضري التقليدي بالاضافة الى تغيير اوسع بالمفاهيم المتعلقة بالفضاء . ركز الفكر الجديد على ان المعلومات تشكل وسائلاً للتفاعل بين الانسان وبيئته. فقد فصلت التكنولوجيا الالكترونية الجديدة والميديا الرقمية المطورة الحقيقة عن عالم الجسم، وحولت التجارب الى صيغة حدث و خلقت سيطرة للعالم الافتراضي. يطلق على الفضاء الجديد من هذا النوع “الفضاء الافتراضي” يقع هذا الفضاء بين الفضاء الفيزيائي والفضاء العقلي وذلك لانه يقدم للمصممين ليس فقط تصوراً مطلقاً للفضاء العقلي ولكن ايضا الاحساس بالعيش في داخل الفضاء الفيزيائي. ففيزيائية ومادية الفضاء لم تعد فكرة مهمة بالعمارة نتيجة ظهور افكار جديدة عن الفضاء مع دخول تكنولوجيا المعلومات. فقد حررت الكومبيوترات (الوسائل الرقمية الجديدة) المفاهيم الثنائية للفضاء في الحضارة الانسانية. فأطلقت قوة الانشاء والمحاكاة للوسائط الرقمية كل انواع التخيلات اللامحدودة . يهدف البحث الى توضيح مفهوم (الفضاء) بلغة اليوم اي باللغة التكنولوجية وتوضيح معنى الفضاء الذكي الذي نتج كحتمية للتغير الحاصل في مفهوم الفضاء في عصر تكنولوجيا الثورة المعلوماتية .

الكلمات الرئيسية

الفضاء، المكان، الفضاء الذكي، الفضاء الحضري المعاصر، الفضاء الافتراضي، التكنولوجيا المعلوماتية، الاتصالات.

The Space in the Age of Information

ABSTRACT

Three revolutions characterize the age of information: Information Revolution, Technology Revolution and Media Revolution. These revolutions developed and interacted with each other in an amazing way. Way to an extent that it becomes a title to our contemporary architecture. These revolutions changed people's thoughts, behaviors, and traditions.

The effect of technology on the urban structure generally and the urban space specifically changed the physical structure of these spaces as a necessary result to the change of intellectual structure in community. The information revolution changed a lot of the common urban space's characteristics and concepts as well as an extreme change in concepts related to the space.

The new thought concentrated on the fact that information represents the tools for the interaction between man and his environment. The new electronic information and the improved digital media split the reality out of the realm of body, convert the experiments to the form of event and create a control of the virtual reality. The new space of this kind is called "Virtual Space". This new space lies between the physical space and the mental space as it presents to the designers not only infinity image to the mental space but the sense of being in the physical space. The physicality of space is no more an important concept in architecture as a result to the emergence of new concepts of space with the effect of information technology. The new digital tools (computers) set free the dual concepts of space in human civilizations. The power of structure and the imitation of the digital media released all types of unlimited imagination.

The research aims to explain the concept of (space) in the language of today (the technological language) and clarify the meaning of intelligent space as a result of the change in the concept of space in the age of Informational Technology Revolution .

المقدمة

مع دخول انظمة المعلومات (الانظمة الذكية) الى الفضاء الحضري، ينظر الى مفهوم المكان في كونه الحيز المخصص للتفاعل ضمن الزمان الذي يوجد فيه الانسان للقيام بنشاطاته المختلفة الفيزيائية واللافيزيائية كانعكاس واضح للتحوّل الحاصل في رؤية المكان. ان فكرة المكان هنا تبرز بأحلال مفهوم الاطار او النطاق الخاص بالفعالية وبالتالي زيادة اتساع المكان الذي يوجد فيه الانسان، وعدم تحده ضمن مكان منفرد يقضي فيه زمنه، وبارتباطه التام بفعالية المنظومة. فإن المكان الذي يبرز كمعز أو معيق لها تكون اهميته في تحقيق الفعالية ضمنه. لذلك نجد ان مجمل التوجه في رؤية حقيقة المكان يتم من خلال سلوك الفرد خلاله في اي صفة كانت (شكاره، 1998، ص 70)

فالمكان (Place) هو فكرة اساسية بالعمارة والتصميم الحضري، ومن هذا المنطلق او التوجه يفكر بالفضاء الافتراضي أو بأنظمة الاتصالات والمعلوماتية : فالمكان يشتق من التباين بين الاتصال والاختلاف اكثر من كونه ناتج عن بنية ثلاثية الابعاد، وهذا مشابه لما هو موجود في انظمة الاتصالات.

ف(الفضاء) هو تنظيم مكاني، وحين يؤطر بسلوك تفاعلي يصبح (مكان)، (فالفضاء فرصة في حين ان المكان حقيقة مدركة) Space is the Opportunity, Place is the Understood Reality (Huber,2000,p.1).

يتناول هذا البحث توضيح الفضاء في انظمة الاتصالات، ومن ثم يتطرق البحث الى الافكار المتعلقة بالمكان وصولاً الى الفضاءات الذكية.

-الفضاء:

يبني الفضاء الفيزيائي بناء على الاستعمال والحاجة للتفاعل، وقد استعار كثير من المصممين الحضريين بالفضاء الفيزيائي عامة والحضري خاصة لتسهيل ادراكنا للفضاءات الافتراضية. وقد ازداد استخدام الاستعارة المكانية والتنظيم المكاني في الفترة الاخيرة بأنظمة الاتصالات وهذه بعض الانظمة (Harrison & Dourish,2002, p.2):

1. الحقيقة الافتراضية (Virtual Reality)
2. المجال المتعدد المستخدمين (MUDs : Multi User Domain)
3. الاتصالات المتعددة الاعلام (Multimedia Communication).

مميزات الفضاء :

هناك عدة محاور للعالم الواقعي التي يمكن ان تكون جزءاً من نموذج مكاني لانظمة الاتصالات :

- **التبادل وتوجيه الاتصال (Relational Orientation and Reciprocity) :** التنظيم المكاني في العالم هو نفسه بالنسبة لكل، (أسفل) فهو باتجاه مركز الارض، (أعلى) نحو السماء، وكذلك بالمسبة لـ (أمام) و(خلف). فالتوجه المعرف بالعالم الفيزيائي يعتبر مصدراً ذا قيمة عالية في تمثيل وتفسير الفعاليات والتصرفات .

فنحن نعلم بأن العالم منشئ فيزيائياً للآخرين بنفس الطريقة لنا. وهذا ما يجعلنا نشير باتجاه الاشياء، او نستخدم وصفاً مكانياً لتوضيح مصدر ما. وان المصدر يمكن ان يعتمد على تجربة مشتركة، كما في الوجود في فضاء ما ونقول لشخص ما (الباب على جهة اليسار كما لو كنت قادماً من زاوية الشارع). (Ibid, p.2).

- **القرب والفعل (Proximity And Action) :** في حياتنا اليومية، نحن نقوم بأفعال (اكثر او اقل) اعتماداً على مكان وجودنا. فنحن نلتقط الاشياء الاقرب لنا، ونتحدث مع الناس الاقرب لنا، لان الصوت ينتقل خلال مسافة اقل، ونحمل اشياء معنا ونقترب لرؤية الاشياء بوضوح. هذه الخصائص مشابهة لما يوجد بالفضاءات الافتراضية. مفهوم القرب يساعدنا على ربط الناس بالفعاليات وربط بعضهم ببعض. فعندما نشاهد مجموعة من الافراد يجتمعون حول منصدة ما نفهم

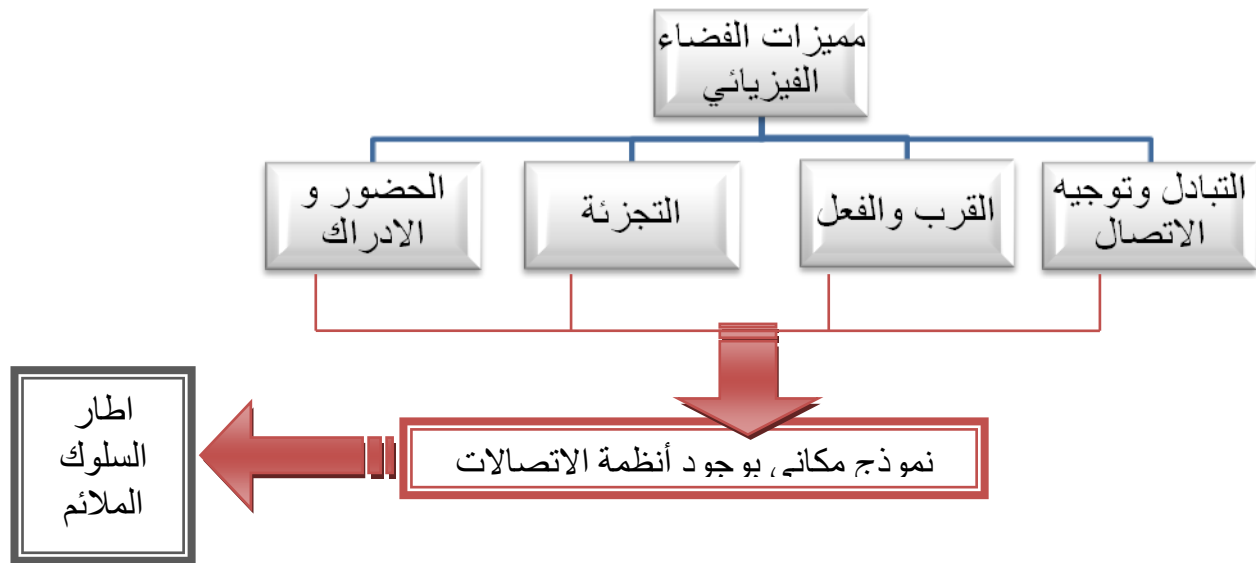
بأن هناك شيئاً ما حول فعاليتهم، ونعرف من وجود شخص ما على مقربة منهم بأنه لا يرغب بالمشاركة بنشاطاتهم (ibid,p.2) .

- **التجزئة (Partitioning):** كما في فكرة القرب والتفاعل، فكرة التجزئة، فمادام الفعل والتفاعل مرتبطين بالمسافة، فالمسافة ممكن ان تستخدم لتجزئة نشاط او لتوسيع امتداد فعالية ما (Ibid, p.2) .
- **الحضور والادراك (Presence and Awareness):** لا تمثل حياتنا اليومية فقط بالحقائق الصناعية والادوات والحضور لأعمالنا، ولكن بناس آخرين مع اشارة لنشاطاتهم، (حضور الاخر) يسمح لنا بأنشاء فعاليتنا الخاصة. وهذا ما يحدث، فالتنظيم المكاني في بيئات الاتصالات يمثل منظوراً لافراد آخرين وفعالهم مع نفس البيئة التي تمثل نشاطاتهم وتحمل الانتاج الصناعي للعمل (ibid,p.2-3).

اطار السلوك الملائم (Appropriate Behavioral Framing) :

ان المفاهيم المذكورة في الفقرة السابقة تسمح لنا بتنظيم سلوكنا الملائم فمثلاً نتحرك باتجاه الآخرين لتحدث اليهم، او نشير الى الاشياء ليتمكن الآخرين من ايجاد ما يبحثون عنه. يستغل الفضاء الافتراضي محاور الفضاء (الميكانيكية المكانية، توفير الهوية، التوجيه، تركيز الفعالية، ونوع السيطرة) والتي تعتبر وسيلة قوية في التصميم، لكن هذه الكنايات المكانية تحمل معها سلوكاً مكانياً، لا يمكن استعارته، فهو ينتج عن اختبار كل يوم في العالم الفيزيائي. فان الذي يساند بنماذج الاتصال المكانية هو طريقة لفعالية منظمة مستمرة بخصائص الاتصال، نطلق على هذا الذي سبق بأطار السلوك الملائم (Ibid, p.4) .

والمعنى المتضمن هنا: إذا صممنا انظمة الاتصال وفق فكرة الفضاء الذي يقلد التنظيم المكاني للعالم الواقعي، نستطيع بعد ذلك مساندة ظهور انماط من السلوك والتفاعل الانساني الذي يعرض في كل يوم من حياتنا اليومية. بكلمات اخرى، انظمة التنظيم المكاني تساند السلوك المنظم المكاني (Spatially-Managed Behavior –Spatially- Organized Systems) . مخطط رقم (1)

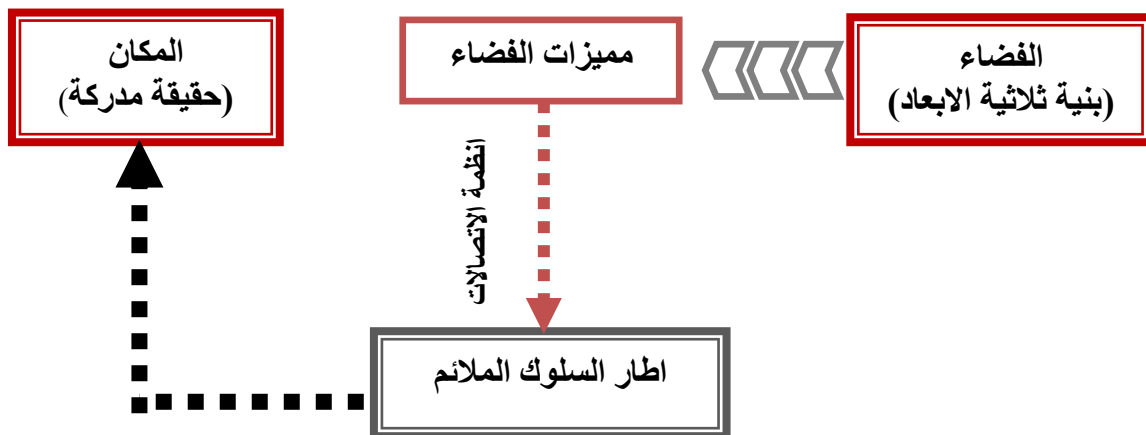


مخطط رقم (1)

العلاقة بين مميزات الفضاء الفيزيائي واطار السلوك الملائم (الباحثة)

من الفضاء الى المكان (From Space to a Place):

الفضاء هو بنية العالم وهو بيئة ثلاثية الابعاد، حيث تجري المواضيع والاحداث فيه، وله وضع واتجاه معين. ناقشنا بان مميزات الفضاء استغلت بالانظمة المتطورة لاستعادة الادراك والاحساس بأطار السلوك الملائم (Appropriate Behavioral Framing) الذي تمت ملاحظته في العالم الفيزيائي، ففي كل فعالية في حياتنا اليومية، لا يأتي هذا الاطار من ادراك الفضاء (Sense of Space) ولكن من الاحساس بالمكان (Sense of Place). فالفضاء هو ملائمة والمكان هو حقيقة مدركة. مخطط رقم (2).



مخطط رقم (2)

من الفضاء الى المكان (الباحثة)

المكان :

يعرف هايدكر المكان على انه الموضع الذي يوفر كافة الفعاليات الانسانية ، الفيزيائية، والاقتصادية والثقافية، وفي نفس الوقت يؤثر ويتأثر بالسلوك الثقافي والاجتماعي.

عرف المكان على انه الحيزية التي حدودها تعرف بالاحساس بالوجود بالداخل (Inside) وهذا يدعم الاحساس بالوجود بمكان ما (Somewhere) على العكس من مجرد مكان (Anywhere). ويجب على المكان ان يشير الى وجود الاخر و يتفاعل مع البيئة. فالمكان موجود في اعماق الفعل الاجتماعي الانساني بالمفاهيم الثقافية.اي ان المكان هو فضاء، مفعّل بالتفاعل الاجتماعي، وموظف بالمفاهيم الثقافية (Harrison & Dourish, 2002,p.39)

فاذا كان المكان سلسلة من الفعاليات والمفاهيم لساكني الفضاء، فالفضاء او المعززات الفيزيائية التي تؤطر تلك الفعاليات، تجهز مكاناً قابلاً للمشاركة الاجتماعية للفعاليات بمصطلحات تنظم وتوجه التطرف الاجتماعي المناسب في ذلك المكان الجزئي. (باشلار، 1980، ص226)

وبناءً على ما تقدم فإن الاختلاف الذي يظهر في مفهوم المكان ينبع اساسا من التحول الحاصل في المكان الافتراضي وليس في المكان الوجودي .

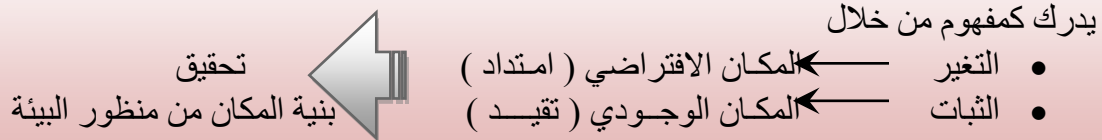
المكان الوجودي (الفيزيائي)

وهو المرتبط بوجود ذات الشيء وقيام كينونته فيه والذي يعطيه الدلالة لتحقيقه ضمن عالم الممكنات. ووجود الانسان ضمن هذا المكان هو استقراره، ويكون ممتدا ومشتتاً الى ابعد مايصل اليه وجوده الفيزيائي او ارادته من سلطة على البيئة الفيزيائية، الذي يظهر كرمز مباشر لوجوده. فعندما يقول (نويل ارنو) ان المكان الذي اوجد فيه او كما يقول (باشلار) ذلك المكان الذي يستقر وجوده فيك (المصدر السابق، ص225).

المكان الافتراضي (الاتصالي)

يمثل الحالة الامكانية (الاحتمالية) بما توفره الوسائل التكنولوجية للانسان والتي يجب ان لا ننظر اليها بانها حالة تشابه التواجد الحقيقي في المكان، وانما هي صورة من صور وجود الذات ضمن المكان والتي تاخذ ابعادا وشكلا تقتزن بطبيعة الوسيلة المستخدمة . وهي لا توجد فقط في وقتنا هذا، فما ينطبق على الوسائل التكنولوجية الحديثة في ايجاد الشخص في اكثر من مكان ينطبق لما هو ظاهر في ايصال الخطابات والرسائل الا انها تاخذ ابعادا فيزيائية اكثر تجسيدا واقرب من الحقيقة وليست الحقيقة ذاتها، وبالتالي تحقيق مفهوم المجتمع عن بعد (Telecommunity) (توفلر، 1990، ص408). مخطط رقم (3)

المكان



مخطط رقم (3)

مفهوم المكان ضمن الامتداد والتقييد (السهيل، 1999، ص51)

يمكن توضيح بعض النقاط الناتجة عن المكان والفضاء في عصر الثورة المعلوماتية:

- ان الفضاء والمكان شيان مختلفان (Spaces are not Places):
- يعكس المكان مفاهيم اجتماعية وثقافية، اماكن يمكن ان تمتلك صفات مؤقتة. فالفضاء نفسه يمكن ان يكون مكاناً مختلفاً في وقت مختلف، واذا كانت الفضاءات تمتلك (اعلى، اسفل، يمين، يسار)، فإن الاماكن تمتلك (امس، غداً، جيد، سيء) (Harrison & Dourish, 2002, p.10).
- يوفر المكان - وليس الفضاء - اطاراً للسلوك الملائم (Places, not Spaces, frame Appropriate Behavior):
- ان السلوك لا يرتبط بالفضاء، ولكن يرتبط بالمكان: فقاعة الاجتماعات يمكن في امسيات مختلفة ان تستخدم للرقص والغناء او لممارسة الرياضة او مكان لعمل ما. وفي هذه الحالات فان بنية الفضاء ليست هي التي تؤثر سلوك الناس ولكن المكان الذي وجدوا انفسهم فيه (Ibid, p.10).
- يمتلك المكان قيمة اجتماعية (Places have Social Meaning)
- ان القيم التي يمتلكها مكان ما هي قيم اجتماعية، تترسب في تطبيقات مفاهيم المجتمعات. وتظهر بمرور الزمن كتطبيق نتج وتحول بفعل المجموعة التي توجد فيه، حيث تظهر نتائجه في محوريين:
- ان المجاميع المختلفة لها مفاهيم مختلفة لنفس الاماكن ونفس الافكار، وهذا يتغير بمرور الزمن.
- يجب ان تخلق الاماكن من خلال التطبيق والملائمة، بحيث تتلائم مع ثقافة تلك المجموعة.
- فيمكن ان يصمم للمكان ولكن لا يمكن ان يصمم فيه (Placeness can be designed for, but it can't be designed in) (Ibid, p.10).
- يولد اختلاف الوسائل اماكن مختلفة (Different Media have Different Spatial properties):

ان الاعلام الواضح الذي يمكن ان نستخدمه لخلق البنية المعلوماتية ، يسير في نصوص او رسوم ثلاثية الابعاد (صوت، صورة، فيديو، الخ...) وهذه تعرض خصائص مختلفة.

وان هذه الخصائص هي بدورها انماط استخدام قوية التأثير، تتبنى و تتكيف للبنية الاعلامية. كما وضحنا فيما سبق كيف ان الصوت والصورة تجسد كل منهما افكاراً مختلفة عن (الوصول) و (المشاركة) (Ibid,p.10).

وان النقاط السابقة كلها تعزز من الفكرة (الفضاء هو فرصة ، والمكان هو الحقيقة المدركة).

المكان والاطار السلوكي (Place and Behavioral Framing) :

فيزيائياً : المكان هو فضاء مستمر بمفاهيم ملائمة سلوكية وتوقعات ثقافية. فنحن نحدد ب (فضاء) ولكن نتفاعل في (مكان). فالاماكن هي فضاءات ذات قيمة معينة. والاختلاف كما في كلمتي منزل (House) و بيت (Home) ، فالمنزل يمكن ان يقي من الريح، المطر، ولكن البيت هو حيث نعيش وننتمي. تشترك قاعة المؤتمرات والمسرح بعدة مميزات مكانية (كالتوجيه، الانارة، التصميم العام) ولكنه نادراً مانغني او نرقص عند تقديم اوراق المؤتمر واذا حدث هذا سيكون تصرفاً شاذاً (يحتاج الى تفسير). لانصف هذا التصرف بأنه خارج عن الفضاء (out of space) ولكنه خارج عن المكان (out of place)، فإن الاحساس بالمكان هو مايمنعنا من الغناء في المأتم، فالمكان وليس الفضاء هو الذي يؤطر التصرف الملائم. وعلى العكس فإن نفس الموقع بدون تغير في التنظيم المكاني او في التخطيط يمكن ان يوظف كمكان مختلف في وقت اخر. فمثلاً : المكتب يمكن ان يوظف للالتقاء والكلام غير الرسمي وحتى النوم، خارج وقت العمل المعتاد (Ibid, p.4). فالمكان اكثر تحديداً من الفضاء، والفضاء دائماً كما هو ولكن المكان هو كما يستخدم.

المكان في الفضاء (Place is in Space) :

هناك سبب واحد يجعل من الصعب التمييز بين المكان والفضاء، هو انه في حياتنا اليومية، يوجد المكان بصورة كبيرة مع الفضاءات. المكان بصورة عامة هو فضاء مع شيء ما مضاف اليه (معنى اجتماعي، تقليد، مفاهيم ثقافية ، وظيفة والخ...). هذا الاحساس هو ما يحول الفضاء الى مكان. يصنف الرواق الخارجي مثلاً حيث يجتمع المدخنون كفضاء غير مرحب او مرغوب به، ولكنه يقيم كمكان نسبة الى مستخدميه حيث يستخدم للكلام والاسترخاء، ولكنه يظل فضاء على الرغم بأن كونه مكاناً هو ما يهم. ان عالمنا عالم ثلاثي الابعاد، حيوي، فتتغلغل فكرة الفضاء في كل تجربة من حياتنا اليومية. فكل شيء في عالمنا يحدد بفضاء، وبناء على هذا يرتبط (المكان) به ايضا. فهو جزء لكل كناية تنتشيء لغتنا. على الرغم من ان العلاقات المكانية تحمل معنى فمعنى (اعلى) يعطي معنى (جيد) ومع (اسفل) يعطي معنى (سيء). وهذا ماأشار اليه Lakott و Johnson كاستعارة موجهة واعطاها قائمة طويلة من الامثلة. (ibid, p.5)

تدبير المكانية كل تجاربنا في كل مكان. تشتق الاماكن كثيرا من المعنى، ومن ثم من حيزيتها. فالاحساس بالمكان اكثر من كونه مجرد تنظيم مكاني واكثر من كونه تنظيماً ثلاثي الابعاد للحقائق الاصطناعية، وهو يعتمد كثيراً على مفاهيمنا. فالمكان يحمل مفاهيم ثقافية تساعدنا على تكوين اطار لسلوكنا.

المكان في البيئة العمرانية :

وصف¹ Alexander عام 1987 مبادئ التصميم المعماري، وركز قليلا على بنية المدن والبنائيات وكثيراً على الحياة التي تجري بداخلها وأشار بأن الذين يهتمون بالبنائيات يميلون الى نسيان بأن الحياة والروح للمكان هي من تجربتها هناك، ولايعتمد على البيئة الفيزيائية فحسب ولكن على نمط الاحداث التي تختبر هناك. فالمعماريون والمصممون الحضريون لا يصممون بنية ثلاثية الابعاد (فضاءات) ولكن يصممون (اماكن) لوجود الناس. وان فكرة المكان تشتق من التباين ما بين الارتباط و الاختلاف.

ف الارتباط: هو مدى ملائمة المكان لمحيطه محافظا على النسق بالبيئة المحيطة، او مستجيبا لتلك الانساق، حتى لو لم يحافظ على النسق بوضوح. اما اذا لم يبقَ ضمن هذه العلاقات حينها يوصف بأنه خارج عن المكان (Out of Place). وان احد طرق قياس المكانية هو المدى الذي يمتد به المكان او يعرف نمط السياق الحاوي له. ولكنه ليكون مكاناً يجب ان يتميز عن محيطه اي يكون (جزءاً من Part of) (خارج عن Apart From) سياقه و هذا يعرف بالاختلاف (Harrison & Dourish.,2002, p.5) ان عملية التوفيق بين الاتصال والاختلاف هي طريقة التفكير الواجب اتباعها عند تصميم وتعريف المكان للفضاءات الافتراضية و الفيزيائية، سواءاً على المستوى الحضري او المعماري.

انشاء الامكنة (Making Places) :

يشير Canter بان عمل الاماكن هو عبارة عن عملية خلق للظروف التي توفر وتشجع على انبثاق إحساس جزئي بالمكان، عملية واعية لتنظيم عناصر وفضاءات ملائمة لخلق بيئة توفر الفعاليات المطلوبة، وهي في نفس الوقت ناقله المفاهيم الاجتماعية والثقافية للمتفاعلين ومجتماعتهم العريضة. لا يسيطر المعماريون على كل محاور المكان، في حين شكل المكان يقع تحت سيطرتهم بشكل كبير، تحدد الفعاليات التي تتم داخل المكان نسبة الى المستخدمين لذلك الفضاء. وتخلق مفاهيم المكان عن طريق المجتمع والمحيط، او بواسطة المستخدمين انفسهم (Coynne et al, 1990, p.32) على سبيل المثال يصمم المعماري منزلاً، لكن العائلة التي تسكنه هي التي تجعله بيتاً.

An Architect Can Design a House, but only the Family that inhabits it can make it a Home (Kalay & Marx, 2003, p.20).

اي ان Place = Home وهو نتيجة تفاعل الفضاءات والمفاهيم والفعاليات، في حين House = Space

¹ Christopher Alexander : معماري نمساوي له كتاب (Pattern Language : Towns, Buildings, Construction) مع Sara Ishikawa و Silverstein Murray وان هذا الكتاب الهم حركة Design Pattern في تصنيع ال Software .

ان التنظيم الملائم للفضاءات والعناصر يمكن ان يساعد في خلق الاحساس الجزئي بالمكان (Sense Of Place) (الملائمة تعني: الاشكال التي تلبي الملائمة المفاهيمية بالتوافق بين الشكل)، وتوقعات الساكنين لذلك المكان، وهذه التوقعات ترتبط بالاعراف والسلوك الثقافي، التعليم والمذهب. لهذا السبب عندما نتصدى بالعناصر والفعاليات او بالصراع او عدم التوافق مع التوقعات نشعر بأننا خارج المكان (Out Of Place). مثلاً عندما نكون في قاعة متعددة الاغراض لحضور اجتماع ما، مثل هذه القاعات ممكن ان تستخدم لاغراض اخرى في اوقات اخرى كأن تكون مسرحاً او غيرها من الفعاليات الاخرى التي تستخدم نفس الفضاء بدون تغيرات او اضافات، فنحن في هذه الحالة نشعر (Out of Place) وليس (Out of Space).

تصمم الاماكن عادة في العالم الفيزيائي باستعارة الوظائف، الاشكال والمفاهيم من السابقين (الرموز، الاستعارات والتشبيهات) على افتراض بأن التكوينات هذه ملائمة لظروف سابقة مع اقتباسات ملائمة من السياق الجديد، تستمر لتكون من جديد لنفس الفعالية / المفهوم. يطلق الباحثون على هذا التوجه (التصميم من الانماط Designing From Patterns) وحاليا يوجد مفهوم (Object Oriented Design) ليلائم بصورة دقيقة الحاجات والظروف للسياق "الهدف" (Alexander et al, 1977, p.11) .



مخطط رقم (4)

ينتج المكان نتيجة تفاعل الفضاءات والمفاهيم والفعاليات (Canter, 1977, p.)

مثال :قاعة دراسية في الكلية

- الفضاءات :مثلت حدود القاعة (حجم وابعاد)
 - الفعاليات: مثلت الدراسة التي تتم داخل القاعة
 - المفاهيم: مثلت السلوك داخل القاعة "العلاقة بين الطالب والاستاذ"
- عمل وايجاد الاماكن السايبرية (Making Cyberspace-Places):**

ان الفاصل بين الواقع وغير الواقع ، فاصل ضعيف ويجب الاستفادة مما تقدمه الفضاءات المعلوماتية ولا يجب تجاهلها واعتبارها كأنها غير موجودة. و تختلف الفضاءات المعلوماتية عن الفضاءات الفيزيائية بنقطتين اساسيتين :

- لكي ندرك وتفهم تحتاج الى وسط (الكومبيوتر).

• لاتخضع للقوانين الطبيعية (وهذا ليس عائق بل ميزة وملائمة). (Kalay & Marx.,2003,p.23).

اماكن لافضائية (Complex Forms: Space-Less Places) :

ان الاختلاف بين الفضاء والمكان يشير الى ظهور اماكن بدون فكرة الفضاء اي بدون وجود فيزيائي لها. وضحنا سابقا فكرة ان المكان يكون فضاء مستمراً بمعنى اجتماعي. والفضاءات يمكن ان تكون ناتجة عن الكمبيوتر (افتراضية) وقد تكون فيزيائية. وتبقى اشكالية التواصل والاختلاف هي التي تؤدي الى مفهوم المكانية .

نقدم مثالين للاماكن بدون فضاء فيزيائي

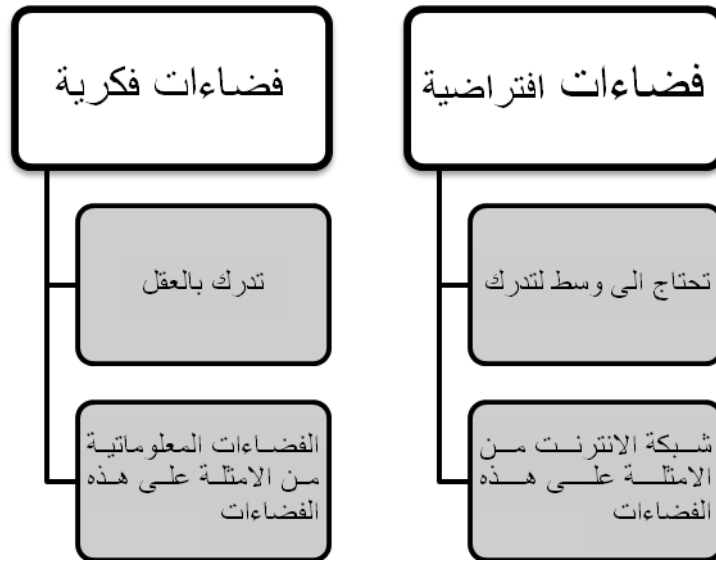
- استخدام شبكة المعلومات (UseNet): هو مصدر واضح على مثل هذه الامثلة . فهي تنتج عن التوتر بين الاختلاف والتواصل. وهذه اماكن مختلفة فهي تتبثق بدون ان تكون تحت فكرة الفضاء.
- فكرة المكان (Idea of place) : ناقش Dourish نماذج مختلفة من الحركة خلال المعلومات ورسم تميز بين الحيزية (Spatial) والرمزية (Semantic) والملاحة الاجتماعية (Social Navigation) . ان الملاحة الاجتماعية هي حركة خلال المعلومات المجموعة على اساس من معلومات مشتقة من فعاليات الآخرين. وهذه حالة جزئية مؤسسة على نموذج مكاني يهدف مساندة و رسم العلاقة بين الفعالية والقرب - الذي ذكر سابقا - وهذه الانظمة تسمح للآخرين بالانتقال لمناطق حيث يجتمع الآخرون، للالتحاق بالتجمع ورؤية مايجري.

كما يوضح Dourish انماط من الملاحة الاجتماعية ، تحدث ايضا خلال (احداث شخصية) في شبكة الانترنت العالمية، وهذه لا تحتاج الى فضاء. يختلف السلوك هنا باختلاف البنية وباختلاف الحركة نسبة لاهتمامات الآخرين.

فهو مثال من تجارب فضاءات اعلامية (الميديا)، حيث تظهر بعد كل تنظيم مكاني استجابة الافراد لاماكن وليست لفضاءات. وتكون لهذه الاماكن بنية الفضاء ولكنها تكون فضاءات فكرية تدرك منطقيا

ويشكل لها وجود في العقل (Conceptual Association). (Harrison & Dourish, 2002, p.6)

تسمى هذه البيئة (الصوتية-الصورية) بفضاءات اعلامية (Media Space) وليس اماكن اعلامية (MediaPlaces). فالمكانية تخلق وتدام بأنماط الاستخدام، فهو شيء لا يمكن تصميمه ومن جهة اخرى المكانية هي التي نصمم لها وندعمها. امتدت الفضاءات الاعلامية لتوفر بنية، بحيث اصبح من الممكن ان تظهر المكانية التي نبحث عنها كما يظهر المكان من الفضاء، فنحن لانصمم للمكان ولكن للناس لعمل اماكن فيها. مخطط رقم (5) ولكن نحتاج الى فهم كيف حول الناس الفضاء الى مكان، يعتبر التكيف والملائمة من العناصر المهمة في ظهور المكان، فكما نقوم بتحويل المنزل الى بيت بتنظيمه ليلائنا ووضعنا للاشياء تعكس حالنا، مثل اخذ صورة و وضعها على الحائط، ترتيب الاثاث او وضع اشياء شخصية في الغرفة، يعمل الناس اماكن بفضاءات الميديا بنفس فكرة التكيف والملائمة ، بهذه الطرق ممكن تحويل الفضاء الى مكان، فالفضاء ياخذ وقتاً ليكون مكاناً.



مخطط رقم (5)

(اماكن لافضائية) اماكن تنتج بدون وجود فيزيائي لها Space-Less Places (الباحثة)

المكان كظاهرة ثقافية (Place as a Cultural Phenomenon):

طورت فكرة الاحساس بالمكان على انه جانب من جوانب السلوك الملائم وسياق للتواجد والافعال المفسرة. وهذا هو جوهر الظاهرة الثقافية. طور هذا المفهوم بمرور الحضارات، وكعضو جديد في اي حضارة، دخلت الى فضاء الميديا ليكتسب العادات الثقافية وكثيرا من مناخ فضاء الميديا. (Harrison & Dourish el., 2002, p.7)

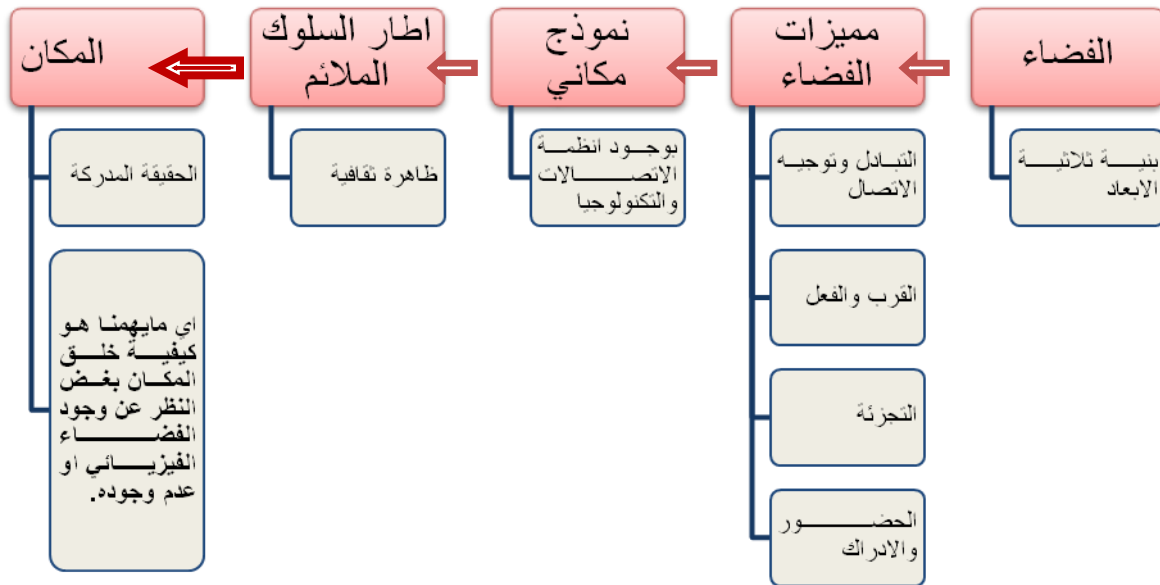
تفرق العادات في الفضاء عن المكان، فتتغير العادات الثقافية وتقدم الجديد كما نلاحظ وعياً من السلوك الملائم يتغير كذلك. حيث يقع في توجهات مختلفة نتيجة الاهتمام بالخصوصية والسيطرة. فالاهتمام بالخصوصية والموازنة بين السيطرة والتواجد والتوجهات الكامنة لمسك المشاكل، هي ليست مطلقة. وهي تنشئ في تشابك الحضارة، وفي القضايا التنظيمية والخاصة في المواقع المختلفة، فنرى طبيعة ومجال الحلول واسعاً لعكسه. ما يهمنا هنا هو العلاقة بين طرق التفاعل وطرق التصرف ونمط الارتباطات الثقافية.

اليوم نحن نفكر بأن (غرفة النوم) هي مكان خاص، ونرى بأن مايجري بداخلها لايجب ان يسمع او يرى من قبل الاخرين، فغرفة النوم مكان خاص جدا يمثل مركزاً لفكرة الخصوصية. وهذا لم يكن كذلك سابقاً، فعند بداية القرون الوسطى كانت اوربا في العصور المظلمة : كان الناس يأكلون وينامون في مجموعة كبيرة في غرفة واحدة. ثم اخترع السرير، حيث تم رفع الاجسام عن الارض الباردة وفصل الناس بعضهم عن بعض وازداد اليها مظلات لجعلها كخيمة، لتظهر كغرف وبذلك وجدت اماكن منفصلة، طورت هذه الفكرة فيما بعد الى غرف النوم المنفصلة. من الصعب القول ان هذه الفكرة التي تسمى الخصوصية كانت رغبة غير منجزة تنتظر اختراعات لحفظ الدفء وعرض الحالة. (ibid, p.9) وعلى اي حال، جذور

الخصوصية في شكل فيزيائي ليس كفكرة مجردة للسيطرة البصرية للآخرين فالتكنولوجيا (جدران، ابواب...) ليست هي الطريقة الوحيدة لخلق الخصوصية وليست كافية بحد ذاتها. ولكن التقاليد الاجتماعية هي التي تعطي معنى للعقل للانفصال البصري. المكان حيث الخصوصية اليوم لها معانٍ مختلفة واستخدام بطرق مختلفة أكثر من الفضاءات للمكاتب او لغرف النوم .

البنية الثقافية والتكنولوجيا:

تعرف المكانية (Placeness) كظاهرة ثقافية، تمثل جذوراً للتفاعل الاجتماعي الانساني ينتج عن معاني حرجة لتصميم أنظمة الاتصالات والتكنولوجيا. فهو يزيح تركيزنا عن تكنولوجيا المكان، مادامت التكنولوجيا تعطينا النتائج لـ (المكانية) من خلال طريقة اعطائها معنى اجتماعياً. مثلاً ابواب المكاتب في العمل تترك مفتوحة عادة ولكن هناك ابواب اخرى تحمل اشارات يشير الى انها مغلقة لابعاد الضوضاء وليس الزوار. وان وجود هذه الاشارات يؤكد العلاقة بين مفاهيم التكنولوجيا والاجتماعية. فهي تركز على المعنى الاجتماعي وتتوفر حتى في غياب الصراع الفيزيائي (الباب المغلق). التشكيلات التكنولوجية لالاماكن الخاصة والهادئة هي نفسها، فهي تميز بالفعل الاجتماعي وليس بالتركيب المكاني. العلاقة بين الفضاء والمكان هي علاقة اجتماعية وليست علاقة تكنولوجية (Harrison & Dourish, 2002, p.12) ولكن بما ان الفضاءات الافتراضية (السايبيرية) تصمم بالاستعارة من الفضاءات الفيزيائية، وبما ان الفكرة الاساسية من تصميم الفضاءات هو التصميم لاحتواء الناس، اي انها يجب ان تكون مكاناً، لذا فأن الاماكن الافتراضية تستعير من طريقة خلق الاماكن بالعالم الفيزيائي بالاضافة الى الجهود الجدية في العالم الافتراضي، مخطط رقم (6)



مخطط رقم (6)

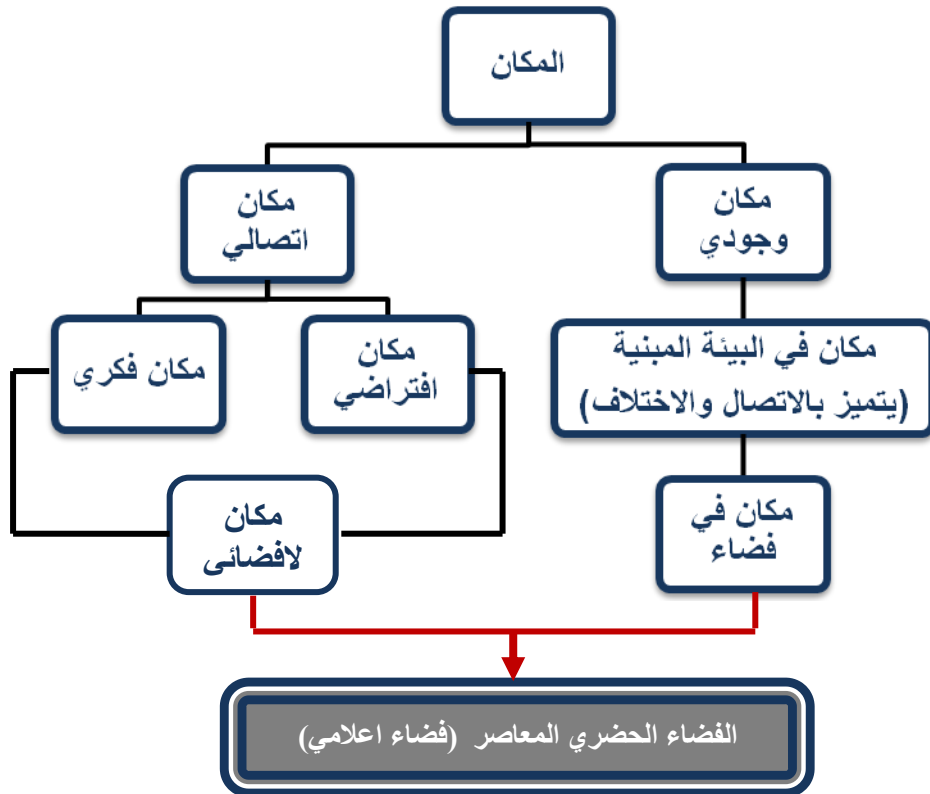
طريقة ايجاد الاماكن (الفكرة الاساسية بالفضاء الحضري ان يكون مكاناً وليس فضاء) (الباحثة)

ويمكن تثبيت ما تم طرحه سابقا من مواضيع وافكار بالجدول والمخطط الاتيين:

جدول رقم (1)

المكان في الفضاء	المكان اللافضائي
مكان في البيئة المبنية	مكان افتراضي يحتاج الى وسط ليذكر
يتميز بالاتصال والاختلاف	يحمل مميزات الفضاء بوجود أنظمة الاتصالات

مكانية الفضاء الحضري المعاصر (الباحثة)



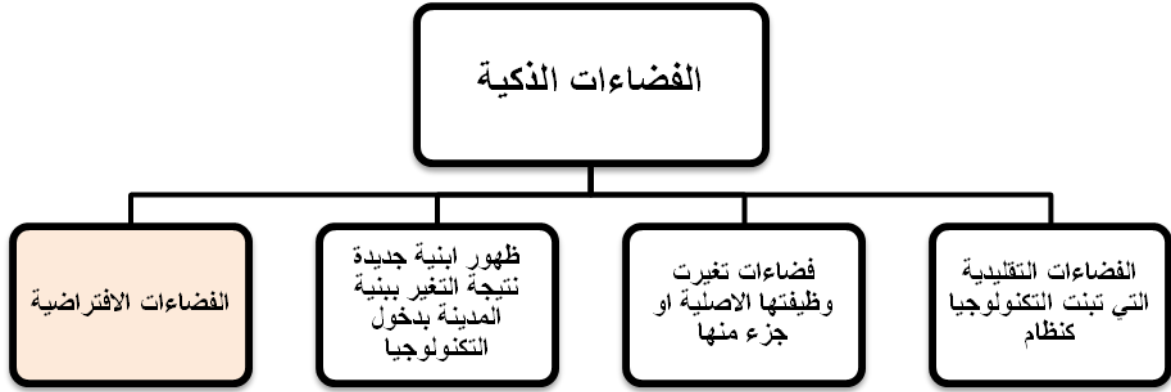
مخطط رقم (7)

الفضاء الحضري المعاصر (الباحثة)

الفضاءات الذكية :

هو الفضاء الذي تغطي سمة المعلوماتية (Informational) عليه، يتميز بوجود عال للتكنولوجيا والعلوم وقد يكون له وجود فيزيائي أو لا يكون، ويظهر هذا الفضاء ليؤدي وظيفة معينة (Function). فنتكامل تقنيات الكمبيوتر لتوفر بنية غنية للاتصال خلال الزمن والفضاء (Firmino, 2001, P3). وهناك اربع تقسيمات للفضاءات الذكية اعتمادا على وظائفها وعلى الاشارات المعمارية التي تحملها مخطط رقم (8):

- الفضاءات التقليدية التي تبنت التكنولوجيا كنظام. كالبنوك
- فضاءات تغيرت وظيفتها الاصلية او جزء منها، المراكز الثقافية والتجارية (كالمولات). شكل (1)، (2)
- ظهرت ابنية جديدة لظهور وظائف جديدة نتجت عن التغير الحالي لدخول معطيات جديدة، ك مقاهي الانترنت، المتنزعات التكنولوجية، اكشاك المعلومات . شكل رقم (3)
- الفضاءات الافتراضية مثل شبكات الانترنت الصناعية ، أو الانترنت نفسه.



مخطط رقم (8)

تقسيمات للفضاءات الذكية اعتمادا على وظائفها وعلى الاشارات المعمارية التي تحملها (الباحثة اعتمادا على (Firmino, 2001, p3)

وهذا الصنف الرابع من الفضاءات الذكية يرتبط بعلاقة قوية مع ظاهرة التحضر الافتراضي (Virtual Urbanization)، والذي دعم بنظريات متطورة عديدة من قبل عدد من المنظرين مثل (Graham & Marvin 1996) و (Castelle 1996) (Mitchelle 1995) و (Horan 2000). والذي جرى توضيحه سابقا. تُنرى العملية الحضرية الافتراضية كسلسلة من الحلول الجديدة والحقائق الاجتماعية والثقافية - التي تظهر في المدن- و توجه العمليات الحضرية التقليدية لتكون اكثر تعقيداً، مدعما بوجود التكنولوجيا ويتحرك باتجاه حاجات جديدة للراسمالية التي تحقق مايسمى (العولمة) للانتاج الاجتماعي والمكاني لحالة العلاقات (Firmino, 2001, p3).



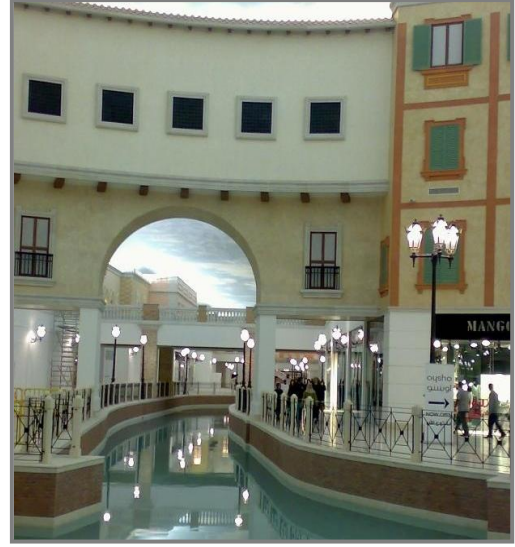
شكل رقم (1)

مول West Edmonton كندا

يعد افضل مكان لجذب السائحين حيث يصل عدد زوار المكان الى 22 مليون لما تحتوي من أماكن الترفيه وفضاءات للعب الاطفال والمحلات التجارية العالمية لتتناسب ذوق جميع افراد الاسره.



شكل رقم (3)
مقهى انترنت



شكل رقم (2)
مول تجاري في قطر يحتوي على نهر
صناعي و قوارب

كما يمكن ان تقسم الفضاءات الذكية تقسيما اخر اعتمادا على وظيفتها التي تؤديها وطريقة اظهارها -
جدول رقم (2)، الى:

- فضاء انتاج ذكي (SIP) Space of Intelligent Production.
- فضاء استعمال ذكي (SIU) Space of Intelligent Usage.

فيمكن أن يكون هناك فضاء فيزيائي من نوع (فضاء انتاج ذكي) ومن نوع (فضاء استعمال ذكي) وكذلك
بالنسبة للفضاءات الافتراضية فهناك فضاءات افتراضية من نوع (فضاء انتاج ذكي) ومن نوع (فضاء
استعمال ذكي) (Firmينو, 2001, p4).

- فالمتنزهات التكنولوجية والجامعات هي فضاءات فيزيائية موجودة بالواقع ذات انتاج ذكي
(Physical Space of Intelligent Production).
- شبكات الشركات الصناعية العالمية الافتراضية، هي فضاءات افتراضية ذات انتاج ذكي
(Virtual Space of Intelligent Production).
- البنوك، المستشفيات والمراكز الثقافية، تصنف كفضاءات فيزيائية ذات استعمال ذكي (Physical Space of Intelligent Usage).
- شبكات الانترنت، هي فضاءات افتراضية ذات استعمال ذكي (Virtual Space of Intelligent Usage).

جدول رقم (2)

الفضاءات الذكية (Intelligent Spaces)			
فضاءات ذات استعمال ذكي (SIU)		فضاءات ذات انتاج ذكي (SIP)	
فيزيائية	افتراضية	فيزيائية	افتراضية
- فضاءات المصرف ذات الحضور الذاتي (Banking-Self Attending Spaces). - اكشاك ومصاطب معلومات المواطنين (Citizens Information Stands or Kiosks). - المراكز الثقافية والترفيهية ، السينمات والخ..	- تداخلات المصرف ذات حضور ذاتي (Banking Self-Attending Interfaces). - اشترك الانترنت البيتي (Internet Home Banking) - شبكات المعلومات المحلية (Municipal Information Networks) - الانترنت بحد ذاته	- المنتزهات التكنولوجية او العلمية (Technology or Science Parks) - الجامعات (Universities) - مراكز البحوث والخ (Research Centers)	- شبكات اتصالات الجامعات (University Communication Networks) - الشبكات الصناعية (Industrial Internates) - الشركات الافتراضية والخ.. (Virtual Companies,)

تصنيف الفضاءات الذكية نسبة الى وظائفها وطرق تمثيلها
(Firmino, 2001, p.4)

مما تقدم يمكن تثبيت بعض النقاط التي نتجت عن الرؤية الجديدة لطبيعة المكان في الفضاءات الذكية (السهيل، 1999، ص68)

- اساس معرفة ونشاط الانسان غير مقيد فيزيائيا للمكان وبالتالي لضرورة لتقيده ضمن مكان محدد.
- القابلية على اشغال عدد من الفعاليات خلال الزمان.
- الامكانية في اشغال واستغلال اماكن مختلفة يرجع اليها ويعرف فيها كمستقر ضمنها، يمكنه القيام بفعله من خلالها .
- تحول النشاط والفعالية من المادية (المقصود به تغير اسلوب وسائل العمل ك الكتابة مثلا) الى وسائل غير مادية من وسائل الخلق (كالمناقسة ومعالجة الافكار والمعلومات).
- إسهام المكان الذي اصبح ذا صفة نطاق بكونه يحفز ويلهم ويحرك ويولد ومشارك بين عدد من فرق العمل.

- تغير مفهوم الاستخدام حيث اظهرت الدراسات ان الزمن الذي يتواجد الانسان فيه ضمن المكان قد تتراوح بين 50-40% بعد ان كان في الانماط الاخرى من اساليب العمل قد يصل الى طوال الوقت الذي يتواجد فيه الشخص ضمن تأدية الفعالية الخاصة به.

الاستنتاجات

- اصبح الفضاء الافتراضي مكاناً معروفاً وهذا يحتم علينا ان نصممه كمكان اكثر من كونه مستندات واكثر من كونه فضاء (Space) فنوعية البيئة والاحساس بالمكان مهمة بالفضاء الافتراضي كما هو الحال في الفضاء الفيزيائي فله نفس الفوائد والتأثير بالزائرين كما تؤثر البيئة الفيزيائية بزائريها. يمكن الاستفادة من المبادئ التي طورت من قابليات التكنولوجيا التي تعطي حرية كبيرة للاماكن الافتراضية اكثر من الاماكن الفيزيائية . والتحدي يكمن في مزج حاجتين متعاكستين فلا نخنق الاماكن الافتراضية بجعلها حقيقة عالية ولا نجعلها افتراضية عالية ، لنقطة تجردها من الاحساس بالمكان .
- من الخطر الارتباك بين فكرة الفضاء والمكان فالمكان بالعالم الفيزيائي لا يملأ فقط بالحقائق والادوات وتمثيل عملنا ولكن ايضا بالناس وعلامات نشاطاتهم. والاحساس بوجود الاخرين والتنبيه لفعاليتهم التي تسمح لنا بأنشاء فعاليتنا الخاصة ومكاملتهم مع فعاليات الاخرين. فتعطي معنى لتصرفاتنا وفعاليتنا. ولهذا نذهب الى الحفلات المباشرة، ولهذا لازلنا نستعير الكتب من المكتبات ومازلنا نزور المتاحف مع انه يمكن زيارتها من خلال شبكة الانترنت ونذهب الى المباريات والاجتماعات مع انه يمكن قراءة النتائج والخطوات في البيت.
- المكان بأماكنيات الامتداد والانتقال الحالية متحققا كقيمة غير ملغية الوجود ولكن بتغير تصورنا نحوه ضمن ماهيته الحالية (الوجودية والافتراضية) فمن خلاله توجد الاشياء ومن مكانه يمكن للانسان ان يبدأ الفعل والتأثير. فلا يمكن لشئ ان يكون الا في المكان، والانسان في طموحه لتحقيق وتأسيس وجوده بسكنه الارض ، لا يمكن ان يتحدد بغياب المكان.
- يظهر عمل وانشاء الاماكن ليكون موضوعاً معقداً. فهو يعكس تنظيمياً واعياً للعناصر لخلق فضاء ملائم للفعالية ، ويعطي تعبير لقيم الشاغلين له ولمجتمعهم. بتعبير اخر : يكون الفضاء مكاناً لمستخدميه.
- عندما نفكر بالفرق ما بين المكان والفضاء من منظور الاعلام، نرى وسائل مختلفة تدخل بتكنولوجيا الاتصالات لتلعب ادواراً مختلفة. فعندما يضاف الصوت او الصورة (الفديو) الى فعالية نصية، تكون النتيجة ليس فقط نوع من نظام مع بيانات اكثر ولكن النتيجة تكون عبارة عن نوع من وسط جديد وبالتالي فكر وسلوك الناس يتأثر تباعا.
- ان طبيعة المكان في الفضاءات الذكية - نتيجة التغير في مفهوم الفضاء في عصر الثورة المعلوماتية - ادى الى زيادة المقدرة الوظيفية ، و اوجد ما يسمى بـ النطاق المتعدد الفعالية .

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القران الكريم يدعو للبحث في تاريخ العمارة

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الخلاصة

يعد علم تاريخ العمارة احد حقول المعرفة التي أولتها الدراسات المعمارية أهمية كبيرة , فهي معبرة عن فكر الأمم و حضارتها و مجسدة لنتاجها المادي . تكمن مشكلة البحث في عدم وجود تصور واضح لأهمية دراسة تاريخ العمارة في الفكر المعماري الإسلامي , و تمثلت فرضية البحث بما يلي " . إن القران الكريم يدعو للبحث في تاريخ العمارة"

لقد تضمن البحث استقراء للآيات القرآنية التي تؤكد أهمية دراسة و تفسير العمارة. وتبعاً لذلك تم تفسير أمثلة من تاريخ العمارة و بما يعزز الفرضية. لقد توصل البحث إلى العديد من الأسباب التي تعزز أهمية دراسة التاريخية، كما افرز البحث استنتاجات مستتبطة من أعجاز القران الكريم

THE HOLLY QURAN ENCOURAGE RESEARCH IN ARCHITECTURAL HISTORY

ABSTRACT

The science of architectural history is considered one of the basic fields of the architectural studies because it reflects civilization, intelligence and creation .The present research problem takes to account the confusion image of the importance of studying architectural history in Islamic architectural theory . Research hypothesis is " The holly quran encourage research history".

The research contain Ayat al quran that in sure the importance of studying history and explain examples from historical buildings the research in sure the importance of studying historical civilization and buildings, and draw some conclusions from al quran miracles.

مقدمة :

لا حاجة للتذكير بالاهمية التي اكتسبتها العمارة الاسلامية ولا تزال ... فمنذ القرن التاسع عشر بدا المستشرقون يبحثون مختلف اوجه العمارة الاسلامية كنتاج حضاري مادي؛ لا تزال الى هذا اليوم تتنوع وتختلف المناهج والتوجهات والرؤى حولها، وتحاول بعض الدراسات استخدام وتطوير احدث الوسائل التحليلية الرقمية لدراستها، وان الاختلاف في وجهات النظر واستمرار المناقشات والبحوث لدليل على اهمية العمارة الاسلامية وقيمتها الحضارية.

ومنذ مطلع القرن الخامس عشر الهجري التي صاحبتهما الصحة الاسلامية . ظهرت توجهات بحثية جديدة يقوم بها باحثون مختصون مسلمون؛ لا تتناول العمارة الاسلامية كمنتج حضاري مادي فقط؛ بل تبحث في تأثير الاسلام . كعقيدة وكشريعة . على هذه العمارة، وتحاول ايجاد السبل لتفعيل دور الاسلام . كعقيدة وكشريعة . لتوجيه المصممين لانتاج عمارة اسلامية معاصرة.

وقد ظهر توجه جديد؛ حديث النشوء نسبيا؛ يحاول التقدم بشكل اعمق ليس لدراسة العمارة الاسلامية فحسب، وليس للتأثير المباشر - للعقيدة والشريعة عليها فقط؛ ولكن يحاول تاصيل منهج فكري اسلامي لتناول مختلف المجالات الفكرية المعمارية سواء لدراسة العمارة الاسلامية - ماضيا وواقعا مستقبلا - او لدراسة العمارة العالمية بشكل عام ... فيجب ان يكون للمسلمين دورهم في القيادة الفكرية في عصرنا الذي اتسم بـ " العولمة " التي تتخذ الصراع الفكري كاهم وسيلة لها ومن هنا تاتي اهمية البحث في بيان اهمية دراسة العمارة العالمية من منظور اسلامي.

- الدراسات القرآنية:

ان الاستهداء بهدي القرآن الكريم في مختلف المجالات المعرفية والعلمية يعد احد محاور المعرفة المهمة؛ فقد ظهرت الكثير من الدراسات في هذا المجال منذ عصر التدوين - القرن الثالث الهجري - والى اليوم، قال تعالى ﴿ ونزلنا عليك الكتاب تبيانا لكل شيء ﴾ (النحل، 98) وهناك الكثير من الايات الاخرى في هذا المعنى فالقرآن الكريم كتاب هداية .

وفي العصر الحديث ظهرت الكثير من الدراسات التي تبين الاعجاز العلمي في القرآن في مختلف مجالات الفلك والجغرافية وعلوم الحياة والطب وعلم النفس وغيرها لكن من المهم اعادة التذكير بان القرآن الكريم ما جاء ليكون كتابا علميا - بمفهوم العلوم بين الناس - ولقد الح بعض المعاصرين على تحميل ايات الله معان وتفسير علمية لم تقصد اليها البتة ... هناك المعرفة القرآنية ذات المصدر الالهي: يتضمن حقائق ومسلمات مطلقة ثابتة لا تتغير ... وهناك المعرفة العلمية ذات المصدر البشري؛ حيث لا توجد في الواقع حقائق نهائية؛ وان معطيات العلم البشري هي (احتمالية) قد تخطيء وقد تصيب (خليل، 1985، ص8-10) - راجع على سبيل المثال منهج بوير في الاحتمالية.

ان القرآن الكريم يقدم اهداف العلم ومبادئه الاساسية ويقدم اشارات للمنهج الصحيح (نفسه ص25، ص71) وفيه الحث والتشجيع على البحث والتقصي او الرؤية والتفكير والتعقل والتعلم في مختلف مجالات الحياة التي اشار لها (خليل، 1985، ص109- 116) .

كما يجب على الباحث ان يكون على قدرة على التعامل مع جانبين: جانب تخصصه، وجانب التفسير القرآني، حيث يمكنه الاستفادة من الاتجاهات الحديثة في مجال التفسير القرآني التي تعتمد مفردات القرآن ومنحنياته البيانية لفهم مضامينه ومعانيه فيما يعرف "بالتفسير البياني للقرآن" والذي من شأنه ان يمنح الباحث ضمانات موضوعية لنشاطه تحميه من الافراط او التقريط في الوصول الى دلالات اللفظ القرآني (خليل، 1985، ص110) وبذلك يتبين اهمية دور العلم في استخدام كنوز الرسالة وتفضيلها في مختلف مجالات المعرفة ومنها العمارة.

*-العمارة في الدراسات القرآنية السابقة:

هناك بعض المحاولات في مجال العمارة، بالرغم ان الدراسات القرآنية قد قطعت اشواطاً بعيدة في مجالات معرفية اخرى فالدراسات القرآنية عن المدينة والبيئة الحضرية فيها محاولات اقدم واكثر (انظر على سبيل المثال: ناجي، 1986، ص27-32) والتي تعتبر اقرب حقل معرفي للعمارة.

من هذه المحاولات في مجال دراسة العمارة (دراسة عبد العزيز ابا الخيل "1989") (بالانكليزية) عن طريق وسائل البناء والتشيد التي يشير فيها الى بعض الوسائل البنائية (البناء بالطين، والطين المفخور، الخيام، البناء بالحديد والزجاج والقباب) التي يحاول من خلال بعض الايات الكريمة تتبع البدايات الاولى - مقارنة مع علم الآثار - لهذه التقنيات البنائية - والتي تبدو انه ربما افراط في تحميل بعضها معنى زائدا يحتاج الى المزيد من التقصي والبحث ما بين الدلالة القرآنية والدلائل التاريخية - مثال ذلك كلامه عن نشوء القباب - (راجع دراسة عبد العزيز ابا الخيل -1989) ومنها دراسة تتناول مصطلحات الانشاء والعمارة التي وردت في القرآن الكريم من حيث المواد الانشائية وطرق البناء ومراحل التنفيذ، لقد اشار الى الكثير من المصطلحات ... لكنه بعيد جدا في كثير منها عن دلالاتها البيانية، وحمل كثير منها معاني لا تتحملها - مثل الاشارة الى خلق الانسان من طين الى ذكر الطين كمادة بناء ، او ذكر حجارة العذاب التي من سجل او مصطلح الثني الانشائي من " يثنون صدورهم " او بقية مفاهيم انشائية مثل الحمل والثقل الى ايات ذات دلالات بعيدة وغيرها (راجع سامي كاظم 1999).

وهناك مثلاً دراسة لغوية دلالية عن الفاظ العمارة في القرآن حيث تتناول الالفاظ القرآنية عن مواد البناء ، والعناصر المعمارية وانواع المباني والافعال المقترنة بعمليات البناء . ان الدراسة تقدم خلفية دلالية مناسبة لكل لفظة متتبعة مصدرها وجذورها اللغوية من المصادر المعجمية ومتتبعة كافة الاشارات لها في مختلف التفسيرات القرآنية ... وكذلك تميز الدراسة ما بين الالفاظ التي جاءت تحمل معنى عاما او تلك التي تحمل معنى معماريا بالخصوص (راجع نجلاء مرعي 2001) .

ان هذه الدراسة قيمة من حيث تتبعها للاصول اللغوية لكل لفظة تدل على البناء واءاء المفسرين فيها، بحيث يمكن للباحث المختص - المعماري - ان يستفيد منها وتغنيه عن البحث في مصادر اللغة والتفسير . وبرزت دراسات تحاول تقديم نظرة شمولية عن اثر الدين الاسلامي على العمارة (راجع العمري، 2000) ودراسة (القرآن الكريم مفتاحا للبحث العلمي في علم العمارة ونظرياتها) والتي عنيت بالاعجاز القرآني (الاعجاز اللغوي، والاعجاز الادبي، والاخبار عن الماضي والحاضر والمستقبل، والاعجاز العلمي) و عن طريق الاستنباط بواسطة المماثلة والقياس يمكن البحث في علم العمارة في تخصصاتها المختلفة - انظر المخطط - 1-و-2 . (راجع العمري، 1998).

وانطلاقا مما تقدم تبرز الحاجة للمزيد من الدراسات ضمن هذا التوجه؛ ويمكن بواسطة زيادة التخصص التوصل الى المزيد من الفهم والعمق ... ويرى البحث اختيار مجال مهم للدراسة في النص القرآني، وهو مجال "تاريخ العمارة" بمفهومها العالمي الواسع وليس العمارة الاسلامية وحدها حيث ان هذا المجال قد اغفله الباحثون العرب والمسلمون بشكل عام (انظر مخطط رقم -2-) وتبرز الحاجة - في زمن العولمة واتصال الحضارات - الى اهمية دراسة هذا المجال وفق نظرة اسلامية شمولية، نظرا لكثرة الاشارة له في القرآن الكريم.

وعليه فان المشكلة البحثية تتمثل في عدم وجود تصور واضح لدعوة القرآن الكريم لدراسة تاريخ العمارة العالمية واهميته في نظريات العمارة الاسلامية وتفسير تاريخ العمارة .

وسيكون الهدف بيان هذه الدعوة واهميتها وعليه يفترض البحث ان القرآن الكريم يدعو الى دراسة تاريخ العمارة العالمية للتوصل الى حقائق علمية في تاريخ العمارة.

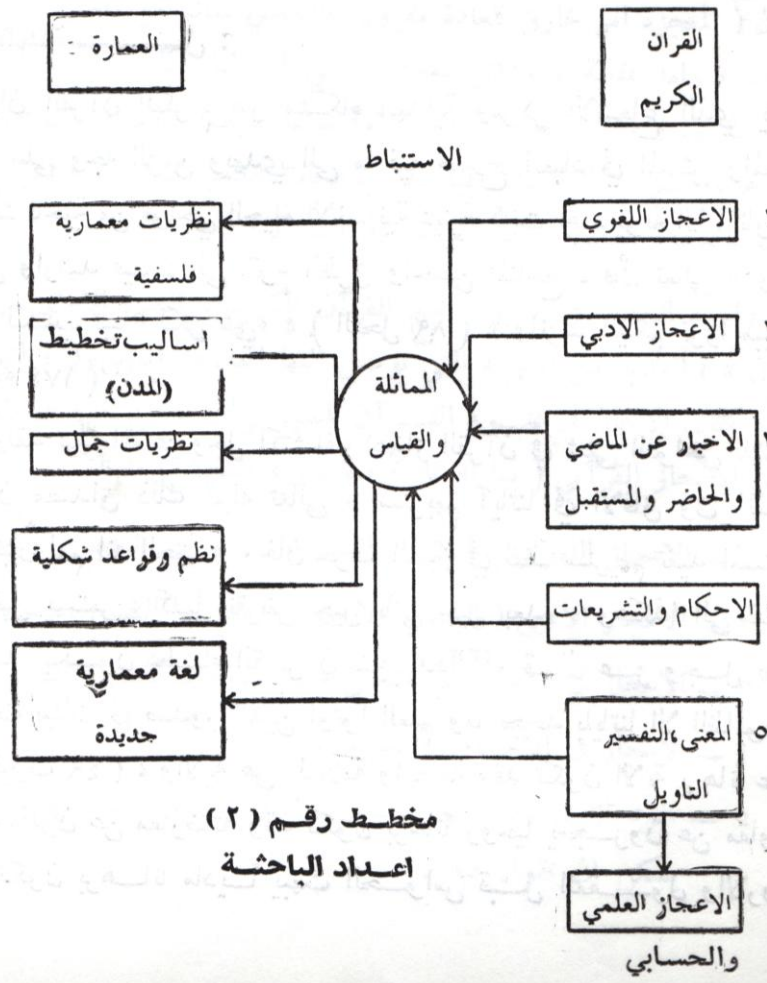
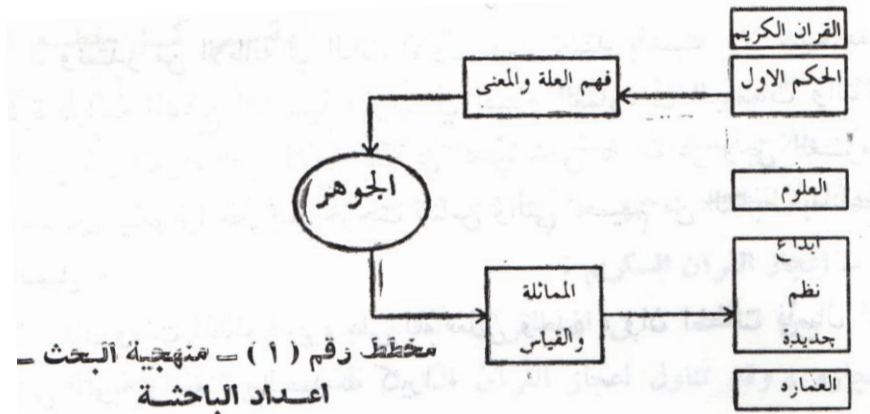
وسيستخدم البحث المنهج الاستقرائي والاستنباطي - باذن الله - :

- تحديد بعض التوجيهات العالمية لدراسة تاريخ العمارة وذلك لبيان :

بيان اهمية الثقافات المسلمين للتخصص للبحث في هذا المجال.

- عزل الايات القرآنية التي فيها اشارات واضحة للتأمل في تاريخ العمارة .

- تحليل امثلة تاريخية وبيان مدى الاستنباط للخروج بنتائج مهمة ونظرا لاتساع الموضوع سيكتفي البحث بتحليل امثلة من العمارة المصرية القديمة.



- بعض التوجهات العالمية لدراسة تاريخ العمارة:

لا حاجة للتذكير بأهمية تاريخ العمارة سواء بالنسبة لممارسة المهنة او بالنسبة للتنظير المعماري، فمنذ عصر النهضة - بالذات - و ظهور الاكاديميات المعمارية، وتاريخ العمارة يستحوذ على مساحات واسعة من الاهتمام ... ويتتبع تطور الممارسة والتنظير والتعليم المعماري في القرون الاربعة المنصرمة (يمكن مراجعة

تجاه التاريخ فهي لاتخرج عن كونها توجهات تفرض وجوب التعامل مع الطرز الكلاسيكية (الاغريقية والرومانية) حيث تعتبرها المصدر المثالي للعمارة وذلك يتبع الايدولوجية الغربية التي تعتبر الاغريق مصدرا للثقافة والحضارة (مثل احيائية عصر النهضة، الكلاسيكية الجديدة في القرن الثامن عشر، انتقائية القرن التاسع عشر، وانتهاء ببعض توجهات عمارة ما بعد الحداثة).

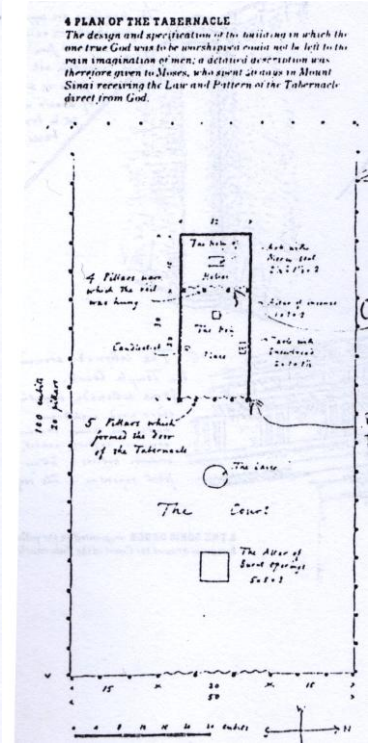
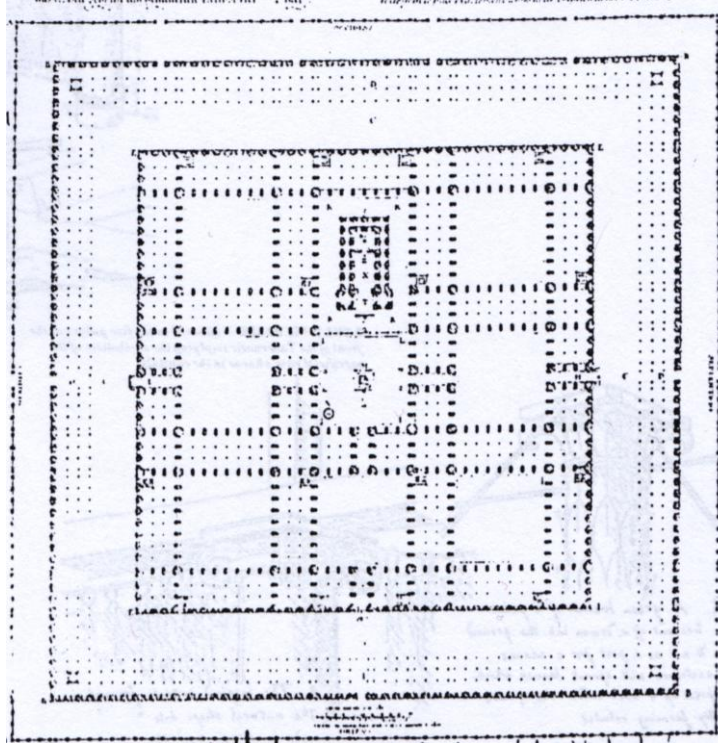
كما برزت توجهات تدعو للثورة على العمارة الكلاسيكية باعتبارها تقيد من حرية المعمار والمجتمع وتدعو الى الانقطاع عن التاريخ، و البحث عن اصول للعمارة في الطبيعة (الكوخ البدائي) او في اسلوبية المعمار الذاتية (رومانسيو القرن الثامن عشر، بعض التوجهات ضمن عمارة ما بعد الحداثة وخصوصا التفكيكية) او تلك التوجهات التي تبحث عن الاصول في التعبير الانشائي او الوظيفي او تبعا للظروف الاقتصادية (عقلانيو القرن التاسع عشر والعمارة الحديثة في النصف الاول من القرن العشرين). او تصورات تبحث عن الاصول الدينية العقائدية للعمارة مثلا باعتبار اصل الاعمدة alters واصل الـ padimen هو الثالث (Vilder 1995).

توجهات تدعو للتعامل مع مناحي معينة من العمارة التاريخية دون اخرى (عقلانيو القرن الثامن عشر الذين اوجدوا فكرة النمط (type) وتوجهات العقلانيين الجدد في عمارة ما بعد الحداثة).

ومن ملاحظة التوجهات اعلاه - يوجد العديد من التصنيفات الثانوية الاخرى ضمنها والتي تتعدد وتختلف حسب مختلف المصادر - يلاحظ ان العمارة ما بعد الحداثة التي بدأت من ستينات القرن العشرين تشمل جميع التوجهات المختلطة، فالممارسة والتنظير في العقود الاخيرة تميزت بالتعددية (Pluralism) (يمكن متابعة ذلك في الممارسة المعمارية في (Jencks, 1996 Architecture Today) .

ان هذه التعددية في وجهات النظر، ومنها التعامل مع التاريخ، هي سمات نظام العولمة الذي بالرغم مما يدعيه من العالمية الا انه متكئ على النموذج الغربي - بالذات الامريكي - (الجابري، 1998، ص137). وهكذا تستمر - من الناحية الايدولوجية والعقائدية - النظرة السائدة حول المركزية الغربية للثقافة والحضارة - وبالتالي سيادة التاريخ الكلاسيكي والطرز المعمارية الكلاسيكية - والى جانبها النظرة المعارضة والتي هي بدورها برغم دعوتها للانقطاع عن التاريخ الا انها ايضا تعتبر الاخر المعارض في نفس المركزية الغربية.

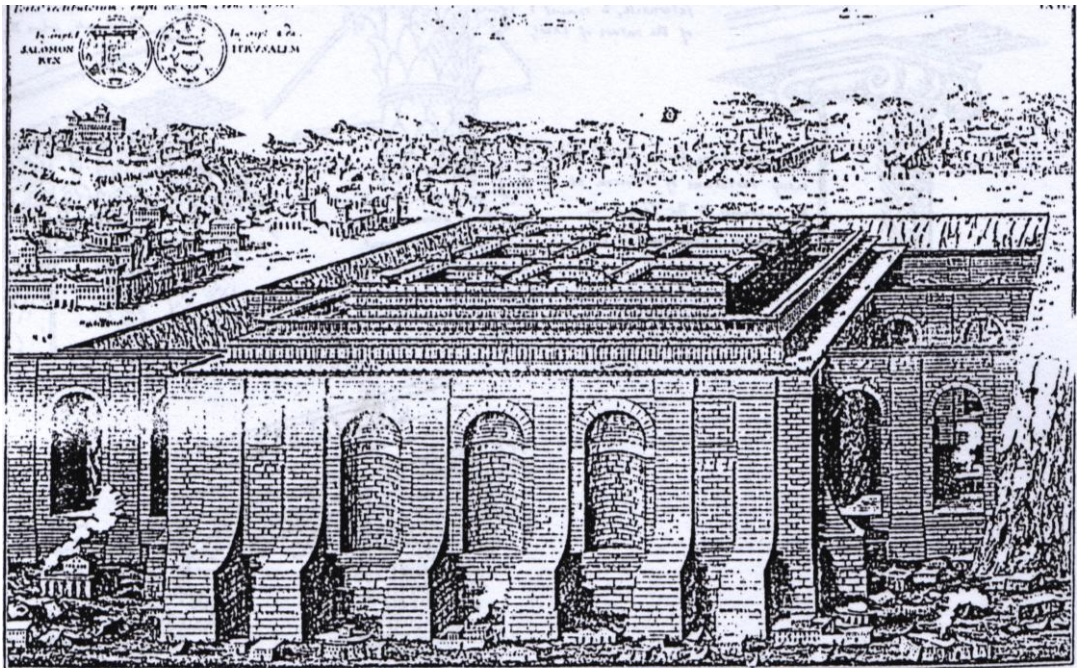
ومع ذلك هناك توجهات اخرى معارضة تحاول ان تجد فيها المساحة المناسبة على المسرح الثقافي، منها على سبيل المثال: بعض التوجهات الماركسية والتي لاتزال لها مؤيدين في الفكر الغربي خاصة في اوربا Esbitt, (1996, PP 36-37) وربما يكون من ابرز ممثليها الايطالي Tafuri Manfredod (1980) فهو يتبنى موقفا تجاه التاريخ، فينتقد المجتمع الرأسمالي الذي شيد المدن والمباني كآلات لتصريف (القيم الغائضة) ويرى ان العمارة الحديثة قد رسمت نهايتها من خلال سياستها التي اثبتت حتميتها التاريخية في الفناء. فهو يرى التاريخ كخزين من الخدع والفشل والطوباويات غير القابلة للتحقيق؛ وهذا برايه سبب يدعو الى الانقطاع عن التاريخ في بعض الطروحات الفلسفية ويدعو الى توجيه الاهتمام بتطوير قيم المجتمع ، اي القيم الماركسية،



مخطط افتراضي لهيكل سليمان (عليه السلام)

مخطط افتراضي لمعبد موسى

(عليه السلام) الوقت في سيناء



منظور افتراضي لهيكل سليمان في القدس

(شكل - 3-) تصورات افتراضية لليهود (Quinlin,1983)

- الآيات القرآنية التي تشير الى تاريخ العمارة:

لقد تم عزل مجموعة من الايات القرآنية التي اشارت الى العمارة او بعض عناصرها او مواردنا والتي جاءت في سياق الحديث عن الاقوام السابقة، ومن الجدير بالذكر ان هناك ايات اخرى فيها اشارات مماثلة في سياق الحديث عن احداث عاصرت الدعوة المحمدية (على صاحبها واله افضل الصلاة والسلام) لم يتطرق لها البحث - فيما يلي هذه الايات مرتبة حسب ورودها في القرآن الكريم:

- ﴿وَإِذْ جَعَلْنَا الْبَيْتَ مَثَابَةً لِّلنَّاسِ وَأَمْنَا وَاتَّخِذُوا مِن مَّقَامِ إِبْرَاهِيمَ مُصَلًّى﴾ (البقرة ، ١٢٥)
- ﴿وَإِذْ يَرْفَعُ إِبْرَاهِيمُ الْقَوَاعِدَ مِنَ الْبَيْتِ وَإِسْمَاعِيلُ﴾ (البقرة ، ١٢٨)
- ﴿كُلَّمَا دَخَلَ عَلَيْهَا زَكَرِيَّا الْمِحْرَابَ﴾ (آل عمران ، ٣٧)
- ﴿إِنَّ أَوَّلَ بَيْتٍ وُضِعَ لِلنَّاسِ لَلَّذِي بِبَكَّةَ﴾ (آل عمران ، ٩٦)
- ﴿تَتَّخِذُونَ مِنْ سُهُولِهَا قُصُورًا وَتَنْحِتُونَ الْجِبَالَ بُيُوتًا﴾ (الاعراف ، ٧٤)
- ﴿فَاصْبِرُوا فِي دَارِهِمْ جَائِمِينَ﴾ (الاعراف ، ٧٨)
- ﴿وَأَوْحَيْنَا إِلَىٰ مُوسَىٰ وَأَخِيهِ أَن تَبَوَّآ لِقَوْمِكُمَا بِمِصْرَ بُيُوتًا وَاجْعَلُوا بُيُوتَكُمْ قِبْلَةً﴾ (يونس ، ٨٧)
- ﴿فَاصْبِرُوا فِي دِيَارِهِمْ جَائِمِينَ﴾ (هود ، ٦٧)
- ﴿فَاصْبِرُوا فِي دِيَارِهِمْ جَائِمِينَ﴾ (هود ، ٩٤)
- ﴿وَكَاوَلُوا يَنْحِتُونَ مِنَ الْجِبَالِ بُيُوتًا عَامِينَ﴾ (الحجر ، ٨٢)
- ﴿لَتَتَّخِذَنَّ عَلَيْهِمْ مَسْجِدًا﴾ (الكهف ، ٢١)
- ﴿فَوَجَدَا فِيهَا جِدَارًا يُرِيدُ أَنْ يَنْقَضَ فَأَقَامَهُ﴾ (الكهف ، ٧٧)
- ﴿فَجَعَلْ بَيْنَنَا وَبَيْنَهُمْ سَدًّا ، قَالَ مَا مَكَّنِّي فِيهِ رَبِّي خَيْرٌ فَأَعِينُونِي بِقُوَّةٍ أَجْعَلْ بَيْنَكُمْ وَبَيْنَهُمْ رَدْمًا ، عَائُونِي زُبَرَ الْحَدِيدِ حَتَّىٰ إِذَا سَاوَىٰ بَيْنَ الصَّدَفَيْنِ قَالَ انْفُخُوا حَتَّىٰ إِذَا جَعَلَهُ نَارًا قَالَ عَائُونِي أُفْرِغْ عَلَيْهِ قِطْرًا﴾ (الكهف ، ٩٤ - ٩٦)
- ﴿فَخَرَجَ عَلَىٰ قَوْمِهِ مِنَ الْمِحْرَابِ﴾ (مريم ، ١١)
- ﴿وَإِذْ بَوَّأْنَا لِإِبْرَاهِيمَ مَكَانَ الْبَيْتِ﴾ (الحج ، ٢٦)
- ﴿لَهُدًى مِّن مَّوَاقِعٍ وَبَيْعٍ وَصَلَوَاتٍ وَمَسَاجِدَ﴾ (الحج ، ٤٠)
- ﴿فَأَخْرَجْنَاهُمْ مِنْ جَنَّاتٍ وَعُيُونٍ ، وَكُنُوزٍ وَمَقَامٍ كَرِيمٍ﴾ (الشعراء ، ٥٧ - ٥٨)
- ﴿أَتَبْنُونَ بِكُلِّ رِيعٍ غَايَةً تُعْبَثُونَ ، وَتَتَّخِذُونَ مَصَانِعَ لَعَلَّكُمْ تَخْلَدُونَ﴾ (الشعراء ، ١٢٨-١٢٩)
- ﴿وَتَنْحِتُونَ مِنَ الْجِبَالِ بُيُوتًا فَارِهِينَ﴾ (الشعراء ، ١٤٩)

- ﴿قِيلَ لَهَا ادْخُلِي الصَّرْحَ فَلَمَّا رَأَتْهُ حَسِبَتْهُ لُجَّةً وَكَشَفَتْ عَنْ سَاقِهَا قَالَ إِنَّهُ صَرْحٌ مُّمَرَّدٌ مِنْ قَوَارِيرَ﴾ (النمل ، ٤٤)

- ﴿فَأَوْقَدْ لِي يَاهَامَانُ عَلَى الطِّينِ فَاجْعَلْ لِي صَرْحًا﴾ (النمل ، ٣٨)

- ﴿يَعْمَلُونَ لَهُ مَا يَشَاءُ مِنْ مَحَارِبَ وَتَمَاثِيلَ﴾ (سبا ، ١٢)

- ﴿لَقَدْ كَانَ لِسَبَإٍ فِي مَسْكِنِهِمْ آيَةٌ جَنَّتَانِ عَنْ يَمِينٍ وَشِمَالٍ كُلُوا مِنْ رِزْقِ رَبِّكُمْ وَاشْكُرُوا لَهُ بَلْدَةٌ طَيِّبَةٌ وَرَبٌّ غَفُورٌ﴾ (سبا ، ١٥)

- ﴿قَالُوا ابْنُوا لَهُ بُنْيَانًا فَأَلْقُوهُ فِي الْجَحِيمِ﴾ (الصفاف ، ٩٧)

- ﴿وَفِرْعَوْنُ ذُو الْأَوْتَادِ﴾ (ص ، ١٢٠)

- ﴿وَهَلْ أَتَاكَ نَبَأُ الْخَضُمِ إِذْ تُسَوِّرُوا الْمِحْرَابَ﴾ (ص ، ٢١)

- ﴿وَالشَّيَاطِينَ كُلَّ بَنَّاءٍ وَغَوَّاصٍ﴾ (ص ، ٣٧)

- ﴿وَقَالَ فِرْعَوْنُ يَاهَامَانُ ابْنِ لِي صَرْحًا﴾ (غافر ، ٣٦)

- ﴿كَمْ تَرَكُوا مِنْ جَنَّاتٍ وَعُيُونٍ ، وَزُرُوعٍ وَمَقَامٍ كَرِيمٍ﴾ (الدخان ، ٢٥ - ٢٦)

وبالإضافة للآيات المتقدمة التي فيها اشارات لعمارة الاقوام السابقة ، هناك آيات اخرى كثيرة حث واسارة للمؤمنين على التدبر والنظر في آثار هذه البنايات .

- ﴿الَّذِينَ يَرَوْنَ كَمْ أَهْلَكْنَا مِنْ قَبْلِهِمْ مِنْ قَرْنٍ مَكَّنَّاهُمْ فِي الْأَرْضِ مَا لَمْ يُمْكِنْ لَكُمْ﴾ (الانعام ، ٦)

- ﴿وَأَيُّهَا لَيْسِيلُ مُقِيمٌ ، إِنَّ فِي ذَلِكَ لَآيَةً لِلْمُؤْمِنِينَ﴾ (الحجر ، ٧٦ - ٧٧)

- ﴿وَسَكَنْتُمْ فِي مَسَاكِينِ الَّذِينَ ظَلَمُوا أَنْفُسَهُمْ﴾ (ابراهيم ، ٤٥)

- ﴿فَكَأَيِّنْ مِنْ قَرْيَةٍ أَهْلَكْنَاهَا وَهِيَ ظَالِمَةٌ فَهِيَ خَاوِيَةٌ عَلَى عُرُوشِهَا وَبُثْرٌ مُعْطَلَةٌ وَقَصْرٌ مَشِيدٌ﴾ (الحج ، ٤٥)

- ﴿وَلَقَدْ أَتَوْا عَلَى الْقَرْيَةِ الَّتِي أَمْطَرْنَا مَطَرَ السَّوْءِ أَفَلَمْ يَكُونُوا يَرَوْنَهَا﴾ (الفرقان ، ٤٠)

- ﴿فَإِنَّكَ بَيُّوتُهُمْ خَاوِيَةٌ بِمَا ظَلَمُوا﴾ (النمل ، ٥٢)

- ﴿فَإِنَّكَ مَسَاكِينُهُمْ لَمْ تَسْكَنْ مِنْ بَعْدِهِمْ﴾ (القصص ، ٥٨)

- ﴿وَعَادَا وَتَمُودَ وَقَدْ بَيَّنَّا لَكُم مِّن مَّسَاكِينِهِمْ﴾ (العنكبوت ، ٣٨)
- ﴿أَو لَمْ يَسِيرُوا فِي الْأَرْضِ فَيَنْظُرُوا كَيْفَ كَانَ عَاقِبَةُ الَّذِينَ مِن قَبْلِهِمْ كَانُوا أَشَدَّ مِنْهُمْ قُوَّةً وَأَنَارُوا الْأَرْضَ وَعَمَرُوهَا أَكْثَرَ مِمَّا عَمَرُوهَا﴾ (الروم ، ٩)
- ﴿أَو لَمْ يَهْدِ لَهُمْ كَمْ أَهْلَكْنَا مِن قَبْلِهِمْ مِنَ الْقُرُونِ يَمْشُونَ فِي مَسَاكِينِهِمْ﴾ (السجدة ، ٢٦)
- ﴿وَإِلَّكُمْ لَتَمُوتُنَّ عَلَيْهِمْ مُّصْبِحِينَ ، وَبِاللَّيْلِ أَفَلَا تَعْقِلُونَ﴾ (الصفافات ، ١٣٧-١٣٨)
- ﴿تَذَمَّرُ كُلُّ شَيْءٍ بِأَمْرِ رَبِّهَا فَأَصْبَحُوا لَا يُرَى إِلَّا مَسَاكِينُهُمْ﴾ (الاحقاف ، ٢٥)
- ﴿أَلَمْ تَرَ كَيْفَ فَعَلَ رَبُّكَ بِعَادٍ ، إِرَمَ ذَاتِ الْعِمَادِ ، الَّتِي لَمْ يُخْلَقْ مِثْلُهَا فِي الْبِلَادِ ، وَتَمُودَ الَّذِينَ جَابُوا الصَّخْرَ بِالْوَادِ ، وَفِرْعَوْنَ ذِي الْأَوْتَادِ﴾ (الفجر ، ٦- ١٠) .
- وهناك آيات اخرى كثيرة فيها ذكر للمدن والقرى للاقوام السالفة لم يتطرق اليها لبحث (راجع ناجي ، ١٩٨٦ ، مصطفى ، ١٩٨٨) .

وبعد عرض كل ماتقدم من الايات الكريمة، وهذا مما يوضح دعوة القرآن الكريم للنظر في اثار الاقوام السالفة ودراسة عمارتها مثلا قوله تعالى ("افلا يعقلون"، "افلا يسيروا في الارض فينظروا"، "الم يروا كم اهلكنا قبلهم من القرون"). ومن الغريب حقا ان الاختصاصيين في المجالات المعرفية الاخرى - خصوصا العلمية- قد التقطوا كل شاردة وواردة من الفاظ القرآن الكريم الذي لاتفنا عجائبه ، ولكي يوغلوا النظر اكثر في اختصاصهم ، وبقي المعماريون بعيدين عن التقاط المعنى عن تاريخ العمارة في كل هذه الايات الكثيرة؟...

من كل ما تقدم يمكننا الاستنتاج بان في القرآن الكريم دعوة ملحة لدراسة عمارة الاقوام السالفة، ولاشك ان المختصين في العمارة هم اولى الناس بذلك؛ لكي يقارنوا ما يعرفوه من عملهم مع ما تدل عليه الايات من معان ... وقبل محاولة تحديد المجالات التي يمكن التعامل بهامع تاريخ العمارة في القرآن، سيتم اولا استعراض سريع لابرز التوجهات العالمية لدراسة تاريخ العمارة .

- تاريخ العمارة في القرآن الكريم:

من كل ما تقدم يتبين بوضوح اهمية ان يكون للمسلمين رؤيتهم الخاصة بهم للتاريخ بشكل عام، وبشكل خاص ان تكون هناك نظرة خاصة تجاه تاريخ العمارة، فقد تبين كيف ان هناك منافسة و"صراع" لكل فئة في ان تنشر افكارها وايدلوجياتها في مختلف المجالات ومنها هذا الحقل المعرفي المهم ... وربما بسبب هذه الاهمية لتاريخ العمارة التي اكتسبت هذه الابعاد الايدلوجية والعقائدية والتي لم تكن في سالف الازمان، والتي تزداد

اهميتها بمرور الايام، قد يكون لهذا السبب بالذات هذا اللاحاح المتكرر في القرآن الكريم على الدعوة للتأمل في اثار ومساكن الامم السالفة حيث يمثل القرآن الكريم المصدر المعرفي الاصيل في هذا المجال. ويمكن تحديد بعض جوانب الاهمية لهذا الموضوع في علم العمارة فيما يلي، والتي يرجى ان تتلوه بحوث اخرى ونقد ما فيها وتلتفت الى جوانب اخرى لم تلاحظ هنا:

اولا : استخلاص العبر العامة:

يعد مجال استخلاص الحكمة والعبر من تاريخ الامم السالفة (خليل (أ)، 1986، ص97)، المجال المباشر وقد يكون المجال الوحيد الذي تناوله المفسرون منذ قرون ، والى اليوم ، وقد يكون من الممكن في عصرنا هذا استخلاص المزيد من العبر اذا ما درست بعناية العلاقة بين الحياة الاجتماعية لتلك الاقوام وما بين عمارتهم ... وهي تدلنا على سنن الله في تطور الحضارات منذ التصور وحتى السقوط (خليل (أ)، 1986، ص265-284) فمهما كان التصوير بليغا من خلال الكلام ، فانه لن يغني عن المشاهدة الواقعية. فيتأمل عمارة الاقوام السالفة يمكن للمرء ان يتصور ما كانوا عليه من قوة ومن نعمة انعمها الله عليهم. [مثلا من مشاهدة معبد Pantheon او ملعب Colosseum يمكن تصور القوة والتمكن التي كان عليها الروم] و التاكيد على ان ما بلغته هذه الاقوام لايدوم بدون تقوى الله ﴿ افمن اسس بنيانه على تقوى من الله خيرا ممن اسس بنيانه على جرف هار فنهار ربه به في نار جهنم ﴾ .

ثانيا : الاستفادة من الخبرة الحضارية المعمارية المتراكمة :

ان الحكمة ضالة المؤمن وبالرغم من ان اثار الاقوام السالفة قد تدل على الظلم وعلى عاقبة الهلاك الا ان ما شيدته الاقوام السالفة من ابنية وعمران "ان كان اريد بها رضى الله تعالى بنفع عبيده كانت جديرة بالثناء عاجلا واجلا، فاما اذا اهمل ارضاء الله تعالى واتخذت للرياء والغرور والعظمة وكانوا معرضين عن التوحيد وعن عبادة الله انقلبت عظمة دنيوية محضة لا ينظر فيها الى جانب النفع ولا تحث الناس على الاقتداء في تاسيس امثالها، فصار وجودها عبثا لانها ضلت عن روح المقاصد الحسنة" (قطب، ج6، ص103) وهكذا بدراسة تلك الابنية والخبرات المتراكمة مؤسسة خزين معرفي معماري يمكن للمعماري المعاصر مثلا ان يستفيد من منهجها واساليبها العمرانية بعض ما فيها من حلول انشائية او بيئية او غيرها.

ثالثا : تدوين تاريخ العمارة بشكل محايد:

لقد مر اعلاه كيف ان معظم التوجهات العالمية تحاول ان تدون تاريخ العمارة بشكل يؤيد ايدولوجيتها .. ان الباحث المسلم غير مطالب باقحام تغيرات معينة على تاريخ العمارة، وانما يجب ان يبحث عن الحقيقة المطلقة فحسب، فالاسلام دين الفطرة البعيدة عن التزييف.

والمسلم مطالب بالبرهان في كل مجال ﴿ قل هاتوا برهانكم ﴾ ويجب اتباع في ذلك المنهج العلمي للتاريخ الذي يفضل ان يتصف - الى جانب المهارة في تناول الجوانب المعمارية بما يلي:

(خليل (ب) ، 1986، ص115-123) .

-الحس النقدي التاريخي للمصادر - بما فيها الروايات في مصادر المسلمين نفسها.

-تحقيق التوازن ما بين مختلف الجوانب الحضارية.

-الابتعاد عن اتخاذ مواقف فلسفية تجاه الواقع.

-اتخاذ موقف علمي تجاه معطيات المؤرخين الآخرين - بما فيهم المستشرقين على مستوى المنهج

والموضوع وعدم التسليم المطلق بها او تجاوزها.

ومن الملاحظ ان هذه الشروط في البحث التاريخي تتفق مع الشروط التي وضعها توماس كوهن فيلسوف

ومؤرخ العلوم في كتابه تاريخ العلوم والمهن الاخرى (كوهن ، 1989 ، ص100-123).

رابعا: علاقة العمارة بالظواهر الحضارية :

من خلال دراسة تاريخ العمارة يمكن تفهم علاقة العمارة بالجوانب الثقافية والاجتماعية - الاقتصادية

بشكل افضل ، حيث ان الايات الكريمة - التي ذكرها - تشير الى العمارة في سياق وصفها لبعض المظاهر

السلبية منها والايجابية - الحضارية للاقوام السابقة ، وهي ما يسميه البعض "التاريخ الخارجي" (

كوهن، 1989، ص104)، وان استخلاص العبر منها يساعد في فهم العمارة المعاصرة كذلك ، ويساعد على تفهم

ما يجب ان يحاول المصممون لابتنيهم المستقبلية. وقد يفيد التعاون في هذا المجال البحثي ما بين المماريين

والمؤرخين والاثاريين وعلماء الاجتماع ومما يوضح التغيرات الحضارية على تطور علم العمارة

خامسا : دراسة تطور المنطق الذاتي للعمارة :

يقصد بذلك الجوانب المعمارية البحتة من حيث الوظيفة والتكوين والنظام الانشائي، او ما يسميه البعض

"التاريخ الداخلي" (كوهن ، 1989، ص104)، ولئن كانت الايات - سالف الذكر - كان فيها القليل من

الاشارات لذلك (مثل: رفع ابراهيم لقواعد البيت، او ايقاد النار للطين لبناء الصرح لفرعون، او مراحل بناء سد

ذي القرنين ...) فهي تكفي للاهتمام بهذا المجال ، وكذلك هناك آيات اخرى وردت في غير سياق الكلام عن

الامم السالفة فيها ذكر لبعض هذه الجوانب مثل قوله تعالى ﴿ فَأَتَى اللَّهُ بُنْيَانَهُمْ مِنَ الْقَوَاعِدِ فَخَرَّ عَلَيْهِمُ

السَّقْفُ مِنْ فَوْقِهِمْ ﴾ (النحل ، 26) التي فيها بوضوح اشارات قوية لمنطق النظام الانشائي ، وكذلك

﴿ لَبِيتُكُمْ سَقْفًا مِنْ فِضَّةٍ وَمَعَارِجَ عَلَيْهَا يَظْهَرُونَ، وَلِبَيتُكُمْ أَبْوَابًا وَسُرًّا عَلَيْهَا يَتَكْنُونَ، وَزَخْرَفًا وَإِنْ كُلُّ ذَلِكَ

لَمَّا مَتَاعُ الْحَيَاةِ الدُّنْيَا ﴾ (الزخرف ، 23-35) . فالبيت في هذه الآيات يشير لنوع وظيفي وهي شاملة لمختلف

النظم المعمارية :ف السقف اشارة للنظام الانشائي، والمعارج اشارة الى نظام الحركة والابواب اشارة لعلاقة الداخل

بالخارج، والسرر اشارة الى التأثيث والتصميم الداخلي، والزخرف - كما هو واضح - اشارة الى الزخرفة والتزيين

. ومن الملاحظ ان لفظة زخرف جاءت في اية منفصلة لوحدها مما يشير الى امكانية استغناء العمارة عنها

وكونها من العناصر الكمالية فيها . وقد تكون هذه الالية الكريمة من اشمل الايات التي فيها اشارة الى جميع

نظم العمارة واهميته والجمال في العمارة ... والله اعلم.

سادسا : الاهتمام بالحقب المعمارية:

ان مما يشغل مؤرخي العمارة هو تصنيفها الى فترات زمنية، او مجموعات طرازية، او تصنيفها حسب تطورها التقني، لقد رتب القران في كثير من سوره التابع الزمني للاقوام السالفة، وبالتالي يمكن ترتيب تطور العمارة لتلك الامم.

وهناك اية كريمة تشير الى تطور علاقة الانسان بالسكن والعمارة في قوله تعالى ﴿ وَاللّٰهُ جَعَلَ لَكُمْ مِنْ بُيُوتِكُمْ سَكَنًا وَجَعَلَ لَكُمْ مِنْ جُلُودِ الْاَنْعَامِ بُيُوتًا تَسْتَخِفُّونَهَا يَوْمَ ظَعْنِكُمْ وَيَوْمَ اِقَامَتِكُمْ وَمِنْ اَصْوَافِهَا وَاَوْبَارِهَا وَاَشْعَارِهَا اِثَاثًا وَمَتَاعًا اِلَى حَيْنٍ، وَاللّٰهُ جَعَلَ لَكُمْ مِمَّا خَلَقَ ظِلَالًا وَجَعَلَ لَكُمْ مِنَ الْجِبَالِ اَكْنَانًا ﴾ (النحل، 80-81)، وفيها بشكل واضح ترتيب معكوس لتطور علاقة الانسان مع السكن: من الكهوف، الى السكن المتنقل (الخيام) الى السكن الثابت ... وكان فيها دعوى للتساؤل عن التطور من الوضع الحالي الى الاقدم، وهذا عادة ما يحدث عندما تستشير ظاهرة معينة الانسان فيبدأ بالتقصي عن اصولها بشكل معكوس، اي من حاضره الى الماضي ... والله اعلم .

سابعا : فهم اصول العمارة الاسلامية :

ان الاختلاف حول اصول وتطور العمارة الاسلامية لا تزال تشغل حيزا كبيرا، وانه لما يؤسف له ان الباحثين المسلمين قد توسعوا واجتهدوا كثيرا في دراسة العمارة الاسلامية ذاتها، وهناك القليل فقط ممن تعرض لدراسة عمارة الاقوام السابقة او المجاورة ، ناهيك عن من تخصص في دراسة تلك التي تعتبرها "اجنبية" عن الامة ... ولاشك ان التوسع في دراسة عمارة الشعوب يساعد في التقصي الصحيح والموضوعي لاصول العمارة الاسلامية وكذلك استخدام المنهج التحليلي والاستنباطي للخروج بنتائج دراسة عمارة الشعوب المجاورة يساعد في الكشف عن التاثر والتاثير. ولايفوتنا ان نذكر باهمية هذه البحوث في بيان اعجاز القران في الاخبار عن الامم السابقة ومما لذلك من تعزيز اركان الايمان وتثبيت الدعوة .

-امثلة من العمارة المصرية القديمة:

فيما يلي فقط بضعة امثلة لبعض الجوانب التي تقدم ذكرها اعلاه. وقد تم اختيار العمارة المصرية لانها من اكثر طرز العمارة التي تعرضت للتنقيب الاثاري والتوثيق والدراسة، اضافة الى الاشارات الكثيرة عن مصر في القران الكريم.

اولا : فرعون ذو الاوتاد :

لقد وصف فرعون بهذه الصفة في سورة (ص، اية 12) وفي سورة (الفجر، اية 10). وبالرجوع الى المصادر التفسيرية القديمة ، فانها اختلفت في تفسير هذه الصفة كالتالي:

انها ملاعب من اوتاد يلعب بها ، انها اوتاد لتعذيب الناس، او ان معناها : ذو العز والملك الثابت، او لان عساكره كثيرة ولهذا تكثر خيامهم والوتاد التي تحملها، وكذلك ذهب اخرون الى انها اشارة للبنيان ... وحتى

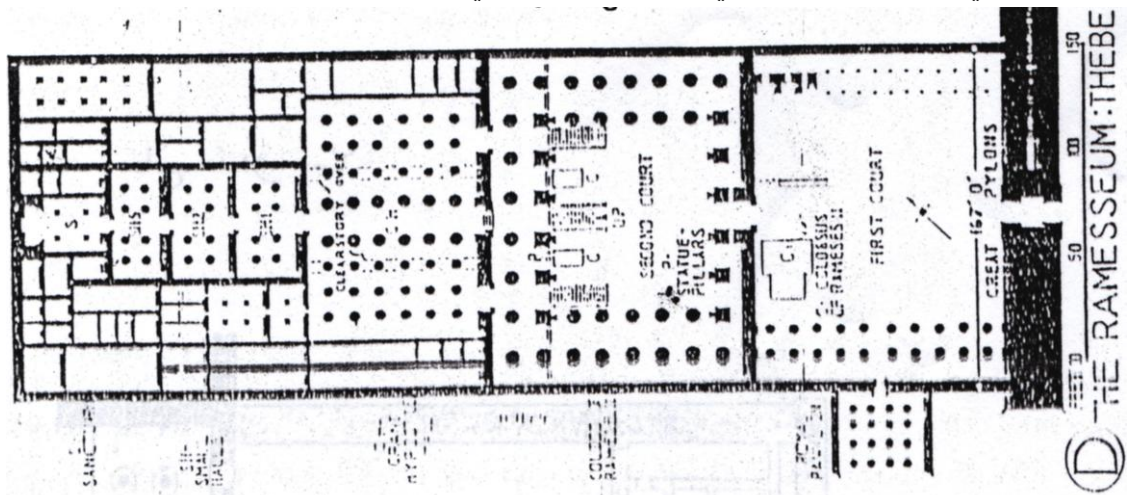
عند ذكر البنيان فان بعض المفسرين المعاصرين، محمد عبده وسيد قطب، اشاروا الى انها الاهرام (مرعي، 2001، ص128-129). ويبدو ان الصحيح هو المراد الابنية، لكنها ليست الاهرام، فموسى (عليه السلام) حسب اتفاق غالبية المؤرخين المعاصرين، عاصر الاسرة التاسعة عشرة، في حين ان الاهرام بنيت قبلها باكثر من الف سنة، مع الاسرة الرابعة او الخامسة ... اما فترة الاسرة التاسع عشرة فقد اشتهرت ببناء المعابد الفخمة ذات البوابات الصرحية وذات القاعات المليئة بالاعمدة التي تسمى بـ (Hypostyle) اي (القاعة متعددة الاعمدة) وهي ذات مقاييس صرحية وتكون الاعمدة متقاربة مثل اشجار الغابة - وهي تختلف عن المساجد الاسلامية الاولى المتعددة الاعمدة ذات المقياس الانساني.

اما اذا انتقلنا الى تحديد المؤرخين المعاصرين لرمسيس الثاني فرعون موسى، وبالرجوع الى اثار هذا الفرعون، ليتبين فعلا انه اكثر فرعون اشتهر ببناء الابنية الضخمة ذات الاعداد الهائلة من الاعمدة من بين من سبقه ومن تبعه من الفراعنة!

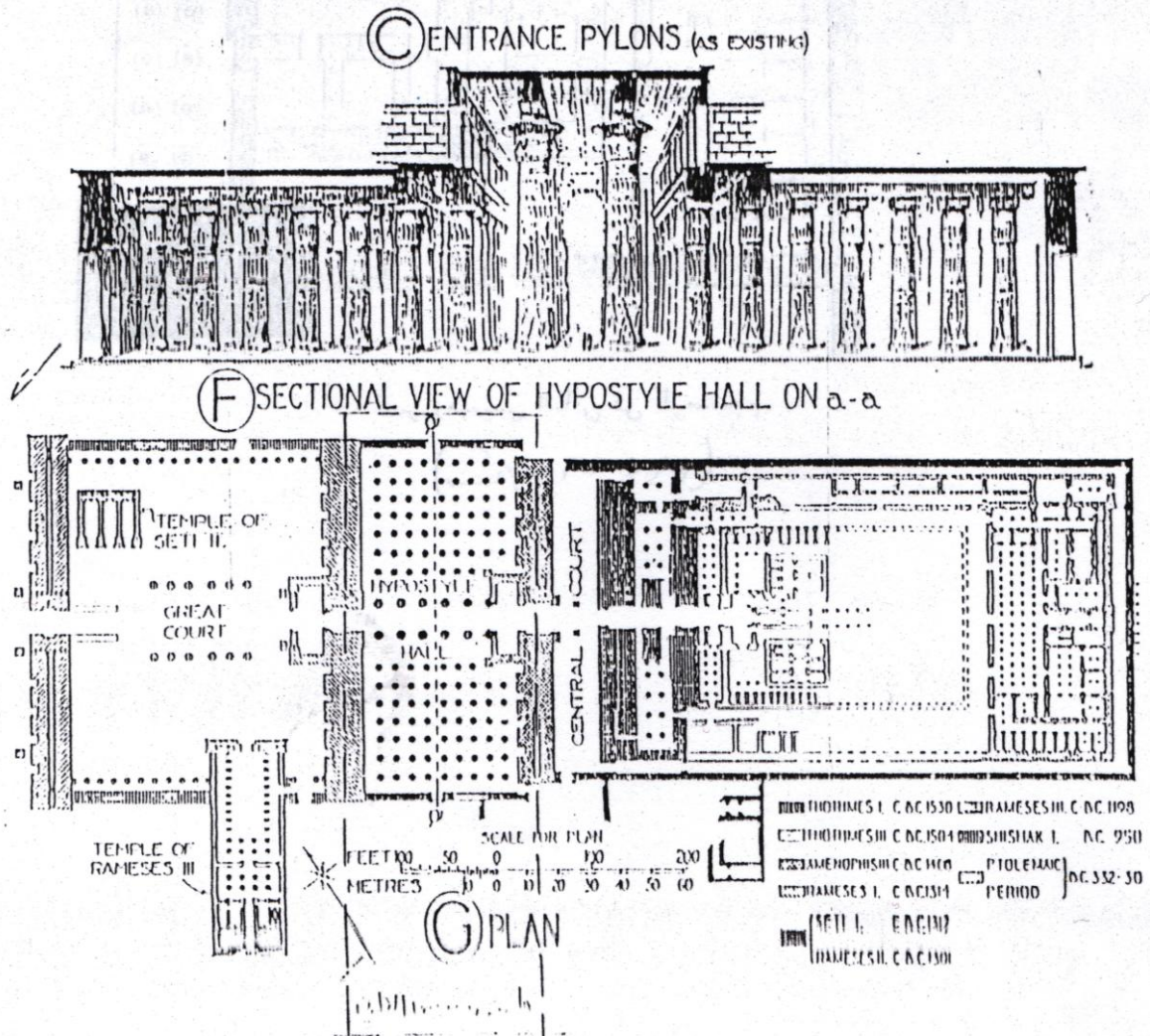
ومن هذه الابنية : معبد الرمسيوم، وهو المعبد الجنائزي الذي بناه لكي يخله، وقد قصد عند بنائه ان يفوق به امجاد اسلافه وكل مجد يمكن ان يرنو اليه احد من خلفائه (شكل 4) (شكري، 1970، ص418). ويمكن بالرجوع الى كتب تاريخ العمارة المصرية مقارنة مع المعابد السابقة واللاحقة ليتبين انه اكثرها في "الوتاد".

وكذلك الجزء الذي بناه في معبد امون الكبير في الكرنك (شكل 5): ان هذا المعبد من اقدم المعابد المصرية، وقد بني في فترات متلاحقة، كل فرعون يبني جزء ليخلده ... وهنا ايضا يكون الجزء الذي ببناؤه سني الاول ابنه رمسيس الثاني اكثر جزء ممثلي بالاعمدة. وكذلك يبرز قصر رمسيس الثاني (شكل 6) (شكري، 1970، ص192) من بين قصور الفراعنة اضخم قصر ممثلي بالوتاد! (شكري، 1970، ص128).

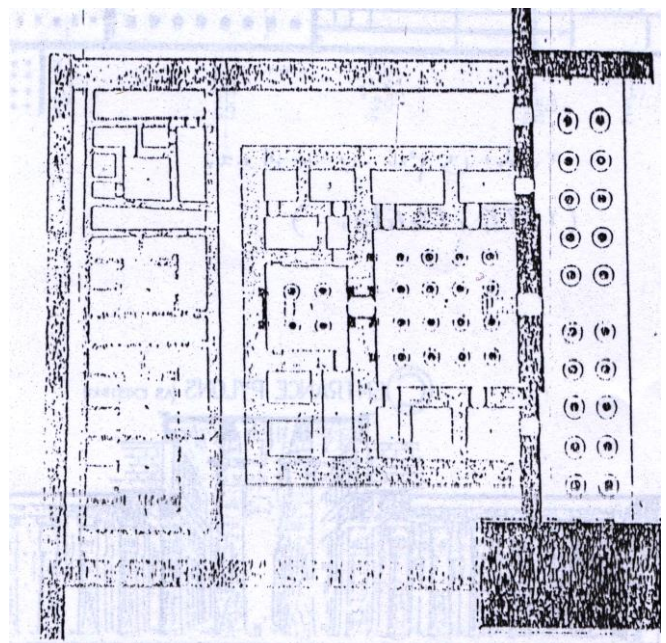
وبعد كل هذه الملاحظات يترجح ان معنى الوتاد هي هذه الاعمدة - او الاساطين - الضخمة التي بناها رمسيس الثاني حيث ان الاعمدة هي احدى العناصر التي تعد من الهيبة.



(شكل 4-) معبد الرمسيوم (Fletcher, 1964, P.32)



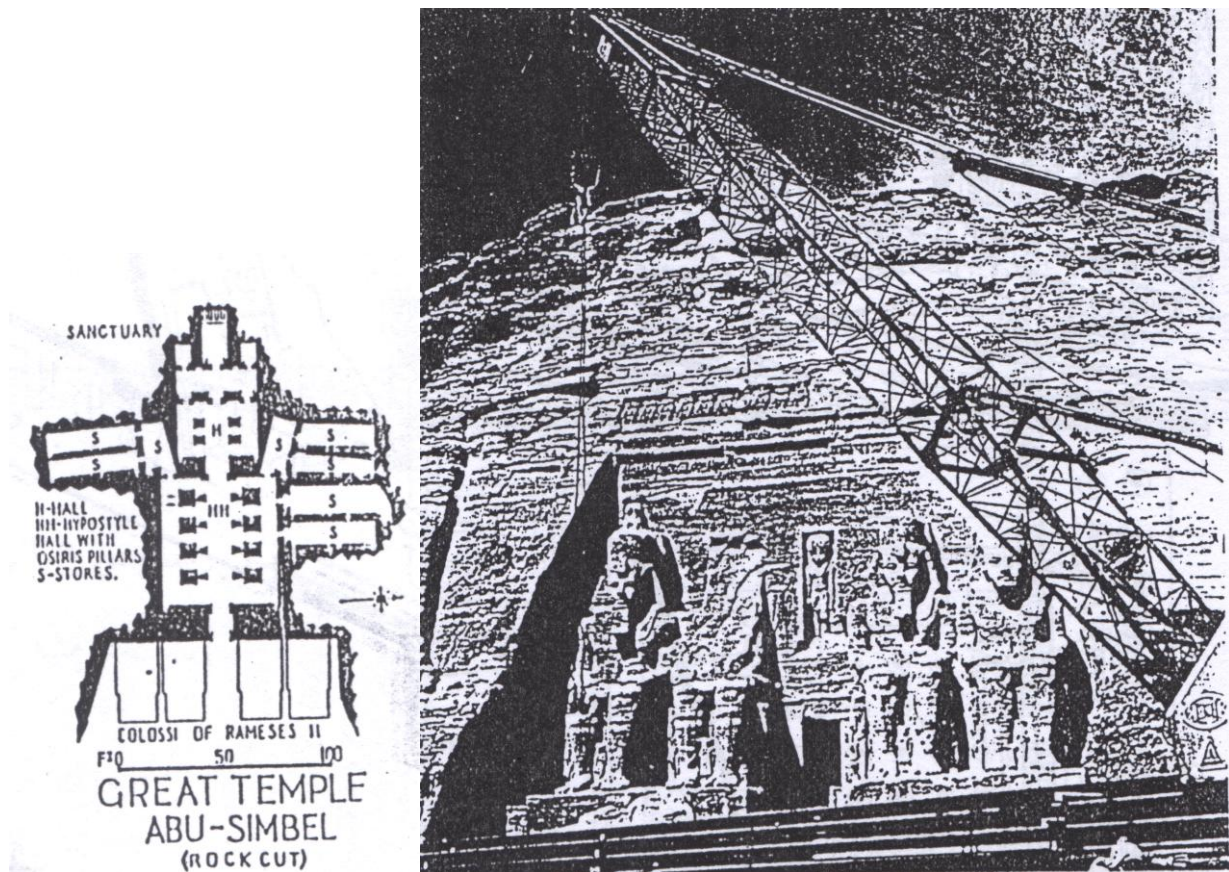
(شكل -5-) معبد امون الكبير في الكرنك (Fletcher, 1964, P.32)



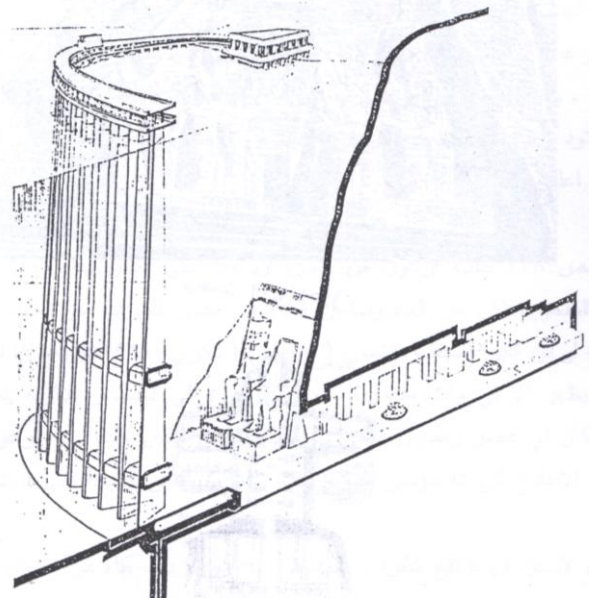
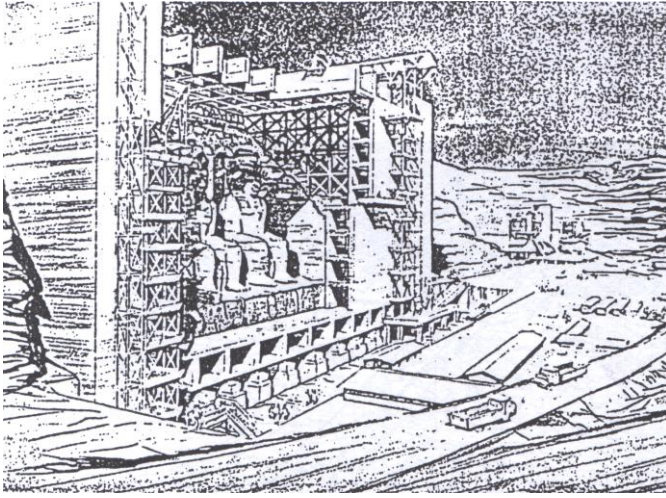
(شكل -6-) قصر رمسيس الثاني (Fletcher, 1964, P.32)

ثانيا : ﴿ فاليوم ننجيك ببدنك لتكون لمن خلفك آية ﴾ (يونس ، 92)

لقد اشتهرت مومياة رمسيس الثاني التي توعده الله بحفظها، لقد راجت الاخبار كيف سخر الله من يحفظ ويدوم على علاج وحفظ هذه الممياة حتى يومنا هذا ... لقد اشتهر كذلك معبد ومنطقة ابو سمبل (شكل - 7) ، وهو من نوع المعابد المنحوتة في صخر الجبال وقد بناه ايضا رمسيس الثاني ليبدل على تجربته وطغيانه (شكري ، 1970 ، ص 242) ، ومعروف كذلك الجهود العالمية - التي سخرها الله - لانقاذ هذا المعبد من الطوفان بفعل بحيرة سد ناصر الذي شيد في ستينات القرن العشرين (لاحظ شكل - 8) فهل حفظ هذا المعبد الخاص - الذي يحوي اربع تماثيل صريحة هي من اضخم المنحوتات في تاريخ البشرية (Macqiy, 1965) - هو كذلك لحفظ ذكرى هذا الفرعون الذي توعده الله بحفظه والله اعلم .



(شكل - 7) معبد ومنطقة ابو سمبل (شكري ، 1970 ، ص 242)



(شكل - 8) مقترحات انقاذ المعبد (Macqiy, 1965)

ثالثا: ﴿ اذ قالت رب ابن لي عندك بيتا في الجنة ﴾ (التحریم ، 11)

قد يتساءل المرء لماذا دعت امرأة فرعون الصالحة بهذا الدعاء ؟ ولماذا لم تدع " اللهم ادخلني الجنة " او " اللهم اسألك الجنة " او حتى اذا تمنيت بيتا في الجنة ؟ فلماذا طلبت منه تعالى ان يبني البيت، ولم تقل " رب اجعل لي بيتا " ... بالرجوع الى علاقة الحياة الاجتماعية والدينية بالعمارة في مصر القديمة يكشف لنا بعض الجوانب.

من المعروف ان للفراعنة تصورا منحرفا عن الآخرة، فهم يتصورونها بشكل عمارة يمكن اكثر من بناء دور سكن ومدن الاحياء. فالعمارة الفخمة - المقابر والمعابد - هي في الجزء الغربي لنهر النيل بمبانيها الحجرية الصلبة، وعمارة مدن الاحياء - الى الشرق من نهر النيل - عمارة طينية بسيطة، وحتى بيوت الوجهاء كانت بسيطة. وهكذا فامرأة فرعون متأثرة بهذا التصور عن الآخرة على شكل بناء، لهذا طلبت منه تعالى ذلك البناء او البيت عنده سبحانه في الجنة.

وكذلك كان فرعون لا يصف نفسه بالاله ! بل انه الزعيم الاوحد، والقائد الاشجع ... الخ ولذلك وصف بانه رئيس البنيائين ، وكان يشرف بنفسه على وضع اساس البناء بيده ويتابع باقي المراحل ... وهكذا فان امرأة فرعون التي تود النجاة من ظلم فرعون تريد كذلك ان تبوء من "بناءه" وتطلب من الله تعالى وحده ان "يبني " لها ... والله اعلم.

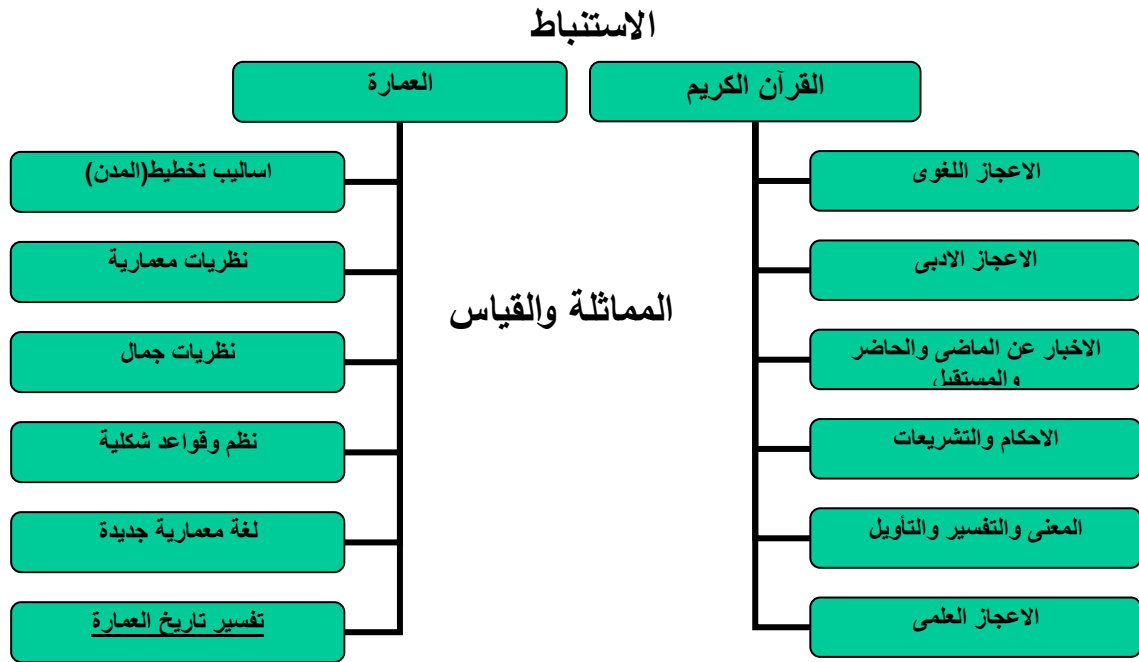
رابعاً: إيقاد الطين:

في اية القصص 138 طلب فرعون من هامان ان يوقد على الطين لبناء الصرح ، وهذا يعني: استعمال الطابوق المفخور، لكن من المعروف ان البناء في مصر كان اما من الحجارة وانواع الرخام (للمعابد والمقابر) او من اللبن المجفف بالشمس (للبيوت) (شكري ، 1970، ص40-44) ، وان الطابوق المفخور بالنار لم يظهر الا في وقت متأخر ... ومن الرجوع الى المصادر الاثرية يتبين ان اول بناء بالطابوق المفخور كان في عصر رمسيس الثاني !! فالبناء بالحجارة كان بطيئاً ... وفرعون كان في عجلة من امره لانه يريد الاطلاع الى اله موسى بأسرع وقت وهذا يتبين من النتيجة التي فرضها سلفا بانه من الكاذبيين! والبناء باللبن لايمكن ان يرتفع كثيراً ، ولهذا قرر - وربما ذلك جاء من اتصالهم بخبرات البلدان المجاورة، فالاسرة التاسعة عشرة كان لها علاقات مع دول الجوار .. البناء بالطابوق، الذي يكون البناء فيه سريعاً ، ويمكن ان يصل الى الاعالي ... والله اعلم.

ان ما تقدم هي امثلة بسيطة فقط ، وهناك الكثير مما يمكن دراسته، خصوصاً حول اثار الجزيرة العربية التي لم تبدأ الكشوفات الاثرية فيها الا في نهاية القرن العشرين (هاملين، 1986) - على عكس التقنيات في مصر التي بدأت مع مطلع القرن التاسع عشر. فالجزيرة العربية كانت هي مهد معظم الرسالات، وهي موضع اول بيت وضع بمكة.

الاستنتاجات :

- توصل البحث ولاول مرة الى نتائج مهمة فيما يخص تاريخ العمارة المصرية .
- هناك الكثير من الايات الكريمة التي فيها الحث على تدبر ودراسة العمارة للاقوام السابقة .
- الاهتمام العالمي بتاريخ العمارة، وتصارع الایدولوجيات حولها يحتم على المسلمين ان يكون لهم موقف نابع من عقيدتهم وكتابهم الكريم .
- على المسلمين التخصص والاهتمام بدراسة تاريخ العمارة القديمة، وعمارة الشعوب الاخرى، جنباً الى جنب لاهتمامهم بالعمارة الاسلامية .
- ان من يبحث في تاريخ العمارة بهدي القرآن الكريم يجب ان يكون متضلعا في علم العمارة الى جانب اطلاعه على اساليب التفسير البياني للقرآن الكريم .
- ان القرآن الكريم يحثنا على دراسة تاريخ العمارة ويترك تفاصيلها للبشر للتوسع في البحث.
- اثبت البحث الفرضية (دعوة القرآن لدراسة تاريخ العمارة)، وان القرآن الكريم يعتبر مصدر اساسي للتوصل الى حقائق حول تاريخ العمارة وتطورها ،واضاف محور تفسير العمارة على (المخطط رقم 2 - (وكما موضح في(مخطط رقم 3-).



(مخطط رقم -3-) استنباط محور تفسير تاريخ العمارة من اعجاز القرآن الكريم(اعداد البحث)

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تأثير الضغط الابتدائي على سرعة انتشار اللهب لخليط هواء-ميثان

د.محمد ناصر حميد

الجامعة التكنولوجية / قسم هندسة المكائن والمعدات

الخلاصة:

تم اجراء دراسة عملية لتأثير الضغط الابتدائي على سرعة جبهة اللهب الطباقية لخليط الميثان-هواء ولمدى واسع من النسب المكافئة. ولاجراء ذلك تم تصميم منظومة قياس استخدم فيها طريقة الحجم الثابت وتقنية المزدوجات الحرارية لقياس سرعة جبهة اللهب. وتم استخدام طريقة نسبة الكثافة لقياس سرعة انتشار اللهب. ان مقارنة النتائج التي تم الحصول عليها في البحث الحالي مع النتائج المنشورة بين وجود توافق كبير بينها، مما يدل على نجاح ودقة التقنية والحسابات المستخدمة في هذا البحث.

Effect Of Initial Pressure Upon Laminar Burning Velocity Of Methane-Air Mixtures

ABSTRACT

The effect of the initial pressure upon the laminar flame speed, for a methane-air mixtures, has been detected paractically, for a wide range of equivalence ratio. In this work, a measurement system is designed in order to measure the laminar flame speed using a constant volume method with a thermocouples technique. The laminar burning velocity is measured, by using the density ratio method. The comparison of the present work results and the previous ones show good agreement between them. This indicates that the measurements and the calculations employed in the present work are successful and precise.

المصطلحات والرموز

الرمز	المعنى	الوحدات
S_u	سرعة انتشار اللهب الطباقية (laminar burning velocity)	cm/sec
S_f	سرعة جبهة اللهب الطباقية (laminar flame velocity)	cm/sec
I	معامل سمك جبهة اللهب (flame thickness factor)	
N	النسبة المولية (mole ratio)	
n	عدد المولات (number of moles)	mol
n_c	عدد ذرات الكربون (number of carbon atoms)	
P	الضغط (pressure)	bar
P_{atm}	الضغط الجوي (Atmospheric pressure)	atm
P_u	(initial pressure)	bar
r_f	نصف قطر جبهة اللهب (flame radius)	mm
T	درجة الحرارة المطلقة (absolute temperature)	K
T_{ad}	درجة حرارة اللهب الاديباتية (adiabatic temperature)	K
T_{atm}	درجة حرارة الجو المحيط	K
T_f	درجة الحرارة اللهب (درجة حرارة الغاز المحترق) (flame temperature)	K
T_u	درجة الحرارة الابتدائية (درجة حرارة الغاز غير المحترق) (unburned gas temperature)	K
ρ	الكثافة (density)	kg/m ³
$\bar{\rho}_f$	متوسط كثافة الغازات المحترقة عند نصف قطر r_f	kg/m ³
ρ_u	كثافة الغازات غير المحترقة	kg/m ³
ϕ	النسبة المكافئة (equivalence ratio)	

المقدمة

سرعة انتشار اللهب تعرف بأنها ثابت فيزيوكيميائي (physicochemical) لخلائط الوقود-الهواء. وتعرف بأنها السرعة التي تنتشر بها جبهة اللهب وبشكل عمودي على سطحها خلال الغازات غير المحترقة [Barnard & Bradley 1985].

ان دراسة انتشار اللهب الطباقى والاضطرابى مهمة لتحليل عمليات الاحتراق المسيطر عليها كما في محركات الاحتراق الداخلى والتوربينات الغازية والافران. اجريت دراسات كثيرة لسرعة انتشار اللهب الطباقية وتقنيات اختبار مختلفة الا ان الحاجة مازالت ماسة لاجراء المزيد من الدراسات بسبب حاجتنا لقيم عملية لسرعة انتشار اللهب الطباقية في تصميم منظومات الاحتراق المختلفة والموديلات الرياضية التي تهتم بدراسة سرعة انتشار اللهب الاضريبية وتحت ظروف ابتدائية مختلفة من ضغط ودرجة حرارة.

في هذا البحث تم استخدام طريقة الحجم الثابت (constant volume method) والتي استخدمت من قبل عدد من الباحثين وبتقنيات قياس مختلفة، [Andrews & Bradley 1973], [Al-Khishali 1984], [Hamid M.N. 1986], [Kwon et. al, 1992], [Bradley & Hicks 1998], [Stone 2004], [Al-Shahrany & Bradley 2005]. والتقنية المستخدمة هنا هي المزدوجات الحرارية لقياس سرعة انتشار اللهب الطباقية لخليط الميثان الهواء وهذه الطريقة يستخدم فيها وعاء صلد مغلق اما ان يكون كروي او اسطوانتي ويكون في الغالب بقطر (30 cm) حيث عند اشعال الخليط تتكون جبهة لهب كروية تنتشر خلال الخليط غير المحترق مما يسبب زيادة في الضغط ودرجة الحرارة. وتمتاز هذه الطريقة عن الطرق الاخرى بحيث يمكن تغيير الظروف الابتدائية للخليط وعند اشعاله مركزيا سيعطي سرع مختلفة عند الظروف المختلفة.

الجهاز المستخدم للقياس:-

تم تصميم منظومة لقياس سرعة جبهة اللهب تتكون من الاجزاء الرئيسية التالية:

ا- اسطوانة اللهب وملحقاتها

ب- وحدة تحضير الخليط

ج- وحدة قياس سرعة جبهة اللهب

د- وحدة الاشعال والسيطرة

يتم تحضير خليط هواء-ميثان بوحدة الادخال (اعداد الخليط) اعتمادا على قانون دالتون Dalton law وتجهيزه الى غرفة الاحتراق (الاسطوانة) حيث يتم تحديد الضغط الابتدائي ودرجة الحرارة الابتدائية للخليط بعدها يتم الاشعال عن طريق وحدة الاشعال وتقاس سرعة جبهة اللهب (S_f) للخليط المذكور.

الشكل (1) يوضح الاجزاء الرئيسية المستخدمة في جهاز الاختبار. وهذه الاجزاء تم تصنيعها في الجامعة التكنولوجية حيث تم استخدام اسطوانة ذات قطر (305 mm) وطول (305 mm) وسمك (11mm) من الحديد المصلب ويتم الاشعال فيها مركزيا واستخدمت تقنية المزدوج الحراري لتحديد موقع جبهة اللهب التي تأتي نتيجة الاشعال حيث يكون نمو نواة اللهب كرويا ووضع المتحسسات (المزدوج الحراري) في منطقة (فترة ثبوت الضغط) (pre-pressure period) وربطت مع الحاسبة من خلال جهاز سيطرة (interface) صمم لهذا الغرض وتم بناء برنامج لحساب سرعة انتشار اللهب باعتماد طريقة نسبة الكثافة (Density Ratio Method) التي اوردها (Andrews & Bradley 1972) بالمعادلة التالية:

$$Su = S_f \frac{\rho_b}{\rho_u} \dots\dots\dots(1)$$

$$\frac{\bar{P}}{\rho_u} = \frac{T_u}{T_f} \cdot N \cdot I \dots\dots\dots(2)$$

حيث تم احتساب

$$N = \frac{\sum n_r}{\sum n_p} \dots\dots\dots (3)$$

كما مبين في الشكل (2)

وتم احتساب قيمة (I) (معامل سمك جبهة اللهب (Flame Thickness Factor) عن طريق

$$I = \frac{1.04}{r_b^3} \left[(r_b - \delta)^3 + \frac{3T_b r_b^2 \delta}{(T_b - T_u)} \ln \left| \frac{T_b}{T_u} \right| \right]$$

وهذه العلاقة التي اوردها الباحث (Andrews & Bradley 1973) كما في الشكل (3)

$$Su = Sf \cdot \frac{T_u}{T_{ad}} \cdot N \cdot I \dots\dots\dots (5)$$

T_{ad} هي درجة الحرارة الاديباتية لايحادها تم استخدام معادلة الباحث (Al-Ani 1994) وكما مبين في

الشكل (4).

النتائج والمناقشة:

تم قياس سرعة جبهة اللهب (S_f) كما مبين في الشكل (5) ولضغوط ابتدائية مختلفة حيث يلاحظ ان سرعة تزداد بزيادة النسبة المكافئة والعلاقة بين سرعة جبهة اللهب والنسبة المكافئة علاقة اسية (polynomial relationship) ، او كلما ازدادت النسبة المكافئة (ϕ)، تزداد سرعة جبهة اللهب الى ان تصل الى قيمة عظمى بالقرب من نسبة الخلط الكيميائي الصحيح ثم تبدأ بالنقصان كلما ازدادت النسبة المكافئة و قورنت النتائج مع باحثين اجروا تجاربهم عند ضغط (1 bar) وكانت النتائج متوافقة مع الباحثين تحت نفس الظروف وبتقنيات مختلفة كما في الشكل (6).

ان هذا السلوك لسرعة جبهة اللهب ناتج عن ارتباط سرعة جبهة اللهب بدرجة حرارة اللهب (KUO 1986). الشكل (7) يمثل علاقة سرعة انتشار اللهب مع النسبة المكافئة لضغوط ابتدائية مختلفة وهذا التأثير مشابه الى تأثير سرعة جبهة اللهب التي تم شرحها سابقا.

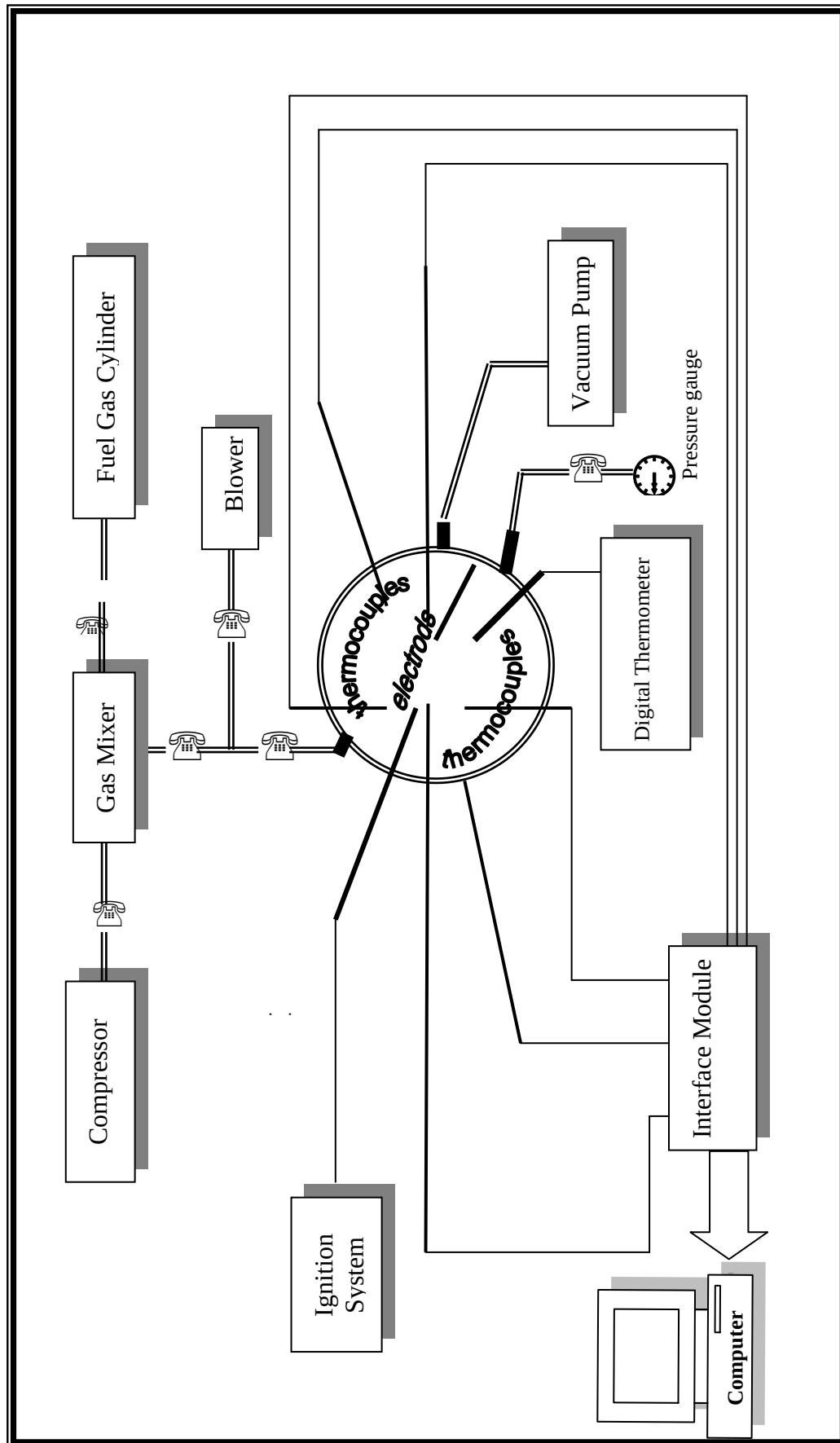
الاستنتاجات:

- يمكن استخدام تقنيات المزدوجات الحرارية في الحجم الثابت لقياس سرعة انتشار اللهب وبدقة مقبولة جدا.
- بزيادة الضغط الابتدائي لخليط هواء-ميثان تقل سرعة انتشار اللهب والعكس صحيح.
- تم ايجاد بيانات لتأثير الضغط الابتدائي لقيم اقل من الضغط الجوي وقيم اعلى من الضغط الجوي وبيان مدى تأثير الضغط على سرعة انتشار اللهب.

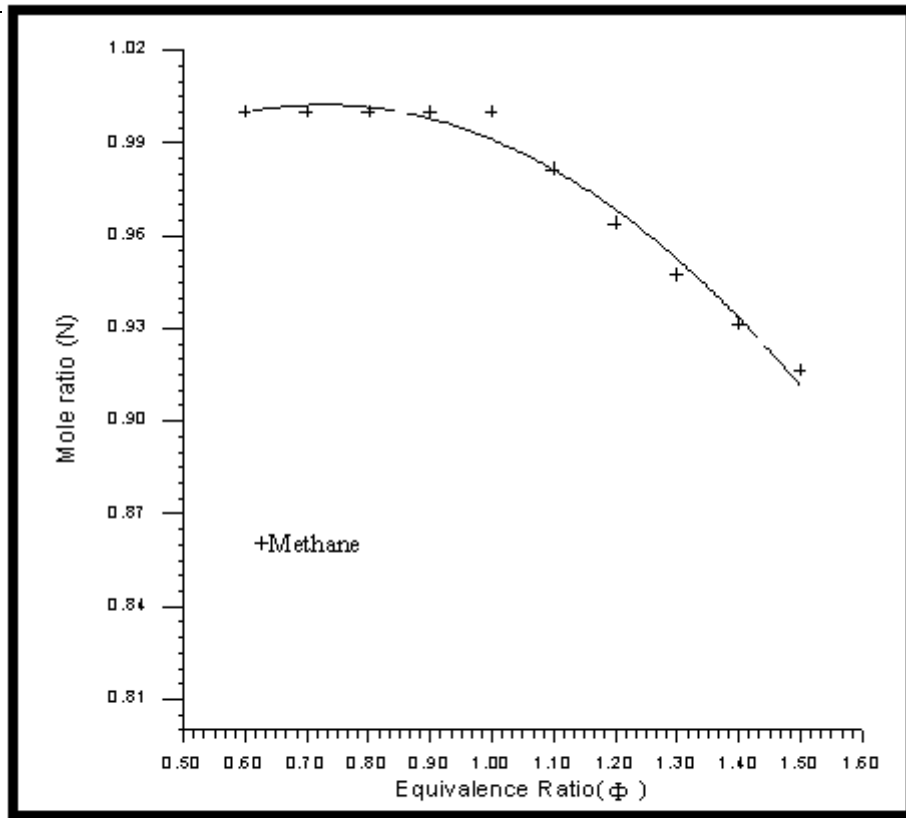
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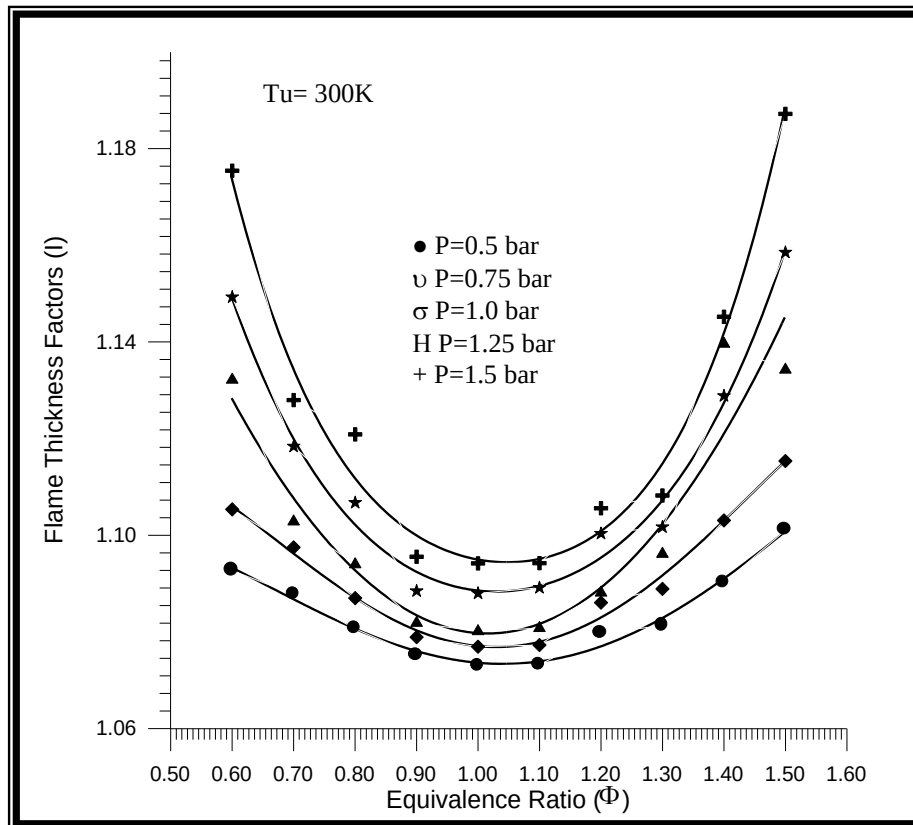
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الشكل (1) المخطط العام لمكونات الجهاز وملحقاته

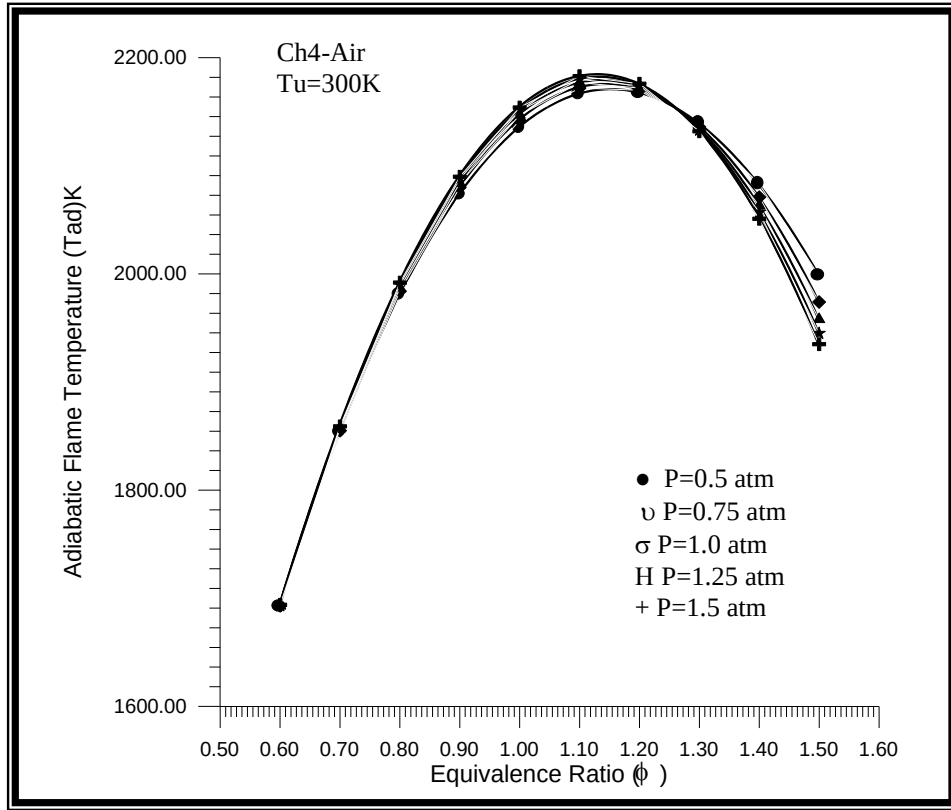


الشكل (2) تغير النسبة المولية (N) مع النسبة المكافئة (Φ) لخليط الميثان مع الهواء

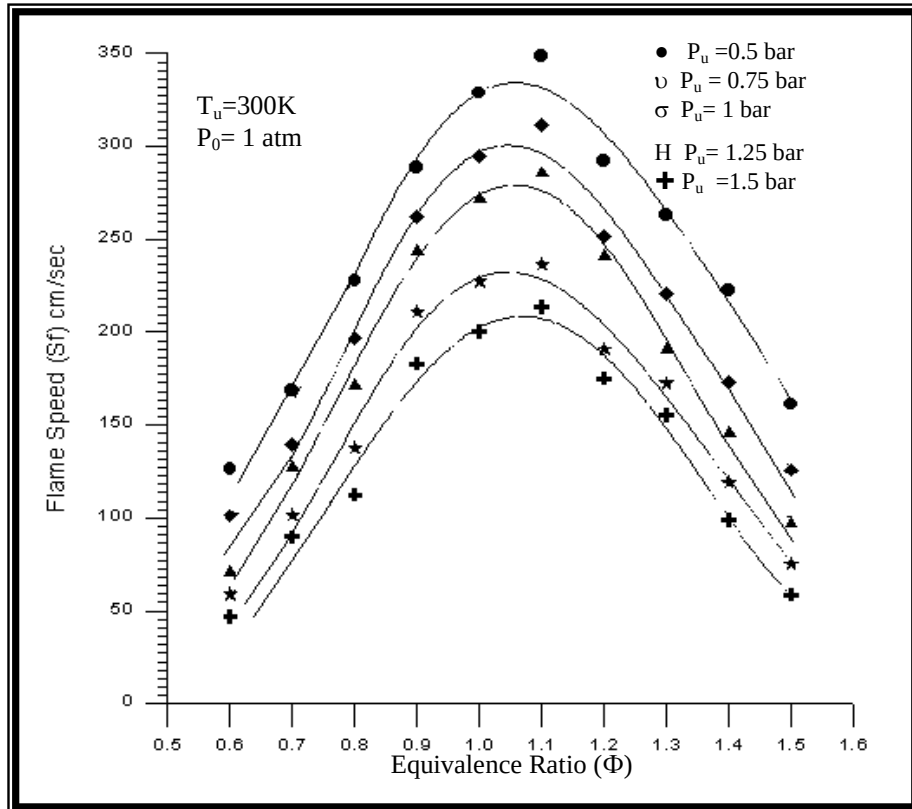


الشكل (3) معامل سمك جبهة اللهب مع النسبة المكافئة (Φ) لخليط الميثان

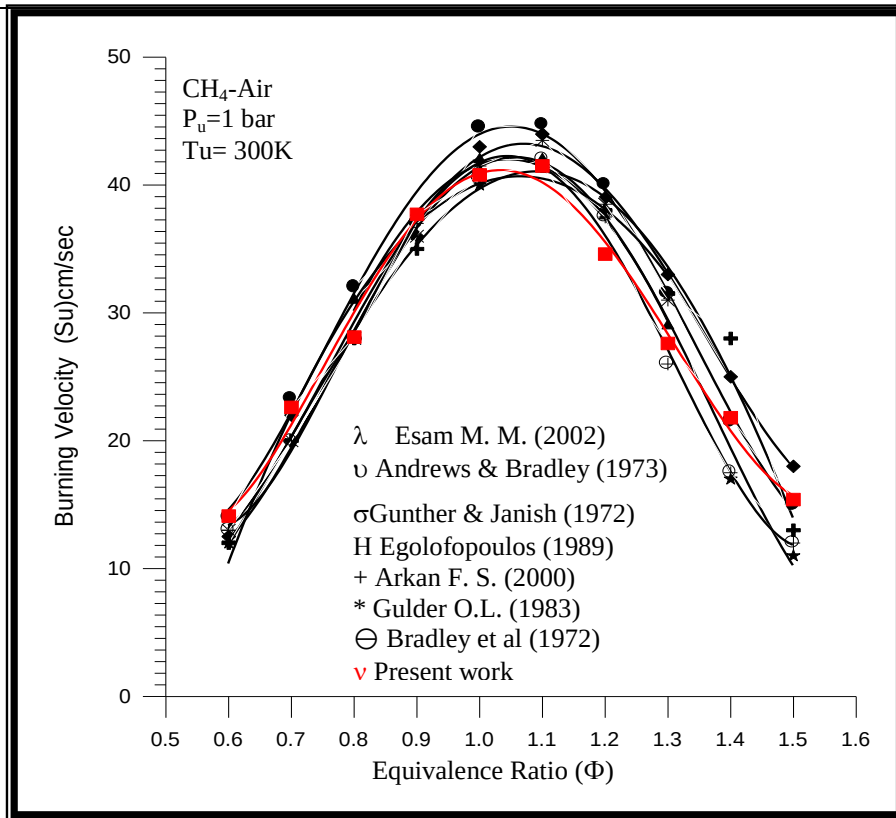
مع الهواء عند ضغوط ابتدائية مختلفة



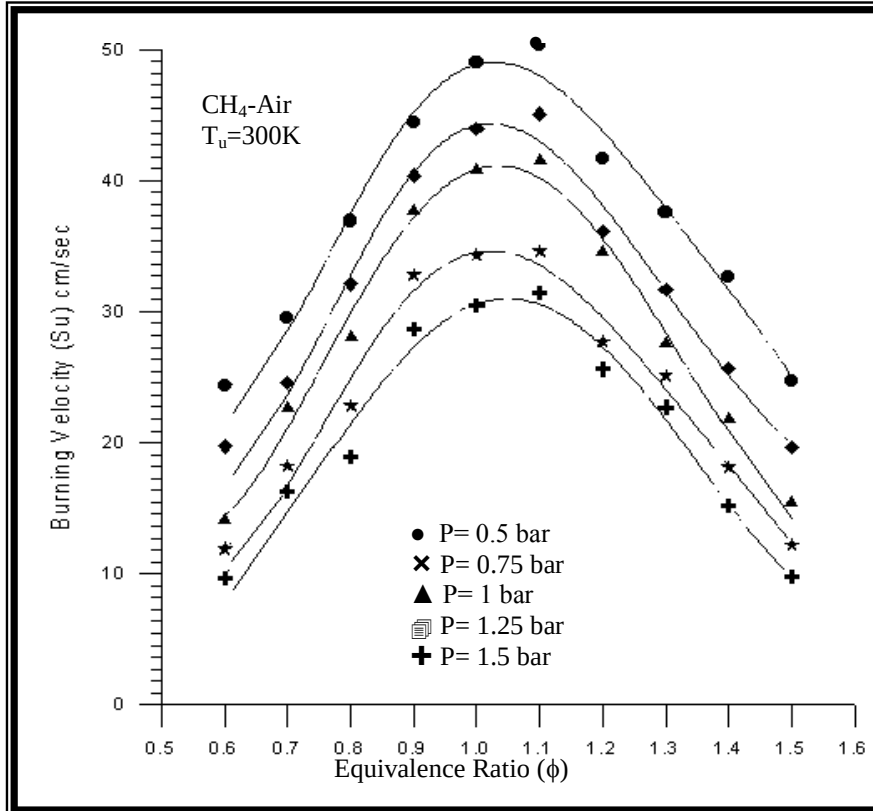
الشكل (4) درجة الحرارة الاديباتية مع النسبة المكافئة (Φ) لخليط الميثان مع الهواء عند ضغوط ابتدائية مختلفة



الشكل (5) سرعة جبهة اللهب مع النسبة المكافئة (Φ) لخليط الميثان مع الهواء عند ضغوط ابتدائية مختلفة



الشكل (6) مقارنة النتائج العملية لسرعة انتشار اللهب مع النتائج العملية المنشورة



الشكل (7) سرعة انتشار اللهب مع النسبة المكافئة (Φ) لخليط الميثان مع الهواء عند ضغوط ابتدائية مختلفة

دراسة أهم المتغيرات الأيروديناميكية لطائرة ذات سرعة تحت صوتية باستخدام برنامج AAA

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الخلاصة

الدراسة توضح أهم المتغيرات الأيروديناميكية لطائرة ذات سرعة تحت صوتية باستخدام برنامج AAA بالإضافة إلى استعراض شامل لبعض المعادلات التجريبية والرياضية الخاصة في عملية التحليل. الدراسة تمت في مرحلة التحليق للطائرة بسبب أهمية هذه المرحلة، فترة بقاء الطائرة فيها تكون كبيرة مقارنة مع الإقلاع، التسلق، الانحدار، والهبوط حيث تخضع عملية التحليل هذه إلى العديد من الحالات التكرارية المستمرة إلى أن نصل إلى الحل الدقيق. أهم المتغيرات المدروسة كانت توزيع معاملات الرفع، الكبح، العزم على أسطح الرفع المتمثلة بالجنح والذنب الأفقي، بالإضافة إلى دراسة تأثير سقف الطيران، سرعة الطائرة، النسب الباعية لأسطح الرفع على منحنى الرفع. أخيراً تم دراسة شكل العلاقة بين معامل الرفع، معامل الكبح عند قيم رقم ماخ مختلفة. النتائج أظهرت أن زيادة مستوى الطيران، معامل الحمل، النسبة الباعية لأسطح الرفع يؤدي إلى زيادة قيم معامل الرفع بينما يحدث العكس في حالة زيادة سرعة الطائرة.

STUDY OF IMPORTANT VARIABLES OF AERODYNAMICS FOR SUBSONIC AIRCRAFT USING ADVANCED AIRCRAFT ANALYSIS SOFTWARE

ABSTRACT

This study presents the important variables of aerodynamics of subsonic aircraft using AAA software, moreover to comprehensive preview of some imperical and mathematical equations where needs in this analysis process. Cruise mission chose for this study comparing with another mission of flight such as Take-off, Climb, Dive & Descent, and Landing according to important of the mission and cruise mission has large rung during the flight mission. These analyses of process submit to more and complex iteration process until we access to correct solution. Lift, drag, and moment coefficients along the lift surfaces such as wing, and horizontal tail were showed. Also this paper explain the effect of flight level, aircraft speed, aspect ratio of lift surfaces on lift curve. Results show that, increase the value of altitude, load factor,

aspect ratio leads to increase the value of lift coefficient and decrease the airplane velocity.

KEYWORDS: Aerodynamics, Aircraft Design, Lift and Drag.

قائمة الرموز

الرمز	المعنى	الوحدة
A	النسبة الباعية	-----
AAA	Advanced Aircraft Analysis Software	-----
c_t	طول وتر الطرف للجناح	m
C_L	معامل الرفع	-----
$C_{L\alpha}$	ميل منحنى الرفع	$(1/rad)$
C_D	معامل الكبح	-----
C_M	معامل العزم	-----
$\bar{c}_w$	متوسط الوتر الهندسي للجناح	m
D	قوة الكبح	N
$K_{\lambda x}$	معامل نسبة الاستدقاق	-----
H	سقف الطيران	m
L	قوة الرفع	N
l_h	المسافة باتجاه x بين المركز الأيرودينامي للذنب الافقي ومركز ثقل الطائرة	m
L_c	المسافة باتجاه x بين المركز الأيرودينامي للجناح الأمامي (canard) ومركز ثقل الطائرة	m
M	عدد ماخ	-----
n	معامل الحمل	N/m^2
q_1	الضغط الدينامي	N/m^2
Re	عدد رينولدز	-----
S_w	مساحة الجناح	m^2

-----	نسبة سمك مقطع الجناح الى الوتر الايرودينامي	(t/c)
m/sec	سرعة التيار الحر	u_1
km/hr	سرعة الطائرة	U
km/hr	سرعة الأنهواء	V_s
kN	وزن الطائرة	W
kN	وزن الطائرة عند الإقلاع	W_{TO}
Greek symbol		
deg.	زاوية الهجوم	α
kg./m.sec	لزوجة الهواء	μ
kg/m ³	كثافة الهواء	ρ
Greek symbol		
deg.	زاوية انحراف الرافعة	δ_e
-----	نسبة الاستدقاق	λ
deg.	زاوية الامتداد (التراجع) عند خط ربع الوتر	$\Lambda_{c/4}$
Subscript		
	بدون تأثير القلب	clean
	الذنب الأفقي	h
	طفيلي	i
	أقصى	max
	طرف الجناح	t
	جذر الجناح	r
	الجناح	w
	زاوية هجوم صفر أو المحتث	o
	الذنب العمودي	v
	الحالة المستقرة	1
	تأثير زاوية انحراف الرافعة	δ_e

المقدمة

أن الطائرة بوصفها جسماً مرناً أثقل من الهواء يطير خلال المجال الجوي (Airspace) تطير على امتداد مسارات (Paths) تحدد بواسطة خواص القصور الذاتي للطائرة , قوة الجاذبية الأرضية وقوة الدفع التي تولدها محطة قدرتها. القوى الأيروديناميكية والعزوم التي تتولد عليها بسبب رد الفعل الخاص بين الطائرة والهواء التي تتحرك خلاله تعتمد هذه القوى والعزوم المتولدة, على سرعة الطائرة, كثافة الهواء الذي تطير خلاله, الشكل الهندسي لها وأخيراً

الزاوية التي تكونها الطائرة مع الريح النسبي [Perkins, 1976] . لذلك يجب معرفة هذه القوى وكيفية توزيعها على الطائرة وشكل تغيرها المستمر أثناء مراحل الطيران المختلفة.

مواصفات الطائرة المدروسة

لدراسة عملية تحليل العوامل الأيروديناميكية للطائرة تم اختيار طائرة ذات سرعة تحت صوتية من أجل إجراء تحليل شامل لها لمعرفة أهم المتغيرات الأيروديناميكية المؤثرة على الطائرة طبقاً إلى علاقات ومعادلات تجريبية لشركات طيران متقدمة في هذا المجال. الطائرة المستخدمة تحت صوتية ذات مقعد واحد تسمى (Single seat subsonic aerobatic Hombuilt) ذات بيانات تصميمه تتمثل بمحرك مكبسي (Piston engine) ذا قدرة (150 hp) وسرعة دورانية (2700 r.p.m) وطول (76.2cm) , عرض (81.28cm) وارتفاع (58.42cm). عملية التحليل والدراسة تمت باستخدام برنامج .AAA

ديناميكية الهواء

تعتبر الطائرة بجميع أجزائها كنقطة في الفضاء وهذه النقطة يتركز فيها مركز ثقل الطائرة والمركز الأيروديناميكي وبذلك يمكن تمثيل القوى المؤثرة عليها كما بالشكل (1) والتي هي [Clancy, 1975]:

I. محصلة القوى الأيروديناميكية ويرمز لها بالرمز (R)

II. قوة دفع محركات الطائرة ويرمز لها بالرمز (T)

III. وزن الطائرة ويرمز لها بالرمز (W)

حيث يمكن تحليل القوى الديناميكية إلى مركبتين هما:

□ قوة الرفع (lift force) ويرمز لها بالرمز (L) وهي القوة العمودية على محصلة سرعة الطائرة (V) .

□ قوة الكبح (Drag force) والتي يرمز لها بالرمز (D) وهي القوة التي تؤثر بشكل معاكس وموازي لمحصلة السرعة (V) .

عندما تكون ظروف الطيران بشكل يجعل من قوة الرفع مساوية إلى قوة الوزن فإن الطائرة سوف تطير بارتفاع ثابت وهذا يسمى بالطيران الأفقي المستقيم (Straight level flight)، وعندما تزيد قوة الرفع عن قيمة وزن الطائرة فإن الطائرة تتجه إلى الأعلى بسلوك طيران التسلق (Climbing flight) وبالعكس في حالة زيادة قوة الوزن عن قوة الرفع فإن الطائرة تتجه نحو الأسفل بسلوك طيران الانحدار (Descending)

(flight) , أما في حالة تساوي قوتي الدفع والكبح فان طيران الطائرة يعرف بالطيران المستقر (Steady flight) , وعندما تزداد قوة الدفع على قوة الكبح فان الطيران يعرف بطيران التعجيل (Accelerated flight) وبنفس المفهوم فان الاستدارة إلى اليمين واليسار من جراء عدم الاتزان وتساوي القوى المؤثرة على الطائرة في هذه المستويات سيؤدي إلى حدوث طيران الاستدارة (Turning flight). بعض المعاملات المهمة يمكن توضيحها أدناه:

• أقصى معامل رفع للمطيار (Max. lift coefficient of airfoil)

معامل الرفع بصورة عامة سواء كان محسوب عند مقطعي الطرف أو الجذر فانه هو دالة لمتغيرات كثيرة أهمها عدد رينولدز , نسبة سمك مقطع الجناح إلى الوتر ومواصفات المطيار , كما مبين أدناه [Roskam, part I, 2003]:

$$C_{L_{max}} = f(Re, t/c, airfoil) \quad \dots\dots(1)$$

أما قيمة عدد رينولدز عند قمة الوتر الايرودينامي فتكون:

$$Re_t = \frac{\rho \cdot V_s \cdot c_t}{\mu} \quad \dots\dots(2)$$

حيث أن V_s تمثل سرعة الأنهاء (Stall speed) والتي تحسب بالشكل التالي:

$$V_s = \sqrt{\frac{W_{TO}}{0.5 \cdot \rho \cdot C_{L_{max_{clean}}}}} \quad \dots\dots(3)$$

• معامل الرفع الأقصى (Max. Lift coefficient)

المعادلات أدناه مطبقة على أسطح الرفع (الجناح, الذنب الأفقي) لإيجاد أقصى معامل رفع على تلك الأسطح بدون تأثير القلاب (flap) وكما يلي:

$$C_{L_{max_{x-clean}}} = k_{\lambda_x} \cdot \frac{\cos \Lambda_c / 4_x \cdot (C_{L_{max_{xr}}} + C_{L_{max_{xt}}})}{2} \quad \dots\dots(4)$$

حيث أن k_{λ_x} يمثل معامل نسبة الاستدقاق (Taper ratio factor) كما موضح أدناه:

$$k_{\lambda_x} = -0.117 \cdot \lambda_x + 0.997 \quad \dots\dots(5)$$

كما أن أقصى رفع للجناح بدون تأثير القلاب (Flap) يحدد أقصى معامل رفع نقي للطائرة بالشرط التالي:

$$\left| \frac{C_{L_{max_{w-clean}}}}{f_{couple}} - C_{L_{max_{clean}}} \right| < 0.05 \quad \dots\dots(6)$$

حيث أن:

$$\frac{C_{L_{\max w-clean}}}{f_{couple}} > C_{L_{\max clean}}$$

$$IF \frac{l_h}{c\bar{w}} \text{ or } \frac{l_c}{c\bar{w}} > 5.0 \Rightarrow f_{couple} = 1.05$$

$$\frac{l_h}{c\bar{w}} \text{ or } \frac{l_c}{c\bar{w}} < 3.0 \Rightarrow f_{couple} = 1.10$$

أن الشرط الموضح أعلاه إذا لم يتحقق يجب إعادة التصميم الخاص بالجنح عن طريق اختيار مقطع مطيار جديد إلى أن يتحقق هذا الشرط من أجل الاستمرار بالعملية التصميمية.

• رفع الطائرة الكلي (Total airplane lift)

قيمة عدد ماخ لحالة الطيران المستقر يمكن إيجاده من البيانات المتوفرة لحالة الطيران،

كما أن قيمة الضغط الدينامي (Dynamic pressure) يحسب من العلاقة التالية:

$$\bar{q}_1 = 0.5 \cdot \rho_{air} \cdot u_1^2 \quad \dots\dots(7)$$

أن قيمة معامل الرفع لحالة الطيران هذه يتم إيجاده بالشكل التالي:

$$C_{L_1} = \frac{n \cdot W_{current}}{\bar{q}_1 \cdot S_w} \quad \dots\dots(8)$$

كما أن قيمة زاوية الهجوم (Angle of attack α) تعتمد على معاملات الرفع الناتجة من حركة أسطح الرفع كما موضح أدناه:

$$\alpha = \frac{1}{C_{L\alpha}} (C_{L_1} - C_{L_0} - C_{L_{ih}} \cdot i_h - C_{L_{\delta e}} \cdot \delta e) \quad \dots\dots(9)$$

حيث أن في بداية العمليات الحسابية يتم فرض ميلان كل أسطح السيطرة صفراً، وبذلك فإن زاوية الهجوم في حالة الرفع الصفري (Airplane zero lift angle of attack) تكون:

$$\alpha_o = \alpha - \frac{C_{L_1}}{C_{L\alpha}} \quad \dots\dots(10)$$

• معامل الرفع (Lift coefficient)

تم دراسة معامل الرفع على كل أسطح الرفع المتمثلة بالجنح، الذنب الأفقي والعمودي من أجل معرفة توزيعه على تلك الأسطح ولكي نجد هذا التوزيع يجب أن نجد أولاً معامل الرفع لمقطع المطيار ($C_{L_{airfoil}}$)، ثم معامل الرفع للسطح ($C_{L_{surface}}$) وأخيراً إيجاد توزيع معامل الرفع على طول السطح.

من أجل إيجاد معامل الرفع للمطيار لكل سطح رفع يجب إدخال بعض البيانات إلى برنامج (AAA) متمثل بنسبة السمك إلى الوتر الخاصة بالمطيار عند كل من الجذر والرأس التي يمكن أن نستخرجها من مواصفات المطيار القياسية بالإضافة إلى إدخال قيمة معامل الرفع النقي ($C_{L_{clean}}$) إلى البرنامج وبذلك يمكننا إيجاد سرعة الأنهواء لكل سطح ورقم رينولدز عند الجذر والرأس للسطح بالإضافة إلى حساب أعلى معامل رفع. بعد ذلك يتم

حساب أقصى معامل رفع نقي ($C_{Lmax_{clean}}$) لكل من سطح الرفع وزاوية الهجوم. أخيراً يتم حساب توزيع معامل الرفع على طول أسطح الرفع (الجناح, الذنب الأفقي) كما واضح في فصل النتائج حيث يتم ذلك بعد إدخال قيم كل من (C_{Lw}, C_{Lh}, C_{Yv}) المستخرجة من مشتقات الاستقرار والسيطرة.

• معاملات الكبح (Drag coefficients)

أن تخمين قوة الكبح التجريبي للطائرات يكون مهماً للمصمم لحساب مفردات الأداء من الانطلاق العالي, المدى, معدل التسلق, ويمكن ان ينجز تخمين قوة الكبح هذه بواسطة طرق عديدة ومختلفة تعتمد على مرحلة تطور الطائرة. أن المرحلة الأولى في تخمين قوة الكبح للطائرة في الجريان الأنضغاطي يمكن أن تجري بواسطة جمع قوى الكبح المنفصلة لمكونات الطائرة, ويطلق على هذه الطريقة الشائعة بطريقة تجزئة قوة الكبح, وتتخذ بنظر الاعتبار أولاً الميزة الأساسية لمعادلة قوة الكبح. أن التحليل الذي اجري لقطبي قوة الكبح يشير إلى أن منحنى معامل قوة الكبح المرسوم ضد معامل قوة الرفع يكون تقريباً على شكل قطع مكافئ (Parabolic) كما يظهر أن معامل الكبح للطائرة يساوي حاصل جمع معاملي قوتي الكبح المحتث والطفيلي وكما موضح أدناه [Roskam, part II, 2003]:

$$C_D = C_{D0} + C_{Di} \quad \dots\dots(11)$$

أهم معاملات الكبح المدروسة لأجزاء الطائرة ذات السرعة تحت الصوتية هي معامل الكبح الناتج من الجناح, المقصورة, جسم الطائرة, الذنب الأفقي والعمودي, تأثير حاجز الريح, تأثير العجلات, وأخيراً معامل الكبح الناتج من الرفاس. لذلك من اجل حساب معامل الكبح الكلي للطائرة (C_D) يجب أولاً حساب معاملات الكبح لأجزاء الطائرة المتمثلة بالجناح, الذنب الأفقي, الذنب العمودي, جسم الطائرة, المقصورة, العجلات, والرفاس.

• توزيع العزم (Moment distribution)

بالإضافة إلى البيانات السابقة المستخرجة يتم إدخال بعض البيانات الضرورية إلى برنامج (AAA) من اجل حساب توزيع العزم على تلك الأسطح ومن أهم تلك البيانات قيمة النسبة بين متوسط الوتر الايرودينامي والوتر عند كل من الجذر والرأس لسطح الرفع.

النتائج

في هذا البند تم دراسة العديد من المتغيرات المؤثرة على قيم معامل الرفع, معامل الكبح, ومعامل العزم المتولد على أسطح الرفع الرئيسية المتمثلة بالجناح والذنب الأفقي بالإضافة إلى دراسة متغيرات أخرى موضحة أدناه:

▪ تأثير تغير مستوي الطيران على العلاقة بين معامل الرفع وزاوية الهجوم.

الشكل (2) يوضح العلاقة بين معامل الرفع وزاوية الهجوم لحالات مختلفة من مستويات الطيران متمثلة بالارتفاعات ($H=2.438, 5, \text{ and } 7.5 \text{ km}$) فيلاحظ أن قيمة معامل الرفع تزداد مع زيادة قيمة مستوي الطيران بثبوت قيمة زاوية الهجوم نتيجة زيادة الانخفاض بقيمة الكثافة مع زيادة مستوي الطيران، حيث يلاحظ أن عند مستوي طيران ($H=7.5\text{km}$) زيادة قيمة معامل الرفع مقارنة مع المستويات الأخرى بالإضافة إلى زيادة قيمة زاوية الهجوم قبل أن يصل المنحني إلى حالة الأنهواء.

▪ تأثير تغير معامل الحمل على العلاقة بين معامل الرفع وزاوية الهجوم.

الشكل (3) يوضح العلاقة بين معامل الرفع وزاوية الهجوم لحالات مختلفة من قيم معامل الحمل ($n=L/W=1, 3, 4$) فيلاحظ زيادة قيم معامل الرفع مع زيادة قيمة معامل الحمل بثبوت زاوية الهجوم حيث يعود تفسير ذلك إلى أن زيادة قيمة معامل الحمل تؤدي إلى زيادة قيمة قوة الرفع ومن ثم إلى زيادة قيمة معامل الرفع.

▪ تأثير تغير سرعة الطائرة على العلاقة بين معامل الرفع وزاوية الهجوم.

الشكل (4) يوضح العلاقة بين معامل الرفع وزاوية الهجوم لحالات مختلفة من قيم سرعة الطيران ($U=180, 212, \text{ and } 250 \text{ km/h}$) فيلاحظ أن زيادة سرعة الطائرة يؤدي إلى انخفاض قيمة معامل الرفع بثبوت زاوية الهجوم وهذا واضح من العلاقة العكسية بين سرعة الطيران ومعامل الرفع، بالإضافة إلى أن زيادة سرعة الطيران تؤدي إلى الوصول إلى حالة الأنهواء عند قيم زوايا هجوم أقل.

▪ تأثير تغير النسب الباعية لأسطح الرفع على منحنى الرفع.

الشكل (5) يوضح العلاقة بين معامل الرفع وزاوية الهجوم لحالات مختلفة التطبيقات حيث تم اخذ ثلاث حالات للدراسة يتم فيها تغيير قيمة النسب الباعية لأسطح الرفع المتمثلة بالجنح، الذنب الأفقي، والذنب العمودي وتأثير ذلك على شكل منحنى الرفع فيلاحظ أن زيادة النسبة الباعية يؤدي ذلك إلى ارتفاع منحنى الرفع نحو الأعلى مع انخفاض قيمة زاوية الهجوم عند تلك الحالة.

▪ توزيع معامل الرفع (Lift coefficient distribution)

الشكل (6) يوضح توزيع معامل الرفع على طول الجناح، حيث يبين بعض المواصفات الخاصة بالجناح من مساحة، نسبة باعية، زاوية استدقاق، وقيم معامل الرفع عند جذر وراس

المطيّار بالإضافة إلى قيمة رقم ماخ عند الحالة المدروسة. يمثل المنحني توزيع الرفع على طول الجناح وان هذه القيم لمعامل الرفع ما هي ألا محصلة رفع المطيّر (Airfoil lift) الموضح بالشكل بالإضافة إلى رفع الجناح الطبيعي (Basic lift) ورفع الجناح المضاف (Additional lift). توزيع قيم معامل الرفع الكلي (Total lift) على طول الجناح (Spanwise station) يكون أعلى ما يمكن عند المنطقة المحصورة بين (60-70%) من طول الجناح حيث يلاحظ أن قيمة معامل الرفع تبدأ بالزيادة تدريجياً إلى أن تصل إلى أقصى قيمة لها ثم تبدأ بالانخفاض إلى أن تصل إلى نهاية الجناح.

أما الشكل (7) فيوضح توزيع معامل الرفع على طول الذنب الأفقي حيث يلاحظ أن قيم معامل الرفع الكلي على طول الذنب الأفقي تكون سالبة حيث يبدأ المنحني من قيمة صغيرة عند الجذر ثم يزداد زيادة ضئيلة إلى أن يقل الرفع بصورة كبيرة عند رأس الذنب الأفقي مع ملاحظة أن قيم معامل الرفع ذات إشارة سالبة نتيجة أن قيم الرفع المتولدة على طول الذنب الأفقي تكون ذات إشارة سالبة طبقاً للبيانات المستخدمة في حالة التصميم المدروسة حيث يساعد ذلك على موازنة الطائرة والوصول إلى حالة الاستقرار.

▪ توزيع معامل الكبح (Drag coefficient distribution)

الشكل (8) يوضح توزيع معامل الكبح على طول الجناح فيلاحظ أن المنحني يبدأ عند قيمة $(C_D=0.075)$ عند جذر الجناح ثم يبدأ بالزيادة إلى أن يصل أقصى قيمة له $(C_D=0.095)$ عند نسبة (60%) من طول الجناح، بعد ذلك يبدأ المنحني بالانخفاض إلى أن يصل إلى قيمة $(C_D=0.013)$ عند رأس الجناح. أما الشكل (9) فيوضح توزيع معامل الكبح على طول الذنب الأفقي حيث يلاحظ ثبوت قيمته تقريباً لتساوي $(C_D=0.098)$ عند كل من جذر ورأس الذنب الأفقي وزيادتها إلى $(C_D=0.1)$ عند المنطقة المحصورة بين (60-70%) من طول الذنب الأفقي.

▪ توزيع معامل العزم (Moment coefficient distribution)

الشكل (10) يوضح توزيع العزم على طول الجناح حيث أن القوى المتولدة على الجناح سوف تؤدي إلى توليد عزوم مختلفة مؤثرة على الجناح عند مواقع مختلفة حيث أن هذا ينطبق على جميع أسطح الرفع. حيث يلاحظ أن المنحني يبدأ عند جذر الجناح بقيمة $(C_M=-0.9)$ ثم يبدأ المنحني بالانخفاض إلى أن يصل أقل قيمة له $(C_M=-1.85)$ عند (80-90%) من طول الجناح ثم بعد ذلك تبدأ قيم معامل العزم بالزيادة إلى أن تصل $(C_M=-0.8)$ عند رأس الجناح. قيم توزيع العزم على الجناح يكون ذا قيم سالبة وذلك لمعادلة العزوم

الخارجية المؤثرة على الطائرة حيث تقوم الطائرة بتوليد عزم سالب عكس العزوم المؤثرة ليرجع الجناح إلى وضعه الطبيعي [Ramyer, 1992].

أما الشكل (11) فيوضح توزيع معامل العزم على طول الذنب الأفقي حيث أن قيمة معامل العزم تبدأ بقيمة تساوي ($C_M=0.5$) عند جذر الذنب الأفقي ثم يبدأ المنحني بالزيادة إلى أن يصل أقصى قيمة له تساوي ($C_M=1.1$) عند نسبة (80-85%) من طول الذنب الأفقي، بعد ذلك يبدأ المنحني بالانخفاض إلى أن يصل لقيمة ($C_M=0.31$) عند طرف الذنب الأفقي.

▪ تأثير تغيير رقم ماخ على العلاقة بين معامل الرفع ومعامل الكبح

الشكل (12) يوضح العلاقة بين معامل الرفع ومعامل الكبح لقيم مختلفة من رقم ماخ لحالات ($M=0.1, 0.2, \text{ and } 0.3$) لجريان تحت صوتي فيلاحظ أن المنحني يكون على شكل قطع ناقص مع ملاحظة أن زيادة قيم رقم ماخ يؤدي إلى تقليل قيمة معامل الكبح بثبوت قيمة معامل الرفع حيث يؤدي هذا إلى تزييف المنحني نحو نقطة الأصل، أما في حالة زيادة قيمة رقم ماخ بثبوت قيمة معامل الكبح يؤدي هذا إلى زيادة قيمة معامل الرفع تدريجياً بالإضافة إلى اتساع مدى المنحني نحو الأعلى.

▪ تأثير تغيير قيمة معامل الرفع على العلاقة بين معامل الكبح ورقم ماخ

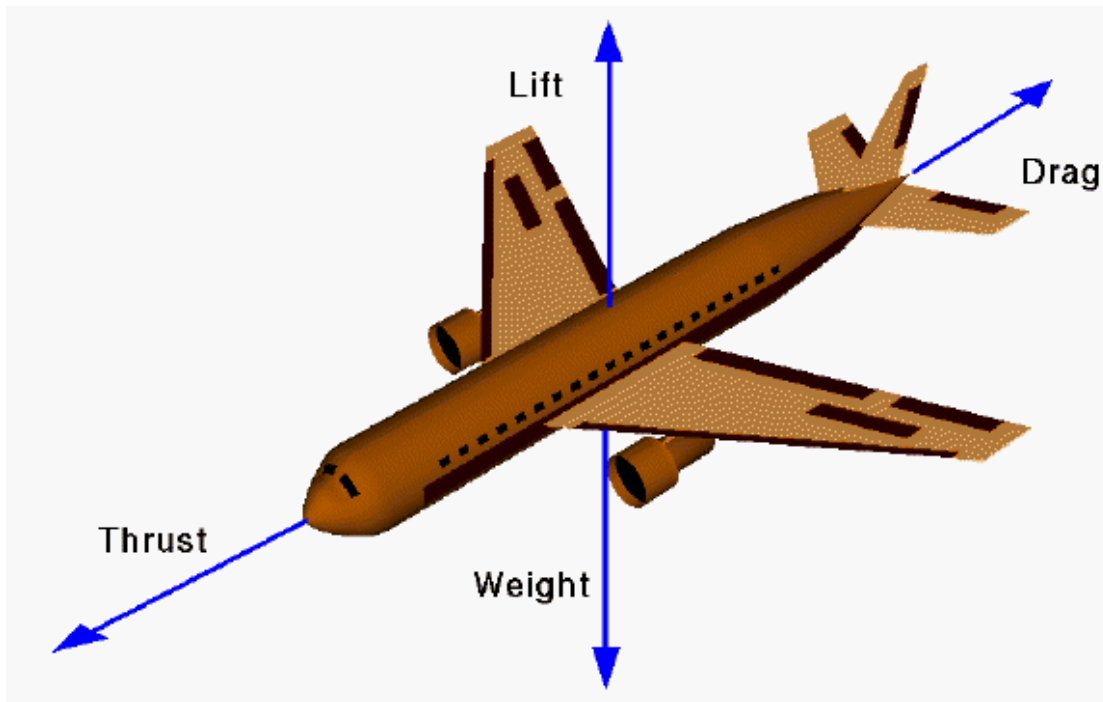
الشكل (13) يوضح العلاقة بين معامل الكبح ورقم ماخ عند حالات مختلفة من قيم معامل الرفع ($C_L=0.5, 1.0, \text{ and } 1.5$) فيلاحظ أن نوع العلاقة تكون على شكل عكسي أي أن زيادة قيمة رقم ماخ بثبوت معامل الرفع يؤدي إلى انخفاض قيمة معامل الكبح إلى أن تصبح ثابتة تقريباً عند قيم لرقم ماخ أكبر من (0.28) أما في حالة زيادة معامل الرفع يؤدي ذلك إلى زيادة قيمة معامل الكبح بثبوت رقم ماخ، بينما يؤدي زيادة قيمة معامل الرفع إلى زيادة قيمة رقم ماخ بثبوت قيمة معامل الكبح.

الاستنتاجات

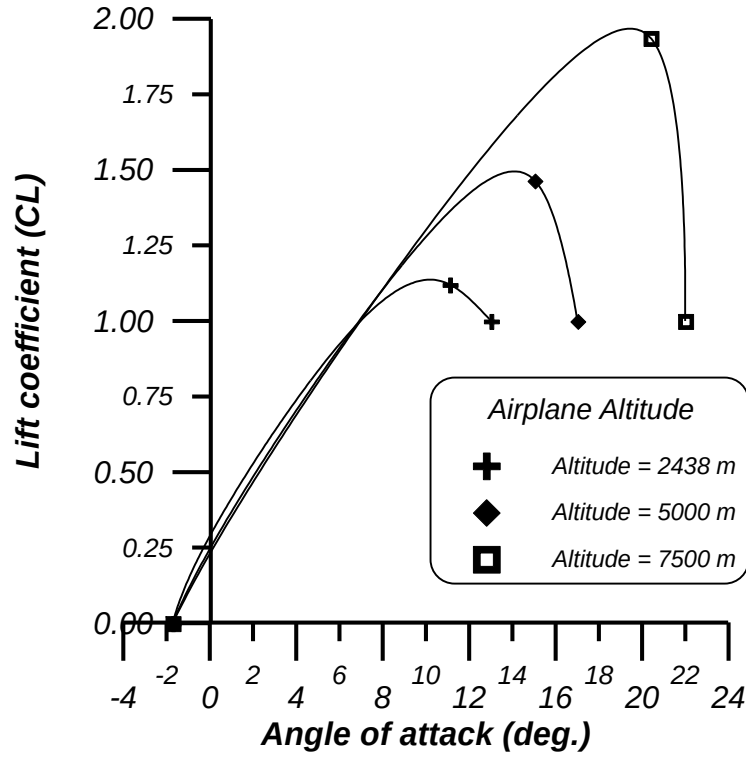
من خلال داسة وتحليل النتائج التي تم الحصول عليها من عملية التحليل الشاملة للطائرة المصممة ذات المقعد الواحد والسرعة تحت الصوتية تم التوصل إلى الاستنتاجات التالية:
I. تم استنتاج أن زيادة مستوي الطيران، معامل الحمل، النسبة الباعية لأسطح الرفع يؤدي إلى ارتفاع منحني الرفع إلى الأعلى وزيادة قيم معامل الرفع بينما يحدث العكس في حالة زيادة سرعة الطائرة.

II. من النتائج نلاحظ توافق النتائج الخاصة بتوزيع كل من معامل الرفع, معامل الكبح, ومعامل العزم على أسطح الرفع (Wing, Horizontal tail, Vertical tail) مع التصرف الحقيقي للجريان فوق هذه الأسطح.

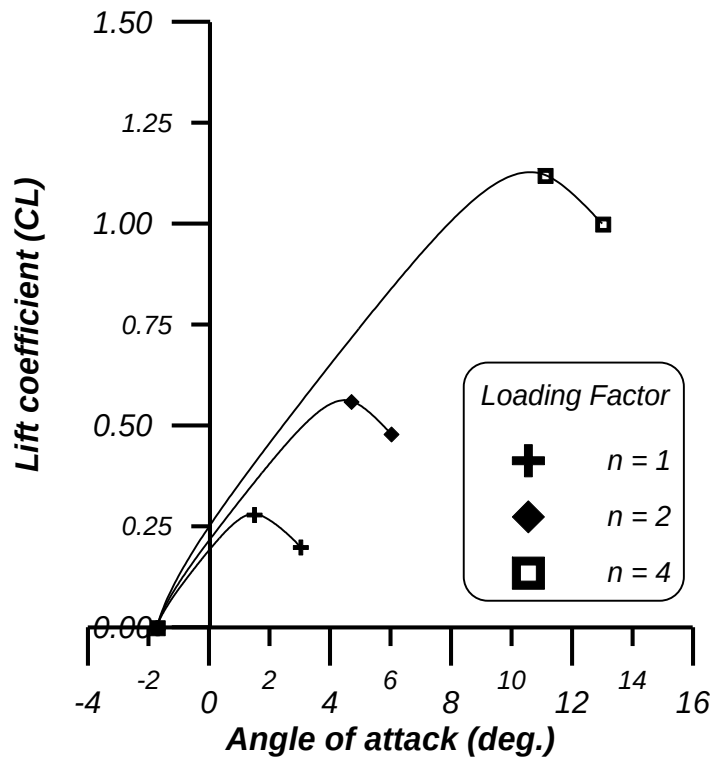
III. أن تأثير قيم رقم ماخ على منحنى معامل الرفع والكبح موضحة من خلال النتائج فيلاحظ أن زيادة قيم رقم ماخ تؤدي إلى تقليل قيم معامل الكبح بثبوت قيم معامل الرفع وهذا يؤدي إلى ترحيف المنحنى نحو نقطة الأصل, بينما أن زيادة قيم معامل الرفع على منحنى معامل الكبح ورقم ماخ تؤدي إلى زيادة قيم معامل الكبح بثبوت رقم ماخ.



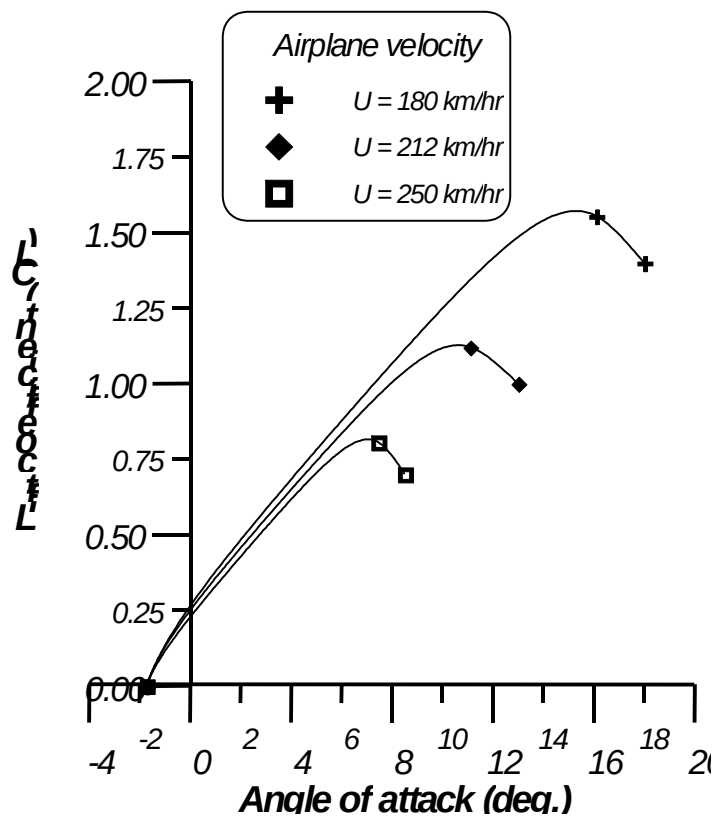
الشكل (1) يوضح القوى الرئيسية المؤثرة على الطائرة.



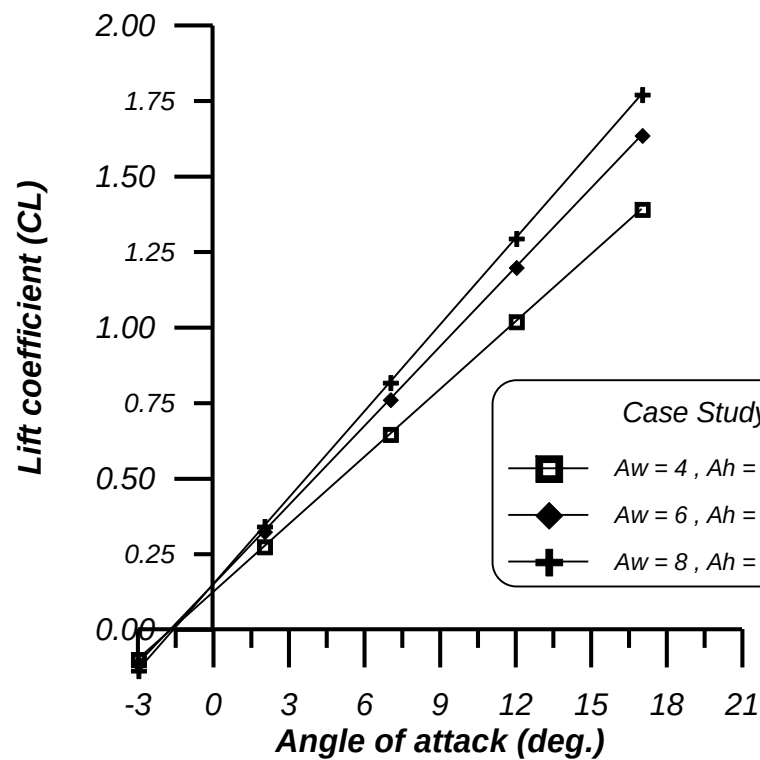
الشكل (2) يوضح تأثير سقف مستوي الطيران على منحنى الرفع.



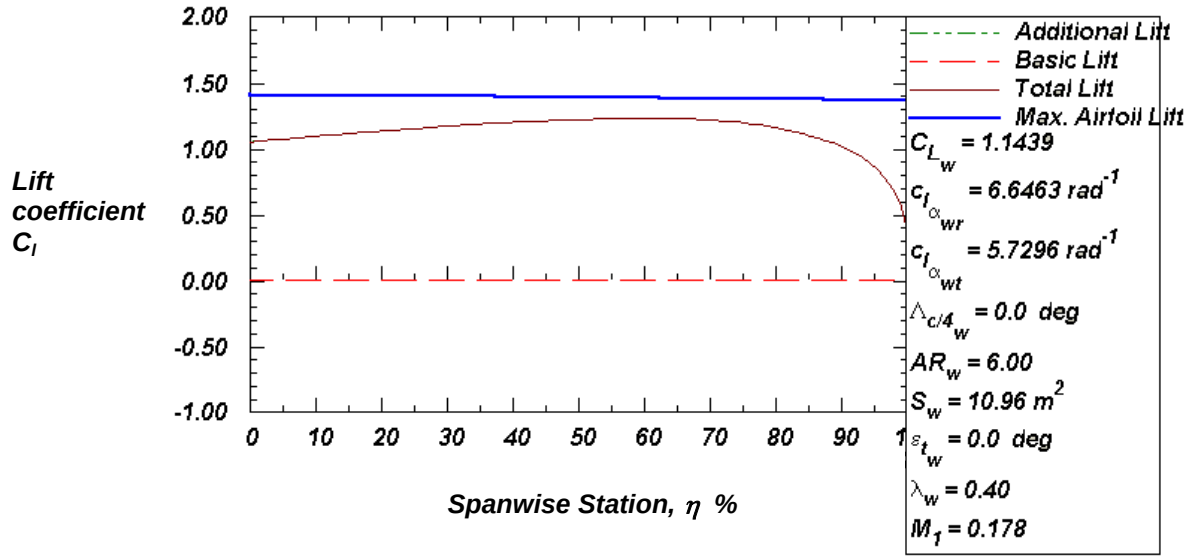
الشكل (3) يوضح تأثير معامل الحمل على منحنى الرفع.



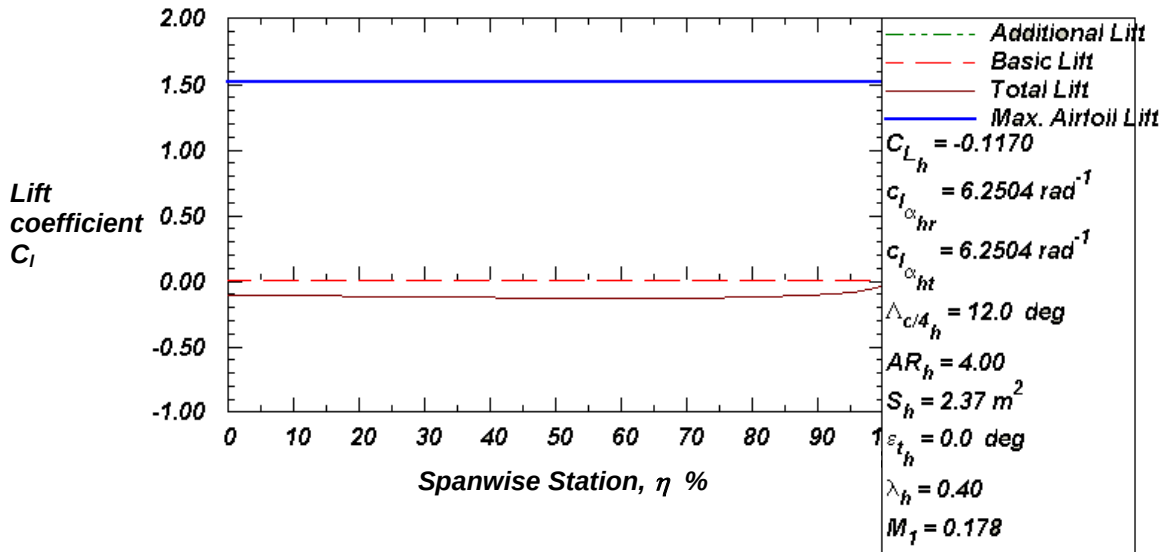
الشكل (4) يوضح تأثير سرعة الطائرة على منحنى الرفع.



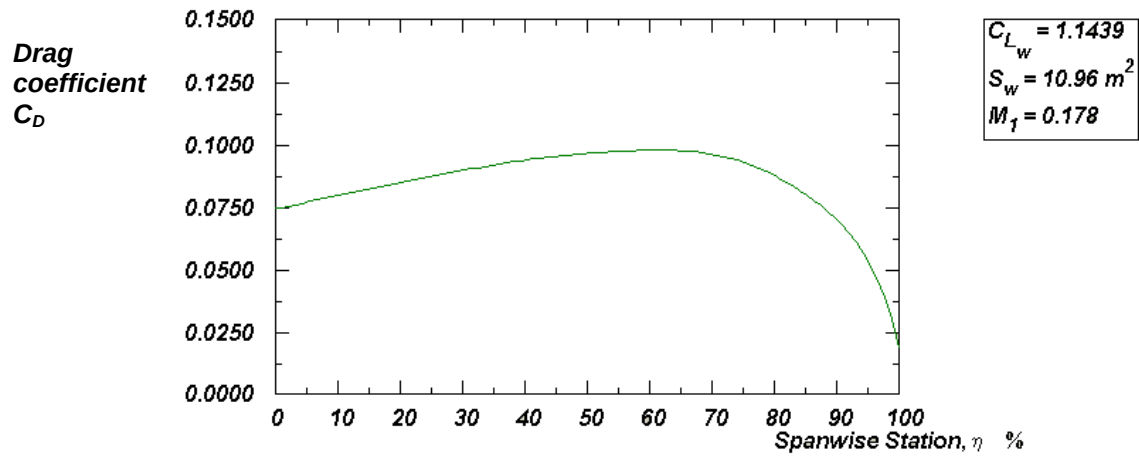
الشكل (5) يوضح تأثير النسب الباعية لأسطح الرفع على منحنى الرفع.



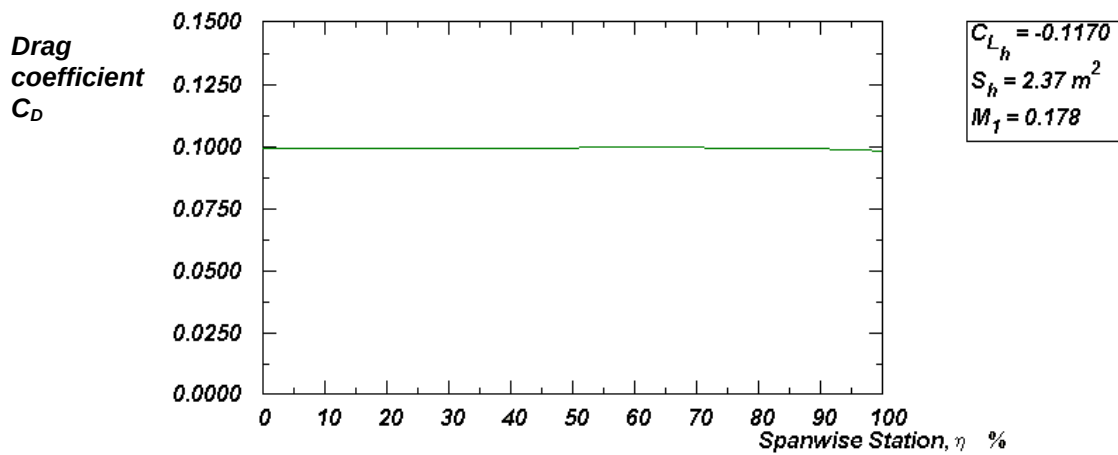
الشكل (6) يوضح توزيع معامل الرفع على طول الجناح.



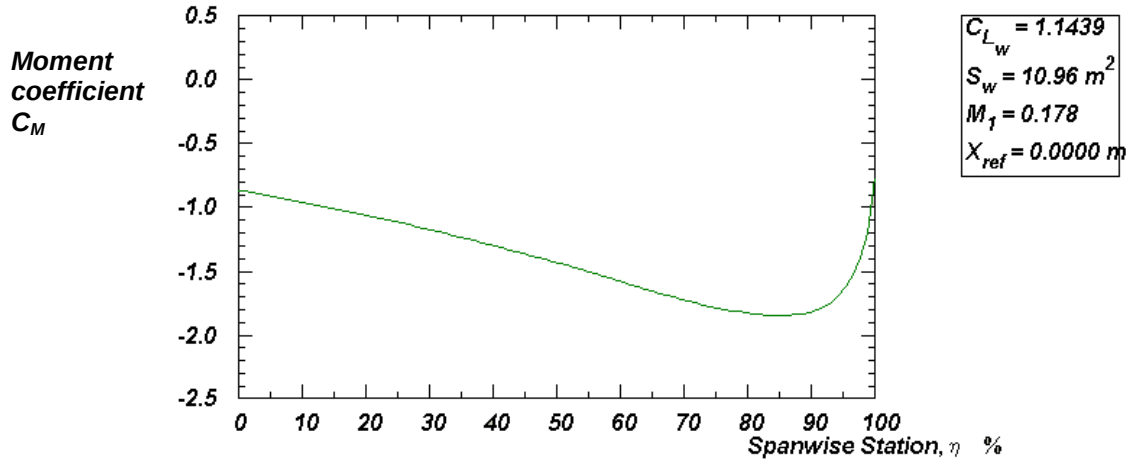
الشكل (7) يوضح توزيع معامل الرفع على طول الذنب الأفقي.



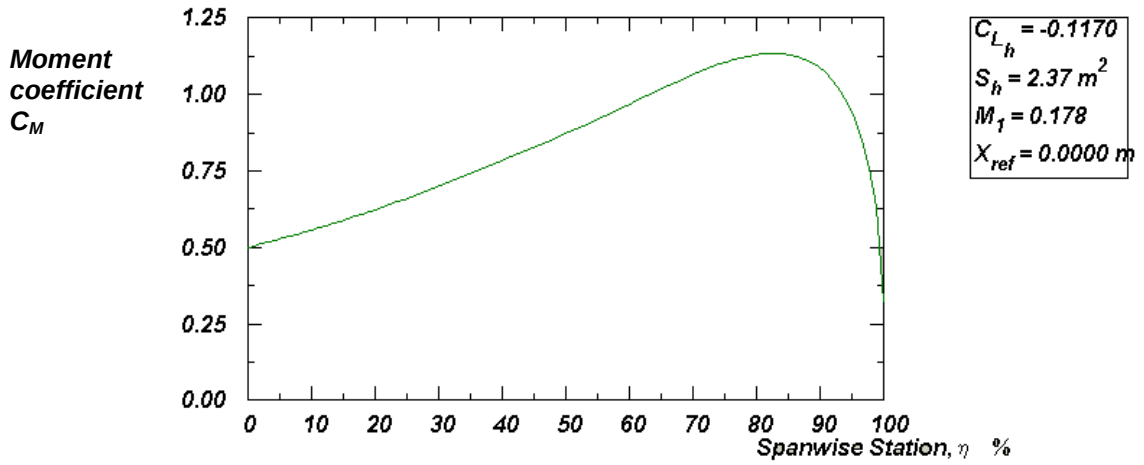
الشكل (8) يوضح توزيع معامل الكبح على طول الجناح.



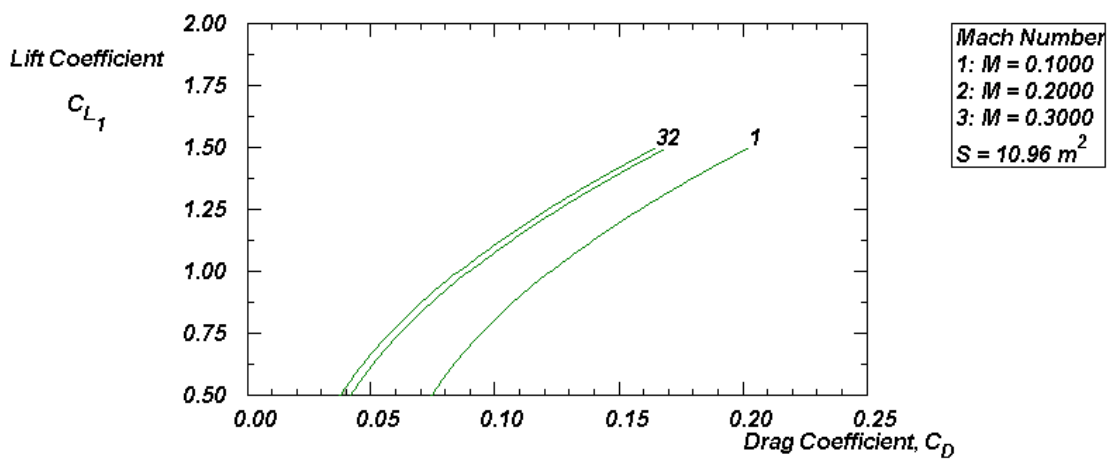
الشكل (9) يوضح توزيع معامل الكبح على الذنب الأفقي.



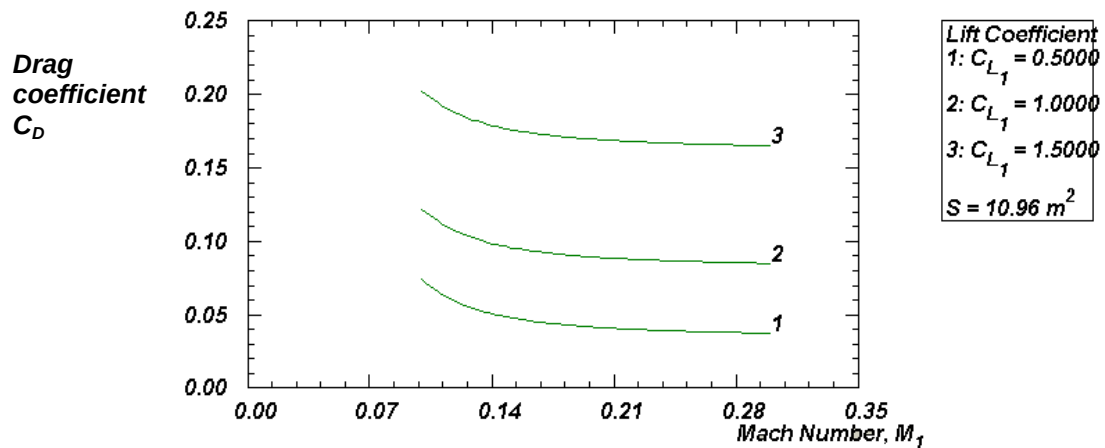
الشكل (10) يوضح توزيع معامل العزم على طول الجناح.



الشكل (11) يوضح توزيع معامل العزم على الذنب الأفقي.



الشكل (12) يوضح تأثير تغيير رقم ماخ على العلاقة بين معامل الرفع ومعامل الكبح.



الشكل (13) يوضح تأثير تغيير معامل الرفع على العلاقة بين معامل الكبح ورقم ماخ.

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