Some Mechanical Properties of Concrete by using Manufactured Blended Cement with Grinded Local Rocks

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ABSTRACT

The use of blended cement in concrete provides economic, energy savings, and ecological benefits, and also provides. Improvement in the properties of materials incorporating blended cements. The major aim of this investigation is to develop blended cement technology using grinded local rocks . The research includes information on constituent materials, manufacturing processes and performance characteristics of blended cements made with replacement (10 and 20) % of grinded local rocks (limestone, quartzite and porcelinite) from cement.

The main conclusion of this study was that all types of manufactured blended cement conformed to the specification according to ASTM C595-12 (chemical and physical requirements). The percentage of the compressive strength for blended cement with 10% replacement are (20, 11 and 5) % , (2 , 12 and, 13) % and (18, 15 and 16) % for limestone , quartzite and porcelinite respectively at (7,28 and 90)days for each compare to the reference mix, while blended cement with 20% replacement are (-3, -5 and -11) ,(6, -4% and -5) and (6, 4 and 6) % for limestone , quartzite and porcelinite respectively at (7, 28 and 90)days compare to the reference mix .The other mechanical properties (flexural tensile strength and splitting tensile strength) are the same phenomena of increase and decrease in compressive strength. The results indicated that the manufacture Portland-limestone cement, Portland-quartzite cement and Portland-porcelinite cement with 10% replacement of cement with improvable mechanical properties while the manufacture Portland-porcelinite cement with 20% replacement of cement with slight improvable mechanical properties and more economical cost.

Key words: blended cement, limestone, quartzite, porcelinite.

بعض الخواص الميكانيكية للخرسانة الحاوية على سمنت مخلوط مع مطحون صخور محلية

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الخلاصة

استخدام السمنت المخلوط في الخرسانة يوفر اقتصاديا, حفظ للطاقة , الفوائد البيئية و كذلك يوفر تحسنا في خواص المواد التي يستخدم فيها السمنت مخلوط. الهدف الرئيسي من هذا البحث هو تطوير سمنت مخلوط من مطحون الصخور المحلية , البحث يتضمن معلومات عن عملية الخلط والتصنيع وخصائص الاداء مع نسب الاستبدال (10 و20)% من مطحون الصخور المحلية (الحجر الجيري , الكوارتزايت و البورسلينايت) من السمنت .

الاستنتاج الرئيسي من هذه الدراسة هو ان جميع انواع السمنت المخلوط المصنع مطابق للمواصفة الامريكية **ASTM C595-12**للمتطلبات الفيزيائية والكيميائية الخاصة بالسمنت المخلوط .نسبة نتائج فحص مقاومة الانضغاط للخرسانة الحاوية على 10 % استبدال من السمنت هي كالاتي (5,11,20)% , (13,12,2)% و (16,15,18)% للحجر الجيري , الكوارتزايت والبورسلينايت على التوالي في (90,28,7) يوم لكل نوع مقارنه بالخلطه المرجعيه , في حين ان الاستبدال مع 20 % من السمنت هي كالاتي (-3,-5,-11)%, (6,-4,-5)% و(6,4,6) للحجر الجيري , الكوارتزايت والبورسلينايت على التوالي في (90,28,7)

يوم. اما الخواص الاخرى (فحص قوة الانثناء ,فحص قوة الانشطار) فمن خلال النتائج يتبين ان الزيادة والنقصان هي في الاتجاه ذاته في فحص مقاومة الانضغاط. النتائج توضح ان افضل نسبة استبدال من السمنت من مطحون (الحجر الجيري , الكوارتزايت و البورسلينايت) هي نسبة 10% مع تحسن جيد بينما يمكن أستخدام 20% لمطحون البورسلينايت مع تحسن طفيف للخواص الميكانية و أقل كلفة .

الكلمات الرئيسية ..السمنت المخلوط , مطحون الحجر الجيري ,مطحون حجر الكوارتزايت , مطحون حجر البورسلينايت

1. INTRODUCTION

The ACI 116, 2000, defined blended cement as a hydraulic cement consisting essentially of an intimate and uniform blend of granulated blast-furnace slag and hydrated lime, or an intimate and uniform blend of Portland cement and granulated blast-furnace slag, Portland cement and pozzolan , or Portland blast-furnace slag cement and pozzolan, produced by intergrading Portland cement clinker with the other materials or by blending Portland cement with the other materials, or a combination of intergrading and blending.

With the extensive use of cement in concrete, there have been some environmental concerns in terms of damage caused by the extraction of raw materials and CO_2 emission during cement manufacture. This has brought pressures to reduce the cement consumption in industry. At the same time, more requirements are needed for the enhancement of concrete durability to sustain the changing environment which is apparently different from old days, **Ishwar**, **2012**.

2. LITERATURE REVIEW

All the cementitious materials have one property in common: they are at least as fine as the particles of Portland cement, and sometimes much finer. Their other features, however, are diverse. This applies to their origin, their chemical composition, and their physical characteristics such as surface texture or specific gravity**.** Some of these materials are cementitious in themselves; some have latent cementitious properties, yet others contribute to the strength of concrete primarily through their physical behavior. It is proposed, therefore, to refer to all these materials cementitious materials, **Neville, 2011.**

Limestone is a sedimentary rock composed primarily of calcium carbonate ($CaCO_3$) in the form of mineral calcite. It is most commonly formed in clear, warm, shallow marine waters. It is usually an organic sedimentary rock that is formed from the accumulation of shell, coral, algal and fecal debris. It can also be a chemical sedimentary rock formed by the precipitation of calcium carbonate from lake or ocean water**.** Most limestone is crushed and used as a construction material. It is used as a crushed stone for road base and railroad ballast. It is used as an aggregate in concrete. It is fired in a kiln with crushed shale to make cement, **Geology, 2014.**

İnan Sezer, 1986, showed that consistency water demand decreases when limestone and clinker are interground together. Studies by **P'era et al., 1999,** suggested an accelerating effect of limestone on the hydration of cement and showed that different hydration products are formed due to the presence of $CaCO_3$. A general observation is that transformation of ettringite into monosulfate is delayed by the calcium carbonate, **Taylor, 1997, Kakali, 2001 and Erdoğdu, 2000,** prepared blended cements with 5, 10, 20, and 30% limestone replacement ratios, and reported that consistency water demand decreases with the increasing limestone replacement.

Al-Taai, 2009, observed that concrete produced from limestone-ordinary Portland cement generally shows enhanced workability properties which are particularly useful in unformed surfaces.

Quartzite is a non-foliated metamorphic rock that is produced by the metamorphism of sandstone. It is composed primarily of quartz. The term quartzite implies not only a high degree of hardening (induration), or “welding,” but also a high content of quartz; similar rocks that contain appreciable quantities of other minerals and rock particles are impure quartzite's, more appropriately called gray wacke, sandstone, or the like, **Britannica.com, 2014**.

Snellings et al., 2013, studied a comparison between the early-age hydration of cements blended with micronized zeolitite and quartzite powders. The Portland cement replacement in the mixes was 30 %, and the effect of introducing a superplasticizer to lower the required water to solid ratio was assessed. The cement pastes were hydrated at 40°C and monitored in situ by time-resolved synchrotron X-ray powder diffraction combined with Riveted quantitative phase analysis.

The quantitative evolution of phase weight fractions showed that the addition of the zeolite tuff accelerated the hydration rate of the main C_3S cement component. Blending with the quartzite powder of similar fineness did not affect the C_3S hydration rate. Reduction of water to solid ratio by introduction of the superplasticiser had a retarding effect on the hydration of the zeolitite-blended cement over the early hydration period up to 3 days and the quartz content in the quartzite blended cement did not present any significant changes over the period of examination. There was no evidence for the pozzolanic reaction between quartz and CH to occur within the experimented time span of 48 h .The researchers explained results of the values for the mean volume weighted crystallite sizes which is 75 ± 2 nm for the clinoptilolite phase in the zeolitite and 410 ±3 nm for quartz as the main component of the quartzite. This effect of crystallinity on the cement hydration was also encountered in a previous study when comparing a well-crystallised chabazite and a typical clinoptilolite tuff of lower clinoptilolite crystallinity **Snellings et al., 2013.**

Porcelanite is one of the important industrial sedimentary rocks in Iraq .it has gone under more than 20 different names, where many are commercial trademarks (e.g. diatomite, diatomaceous earth, kieslelguhr, cellite, filtac .etc), **AL-Jabboory, 1999**.

In 1986, the state company of Geological Survey and Mining discovered Porcelanite rocks in wadi Mallusa in the Iraqi western desert, between Reba, Traibeel and Akashat,.Preliminary studies were made to find its mineral and chemical properties, as well as estimating the reserve of these rocks. Porcelinite rocks are sedimentary deposits associated with clay stone, white to creamy in color and highly cracking.

Al Kassab, 2006, studied the requirements of durability for very severe sulfate attack of ACI 318 – 2005 were tested on local materials. Two sulfate resisting cements having low C_3S (49.4 and 47.5) %, were used with (0, 5, 10 and 15) % porcelinite (natural pozzolana) as addition. Addition of porcelinite to cement increases the 28 days compressive strength of concrete also increases its resistance to sulfate attack at that age. At later ages the compressive strength and sulfate resistance of concrete are the same for both plain cement and cement blended with porcelinite when low C_3S in cement is used (not more than 50%).

3. EXPERIMENTAL PROGRAM

3.1 Materials

3.1.1 Cement

Iraqi ordinary Portland cement manufactured by AL-Mass cement factory (Sulaimaniyah governorate) was used in the investigations the chemical composition and physical properties of the cement are shown in **Tables 1 and 2**. The results conformed to the Iraqi specification **No. 5/1984.**

3.1.2 Fine aggregate

The fine aggregate used throughout this study is brought from AL- Ukhaider region. It re sieved to conform the grading of fine aggregate. The grading and physical properties (specific gravity, absorption, sulfate content and moisture content) are shown in **Table 3**. The used sand is within zone 2 according to the requirements of the Iraqi Standard Specification **No. 45, 1984.**

3.1.3 Coarse aggregate

Crushed gravel of 14 mm nominal size from AL-Soodor district was used. **Table 4** shows the physical properties of coarse aggregate and the grading of coarse aggregate which conforms to the limits of the Iraqi specification **No. 45/1984.**

3.1.4 Water

Tap water was used for mixing and curing of samples.

3.1.5 High range water reducing admixture

Hyperplast PC260 is a high performance super plasticizing type A (Formerly known as Flocrete PC260) admixture based on polycarboxylic polymers with long chains specially designed to enable the water content of the concrete to perform more effectively. **Table 5** shows the technical properties of Hyperplastic PC260

3.2 Raw Material and Grinding Process

The raw material of limestone, quartzite and porcelinite contains rocks being grinded in the Building Research Center/Ministry of construction and, it was crushed, stormed then transformed into a powder finer or equal to fineness of cement for the purpose of getting the most of their effectiveness

3.2.1 Limestone powder

A fine Limestone powder of Iraqi origin (Sulaimaniyah governorate with specific gravity of 2.6 was used. **Table 6** shows the chemical analysis for limestone powder.

3.2.2 Quartzite powder

A fine quartzite powder of Iraqi origin (Al-Anbar governorate) with specific gravity of 2.61 was used. **Table 7** shows the chemical analysis for quartzite powder and it's confirmed to the requirement in, **ASTM 618, 2012.**

3.2.3 Porcelinite powder

A fine porcelinite powder was brought from Akashat district (Al-Anbar governorate) with specific gravity 1.5. **Table 8** shows the chemical analysis for porcelinite powder and it's confirmed to the requirement in, **ASTM 618, 2012.**

3.3 Mortor Mixes and Strength Activity Index of Quartzite and Porcelinite

Mixing of mortar was carried out by a small laboratory mortar mixture according to **ASTMC109/C109 M, 2002, Tables 14, 15 and 16** show the result of mortor mixes for CL, CQ and CP. Control and test mixtures were prepared for strength activity index. The cement or cementations materials (C+ (Q, P) to fine aggregate ratio is 1: 2.75mix proportions according to **ASTM C109, 2002.** The strength activity index is 84% and 96 % for CQ and CP respectively and CL is equal to 75 % according to **ASTM C311, 2002.**

3.4 Concrete Mixes

In this investigation, the reference concrete mixture was designed to give 28 days as characteristic compressive strength of 35 MPa, according to **ACI 211.1,1991.** The proportion of mix was 1:1.6: 2.0 by weight of cement, sand, coarse aggregate respectively. Cement content was 451 kg/m³ and the water to cement ratio was 0.47 to give slump of 100 ± 25 mm. The details of the mixes used throughout this investigation are given in **Table 9**. The slump test method was carried out by **ASTM C143, 2005.**

3.5 Mixing of Concrete

Mixing process of concrete was performed according to **ASTM C192, 2006** .Using pan mixes and drill, in case of blended cement. At beginning, the cement was mixed with limestone, quartzite or porcelinite until the blended cement was homogenous. The interior surface of mixer was cleaned and moistened before placing the materials. For the concrete, the dry constituents were placed in the pan mixer; cement was placed with sand and mixed and then gravel was added. The dry materials were firstly mixed together to attain a uniform mix and then the required quantity of SP and tap water were added. The whole mix ingredients were mixed for a period until homogenous concrete was obtained, and then slump tests were measured immediately after mixing. The slump test was done and followed by the casting of concrete in the molds.

3.6 Testing of Hardened Concrete

3-6-1 Compressive strength test

The compressive strength test was made according to **B.S.1881: part 116** using 100 mm cubes. The compressive strength cubes were tested using a standard testing machine with capacity of 200000 LBS (909kN).

3.6.2 Splitting tensile strength test

The splitting tensile strength test was carried out in accordance with **ASTM C496, 2007.** 100x200 mm cylindrical concrete specimens and tests were performed using testing machine at a rate of 1.1 MPa per minute. The average of three cylinders was taken at each test.

3.6.3 Flexural strength test

This test was carried out on (100×100×400) mm prism specimens in accordance with **ASTM C293, 2006** using (TINIUS OLESN) testing machine with capacity of 650 kN ,

3.6.4 Dry density

This test was performed according to **ASTM C642, 2003** on average of two cubic and the dry density was calculated for ages 7, 28 and 90 days.

4. RESULTS AND DISCUSSION

4.1 The Influence of Manufactured Blended Cement on Chemical Composition

Tables 10, 11 and 12 show the chemical analysis for Portland –limestone cement (type IL), Portland-quartzite cement (type IP) and Portland-porcelinite cement (type IP) respectively with replacement proportion (10 and 20) % for each powder. The (L.O.I), SO_3 content as presented are specified with limits for the specification requirements in **ASTM C595, 2012** for each type of cement.

4.2 The Influence of Manufactured Blended Cement on Physical Properties of Concrete

From an examination of the obtained test results shown in **Tables 14, 15 and 16,** they seem that the standard consistency , compressive strength of Mortor , initial and final time are specified to the requirements in **ASTM C595 , 2012.**

4.3 The Influence Limestone Powder (LP), Quartzite Powder (QP) and Porcelinite Powder) (PP) Replacement on the Physical Properties of Concrete.

4.3.1 Compressive strength

Table 16 and **Fig. 1** show the variation of compressive strength with different replacement of LP, it can be seen that 10% (*ML10-1)* of compensation increases the compressive strength by (20, 11 and 5) % at (7, 28 and 90) days respectively and 20% (*ML20-1)* of compensation resulted in (-3 , -5 and 11)% at (7, 28 and 90) days respectively compared with *M ref -1* ; several combined effects may be called upon to explain strength maintenance. In the presence of filler, the solid skeleton may be strengthened to a more homogeneous distribution of smaller C–S–H crystals, finer pore structure, accelerated cement hydration ,**Mossberg and et al., 2003,** Moreover, the bond between cement paste and sand particles may strengthen the reduction of the wall effect provided by the fine particles filling ,**Lawrence, 2003.**

Table 17 and **Fig. 2** also show the variation of compressive strength with different replacement of QP; it can be seen that a 10 % compensating(*MQ10-1*) increases the compressive strength by (2, 12, and 13)% at (7, 28 and, 90) days respectively compared with the reference mix while 20 % compensating(*MQ20-1*) shows a decreasing (-6,-4, and -6)% at (7,28 and 90) days respectively compared to reference mix concrete . Several combined effects may be called upon to explain strength maintenance. In the presence of quartzite powder ,the silicate ions may react with lime produced from the cement hydration to produce additional calcium silicate hydration products(C-S-H).Such increase in compressive strength of QPC is mainly due to presence of high silica and the pozzolanic reaction of QP the presence of high amount of QP (20 % in this study) leads to low value in compressive strength which may be because the cement paste is not able to coat all fine and coarse particles ,so a drop in the reactive cement component results in significant physical modifications of the material.

Table 18 and **Fig.3** show the variation of compressive strength with different replacement of porcelinite powder (PP); it can be seen the compressive strength is increased by (17, 15, and 18) % at (7, 28, 90) days, respectively, and (6, 4 and, 5.5) %, at (7, 28 and 90) days respectively for (10 and 20) % compensation compared with reference mix concrete; several combined effects may be called upon to explain strength maintenance. The increase in compressive strength of concrete may be due to the formation of the secondary C-S-H products from the reaction of the porcelinite with $Ca(OH)_2$ and filling the pores of cement paste, reducing the permeability of concrete and increasing the compressive strength. Such increase in compressive strength of PPC is mainly due to presence of high silica and the pozzolanic reaction of PP which depends on the activity of pozzolana , **Matched and et al.,2007 .**

4.3.2 Splitting tensile strength

Table 16 and **Fig. 4** show that the splitting tensile strength at *ML10-1* (10) % replacement is found to be (30, 16.5 and 8.7) % at (7, 28 and, 90) days respectively and at *ML20-1*(20) % replacement is found to be (1, -3 and -6) % at (7, 28 and 90) days respectively compared to reference mix concrete.

Table 17 and **Fig. 5** show the splitting tensile strength ; the results percentage is (7.7 , 18.5 and, 7)% at (7,28 , 90) days respectively for 10% QP as replacement of cement and (-1.3 , -3.3 and -4.3)% at (7,28 and 90) days respectively for (20)% QP as replacement of cement relative to the reference M ref-1. The increase mainly may be due to the pozzolanic reaction of the QP with calcium hydroxide liberated during the hydration of cement. This reaction contributes to the densification of the concrete matrix, thereby strengthening the transition zone and reducing the micro cracking leading to a significant increase in tensile strength, **Naik, 2003**.

Average values of three samples for splitting tensile strength are explained in **Table 18** and **Fig. 6** show the splitting tensile strength , the results percentage is (13.2 , 11.52 and 9.7)% at (7,28 and 90) days, respectively and (0.19 , 3.32 and 3.71)% at (7,28 and 90) days, respectively for (10 and 20)% replacement respectively relative to the reference M ref-1.This increase is mainly due to the pozzolanic reaction of the PP with calcium hydroxide liberated during the hydration of cement. This reaction contributes to the densification of the concrete matrix, thereby strengthening the transition zone and reducing the micro cracking leading to a significant increase in tensile strength, **Naik, 2003.**

4.3.3 Flexural tensile strength

Average values of three samples for flexural tensile strength are explained in **Table 16** and **Fig. 7** show the Flexural tensile strength for 10% replacement of LP, it is (14.4 ,5.0 and 4.2)% at (7,28 and 90) days respectively, while the result percentage of 20% replacement of LP is (2.3,-4.3, and -4.2) % at (7,28 and,90) days respectively. 10 % replacement is the best result and that result agrees with compressive strength behavior.

Table 17 and **Fig. 8** show the Flexural tensile strength for 10% replacement (MQ10-1) is (5.2,5.7 and,7.7) % for (7,28 and 90) days respectively, while 20% replacement (MQ20-1) is (-1,-2 and,-4) % for (7,28 and 90) days, respectively.

Table 18 and **Fig. 9** show the Flexural tensile strength; the results percentage is (3.81,4.63,5.51)% at (7,28 and,90) days, respectively, and (2.8,3.6 and 1.9)% at (7,28 and 90) days respectively for (10 and 20)%replacement respectively.

4.3.4 Dry density

Concrete is a porous material with discrete and interconnected pores of different sizes and shapes; the use of cement replacement materials result in pore size refinement.

Average values of three samples for dry density are explained in **Fig. 10** shows the dry density increase with an increase of LP replacement; the result percentage is (0.83 and, 1) % at (28) days for (10 and 20) % replacement respectively. This is interpreted as filler powder first filling voids around sand grains, up to the optimum, **Mehta 1983, Bédérina, and et al., 2005.** For higher filler amounts of 20% replacement of LP, those voids may be completely filled, Filler powder occupies the place of sand grains and hence it diminishes sand proportion, and consequently the mix density, **Heikal and et al., 2005.**

Fig. 11 shows the dry density decrease with increase of replacement of QP; the result percentage is (0.5 and, -0.4) % at (28) days for (10 and 20) % replacement, respectively.

Fig. 12 shows the dry density decrease with increase of replacement of PP. The results percentage is (0.86 and 0.5) % at (28) days for (10 and 20) % replacement of PP respectively, this is interpreted as PP as light weight and porous material.

5. CONCLUSIONS

The following conclusions can be drawn based on the results of each test:-

1- The manufacture of blended cement using (10 and 20) % replacement of different grinded rocks (limestone, quartzite and porcelinite) confirmed the physical and chemical requirement of the specification in ASTM C595-12.
2- The concrete mixes produced from blended cement (Portland-limestone cement) and (Portland-quartzite cement) showed enhancement in the workability properties while blended cement (Portland-porcelinite cement) diminished the workability properties.

3- The mechanical properties using Portland –limestone cement (10and 20) % replacement of cement compared to reference mix for compressive strength with percentage increases is (20, 11 and 5) % at (7, 28 and, 90) days respectively for 10% replacement and decreases percentage is (-3, -5 and -11) % at (7, 28 and, 90) days respectively for 20% replacement.
4- The mechanical properties using Portland –quartzite cement (10and 20) % replacement of cement were compared to reference mix for compressive strength with percentage increase is (2, 12 and 13) % for (7, 28 and, 90) days respectively for 10% replacement and percentage decrease is (-5.9,-4 and, -5.4) % at (7, 28 and 90) days respectively for 20% replacement.
5- The mechanical properties using Portland –porcelinite cement (10 and 20) % replacement of cement were compared to reference mix for compressive strength with percentage increase is (17.6, 15 and 16.3) % at (7, 28 and 90) days respectively for (10%) replacement and (6, 4 and 6) % at (7, 28 and, 90) days respectively for (20%) replacement.

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Table 1. Chemical composition of cement.

Oxide composition	Abbreviation	Percentage by weight	Limit of Iraqi specification No. 5/1984
Lime	CaO	61	-
Silica	SiO_2	19.84	-
Alumina	Al_2O_3	5.08	-
Iron Oxide	Fe_2O_3	4.8	-
Sulphate	SO_3	2.49	≤ 2.8 % if $C_3A \geq 5\%$
Potash	K_2O	0.1	
Soda	Na_2O	0.3	
Equivalent Na_2 O	Na_2O+0.658K_2O	0.36	$\leq 0.6\%$
Magnesia	MgO	2.48	≤ 5.0 %
Loss on ignition	L.O.I.	3.8	≤ 4.0 %
Insoluble residue	I.R.	0.40	≤ 1.5 %
Main Compounds (Bogue′s equations)			
Tri calcium Silicate	C_3S	49.45	-
Di calcium Silicate	C_2S	19.57	-
Tri calcium Aluminate	C_3A	5.34	-
Tetra calcium Aluminate – Ferrite	C_4AF	14.61	-

*chemical tests of cement were made at environmental Laboratory in University of Baghdad

Table 2. Physical properties of cements.

Physical properties	Test results	Limits of Iraqi specification No. 5/1984
Specific surface area (Blaine method) (m2/ kg)	300*	≥ 230
Soundness by Autoclave Method (%)	0.02*	Not more than 0.8
Setting time (Vicat′s method) Initial setting (hrs. : min) Final setting (hrs. : min)	 1 : 40 4: 40	≥ 45 min ≤ 10 hrs.
Compressive strength (MPa) 3 days 7 days	 21 27	 ≥ 15 ≥ 23

* Tests of cement were made at research building center /Ministry of Constructions and Housing
Other tests are carrying out in material Lab. /Civ. Eng. Dep. /University of Baghdad

Table 3. Physicals properties and sulfate content of fine aggregate.

Sieve size (mm)	% passing by weight	Iraqi specifications No.45/1984 (Zone 2)
10	100	100
4.75	94	90-100
2.36	80	75-100
1.18	60	55-90
0.6	44	35-59
0.3	18	8-30
0.15	4	0-10
Material fine than 0.075 mm	2.6	Max. 5
Fineness modulus = 3.0		
Sulfate content (%)*	0.11	Max. 0.5
Specific gravity	2.65	-
Absorption (%)	1.01	-
Moisture Content (%)	6.1	-

* The test was carried out in Building Research Center/ ministry of construction and Housing
Other of tests were carried out in material Lab. /Civ. Eng. Dep. /University of Baghdad

Table 4. Physical properties and sulfate content of coarse aggregate.

Sieve size (mm)	**% passing by weight**	**Iraqi specification No. 45/1984 (5-14)mm**
20	100	100
14	91	90-100
10	72	50-85
5	9	0-10
Sulfate content %	*0.01	Max. 0.1
Specific gravity	2.64	-
Absorption %	1	-
Moisture Content %	1.6	-

* The test was carried out in Building Research Center/ ministry of construction and Housing
Other of tests were carried out in material Lab. /Civ. Eng. Dep. /University of Baghdad

Table 5. Typical properties of hyperplast PC260 .

Technical properties @ 250C	
Color:	Light yellow liquid
Freezing point: ≈	-7°C
Specific gravity:	1.1 ± 0.02
Air entrainment:	Typically less than 2% additional air is entrained above control mix at normal

Table 6. Chemical composition for limestone powder*.

Oxide		**% Content**
Loss on ignition	L.O.I	42.52
Silicon oxides	SiO_2	2.38
Aluminum oxides	Al_2O_3	0.55
Ferric oxides	Fe_2O_3	0.22
Calcium oxides	CaO	51.67
Magnesium oxides	MgO	2.09
Sulphur trioxides	SO_3	0.35

* The test was done in laboratories of state company of Geological Survey.

Table 7. Chemical composition for quartzite powder*.

Oxide		% Content	ASTM C 618-12
Loss on ignition	L.O.I	0.55	Max.10 %
Silicon oxides	SiO_2	98.11	Sum. SiO_2+ Al_2O_3+ Fe_2O_3 not less than 70%
Aluminum oxides	Al_2O_3	0.23	
Ferric oxides	Fe_2O_3	0.3	
Calcium oxides	CaO	0.66	/
Magnesium oxides	MgO	Less than 0.02	/
Sulphur trioxides	SO_3	0.02	Not more than 4%

*The test was done in state company of Geological Survey laboratories.

Table 8. Chemical composition for porcelinite powder*.

Oxide		% Content	ASTM C 618-12
Loss on Ignition	L.O.I	10	Max.10 %
Silicon oxides	SiO_2	67.1	Sum. SiO_2+ Al_2O_3+ Fe_2O_3 not less than 70%
Aluminum oxides	Al_2O_3	4.18	
Ferric oxides	Fe_2O_3	1.24	
Calcium oxides	CaO	11.51	/
Magnesium oxides	MgO	3.39	/
Sulphur trioxides	SO_3	0.03	Not more than 4%

*The test was done in state company of Geological Survey laboratories.

Table 9. Details of the mixes used throughout this investigation.

Symbol of mixes	CEMENT (kg/m^3)	Limestone Powder (kg/m^3)	Quartzite Powder (kg/m^3)	Porcelanite Powder (kg/m^3)	Coarse Aggregate (kg/m^3)	Fine Aggregate (kg/m^3)	Water (ml/m^3)	PC 260 L/100 kg cement.
M ref	451	/	/	/	943	738	119	0.5
ML10	405.9	45.1	/	/	943	738	119	0.5
ML20	360.8	90.2	/	/	943	738	119	0.53
MQ10	405.9	/	45.1	/	943	738	119	0.5
MQ20	360.8	/	90.2	/	943	738	119	0.55
MP10	405.9	/	/	45.1	943	738	119	0.79
MP20	360.8	/	/	90.2	943	738	119	0.97

Table 10. Chemical analysis of Portland-limestone cement.

Requirements	*C (Cement)	**L Limestone Powder	*ML10	*ML20	ASTM C595-12 Type IL
CaO %	61	51.67	60.4	59.1	/
SiO_2 %	19.84	2.38	18.16	17.9	/
Al_2O_3 %	5.08	0.55	4.66	4.2	/
Fe_2O_3 %	4.8	0.22	4.24	3.84	/
MgO %	2.48	2.09	2.45	2.39	/
SO_3 %	2.49	0.35	2.3	2.0	Max. 3
L.O.I %	3.8	42.52	7.4	8.7	Max. 10

*chemical tests of cement were done at enviromentinal Laboratory in University of Baghdad
**The test was done in state Company of Geological Survey Laboratories.

Table 11. Chemical analysis of Portland-quartzite cement.

Requirements	*C (Cement)	**Q Quartzite powder	*MQ10	*MQ20	ASTM C595-12 Type IP
CaO %	61	0.66	57.06	52.11	/
SiO_2 %	19.84	98.11	25.7	33.2	/
Al_2O_3 %	5.08	0.23	4.7	4.27	/
Fe_2O_3 %	4.8	0.3	4.16	3.42	/
MgO %	2.48	0.02	2.33	2.1	Max. 6
SO_3 %	2.49	0.02	2.19	1.9	Max. 4
L.O.I %	3.8	0.55	3.4	2.67	Max. 5

*Chemical tests of cement were done at enviromentinal Laboratory in University of Baghdad
**The test was done in state Company of Geological Survey Laboratories

Table 12. Chemical analysis of Portland -porcelinite cement.

Requirements	*C (Cement)	**P Porcelinite powder	*MP10	*MP20	ASTM C595-12 Type IP
CaO %	61	11.51	56.8	53.18	/
SiO_2 %	19.84	67.1	25.1	28.2	/
Al_2O_3 %	5.08	4.18	5.01	4.9	/
Fe_2O_3 %	4.8	1.24	4.5	4.2	/
MgO %	2.48	3.39	2.61	2.75	Max. 6
SO_3 %	2.49	0.03	1.9	1.7	Max. 4
L.O.I %	3.8	10	4	4.8	Max. 5

*chemical tests of cement were done at enviromentinal Laboratory in University of Baghdad
**The test was done in state Company of Geological Survey Laboratories

Table 13. Physical properties of blended cement (Portland-limestone cement)*.

Requirements	**C (Cement)**	**CL10**	**CL20**	**ASTM C595-12 Type IL**
Consistency %	28	27	26	-
Initial setting time (min.)	125	115	100	Min 45 mints
Final setting time (hrs.)	4:30	5:09	5:30	Max 7 hrs.
*Fineness (cm^2/g.)	3000	3100	3200	-
Comp. at 3 days (MPa)	25	18	17	13
Comp. at 7days (MPa)	30.9	22	20	20
Comp. at28 days (MPa)	35	30	28	25

*the tests were done at research buildings center /Ministry of housing
**Physical tests of cement were done at material Laboratory in University of Baghdad

Table 14. Physical properties of blended cement (Portland-quartzite cement).

Requirements	**C (Cement)**	**CQ10**	**CQ20**	**ASTM C595-12 type IP**
Consistency %	28	27	26	/
Initial setting time (min.)	125	162	170	Min 45 mints
Final setting time (hrs.)	4:30	5:19	5:30	Max 7 hrs.
*Fineness (cm^2/g.)	3000	2950	2900	/
Comp. at 3 days (MPa)	25	18	17	Min 13
Comp. at 7days (MPa)	30.9	25	23	Min 20
Comp. at28 days (MPa)	35	31	29	Min 25

*the tests were made at research buildings center /Ministry of housing
Other tests of cement were done at material Laboratory in University of Baghdad

Table 15. Physical properties of blended cement (Portland-porcelinite cement).

Requirements	**C (Cement)**	**CP10**	**CP20**	**ASTM C595-12 type IP**
Consistency %	28	34	41	/
Initial setting time (min.)	125	170	190	Min 45 mints
Final setting time (hrs.)	4:30	5:20	5:45	Max 7 hrs.
*Fineness (cm^2/g.)	3000	3370	3510	/
Comp. at 3 days (MPa)	25	24	22	Min 13
Comp. at 7days (MPa)	30.9	29	27	Min 20
Comp. at28 days (MPa)	35	34	32	Min 25

*the tests were done at research buildings center /Ministry of Housing
Other tests of cement were done at material Laboratory in University of Baghdad

Table 16. Mechanical properties of concrete (Portland-limestone cement.)

Symbol of mix	**Compressive strength (MPa)**		
	7-days	**28-days**	**90-days**
M ref.	34	45	55
ML10-1	41	50	58
M20-1	33	43	49
Symbol of mix	Splitting strength (MPa)		
	7-days	28-days	90-days
M ref.	2.33	3.0	3.5
ML10-1	3.04	3.5	3.74
M20-1	2.35	2.91	3.3
Symbol of mix	Flexural strength (MPa)		
	7-days	28-days	90-days
M ref.	3.81	4.39	4.7
ML10-1	4.36	4.61	4.9
M20-1	3.9	4.2	4.5
Symbol of mix	Dry density(gm./cm^3)		
	28-days		
M ref.	2.431		
ML10-1	2.451		
M20-1	2.464		

Table 17. Mechanical properties of concrete (Portland-quartzite cement).

Symbol of mix	**Compressive strength (MPa)**		
	7-days	**28-days**	**90-days**
M ref.	34	45	55
MQ10-1	35	48	62
MQ20-1	32	41	52
Symbol of mix	Splitting strength (MPa)		
	7-days	28-days	90-days
M ref.	2.33	3.0	3.5
MQ10-1	2.51	3.56	3.77
MQ20-1	2.3	2.9	3.35
Symbol of mix	Flexural strength (MPa)		
	7-days	28-days	90-days
M ref.	3.81	4.39	4.7
MQ10-1	4.01	4.64	5.06
MQ20-1	3.77	4.29	4.52
Symbol of mix	Dry density(gm./cm^3)		
	28-days		
M ref.	2.431		
MQ10-1	2.443		
MQ20-1	2.421		

Table 18. Mechanical properties of concrete (Portland-porcelinite cement).

Symbol of mix	**Compressive strength (MPa)**		
	7-days	**28-days**	**90-days**
M ref.	34	45	55
MP10-1	40	52	64
MP20-1	36	47	58
Symbol of mix	Splitting strength (MPa)		
	7-days	28-days	90-days
M ref.	2.33	3.0	3.5
MP10-1	2.65	3.35	3.84
MP20-1	2.34	3.1	3.63
Symbol of mix	Flexural strength (MPa)		
	7-days	28-days	90-days
M ref.	3.81	4.39	4.7
MP10-1	4.32	4.63	5.1
MP20-1	4.04	4.53	4.8
Symbol of mix	Dry density(gm./cm3)		
	28-days		
M ref.	2.431		
MP10-1	2.452		
MP20-1	2.443		

NOMENCLATURE

Notation	**Description**
CL10	Blended cement with replacement 10% of limestone powder
CL20	Blended cement with replacement 20% of limestone powder
CQ10	Blended cement with replacement 10% of quartzite powder
CQ20	Blended cement with replacement 20% of quartzite powder
CP10	Blended cement with replacement 10% of porcelinite powder
CP20	Blended cement with replacement 20% of porcelinite powder
LP	Limestone powder
QP	Quartzite powder
PP	Porcelinite powder
PLC	Portland-limestone cement
PQC	Portland-quartzite cement
PPC	Portland-porcelinite cement

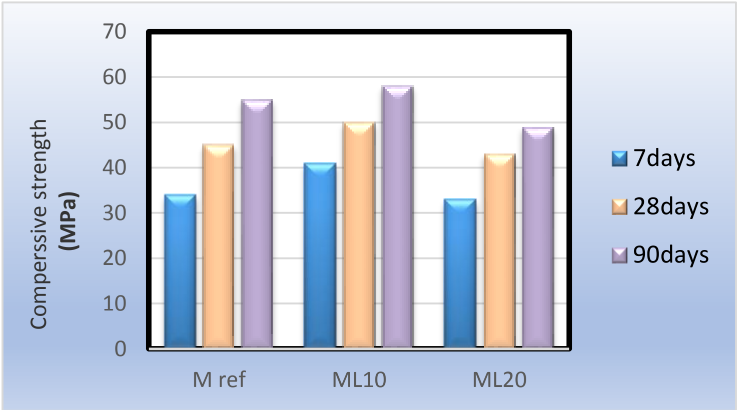

Figure 1. Compressive strength of concrete using Portland-limestone cement.

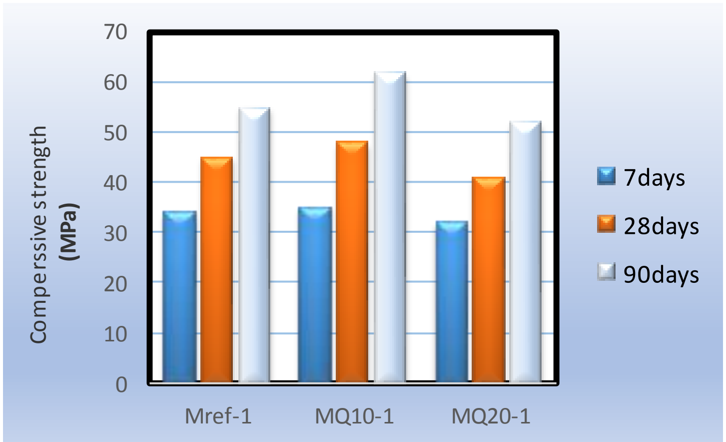

Figure 2. Compressive strength of concrete (Portland-quartzite cement).

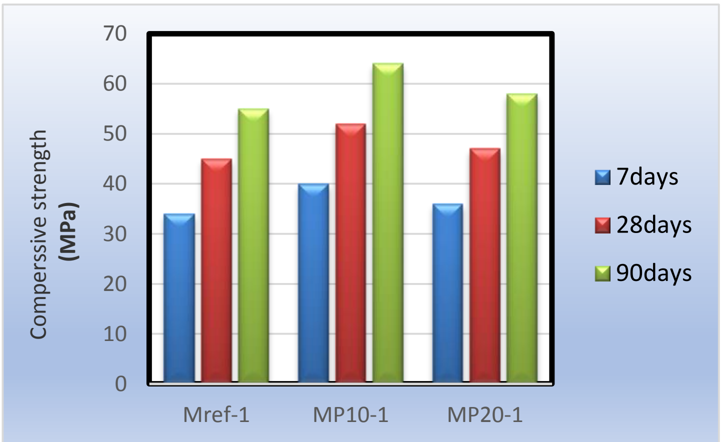

Figure 3. Compressive strength of concrete Portland-porcelinite cement.

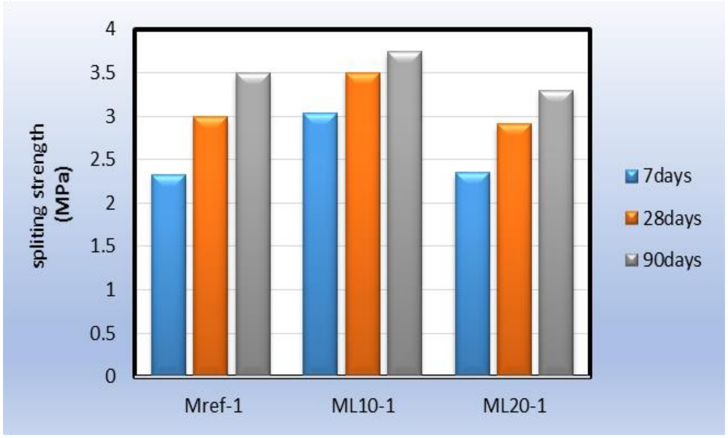

Figure 4. Splitting strength of concrete Portland-limestone cement.

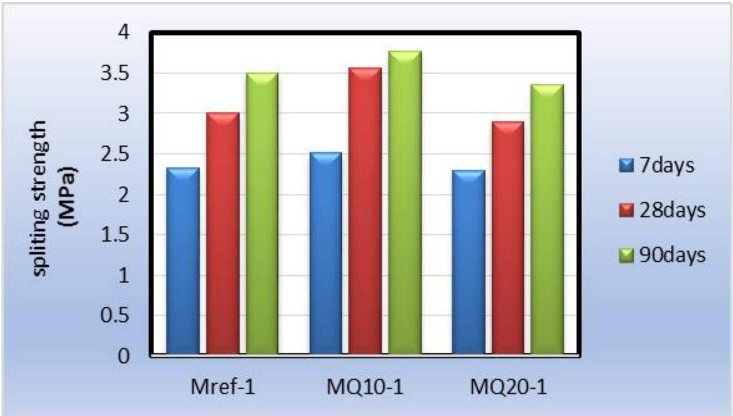

Figure 5. Splitting strength concrete of Portland-quartzite cement.

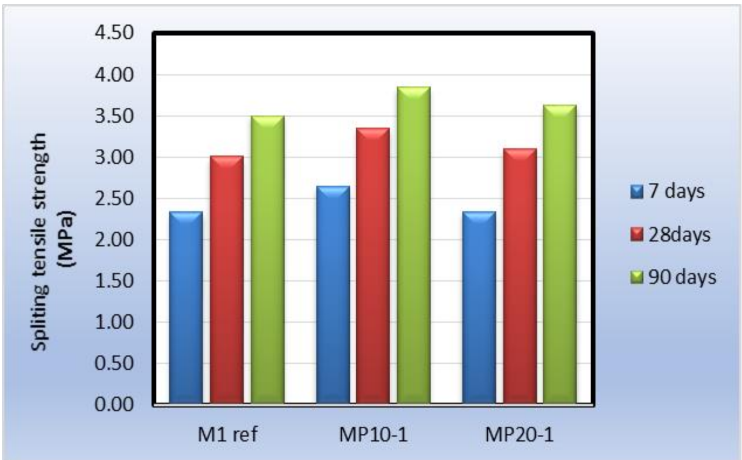

Figure 6. Splitting strength concrete of Portland-porcelinite cement.

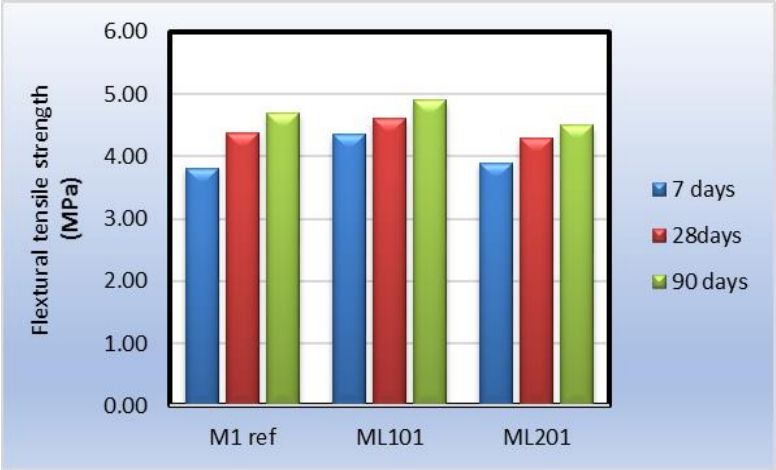

Figure 7. Flexural tensile strength of concrete (Portland-limestone cement.)

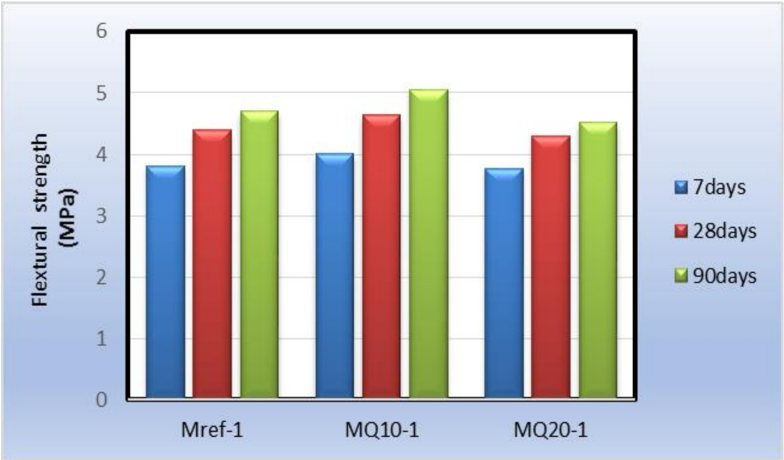

Figure 8. Flexural tensile strength of concrete Portland-quartzite cement.

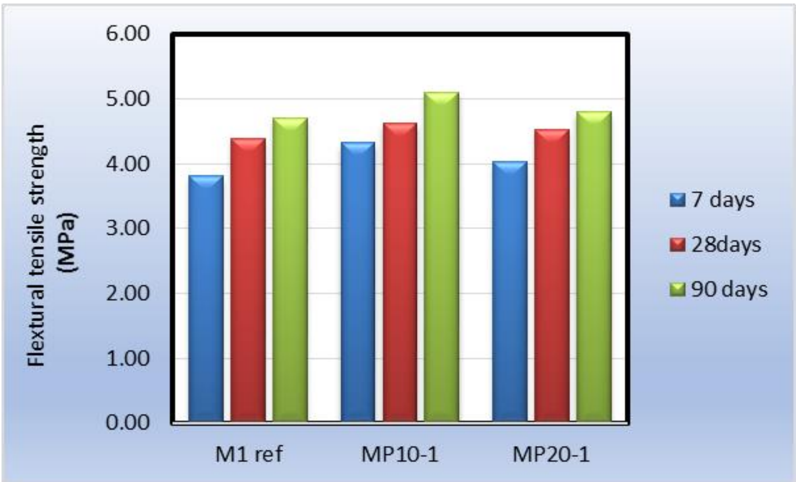

Figure 9. Flexural tensile strength of concrete Portland-porcelinite cement.

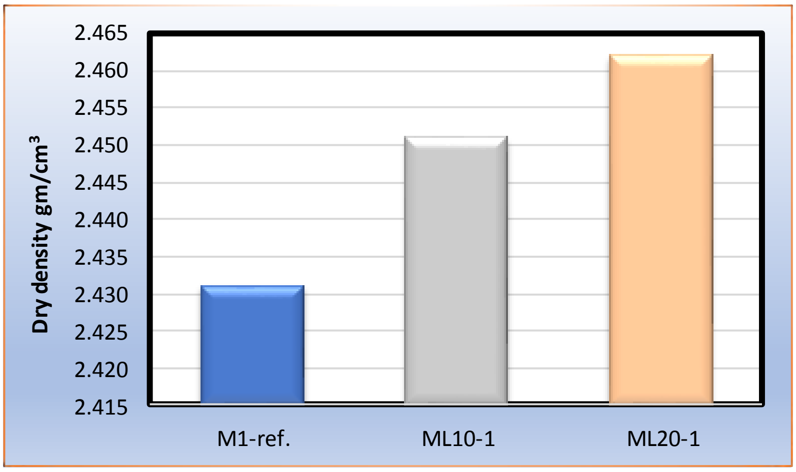

Figure 10. Dry density of concrete Using Portland-limestone cement.

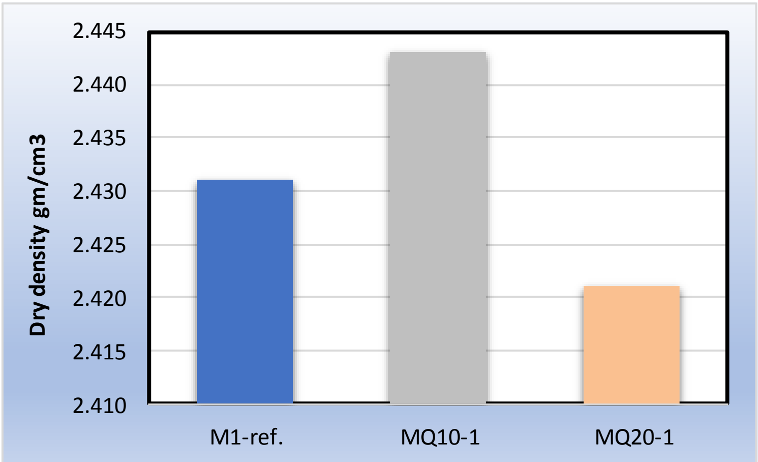

Figure 11. Dry density of concrete Portland-quartzite cement.

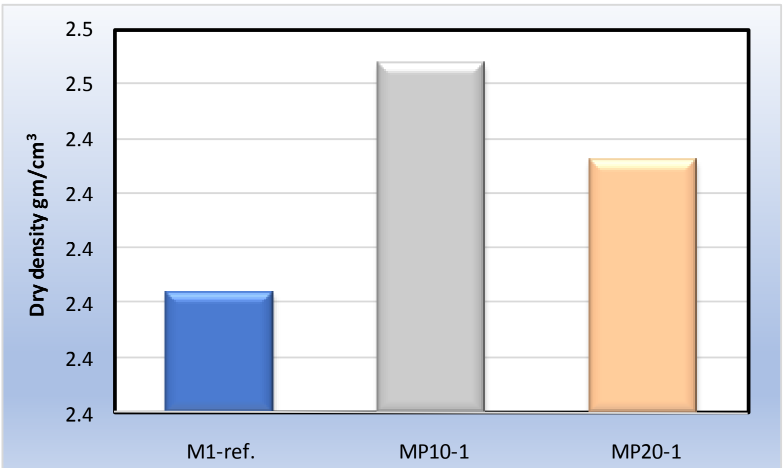

Figure 12. Dry density of concrete Portland-Porcelinite cement.

The Catalytic Activity of Modified Zeolite Lanthanum on the Catalytic Cracking of Al-Duara Atmospheric Distillation Residue.

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ABSTRACT

Atmospheric residue fluid catalytic cracking was selected as a probe reaction to test the catalytic performance of modified NaY zeolites and prepared NaY zeolites. Modified NaY zeolites have been synthesized by simple ion exchange methods. Three samples of modified zeolite Y have been obtained by replacing the sodium ions in the original sample with lanthanum and the weight percent added are 0.28, 0.53, and 1.02 respectively. The effects of addition of lanthanum to zeolite Y in different weight percent on the cracking catalysts were investigated using an experimental laboratory plant scale of fluidized bed reactor.

The experiments have been performed with weight hourly space velocity (WHSV) range of 6 to 24 h^{-1}, and the range of temperature from 450 to 510 ^{o}C.

The activity of the catalyst with 1.02 wt% lanthanum has been shown to be much greater than that of the sample parent NaY. Also it was observed that the addition of the lanthanum causes an increase in the thermal stability of the zeolite.

Key words: lanthanum exchange NaY, rare earth elements, atmospheric residue fluid catalytic cracking,

تأثيرالفعليه الحفازيه للزيولايت المطور باللنثانيوم على التكسير الحفازي لمتبقي التقطير الجوي لمصفى الدوره

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الخلاصة:

تم اختيار تفاعل التكسير الحفازي المائع لمتبقي التقطير الجوي كمجس لاختبار الفعالية الحفازية للزيولايت المحسن والمحضر نوع NaY . الزيولايت المطور تم تصنيعه بطريقة التبادل الايوني البسيط .ثلاثة نماذج من الزيولايت المطورتم الحصول عليها عن طريق استبدال ايون الصوديوم في النموذج الاصلي باللنثانيوم وبالنسب الوزنية المؤيه التالية, 0.28, 0.53 , 1.02 .

تأثير اضافة اللنثانيوم للزيولايت وبنسب وزنية مختلفة على الفعالية التكسيرية تم بحثه باستخدام منظومه مختبريه تجريبيه لمفاعل الطبقة المميعة . التجارب المختبرية اجريت عند سرع وزنية فراغيه بين 6 الى 24ساعه$^{-1}$ وبدرجة حرارة من 450 الى 510 درجة مئوية.

الفعالية الحفازية للعامل المساعد المحتوي على نسبه وزنية من اللنثانيوم بمقدار 1.02 كانت اكبر بكثير من الفعالية الحفازية للعامل المساعد الاصلي . وكذلك تم ملاحظة ان اضافة اللنثانيوم ادت الى زيادة الثباتية الحرارية للزيولايت .

الكلمات الرئيسية: استبدال اللنثانيوم بالزيولات NaY, عناصر الارض النادرة, التكسير الحفازي لمتبقي التقطير الجوي.

1. INTRODUCTION

During the atmospheric distillation of crude oil, as employed on a large scale in the refineries for the production of light hydrocarbon oil distillates, a residual oil is obtained as a byproduct. **Jakob and Peter, 1977.** In the atmospheric distillation of crude oil about half of the crude oil is left behind as distillation residue, it will be clear that there is a pressing need for a process which offers the possibility of converting in an economemically justifiable way hydrocarbon oil residue obtained by atmospheric distillation into light , i.e., low boiling hydrocarbon oil distillate such as gasoline , **Pappal, et al.,2003** . Heavy crude oil and residue have many similarities in composition such as low H/C ratio (1.2–1.4), high metals and sulfur contents. Hence, one of the most important parameters is to convert residue into lighter products by increasing the H/C ratio**, Bartholomew, et al., 1994.**

The demand for high value petroleum products such as middle distillate, gasoline and lube oil is increasing, while the demand for low value products such as fuel oil and residua based products is decreasing. Therefore, maximizing of liquid products yield from various processes and valorization residues is of immediate attention to refiners. At the same time, environmental concerns have increased, resulting in more rigorous specifications for petroleum products, including fuel oils. These trends have emphasized the importance of processes that convert the heavier oil fractions into lighter and more valuable clean products, **Gray,1994.**

Fluid catalytic cracking (FCC) is one of the most important processes in the oil refinery industry. It converts, or cracks, low value heavy ends of the crude oil into a variety of higher-value, light products.The catalytic cracking operation is preferably carried out at a temperature from 400 to 550 ^oC, a pressure 1 to 10 bar ,and weight hour space velocity (WHSV) of from 3 to 200 h^{-1} , **Chen, and Cao,2005** . This process produces not only gasoline and diesel fuel but also raw material, such as light olefins for a number of petrochemical processes , the later application is gaining increasing importance, **Biswas,and Maxwell,1990.**

The FCC catalyst is a key point in the optimization of FCC unit. Basically , the FCC catalysts could be divided into three main categories based on the refineries objective i) maximization of voluble product ,ii) improving of gasoline quality and, iii)minimization of residue, and in order to achieve those goals ,the FCC catalyst has two components ,the zeolite and the matrix. Besides these catalyst it can also have other functional ingredients and or /additives for specified function like enhancing gasoline octane , upgrading the conversion of residue feedstock ,enhancing the resistance to metallic poisons ,promoting the CO combustion ,reduction the NOx and SOx emission , among there, **Costa et al.,2004**.

In the past years rare earth exchanged zeolites have attracted much attention as a stable solid acid catalyst because of their high thermal stability, **Magee, et al.,2002** . Modification of zeolites by ion exchange of exchangeable cations provides a useful means of tailoring their properties to particular application. Thus, introduction of rare earth element, in particular into zeolite Y has been an important means of enhancing the performance of catalyst, for example, FCC catalyst and they are known to increase the activity of zeolites in a variety of reactions due to increased acid strength. For example, LaNa–Y plays an important role in the preparation of catalysts for FCC, one of the most widely applied petroleum refining processes that make use of zeolite as catalyst , **Bejoy, et al.,2006**

Rare earth components, such as lanthanum and cerium, were used to replace sodium in the crystal. The rare earth elements, being trivalent, simply form "bridges" between two to three acid sites in the zeolite framework. Bridging protects acid sites from being ejected and stabilizes the zeolite structure. Rare earth exchange adds to the zeolite activity and thermal and hydrothermal stability. Rare earth serves as a "bridge" to stabilize aluminum atoms in the zeolite structure. They prevent the aluminum atoms from separating from the zeolite lattice when the catalyst is exposed to high temperature steam in the regenerator. the NaY zeolite was mostly ion exchanged with rare earth components. Rare earth components, such as lanthanum and cerium, were used to replace sodium in the crystal. The rare earth elements, being trivalent, simply form "bridges" between two to three acid sites in the zeolite framework. Bridging protects acid sites from being ejected and stabilizes the zeolite structure, **Sadeghbeigi, 2000**.

The modification of faujasite Y zcolites to improve catalyst selectivity and stability has become an integral part of the catalyst manufacturing process. The modification procedure can be accomplished in several ways. Exchanging the native sodium ions for rare-earth ions and protons was shown to increase the hydrothermal stability of the zeolite along with increasing its activity in catalytic cracking. In addition, hydrothermal stability can also be improved by lowering the aluminum content of the zeolite framework, a process called dealumination, **Nery,et al.,1997**.

The aim of present study is to modify the zeolite Na Y prepared from Iraqi kaolin with various weight percents lanthanum exchange. Also the activity of the resulting catalyst were evaluated by using experimental laboratory plant scale fluidized bed reactor by using atmospheric distillation residue as a feed , and the influence of the addition of lanthanum on the thermal stability of the NaY was investigated.

2. EXPERIMENTAL

2.1 Feedstock

Atmospheric residue with boiling range 278^{o}C to 450^{o}C was supplied from atmospheric distillation unit of Al-Duara refinery as a raw material for the catalytic performance of the zeolites synthesized, and its detailed properties are listed in **Table 1**.

2.2 Catalyst

Parent NaY zeolite were prepared from Iraqi kaolin as follows: kaolin was fused by the addition of sodium hydroxide (kaolin/NaOH=1/1.5 by wt.) at 850˚C for three hours. A typical procedure performed as follows. Ten grams of fused kaolin powder and 12.67 grams of sodium silicate were dispersed in 150 ml of deionized water under constant stirring for 1 hour. The resultant slurry which has pH 13.6 was subjected to aging at 50 ^{o}C for 24 hr in a programmable electrical furnace, then the gel slurry was subjected to hydrothermal crystallization at 100 ^{o}C for 48 hr in the same furnace.
Crystallization was carried out at about 100˚C. Subsequently the resultant precipitate was separated from the mother liquor by filtration. The crystalline mass is then washed with deionized water until a pH 11.5 and dried at 100˚C for 16 hours. The dried powder was activated by calcination in a programmable electrical furnace at 500 ^{o}C for 1hr.

2.3 Modified Zeolite Procedure.

Lanthanum exchanged was obtained by contacting Na-Y with 0.5M lanthanum nitrate solution (0.025 moles of lanthanum nitrate / g of zeolite) at 80 ^{o}C for 24 hours ,then filtrate, and washed to obtained 0.28wt% La Na-Y . This exchange cycle was repeated two times with fresh lanthanum nitrate to obtained 0.53wt% La.Na-Y. Na-Y was contacted with fresh 0.5M lanthanum nitrate solution four times to obtained 1.02wt% La Na-Y. All samples were calcined after each exchange at temperature 150 to 500 ^{o}C with heating rate 12 ^{o}C /minute and at 500 ^{o}C for 5 hours. The degree of Lanthanum exchange in the zeolite was determined by the analysis of each zeolite sample to determine the sodium weight percent in the starting and those remaining after the Lanthanum exchange. The sodium weight percent loss converted to equivalent lanthanum.

2.4 Apparatus

Cracking experiments were carried out in the experimental laboratory plant scale of fluidized bed reactor system, shown in **Fig 1**. This unit was found in the laboratories of Chemical Engineering Department, Baghdad University, It is comprised of five sections: atmospheric residue and water input mechanisms, reaction zone, temperature control system, products separation, and collection system.

A specified flow rate of water was pumped into pre-heater; the water was converted to steam by heating system. Steam was used to remove the air from reactor. After that atmospheric residuewas pumped and heated in a pre-heater, and then entered into the reactor, where catalytic cracking reactions took place. The reaction products were cooled and separated into liquid products and gas product. Cracking liquid product was transferd to distillation unit for separation catalytic cracking gasoline from heavy stock. A sample of gaseous product was collected in a gas bag and then analyzed by gas chromatography to determine the chemical composition of the gaseous product. A sample of catalytic cracking gasoline was analyzed by gas chromatography to determine the composition of catalytic cracking gasoline.

Coke content on catalysts was measured by as follws method below. A sample of catalyst from reactor was weighed and dried by electrical programmable furnace at 100 ^oC for 16 hr. The dry sample was weighed and returned to electrical programmable furnace to restore catalyst activity by burning off coke deposition on spent catalyst at 650 ^oC for one hour. The **c**alcined sample after burring coke was weighed. The differences between weight 1 and weight 2 represents moisture and difference between weight 2 and weight 3 represents delta coke. Delta coke is defined as the difference between coke on the spent catalyst after stripping and on the regenerated catalyst. The activity of the catalyst in catalytic cracking was determined by conversion which is defined as the weight percent (wt%)of the feed that is converted into coke, gas and gasoline. The gasoline fraction is that part of the product with a boiling point range between ambient temperature and 220 ^oC.

2.5 **Operating Conditions**

The cracking experiments of atmospheric residue were carried out over parent NaY zeolite and modified zeolite catalysts sampled in the experimental laboratory plant scale of fluidized bed reactor system. Operating conditions were catalyst weight hourly space velocity was 6 , 12 ,18,and 24 h^{-1} , reaction temperature was 450 ,470,490,and 510 ^oC. The effect of regeneration number (it refers to restoring catalyst activity after each complete reaction) on the catalyst activity of the parent NaY zeolite and modified zeolite(1.02wt%) was carried out at 510 ^oC, WHSV= $6h^{-1}$, and atmospheric pressure.

2.6 Analytical Apparatus

The digital flame analyzer by flame photometer Gallen Kamp in The State Company for Geological Survey and Mining was used to determine the sodium content the parent catalyst and modified catalyst after lanthanum ion exchange.

The gas chromatograph Agilent Technologies 6890N equipped with flame ionization detector (FID) was used to determine the composition of the gases produced from experiment. The equation of state for ideal gases converts the volume data to mass.

The composition of cracked gasoline measured by using simulated distillation gas-chromatography Agilent Technologies 6890N .

Chemical analysis according UOP Method 172- 59 was used to measure the concentration of the hydrogen sulfide.

Gas Chromatograph 373 GASUKURD KDGYO was used to determine the concentration hydrogen gas in the gases mixture produced.

All above device was located in Al- Duara Refinery.

3. RESULT & DISCUSSION

3.1 The Effect of Lanthanum Exchange on the Atmospheric Residue Conversion.

The effect of lanthanum exchange and WHSV on the atmospheric residue conversion were studied at different reaction temperatures.**Fig. 2** and **table 2** show the dependence of conversion upon lanthanum weight percent loading and catalyst hour space velocity when cracking was over zeolite catalysts containing different weight percent lanthanum.

At a given catalyst hour space velocity with constant temperature, the zeolite catalysts containing more lanthanum weight percent loading show greater conversion of atmospheric residue and gives more products (gasoline , gases, and coke) than parent Na-Y zeolite, **Fig .2 and Table 2**.This means that the lanthanum indeed contribute to the conversion, which may be explained as a follows :

The effect of sodium ions on the activity of Bronsted type of zeolites in acid reactions has been recognized very early especially in the case of faujasite. It was proposed that these residual cations have a poisoning effect on the acidity i.e., a particular Na^+ ion present within the decationated zeolite has a neutralizing effect over a large number of the existing protons. Low acid amount of Na-Y zeolite might reduce catalyst activity, which is the crucial step in the formation of the desired product.

The total acid amount increased after introducing rare elements (RE) to zeolite sample. There were two possible reasons for the result. Firstly, the hydrothermal stability had been strengthened on account of the addition of the rare elements (RE) cation, which coordinated with the oxygen atoms in the pore channel. Therefore, the dealumination of the framework was restrained during the hydrothermal disposal. So the loss of acidic amounts would reduce. Secondly, silicon hydroxyl and aluminum hydroxyl in the zeolite framework were polarized by the polarization and induction of the RE cation. So the density of the electron cloud in the zeolite framework increased, stronger acidity of the acidic center appeared. And because of the existence of an empty f orbit RE^{3+}**,** the amount of Lewis acid would also increase, **Xiaoning, et al,2007**. The zeolite activity comes from these acid sites, **Hayward** and **Winkler ,1990**. From the above the increasing lanthanum exchanged decreases Na^+ ion in the zeolites and gives more conversion of atmospheric distillation residue.

3.2 The Effect of WHSV on the Atmospheric Residue Conversion.

At a constant temperature with a given lanthanum weight percent loading **Fig. 3** and **table 2** shows that the atmospheric residue conversion increases with decreasing of WHSV. This means that the conversion of reduced crude is a function of reaction time for all catalysts, the increasing of the contact time of the feed molecules with the catalyst increases the atmospheric residue conversion in direct proportion to the amount of the catalyst and inversely proportional to the feed flow rate.

3.3 The Effect of Temperature on the Atmospheric Residue Conversion.

At a given catalyst hour space velocity with constant lanthanum weight percent loading **Fig. 2** and **table 2** show that the atmospheric residue conversion increases with increasing the temperature. This may be attributed to the increase of temperature which accelerates intermolecular motions, assists the transformations of the reactants into new compounds and thus enhances the rate of chemical reaction. It is thermal activation which in the present case acts in conjunction with catalytic activation as mentioned by **Decroocq, 1984**. The higher temperature provided advantages in terms of a better feed vaporization which reduced coke formation by condensation reactions of poorly vaporized feed molecules. Both the higher temperature and the resulting lower coke formation enhanced the diffusion of feed molecules. .

3.4 The Effect of Lanthanum Exchange on the Gasoline Yield.

Fig. 4 and **Table 2** show that the gasoline yields is a function of conversion for the different catalysts when cracking atmospheric residue , when the catalysts contain more lanthanum weight percent loading it gives a higher gasoline yield .Also increasing temperatures and decreasing weight hours space velocity shows graterer gasoline yield obtained . **Table 3** shows chemical composition of cracked gasoline for parent NaY and 1.02 LaNa. This table shows that olefins and naphthenes decreases while paraffins and aromatics increases for 1.02 LaNaY with respect to the parent NaY,due to the rare earth exchanged zeolite that increases hydrogen transfer reactions, hydrogen transfer is a bimolecular reaction in which one reactant is an olefin. Two examples are the reaction of two olefins and the reaction of an olefin and a naphthene. In the reaction of two olefins, both olefins must be adsorbed on active sites that are close together. One of these olefins becomes a paraffin and the other becomes a cyclo-olefin as hydrogen is moved from one to the other. Cyclo-olefin is now hydrogen transferred with another olefin to yield a paraffin and a cyclodi-olefin. Cyclodi-olefin will then rearrange to form an aromatic. The chain ends because aromatics are extremely stable. Hydrogen transfer of olefins converts them to paraffin's and aromatics. In the reaction of naphthenes with olefins, naphthenic compounds are hydrogen donors. They can react with olefins to produce paraffin's and aromatics **Sadeghbeigi,2000**.

On comparing between **Figs. 2 and 4** for the catalyst 1.02 LaNaYat 6 WHSV the reduced crude conversion increases with increasing of temperature at constant WHSV within the limit of study, while, the gasoline yield increases with conversion, with a tendency to reach a maximum (at 490 ^{o}C) and after that the gasoline yield remain approximately constant. This is due to the fact that gasoline yield undergoes the secondary cracking(over cracking) to gaseous products and coke.

From **Table 2** the gases yields and coke yield, as a function of conversion when cracking atmospheric residue for the different catalysts are shown. As seen, the total gases and coke yields depend on the lanthanum weight percent loading, temperatures and weight hours space velocity. The composition of the gas phases, estimated at a conversion of 79.3 wt %(as a sample), is shown in **Table 4**.

3.5 The Effect of Lanthanum Exchange on the Thermal Stability.

Fig. 5 shows the relation between the conversion of atmospheric residue and the number of regeneration for NaY and 1.02 LaNaY catalysts. From this figure the difference in activity between NaY and 1.02 LaNaY for zero regeneration (fresh catalysts) was about 12wt%. For first regeneration about it was about 34wt%, while for second regeneration it was about 37wt%. This means that the catalyst 1.02 LaNaY decreases the activity less than the catalyst NaY due to the fact that sodium ion decreases the hydrothermal stability of the zeolite. It also reacts with the zeolite acid sites to reduce catalyst activity, **Suchuchchai, 2004**. In the regenerator, sodium is mobile. Sodium ions tend to neutralize the strongest acid sites**, Scherzer,1990.** While RE are commonly regarded as insensitive to hydrothermal processes. They have been used as immobile elements, **Lottermoser ,1992.**

To explain this positive effect of the RE elements on zeolites thermal stability, two aspects may be considered: (i) cation valence, and (ii) formation of RE–O–RE bonds in zeolite cavities. In fact, it is acknowledged that divalent cations have a more pronounced stabilizing effect than monovalent cations, whereas zeolites exchanged with trivalent cations tend to be the more stable ones . Moreover, the enhancement on thermal stability has also been attributed to the existence of RE–O–RE bonds in the interior of sodalite cavities, which form bridges with the zeolite tetrahedra, stabilizing the structure, **Trigueiro,et al.,2002.**

4. CONCLUSION

1- The Na–Y modified with La increased cracking activity. The overall conversions obtained on the preparing cracking catalyst show an increasing the gasoline, gas ,and coke yields with increasing lanthanum weight percent.

2-The secondary cracking of gasoline to gaseous products and coke occur at 6 WHSV and $490^{o}C$

3-Lanthanum exchanged zeolites exhibit far better stability towards reaction conditions and on an average they lost almost 11.9 % of their initial activity in 1.02LaNaY whereas, NaY lost 33.6% activity with same condition (6WHSV,$510^{o}C$) for first regeneration and 22.3% to 1.02LaNaY, 50.2% to NaY respectively for second regeneration .

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Table 1: Properties of atmospheric residue.

Density (20 ^oC ,gm / cm^3)	0.908
Molecular weight	486
Carbon residue(wt%)	4.67
ASTM distillation (^oC)	
IBP	278
10%	291
30%	352
50%	396
70%	417
90%	450

Table 3: A comparison between the chemical compositions of cracked gasoline at 6 WHSV and 490 ^oC.

Chemical Composition of cracked gasoline(vol. %)	NaY (C_5-220^oC)	1.02 LaNaY (C_5-220^oC)
Paraffins	19.4	27.8
Naphthenes	5.7	3.2
Olefins	40.1	32.3
Aromatics	34.8	36.9

Table 4: Chemical analysis of gases at 6 WHSV and 510^oC.

Gases	**Yield(wt%)from the total product**
Hydrogen	0.5375
Hydrogen sulfide	0.7485
Methane	2.4820
Ethane	2.8345
Ethylene	2.0677
Propane	4.3310
Propylene	3.4025
Iso Butane	2.5930
N. Butene	3.4835
N.Butane	3.2690
Iso Pentane	0.4813
N. Pentane	0.1695

Table 2: Cracking experiments results of the atmospheric residue at different lanthanum weight percent loading.

Catalyst type	Reaction temperature	WHSV(h^{-1})	Conversion	Gasoline(wt%)	Gases(wt%)	Coke(wt%)	Heavy oil(wt%)
NaY	510	24	43.2	19.1	15.0	9.1	56.8
	490		40.8	18.3	14.0	8.5	59.2
	470		39.3	18.1	13	8.3	60.7
	450		38.4	17.3	13.2	7.9	61.6
	510	18	50.7	22.5	17.1	11.1	49.3
	490		49.4	22.1	16.3	11	50.6
	470		47.8	21.2	16.1	10.4	52.2
	450		45.6	20.4	15..2	10	54.4
	510	12	58.9	26.2	18.7	14.1	41.1
	490		56.8	25.4	18.1	13.5	42.2
	470		55.4	25.1	17.9	12.4	44.6
	450		52.9	24.1	17.3	11.5	47.1
	510	6	67.2	30.2	21	16	32,8
	490		65.7	29.4	20.1	15.2	34.3
	470		63.1	28.0	19.1	15	36.9
	450		60.2	27.0	19	14.2	39.8
0.28La NaY	510	24	47	21.9	15.1	10	53
	490		44.2	21.1	14	9.1	55.8
	470		42.7	20.0	13.3	8.4	57.3
	450		40.3	19.0	13.1	8.2	59.7
	510	18	54.1	25.2	16.9	13	45.9
	490		52.8	24.8	16.5	12.5	47.2
	470		51.1	23.9	16.2	11	48.9
	450		48.6	23.2	15.3	11.1	51.4
	510	12	61.9	28.2	19.9	13.8	38.1
	490		60.1	27.3	19.1	13.7	39.9
	470		57.8	26.1	18.5	13.2	42.2
	450		56.2	25.3	17.9	13.0	43.8
	510	6	71.1	31.9	23.1	16.1	28.9
	490		68.9	30.8	22.3	15.8	31.1
	470		67.2	30.0	21.9	15.3	32.8
	450		64.5	29.8	20.7	14.0	35.5
0.53La NaY	510	24	51.3	21.2	18.0	11.1	48.7
	490		47.5	20.0	17.3	10.2	52.5
	470		45.1	19.2	16.4	9.5	54.9
	450		43.4	18.6	15.7	9.1	56.6
	510	18	57.8	24.5	20.1	13.2	42.2
	490		56.5	24.1	19.6	12.8	43.5
	470		54.3	23.2	19.0	12.1	45.7
	450		52.6	22.7	18.4	11.5	57.4
	510	12	65.7	28.2	22.4	15.1	34.3
	490		63.4	27.1	21.5	14.8	36.6
	470		61.6	26.4	21.0	14.2	38.4
	450		59.1	25.2	20.3	13.6	40.9
	510	6	74.6	33.2	24.0	17.4	25.4
	490		72.8	32.4	23.5	16.9	27.2
	470		70.9	31.6	23.1	16.2	29.1
	450		67.5	29.4	22.2	15.9	32.5
1.02La NaY	510	24	55.8	26.1	18.4	11.3	44.2
	490		52.2	24..2	17.1	10.9	47.8
	470		50.6	23.7	16.5	10.4	49.4
	450		48.6	22.8	16.1	9.7	51.4
	510	18	62.8	29.3	20.4	13.1	37.2
	490		60.5	28.2	20.0	12.3	39.5
	470		58.7	27.4	19.5	11.8	41.3
	450		57.1	27.0	18.8	11.3	42.9
	510	12	70..4	32.3	23.0	15.1	29.6
	490		67.6	31.2	22..4	14.0	32.4
	470		65.9	30.3	21.9	13.7	34.1
	450		63.0	28.8	21.1	13.1	37.7
	510	6	79.3	34.1	26.4	18.8	20.7
	490		77.6	34.2	25.6	17.9	22.4
	470		74.8	33.5	24.1	17.3	25.2
	450		72.5	32.1	23.2	16.2	27.5

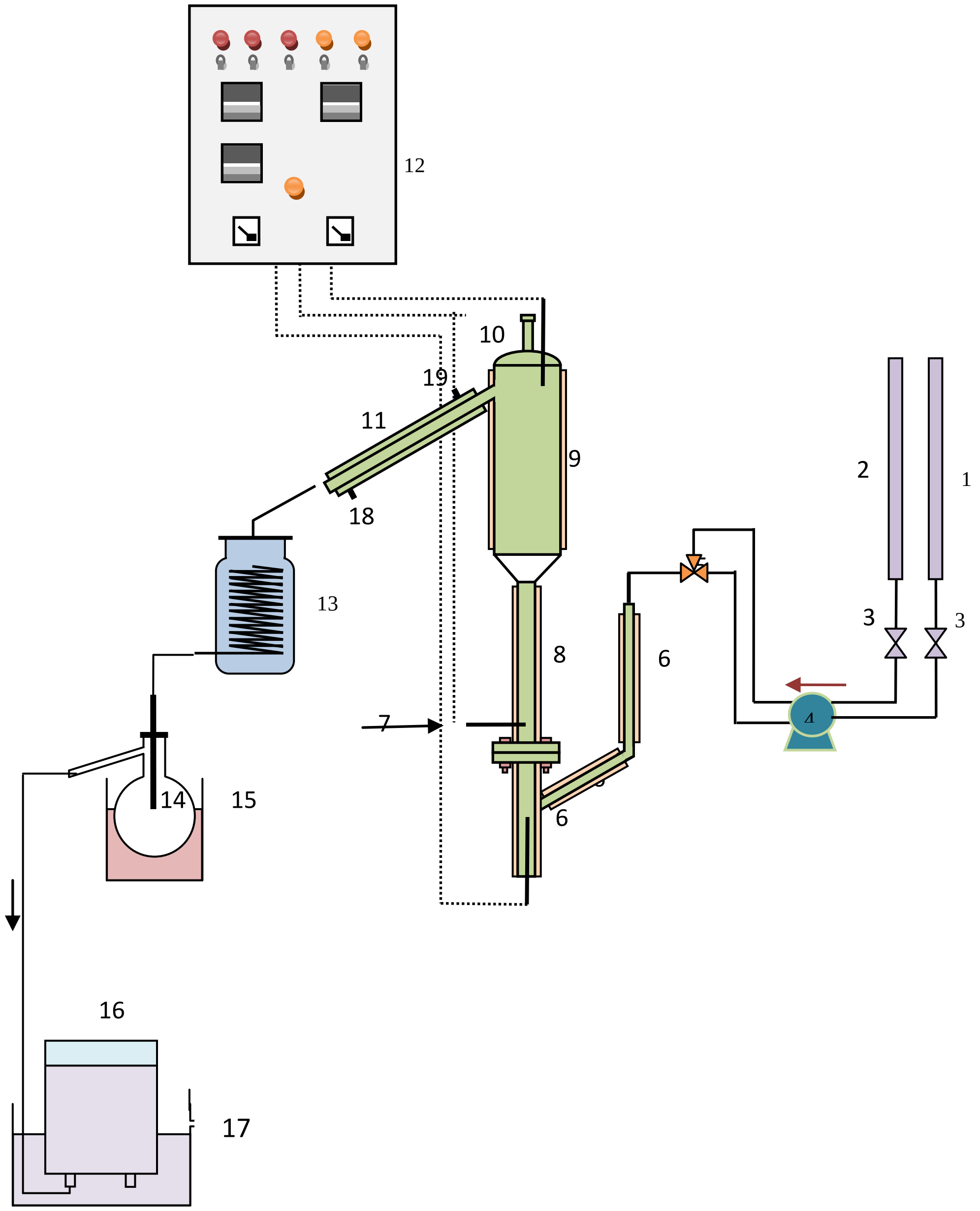

Figure 1. Schematic flow diagram of the fluidized catalytic cracking system:

(1) Burette atmospheric residue feeding; (2) Burette water feeding; (3) Valve; (4) Dosing pump; (5) Three way valve; (6) Preheated section; (7)Distributor (8)Fluidized bed reactor section; (9)Reactor separation section; (10) Catalyst charge inlet; (11) Double pipe heat exchanger; (12) Control panel; (13) Internal tube ice water bath; (14) Separation and collection flask; (15) Ice water bath ; (16) Gas collection ; (17) Water tank; (18) Chilled water in; (19) Chilled water out.

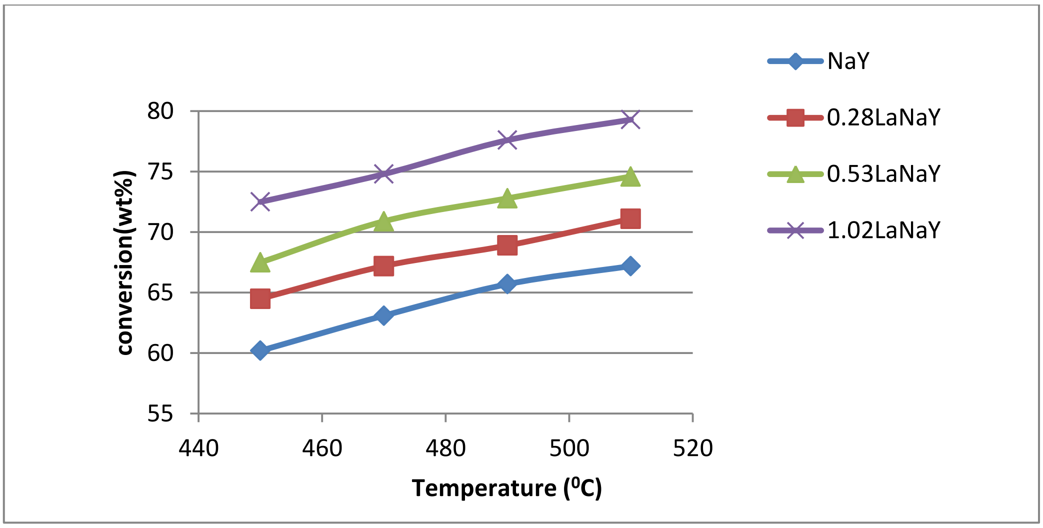

Figure2. Effect of lanthanum weight percent loading on the atmospheric residue conversion at different temperatures and 6 WHSV.

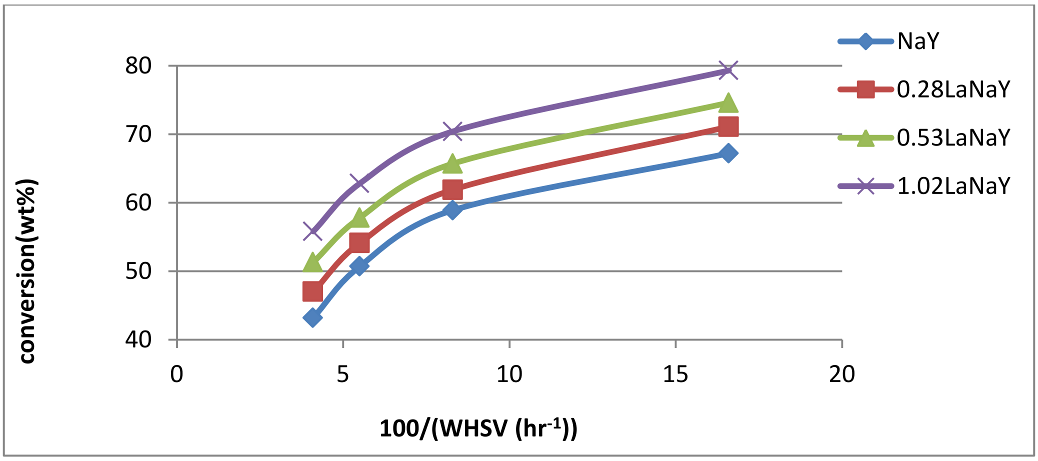

Figure3. Effect of lanthanum weight percent loading on the atmospheric residue conversion at different WHSVand temperatures 510^{o}C.

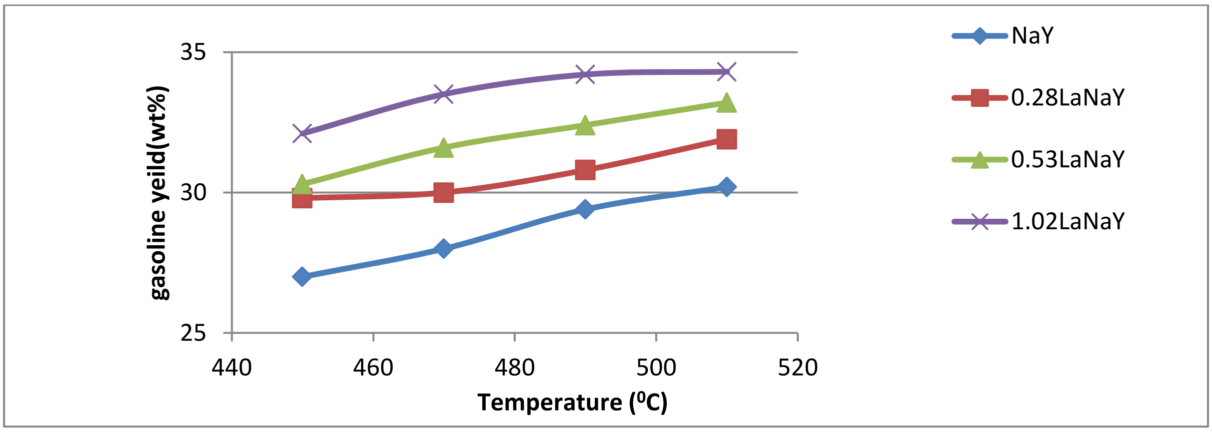

Figure4. Effect of lanthanum weight percent loading on the yield of gasoline at different temperatures and 6 WHSV.

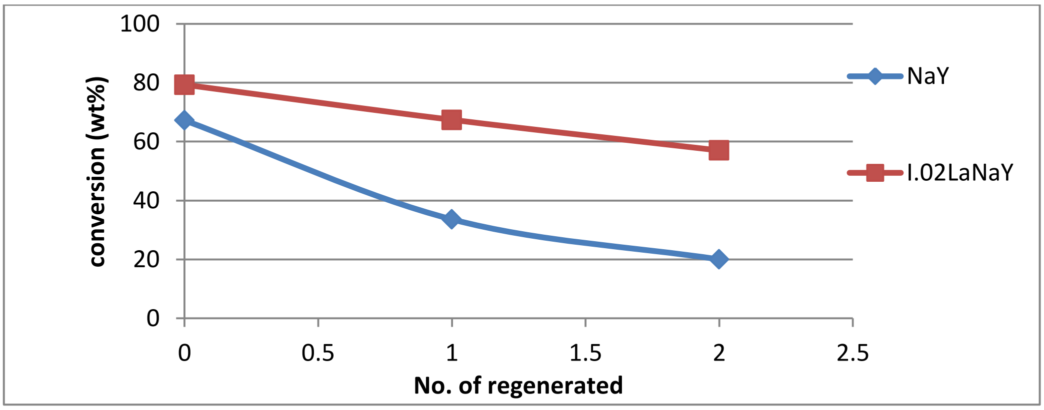

Figure5. Relation between the conversion and the number of regeneration for NaY and 1.02 LaNaY catalysts.

Semi-Batch Reactive Distillation of Consecutive Reaction : The Saponification Reaction of Diethyl Adipate with Sodium Hydroxide Solution

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ABSTRACT

This research presents a new study in reactive distillation by using consecutive reaction: the saponification reaction of diethyl adipate (DA) with sodium hydroxide solution .
The effect of three parameters were studied through a design of experiments applying 2^3 factorial design . These parameters were : the mole ratio of DA to NaOH solution (0.1 and 1) , NaOH solution concentration (3 N and 8 N) , and batch time (1.5 hr. and 3.5 hr.) . The conversion of DA to sodium monoethyladipate(SMA)(intermediate product) was the effect of these parameters which was detected . Also , the percentage purity of the intermediate product was recorded . The results showed that increasing mole ratio of DA to NaOHsolution increases the conversion and percentage purity to a maximum value within the range of study . The effect of NaOH solution concentration decreases the conversion and percentage purity to specified value within the range of study . The effect of batch time on conversion and percentage purity , when NaOH solution concentration (3 N) is as follows : the increasing in batch time decreases the conversion and percentage purity to specified value within the range of study . When NaOH solution concentration (8 N) increasing batch time decreases the conversion , while percentage purity increases with increasing batch time to a maximum value within the range of study . The maximum attainable conversion within the studied range of parameters was eighteen fold of the base case , while the maximum percentage purity was (99.40 %) .
Empirical equation was obtained using statistical analysis of experimental results . The empirical results of relative conversion was drawn . The empirical graphs showed linear variation .
Key words: consecutive reaction, the saponification reaction, diethyl adipate with sodium hydroxide solution, sodium monoethyladipate.

التقطير التفاعلي شبه ذوالدفعات لتفاعل متسلسل : صوبنة ثنائي أثيل أديبيت مع محلول هيدروكسيد الصوديوم

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الخلاصة

يقدم هذا البحث دراسة جديدة في التقطير التفاعلي بإستخدام تفاعل متسلسل: تفاعل صوبنة ثنائي أثيل أديبيت مع محلول هيدروكسيد الصوديوم .تمت دراسة تأثير ثلاثة عوامل من خلال تصميم تجارب بتطبيق تصميم مفكوك 2^3 . هذه العوامل كانت : النسبة المولية لثنائي أثيل أديبيت إلى محلول هيدروكسيد الصوديوم (0,1 و 1) , تركيز محلول هيدروكسيد الصوديوم (3 عيارية و 8 عيارية) , و زمن الدفعة (1,5ساعة و3,5 ساعة) . إن نسبة تحول ثنائي أثيل أديبيت إلى صوديوم أحادي أثيل أديبيت (المركب الوسطي) كانت تأثير تلك العوامل الذي تم تتبعه . كذلك سجلت نسبة نقاوة المركب الوسطي . لقد بينت النتائج

إن زيادة النسبة المولية لثنائي أثيل أديبيت إلى محلول هيدروكسيد الصوديوم تزيد من نسبة التحول و نسبة النقاوة إلى قيمة عليا ضمن حدود الدراسة . إن تأثير تركيز محلول هيدروكسيد الصوديوم تقلل من نسبة التحول و نسبة النقاوة إلى قيمة معينة ضمن حدود الدراسة . ان تأثير زمن الدفعة على نسبة التحول ونسبة النقاوة , عندما تركيز محلول هيدروكسيد الصوديوم (3 عيارية),هو كما يلي: زيادة زمن الدفعة تقلل نسبة التحول ونسبة النقاوة إلى قيمة معينة ضمن حدود الدراسة .عندما تركيز محلول هيدروكسيد الصوديوم (8 عيارية) زيادة زمن الدفعة تقلل نسبة التحول . بينما نسبة النقاوة تزداد بزيادة زمن الدفعة إلى قيمة عليا ضمن حدود الدراسة . إن أكبر نسبة تحول تم الحصول عليها خلال المدى المدروس للمتغيرات كانت ثمانية عشر ضعفا أكثر من الحالة المرجعية , بينما أعظم نسبة نقاوة كانت (99,40 %) . تم الحصول على معادلة تجريبية باستخدام التحليل الإحصائي للنتائج العملية . رسمت النتائج التجريبية لنسبة التحول نسبة الحالة المرجعية . أظهرت الرسوم التجريبية تغيرخطي.

الكلمات الرئيسية: تفاعل متسلسل, تفاعل الصوبنة, ثنائي اثيل اديبيت مع محلول هيدروكسيد الصوديوم, صوديوم احادي اثيل اديبيت.

1. INTRODUCTION

Reactive distillation (RD) is a process which includes a combination of reaction and separation in a single unit. The concept of combining these two important functions for enhancing the process overall performance is not new in chemical engineering world. The production of ammonia from soda ash by classic Solvay process of the 1860s may be cited as possibly the first commercial applying of this technique**,Sundmacher and Kienle,2002**. Many old operations have made usage of this concept.The combination of reaction and distillation is possible , of course only if the conditions of both operations can be combined. This means that the reaction have to show data for reasonable conversion at temperature and pressure levels that are compatible with separation conditions. The type of catalysis is also important. Homogeneous catalysis is possible in more cases , but requires a separation step for catalyst recycling. This can be eliminated in heterogeneous catalysis , but here special constructions are necessary to fix the catalyst in the reaction zone. If everything harmonizes , considerable advantages arise : for the production of methyl acetate via RD for example , only one column is needed instead of a reactor and nine columns. RD can be used with many chemical processes including acetylation ,**Mufrod, et al.,2013**, amination , esterification , etherification , hydrolysis , hydration , dehydration , hydrogenation , isomerization , etc..

The general utility of RD (till now) is increasing the conversion of reversible reactions , **Laybenand Ching Yu,2008**. This depends on the withdrawal of the product (or one of the products) by evaporation from the reacting mixture. This technique accelerates the forward reaction.RD also provides compactness to the chemical plant and cost effectiveness.

This research presents a new study in RD of a consecutive reaction. The consecutive reaction proposed is the saponification reaction of diethyl adipate with sodium hydroxide solution. This reaction takes place in two steps. The distillation process has the role of withdrawing the intermediate product(SMA) by evaporation from the reacting mixture before the second conversion occurs. This technique is useful in producing the intermediate product(when it is the desired product)as it is the case in many industrial and petroleum processes.

2. KINETICS OF REACTIONS

Saponification reaction of diethyl adipate as studied byNewberger and Kadlec **,Newberger and Kadlec,1973**, represents second order , irreversible , consecutive homogeneous reaction in the liquid phase .
The chemical reactions are represented as follows , **Newberger and Kadlec,1973**:

$$(CH_2)_4(COOC_2H_5)_2 + NaOH \xrightarrow{k1} (CH_2)_4(COONa)(COO\ C_2H_5) + C_2H_5OH$$

Diethyl adipate Sodiumhydroxide Sodium monoethyl adipate Ethanol

$$(CH_2)_4(COONa)(COOC_2H_5) + NaOH \xrightarrow{k2} (CH_2)_4(COO\ Na)_2 + C_2H_5OH$$

Sodiummonoethyladipate Sodiumhydroxide Disodium adipate Ethanol

They found that the rate constant of the first reaction (k_1) to be 9.3 m^3/kmole.s while that of the second reaction (k_2) to be 7.7 m^3/kmole.s. These values were obtained at temperature 293.1 K .
It is obvious that $k_1 > k_2$ i.e. the first reaction is faster than the second .
They also found that the frequency factors of Arrhenius equation , and the activation energies of the two reactions were :

$A_1 = 4.87 * 10^6\ m^3$ / Kmole . s , $A_2 = 3.49 * 10^6\ m^3$ / Kmole . s

E_1 = 42.2 MJ / Kmole , E_2 = 25.0 MJ / Kmole

It is obvious that $E_1 > E_2$, so the first reaction has a higher energy barrier than the second reaction .
In addition , they determined the heats of the two reactions to be :

$\Delta H_1 = -\ 45.2 \pm 3.4$ MJ / Kmole

$\Delta H_2 = -\ 68.0 \pm 4.2$ MJ / Kmole

These quantities were found to contribute at most 0.5 K temperature rise in their tubular reactor , **Newberger and Kadlec,1973**.

3. METHODOLOGY

3.1 Experimental Work

1-Sodium hydroxide solution (NaOH) was prepared and standardized using indicators ,**Vogel,1961**, and pH – meter .

2-Experiments were conducted to compare the case of using distillation with that of without distillation .

3-Measured amounts (20 - 27 ml.) of diethyl adipate (DA) and sodium hydroxide "NaOH" solution (56 – 332 ml.) were mixed in (500 – ml.) distillation flask which was shielded .

4-Keeping the temperature at constant value (50 ℃) and providing good mixing (500 rpm) for the reacting mixture using magnetic stirrer .

5-After a planned period of time (1.5 hr.) the reaction was stopped and flask contents which consist of two layers were transferred immediately to a (500 – ml.) separating funnel .

6-The weight and volume of each layer were measured .

7-FTIR measurement was done for each layer which showed the existence of sodium monoethyladipate (SMA) in the two layers with higher concentration in the upper layer . The unreacted diethyl adipate (DA) was noticed to appear in the two layers too with higher concentration in the upper layer than that of the lower layer .

8-Atomic absorption measurement was done for the upper layer to measure the concentration of sodium monoethyladipate (SMA) .

9-The conversion of diethyl adipate (DA) to sodium monoethyladipate (SMA) was calculated . Relative conversion (conversion of DA to SMA relative to base case* conversion) was adopted to show the enhancement of conversion with respect to base case . Also , the purity of upper layer relative to the lower layer was calculated.

3.2 Experimental Work

1-Sodium hydroxide (NaOH) solution , was prepared and standardized .

2-According to the design of experiment (Table 1) ,(Montgomery,2001) three factors were intended to study (feed mole ratio , sodium hydroxide (NaOH) solution concentration, and batch "distillation" time) within the ranges fixed in Table 2 .

3-Measured amounts (12 – 129 ml.) of diethyl adipate (DA) and sodium hydroxide solution "NaOH" (31 – 332 ml.) were mixed in (500 – ml.) distillation flask which was shielded .

4-Heating the mixture till boiling . The distillate began to appear approximately at about 100 ^{0}C .

5-The distillate was collected in receiving conical flask . It was noticed that it was composed of two layers .

6-The distillate was transferred to a (500 - ml.) separating funnel .

7- The weight and volume of each layer were measured .

8-FTIR measurement was done for each layer which showed that sodium monoethyladipate (SMA) appeared in the dominate upper layer . The unreacted diethyl adipate (DA) appeared in the impaired lower layer .

9- After that atomic absorption was made for the upper layer to measure the concentration of sodium monoethyladipate (SMA) .

10-The conversion(using Eq. (1))and relative conversion (usingEq. (2))were calculated as in the case of without distillation . The percentage purity of distillate upper layer which contains SMA was also calculated(using Eq. (3)) .

11-In order to characterize the final product , i.e disodium adipateDSA (**see Fig. 1**)the measurement of somephysical properties were performed as illustrated in **Table 3** .

*****Base case : is the experiments that carried out at lower values of all the parameters , which is regarded as base (reference) case .

3.3 Illustrations of Relative Conversion and Percentage Purity Calculations

Sodium monoethyladipate (SMA) concentration = sodium (Na) concentration in distillate upper layer

Conversion of diethyl adipate (DA) to (SMA)= $\frac{moles\ of\ reacted\ DA\ to\ SMA}{moles\ of\ DA\ in\ feed} * 100$ (1)

Relative conversion= $\frac{conversion\ of\ DA\ to\ SMA}{base\ case\ (run1) conversion}$ (2)

%Purity= $\frac{wt.of\ distillate\ upper\ layer}{wt.of\ total\ distillate} * 100$(3)

4. RESULTS

4.1 Experimental Results

Fig. 2 shows the variation of sodium monoethyladipate (SMA) concentration with feed mole ratio represented by (x_1) . Two curves were drawn for the same NaOH solution concentration (x_2 = 3 N) and different distillation time (x_3 = 1.5 and 3.5 hr.) . From this figure , it is clear for the two curves that SMA concentration was direct proportional with feed mole ratio in the range (x_1 = 0.1 – 0.3) . The two curves have a maximum SMA concentration at (x_1 = 0.3) . After that, increasing feed mole ratio in the range (x_1 = 0.3 – 1) caused decreasing in SMA concentration. This can be explained as follows : the rate of first conversion reaction (SMA production) is higher than the rate of second conversion reaction (SMA consumption) , **Newberger and Kadlec,1973**. The increasing in feed mole ratio in the range (x_1 = 0.1 – 0.3) activated the first conversion reaction (i.e SMA production increased) and its concentration in distillate increased . Higher increasing in feed mole ratio in the range (x_1 = 0.3 – 1) activated the second conversion reaction (i.e SMA consumption increased) so its concentration in distillate decreased . Also , it is clear from this figure that SMA concentration for the curve of shorter distillation time (t = 1.5 hr.) at (x_1 = 0.1 – about 0.8) was higher than that of longer distillation time (t = 3.5 hr.) . At feed mole ratio (x_1 = 0.3) SMA concentration for the curve of shorter distillation time (106.10 ppm.) , while for the curve of longer distillation time (50.33 ppm.) viz has its half concentration value . This is because longer distillation time activated the second reaction (i.e SMA consumption increased) , meanwhile the other products (ethanol) as well as (water) continued to accumulate in the distillate . So SMA concentration with respect to the upper layer of distillate reduced .

Fig. 3 also shows the variation of SMA concentration with feed mole ratio (x_1) . Again two curves were drawn for the same NaOH solution concentration (x_2 = 8 N) and different batch time (x_3 = 1.5 and 3.5 hr.) . From this figure , it is clear that the two curves have the same trend of variation as in **Fig. 2** with wide difference between them . The peak of the curve of shorter distillation time (119.82 ppm.) was higher than the corresponding one of **Fig. 2**. The peak of the curve of longer distillation time (15.77 ppm.) was lower than the corresponding one of **Fig. 2** .

This is because increasing NaOH solution concentration activated both the first and second reactions . For (1.5 hr.) duration SMA accumulation was greater than its consumption , so SMA concentration increased with increasing NaOH solution concentration . For (3.5 hr.) duration SMA consumption was greater than its accumulation , so SMA concentration decreased with increasing NaOH solution concentration .

Fig. 4 illustrates the variation of SMA concentration with NaOH solution concentration represented by (x_2) . The curve was drawn for feed mole ratio (x_1 = 0.3) and distillation time (t = 2.5 hr.), i.e. the center points of each parameter . From this figure , it is clear that SMA concentration decreased with increasing NaOH solution concentration in the range (x_2 = 3 – 5.5 N) . The curve has a minimum value of SMA concentration (8.67 ppm.) at (x_2 = 5.5 N) . After that SMA concentration increased with increasing NaOH solution concentration in the range (x_2 = 5.5 – 8 N) . As explained before , increasing NaOH solution concentration stimulated both reactions . Also , as explained before in **Figs. 2** and **3** , for (t = 1.5 hr.) and (x_1 = 0.3) NaOH solution concentration (x_2 = 8 N) gave higher SMA concentration than NaOH solution concentration (x_2 = 3 N) , while for (t = 3.5 hr.) NaOH solution concentration (x_2 = 3 N) gave higher SMA concentration than NaOH solution concentration (x_2 = 8N) . For (t = 2.5 hr.) and (x_1 = 0.3) SMA concentration for NaOH solution concentration (x_2 = 8 N) was higher than its concentration for NaOH solution concentration (x_2 = 3 N) . It can be concluded that SMA concentration increased with increasing NaOH solution concentration during (1.5 – 2.5 hr.) , while SMA concentration decreased with increasing NaOH solution concentration during (2.5 – 3.5 hr.) .

Fig. 5 explains the variation of SMA concentration with batch (distillation) time represented by (x_3) . The curve was drawn for feed mole ratio (x_1 = 0.3) and NaOH solution concentration (x_2 = 3 N) . From this figure , it is clear that increasing distillation time in the range (t = 1.5 – 2.5 hr.) decreased SMA concentration progressively .The curve has a minimum in SMA concentration (10.55 ppm.) at (t = 2.5 hr.) . After that, SMA concentration increased with increasing distillation time in the range (t = 2.5 – 3.5 hr.) . This can be explained as follows : the increasing in distillation time in the range (t = 1.5 – 2.5 hr.) for (x_2 = 3 N) decreased SMA concentration because of increasing SMA consumption by means of activating the second conversion reaction, meanwhile other products (ethanol) as well as (water) continued to accumulate in distillate upper layer so SMA concentration decreased progressively . The increasing in SMA concentration with increasing distillation time in the range (t = 2.5 – 3.5 hr.) was because of decreasing SMA consumption . Also , from this figure it is clear that SMA concentration for shorter distillation time (106.10 ppm.) was higher than SMA concentration for longer distillation time (50.33 ppm.) as explained in **Fig. 2** at (x_1 = 0.3) .

Fig. 6 shows the variation of SMA concentration with batch time (x_3) and feed mole ratio (x_1 = 0.3) . The curve was drawn for NaOH solution concentration (x_2 = 8 N) . As explained previously , increasing NaOH solution concentration stimulated the two reactions (first and second conversion reactions) . From this figure , it is clear that when distillation time increased in the range (t = 1.5 - 2.5 hr.) SMA concentration increased . The curve has a maximum SMA concentration (152.37 ppm.) at (t = 2.5 hr.) , this is on the contrary to **Fig. 5** which has a minimum value at (t = 2.5 hr.) . This means higher SMA production be at (t = 2.5 hr.) for (x_2 = 8 N) , while higher SMA consumption be at (t = 2.5 hr.) for (x_2 = 3 N) . After that, SMA concentration decreased when distillation time increased in the range (t = 2.5 - 3.5 hr.) . Also, it is clear from this figure (1.5 hr.) distillation time gave higher SMA concentration (119.82 ppm.) than (3.5 hr.) distillation time (15.77 ppm.)as explained in **Fig. 3**.

Fig. 7 explains the variation of relative conversion with feed mole ratio (x_1) . The curves were drawn for the same NaOH solution concentration (x_2 = 3 N) , and different batch time (x_3 = 1.5 and 3.5 hr.) . From this figure , it is obvious that for the two curves the relative conversion proportionally increased with increasing feed mole ratio in the range (x_1 = 0.1 - 0.3) . The two curves have a maximum relative conversion at (x_1 = 0.3) which seems to be the best value in our range of feed mole ratios . After that increasing feed mole ratio in the range (x_1 = 0.3 – 1) decreased relative conversion . The increasing in relative conversion with increasing feed mole ratio in the range (x_1 = 0.1 – 0.3) was because of the increasing in SMA concentration in this range of feed mole ratios as shown in **Fig. 2**. The decreasing in relative conversion for the range (x_1 = 0.3 - 1) is due to the decreasing in SMA concentration. The curves have the same trend of variations as in **Fig. 2** . Relative conversion is a function of SMA concentration, weight of distillate upper layer , and DA volume . It varies proportionally with SMA concentration and the weight of the upper layer and it varies inversely with DA volume . At (x_1 = 0.3) relative conversion for the curve of shorter distillation time was (18.58) , while for the curve of longer distillation time was (9.76) . This was because SMA concentration for (t = 1.5 hr.) was higher than its concentration for (t = 3.5 hr.) as shown in **Fig. 2**. It was noticed thatat feed mole ratios approximately above (x_1 = 0.6) the variation of relative conversion with feed mole ratio becomes linear .

Fig. 8 also explains the variation of relative conversion with feed mole ratio (x_1) and different batch time (x_3 = 1.5 and 3.5 hr.) . The two curves were drawn for the same NaOH solution concentration (x_2 = 8 N) . From this figure , it is clear that for the curve of shorter distillation time , relative conversion increased with feed mole ratios in the range (x_1 = 0.1 - 0.3) . The curve has a maximum value of relative conversion (2.76) at (x_1 = 0.3) . After that the relative conversion decreased when feed mole ratio increased in the range (x_1 = 0.3 – 1) . This curve has this behaviour due to increasing then decreasing in SMA concentration as shown in **Fig. 3** . This curve has the same trend of variation as the curve of shorter distillation time in **Fig. 7** . The peak of the curve of shorter distillation time (2.76) is lower than the corresponding one of **Fig. 7** . This appears in contradiction with **Figs. 2**and**3** . This is because of lower weight of distillate upper layer and higher volume of DA . For the curve of longer distillation time it is clear that the relative conversion decreased when feed mole ratio increased in the range (x_1 = 0.1 - 0.55) . The curve has a minimum value of relative conversion (0.18) at (x_1 = 0.55) . Then relative conversion increased somewhat till (x_1 = 1) . The decreasing in relative conversion with feed mole ratio in the range (x_1 = 0.1 – 0.55) because of decreasing in weight of distillate upper layer and increasing in DA volume . The increasing in relative conversion for the range (x_1 = 0.55 - 1) was because of increasing in weight of upper layer distillate and increasing SMA concentration . The peak for the curve of longer distillation time (0.62) is lower than the corresponding one of **Fig.7**.This is because of lower weight of distillate upper layer and higher volume of DA as mentioned above.

Fig. 9 shows the variation of relative conversion with NaOH solution concentration (x_2) . The curve was drawn for feed mole ratio (x_1 = 0.3) and batch time (x_3 = 2.5 hr.) . From this figure , it is clear that the relative conversion decreased with increasing NaOH solution concentration in the range (x_2 = 3 – 5.5 N) . The curve has a minimum value of relative conversion (0.39) at (x_2 = 5.5 N) . After that the relative conversion increased when NaOH solution concentration increased in the range (x_2 = 5.5 – 8 N) . The behaviour of this curve was due to the decreasingthenincreasing of SMA concentration with NaOH solution concentration as shown in **Fig. 4**.

Fig. 10 explains the variation of relative conversion with distillation time (x_3) . The curve was drawn for feed mole ratio (x_1 = 0.3) and NaOH solution concentration (x_2 = 3 N) . From this figure , it is clear that the relative conversion decreased when distillation time increased in the range (t = 1.5 – 2.5 hr.) . The curve has a minimum value of relative conversion (0.68) at (t = 2.5 hr.) . After that, the relative conversion increased with increasing distillation time in the range (t = 2.5 – 3.5 hr.) . This behaviour due to the decreasingthen increasing of SMA concentration with distillation time as shown in **Fig. 5** .

Fig. 11 also explains the variation of relative conversion with distillation time (x_3) , and feed mole ratio (x_1 = 0.3) . The curve was drawn for NaOH solution concentration (x_2 = 8N). From this figure , it is clear that the relative conversion decreased with increasing distillation time . This can be attributed to the decreasing in SMA concentration as discussed in **Fig. 6**.

Fig. 12 illustrates the variation of percentage purity of distillate upper layer with feed mole ratio (x_1) . The two curves were drawn for the same NaOH solution concentration (x_2 = 3 N) and different batch time (x_3 = 1.5 and 3.5 hr.) . From this figure , obvious that the percentage purity for the two curves increased with increasing feed mole ratio in the range (x_1 = 0.1 – 0.3) . The two curves have a maximum value of percentage purity at (x_1 = 0.3) . After that the percentage purity decreased with increasing feed mole ratio in the range (x_1 = 0.3 – 1) . Percentage purity is a function of weight of distillate upper layer and unreacted DA weight in distillate . It is proportionally varies with the weight of distillate upper layer and inversely varies with the weight of unreacted DA in distillate . The increasing in percentage purity with increasing feed mole ratio in the range (x_1 = 0.1 – 0.3) was because stimulating the first conversion reaction (DA consumption increased so the appearance of unreacted DA in distillate decreased and SMA concentration in distillate increased) as explained in **Fig. 2** . The decreasing in percentage purity with increasing feed mole ratio in the range (x_1 = 0.3 - 1) was because stimulating the second conversion reaction (i.e SMA concentration in distillate decreased) as explained in **Fig. 2** . So the weight of upper layer distillate decreased and percentage purity decreased . Also , it is clear from this figure that the percentage purity for the curve of longer distillation time was higher than that of shorter distillation time . For the curve of (t = 3.5 hr.) at (x_1 = 0.3) the percentage purity (98.52 %) , while it is (97.5 %) for the curve of (t = 1.5 hr.) . This is because the accumulation of (ethanol) as well as (water) increased in the distillate for longer distillation time . So the weight of distillate upper layer increased with respect to unreacted DA layer (distillate lower layer) so that percentage purity of distillate upper layer increased .

Fig. 13 also illustrates the variation of percentage purity with feed mole ratio (x_1) .The batch time for the two curves was different (x_3 = 1.5 and 3.5 hr.) . The two curves were drawn for the same NaOH solution concentration (x_2 = 8 N) . From this figure , it is clear that the two curves have the same trend of variation of **Fig. 12** . The peak for the curve of longer distillation time (98.01 %) was lower than the corresponding one of **Fig.12** . Also the peak for the curve of shorter distillation time (97.08 %) was lower than the corresponding one of **Fig. 12** . This is because for (x_2 = 8 N) both first and second reactions were highly activated ,so the accumulation of ethanol and water is much more than for (x_2 = 3 N)for (t = 1.5 hr.) as well as for (t = 3.5 hr.) . So the accumulated distillate for (t = 1.5 and 3.5 hr.) is much more than that for(x_2 = 3 N) in **Fig. 12**. The conclusion , that the maximum percentage purity occurred in low NaOH solution concentration (x_2 = 3 N) for both distillation time (1.5 hr. and 3.5 hr.) .**Fig. 14** shows the variation of percentage purity with NaOH solution concentration (x_2) . The curve was drawn for feed mole ratio (x_1 = 0.3) and batch time (t = 2.5 hr.) . From this figure, it is obvious that the percentage purity decreased with increasing NaOH solution concentration in the range (x_2 = 3 –

5.5 N) . The curve has a minimum percentage purity (95.34 %) at (x_2 = 5.5 N) . After that, the percentage purity increased with increasing NaOH solution concentration in the range (x_2 = 5.5 – 8 N) . This behaviour can be discussed through the decreasing then increasing of SMA concentration in **Fig. 4**.This result is fairly coincident with the conclusion of **Fig. 13**.

Fig. 15 illustrates the variation of percentage purity with distillation time (x_3) . The curve was drawn for feed mole ratio (x_1 = 0.3) and NaOH solution concentration (x_2 = 3 N) . From this figure , it is clear that the percentage purity decreased with increasing distillation timein the range (x_3 = 1.5 – 2.5 hr.) . The curve has a minimum value of percentage purity (97.21 %) at (t = 2.5 hr.) . After that the percentage purity increased with increasing distillation time in the range (t = 2.5 – 3.5 hr.) . The discussion of the curve may be accomplished through **Fig. 5** as the decreasing SMA concentration led to decreasing percentage purity . Then increasing SMA concentration led to increasing percentage purity .

Fig. 16 also illustrates the variation of percentage purity with distillation time (x_3) and feed mole ratio (x_1 = 0.3) . The curve was drawn for NaOH solution concentration (x_2 = 8 N) . From this figure , it is obvious that the percentage purity increased with increasing distillation time in the range (t = 1.5 – 2.5 hr.) . The curve has a maximum percentage purity (99.40 %) at (t = 2.5 hr.) . After that the percentage purity decreased with increasing distillation time in the range (t = 2.5 – 3.5 hr.) . The curve can be discussed through the curve of**Fig. 6**. Increasing SMA concentration in the range (1.5 – 2.5 hr.) led to increasing percentage purity . Then decreasing SMA concentration in the range (2.5 – 3.5 hr.) led to decreasing percentage purity .

4.2 Empirical Equation and Figures

The empirical equation obtained from the statistical manipulation of the design of experiments results is:

$$y = (0.5329)\, x_1 + (1.5376)\, x_2 + (0.6561)\, x_3 + (0.2304)\, x_1x_2 + (0.2809)\, x_1x_3 + (0.2704)\, x_2x_3 + (0.2304)\, x_1x_2x_3 \quad (4)$$

The empirical equation shows neither significance interaction between the parameters nor significance of any parameter except x_2 because all coefficients are < 1 except that for x_2 (1.5376). This indicates that NaOH solution concentration is the most effective parameter on the conversion .

Applying the parameters in the empirical equation, Eq. (4) within the range of parameters studied produced **Figs. 17-21** . **Figs. 17-21**, generally show the linear trend of variation . The reason of linearity is the absence of interactions between the variables (parameters studied , i.e feed mole ratio , sodium hydroxide solution concentration , and batch time) . The close looking of these results with experimental results shows that the empirical equation may well applied on this system at high values of feed mole ratios , high values of sodium hydroxide solution concentration , and low values of batch time . The empirical relation accounts for the general relation or trend of variation and not details . Therefore ; the peaks didn't appear in empirical figures .

5. CONCLUSIONS

From this study the following items can be concluded:

1-Feed mole ratio (x_1) obviously affected the concentration of SMA in the distillate . Accordingly the conversion and purity were also influenced by it . Increasing feed mole ratio caused increasing in the concentration of SMA , conversion of DA to SMA , and percentage purity of SMA in the distillate in the range (0.1 - 0.3) , when the other factors x_2 (NaOH solution concentration) and x_3 (batch time) were fixed at specified values . In the range (0.3 – 1) of x_1 the concentration , conversion , and percentage purity decreased .

2-Increasing sodium hydroxide solution concentration (x_2) increased the concentration of SMA , as well as the conversion and percentage purity with other parameters (x_1 and x_3) were fixed. That was attributed to the effect of NaOH as a reactant which accelerated the reactions with increasing in its concentration . Although , there were some ranges (x_2 = 3 – 5.5 N) of NaOH solution concentration which caused decreasing in SMA concentration , conversion , and percentage purity .

3-Increasing in batch time (x_3) caused decreasing the concentration of SMA and percentage purity till it reached (2.5 hr.) . After this value with other factors made fixed (x_1 = 0.3 and x_3 = 3 N) , the concentration of SMA and percentage purity increased with increasing x_3 . For the set of parameters (x_1 = 0.3 and x_3 = 8 N) increasing x_3 made increasing in the concentration of SMA and percentage purity till (x_3 = 2.5 hr.) . After this value SMA concentration and percentage purity decreased with increasing x_3 .

4-The conversion of DA to SMA for (x_1 = 0.3 and x_2 = 3 N) showed decreasing with increasing batch time (x_3) till (x_3 = 2.5 hr.) . Then the conversion increased with increasing x_3 . For the set of parameters (x_1 = 0.3 and x_2 = 8 N) the increasing x_3 made steady decreasing in the conversion of DA to SMA .

5-The empirical equation well represented the system in the range of high values of x_1 and x_2 and low values of x_3 .Also , it showed no interactions between the parameters and independence on the two parameters ($x_1$andx_3). In other words, it is dependent on x_2 only.

6-The empirical figures showed a linear relationships between the effect (conversion) and the parameters (x_1 , x_2 , and x_3) . It was concluded that the empirical equation didn't consider the detailed behaviour of the function (conversion) . On the contrary , it took into account the global effect of the parameters as a whole .

7- The maximum conversion obtained in this study was 18.58 fold of that for the base case which corresponds to the set of parameters (x_1 = 0.3, x_2 = 3 Nandx_3 = 1.5 hr.).In other words , it corresponds to the center point of x_1, the low value of x_2 and the low value of x_3.The percentage purity for this set of parameters was %97.50 . Although the maximum percentage purity obtained was %99.40 which corresponds to(x_1 = 0.3, x_2 = 8 Nandx_3 = 2.5 hr.), the calculated relative conversion for this set was only 2.40.

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Table 1 . Design of experiments .

Feed mole ratio (x_1) , (mol. DA / mol. NaOH)	**NaOH solution concentration (x_2) , (N)**	**Time (x_3) , (hr.)**
0.1	3	1.5
1	3	1.5
0.1	8	1.5
1	8	1.5
0.1	3	3.5
1	3	3.5
0.1	8	3.5
1	8	3.5

Table 2 . Variation range of parameters.

Factor	Low value (-)	Centre value (0)	High value (+)
Feed mole ratio (x_1) , (mole DA / mole NaOH solution)	0.1	0.55	1
NaOH solution concentration (x_2) , (N)	3	5.5	8
Time (x_3) , (hr.)	1.5	2.5	3.5

Table 3 . Some physical properties of DSA.

Physical property	Measured	Published , [*]
Density , g / cm^3	1.4428(using gas pycnometry) 1.4852(using ultra – pycnometry)	1.7
Melting point , ℃	≥ 250	250

Figure 1 . Disodium adipate from experimental work (with distillation) .

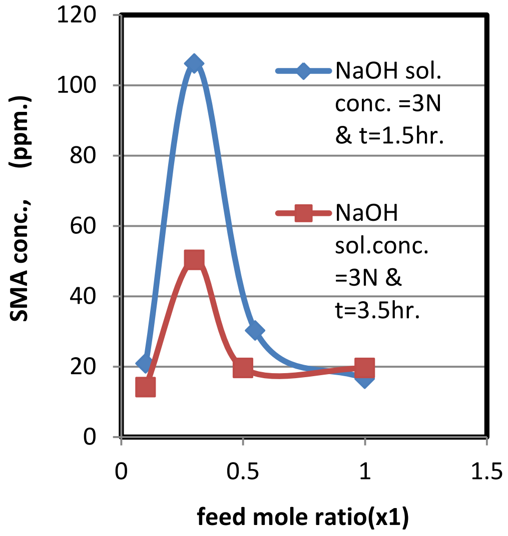

Figure 2 . SMA concentration , (ppm.) vs. feed mole ratio (x_1) for NaOH sol. conc. = 3N and t = (1.5 & 3.5 hr.) .

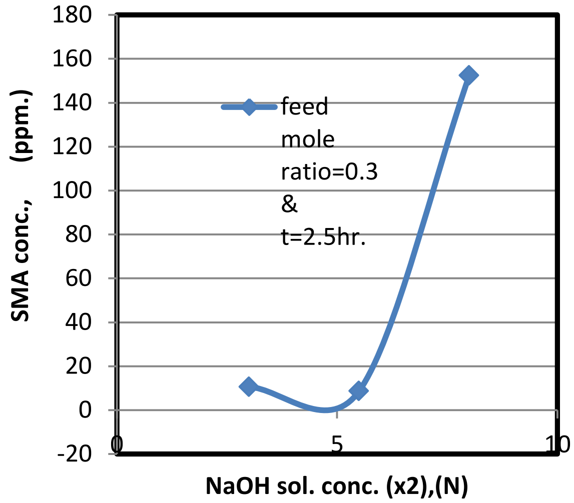

Figure 4 . SMA concentration , (ppm.) vs. NaOH solution concentration (x_2) , (N) for feed mole ratio = 0.3 and t = 2.5 hr.

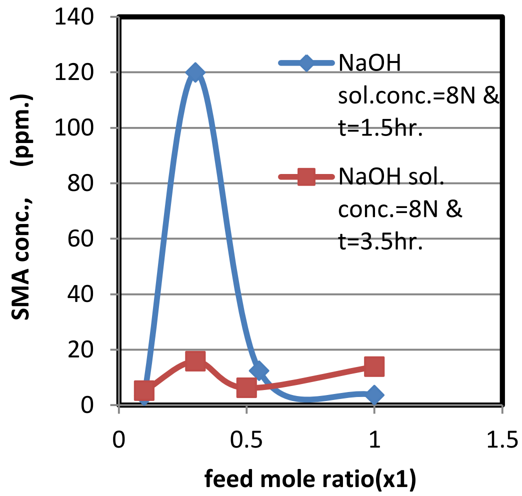

Figure 3 . SMA concentration , (ppm.) vs. feed mole ratio(x_1) for NaOH sol. conc. = 8 N and t = (1.5 & 3.5 hr.)

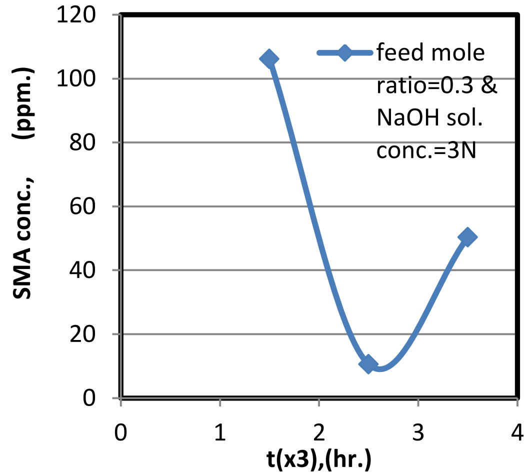

Figure 5 . SMA concentration , (ppm.) vs. t (x_3) , (hr.) for feed mole ratio = 0.3 and NaOH sol. conc. = 3 N .

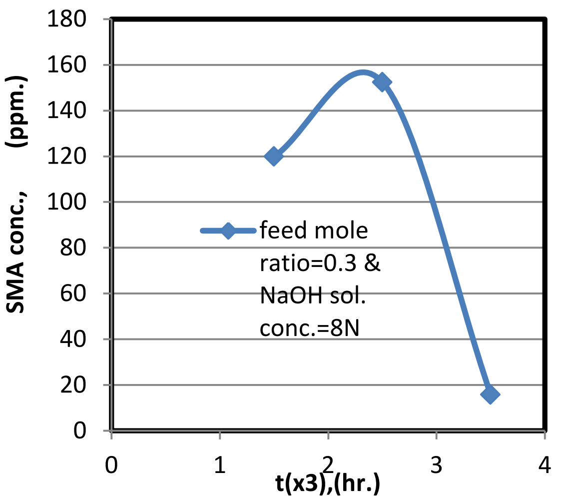

Figure 6 . SMA concentration , (ppm.) vs. t (x_3) , (hr.) for feed mole ratio = 0.3 and NaOH sol. conc.= 8 N .

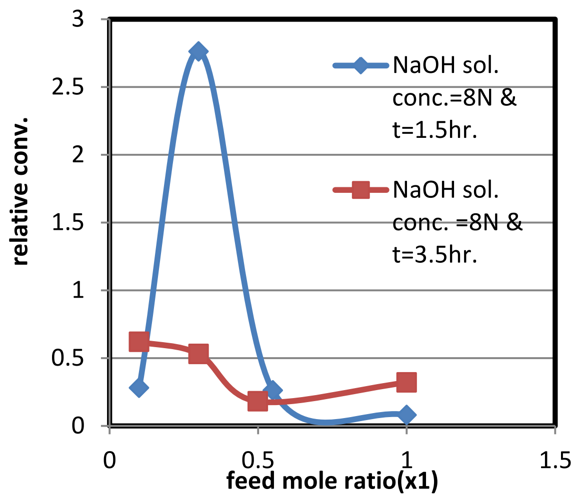

Figure 8 . Relative conversion vs. feed mole ratio (x_1) for NaOH sol. conc.= 8 N and t = (1.5 & 3.5 hr.) .

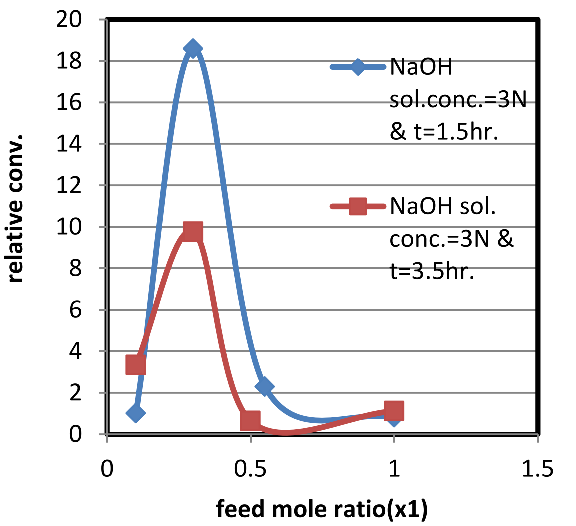

Figure 7 . Relative conversion vs. feed mole ratio (x_1) for NaOH sol. conc. = 3 N and t = (1.5 & 3.5 hr.) .

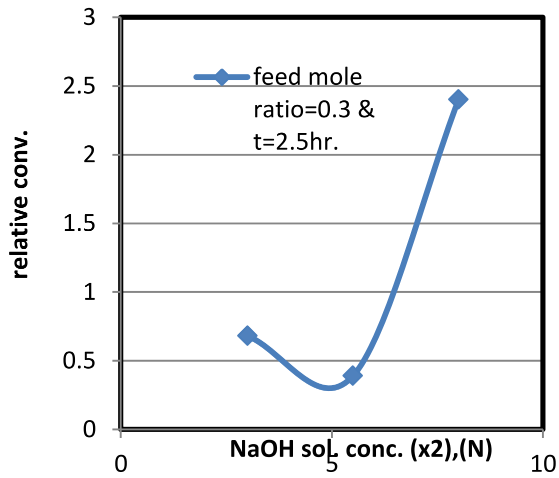

Figure 9 . Relative conversion vs. NaOH solution concentration (x_2) , (N) for feed mole ratio = 0.3 and t = 2.5 hr.

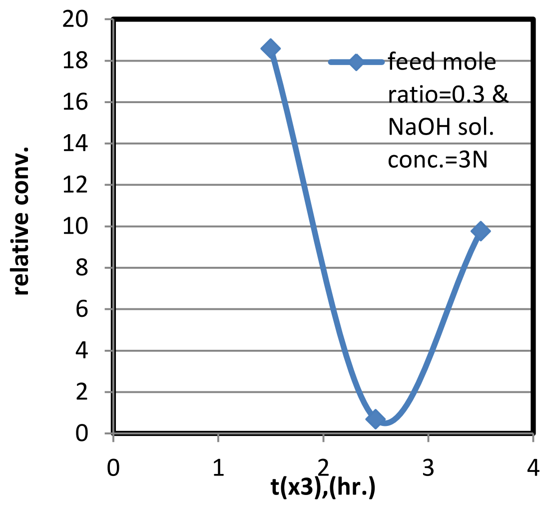

Figure 10 . Relative conversion vs. t (x_3) , (hr.) for feed mole ratio = 0.3 and NaOH sol. conc. = 3 N .

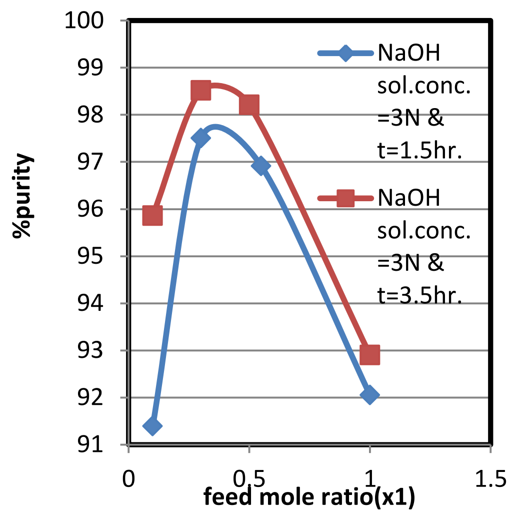

Figure 12 .% purity vs. feed mole ratio (x_1) for NaOH sol. conc. = 3 N and t = (1.5 & 3.5 hr.) .

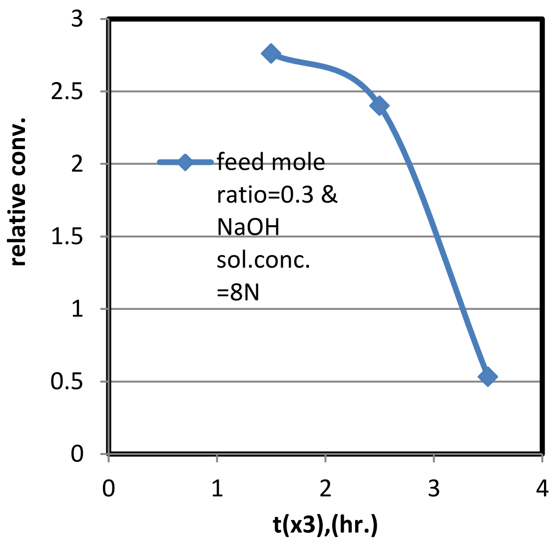

Figure 11 . Relative conversion vs. t (x_3) , (hr.) for feed mole ratio = 0.3 and NaOH sol. conc.= 8 N .

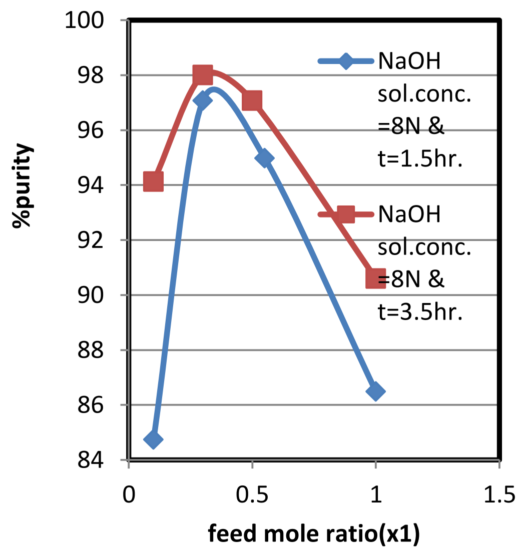

Figure 13 . % purity vs. feed mole ratio (x_1) for NaOH sol. conc. = 8 N and t = (1.5 & 3.5 hr.) .

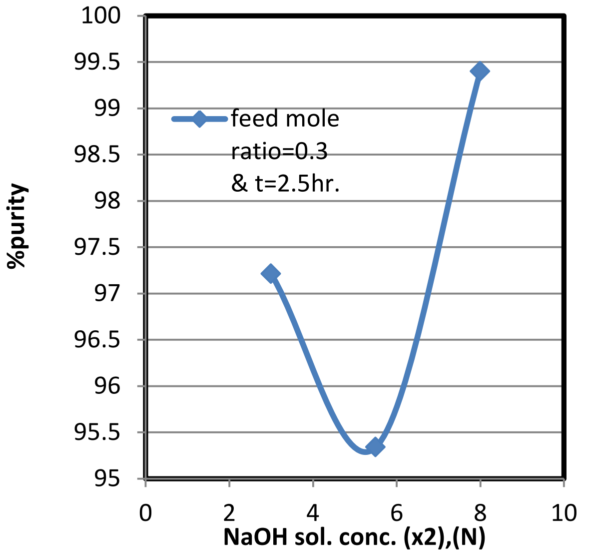

Figure 14 .% purity vs. t (x_3) , (hr.) for feed mole ratio = 0.3 and t = 2.5 hr.

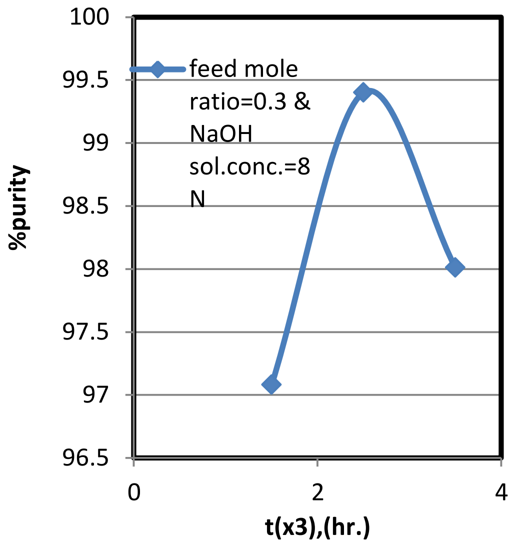

Figure 16 . % purity vs. t(x_3) , (hr.) for feed mole ratio = 0.3 and NaOH sol. conc. = 8 N.

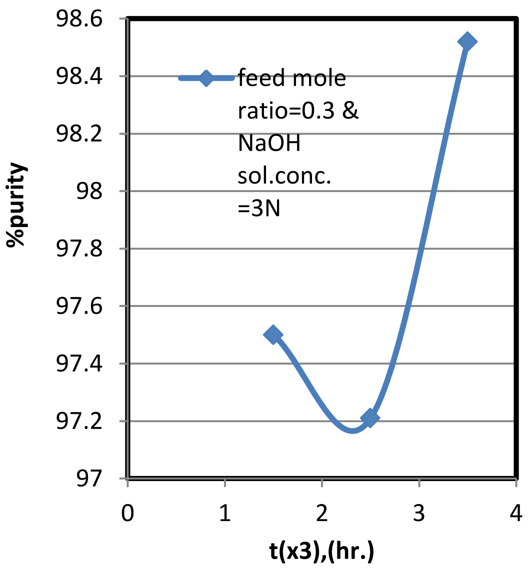

Figure 15 . % purity vs. t(x_3) , (hr.) for feed mole ratio = 0.3 and NaOH sol. conc. = 3 N.

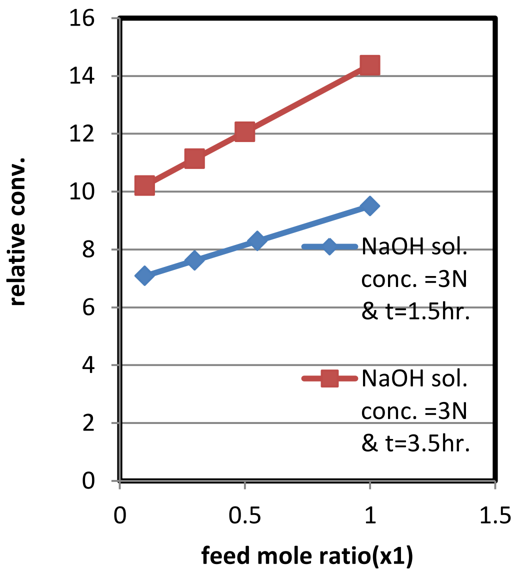

Figure 17 . Relative conversion vs. feed mole ratio (x_1) for NaOH sol. conc. = 3 N and t = (1.5 & 3.5 hr.) .

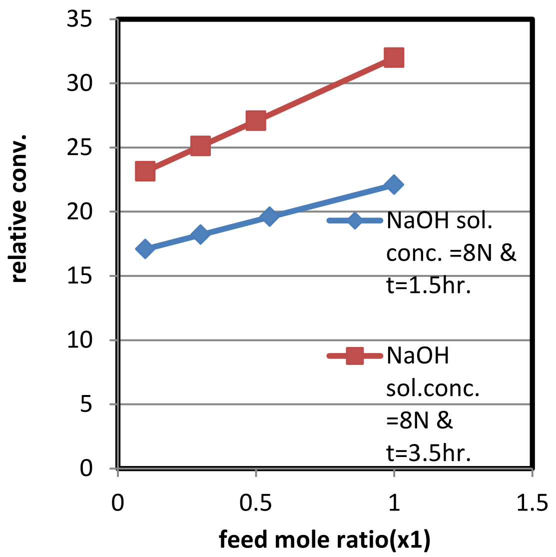

Figure 18 . Relative conversion vs. feed mole ratio (x_1) for NaOH sol. conc. = 8 N and t = (1.5 & 3.5 hr.) .

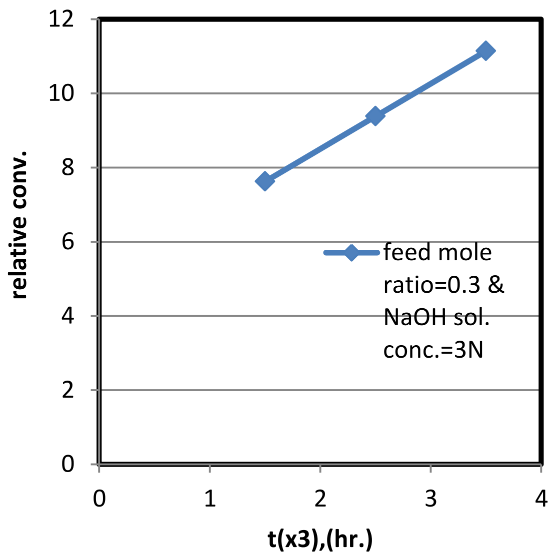

Figure 20 . Relative conversion vs. t (x_3) , (hr.) for feed mole ratio = 0.3 and NaOH sol. conc. = 3 N .

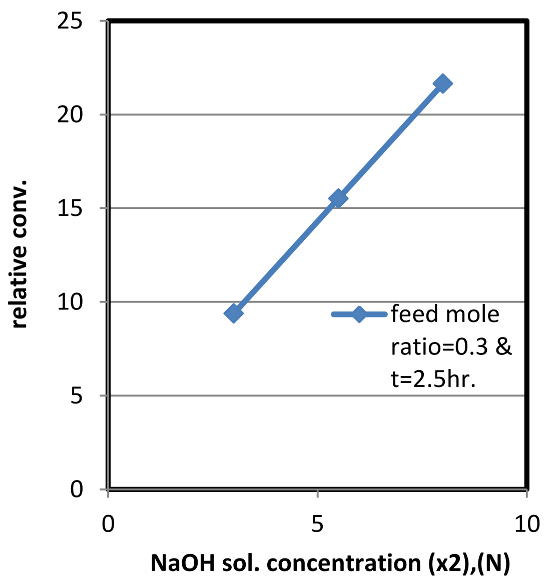

Figure 19. Relative conversion vs. NaOH sol. conc. (x_2) , (N) for feed mole ratio = 0.3 and t = 2.5 hr.

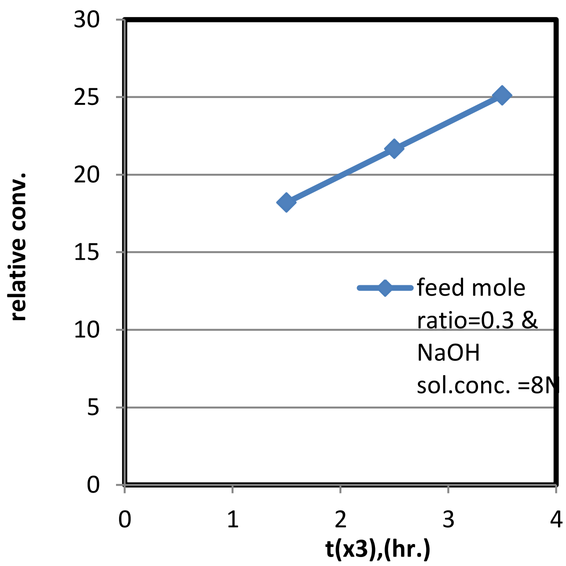

Figure 21 . Relative conversion vs. t (x_3) , (hr.) for feed mole ratio = 0.3 and NaOH sol. conc. = 8 N .

Design and Simulation of Sliding Mode Fuzzy Controller for Nonlinear System

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ABSTRUCT

Sliding Mode Controller (SMC) is a simple method and powerful technique to design a robust controller for nonlinear systems. It is an effective tool with acceptable performance. The major drawback is a classical Sliding Mode controller suffers from the chattering phenomenon which causes undesirable zigzag motion along the sliding surface. To overcome the snag of this classical approach, many methods were proposed and implemented. In this work, a Fuzzy controller was added to classical Sliding Mode controller in order to reduce the impact chattering problem. The new structure is called Sliding Mode Fuzzy controller (SMFC) which will also improve the properties and performance of the classical Sliding Mode controller. A single inverted pendulum has been utilized for testing the design of the proposed controller. Programming and Simulink by Matlab have been used for the simulation results.

Key words: sliding mode control, fuzzy logic control, sliding mode fuzzy control, chattering phenomenon.

تصميم وتنفيذ مسيطرات النمط الأنزلاقي الضبابي لنظام لا خطي

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قسم هندسة السيطرة والنظم

الخلاصة

أن مسيطرات النمط الأنزلاقي هي مسيطرات بسيطة وفعالة للحصول على مسيطر متين وجيد للتعامل مع الأنظمة اللاخطية, وهي طريقة فعالة للحصول على مسيطر متين لا خطي يعطي نتائج ذات مواصفات جيدة ومقبولة. أن ظاهرة التذبذب هي أكثر ظاهرة سيئة تعاني منها أنظمة النمط الأنزلاقي. وتسبب هذه الظاهرة حركة متعرجة على أمتداد السطح الأنزلاقي. لتقليل ظاهرة التذبذب في أنظمة النمط الأنزلاقي تم أقتراح عدد من الطرق. في هذا البحث تم أضافة المسيطر الضبابي الى المسيطر الأنزلاقي من أجل التغلب على مشكلة ظاهرة التذبذب. الشكل الجديد للمسيطر يدعى مسيطر النمط الأنزلاقي الضبابي الذي سوف يحسن مواصفات وخصائص مسيطرات النمط الأنزلاقي. تم أستخدام البندول الأحادي المقلوب لأختبار مسيطر النمط الأنزلاقي الضبابي الذي تم أقتراحه. لقد تم أستخدام البرمجة بلغة ماتلاب لأيجاد النتائج.

ألكلمات الرئيسيه: سيطرة السطح الأنزلاقي, سيطرة السطح الضبابي, سيطرة السطح الأنزلاقي الضبابي, ظاهرة التذبذب.

1. INTRODUCTION

Most nonlinear systems suffer from uncertainty in their dynamic parameters which necessitates the design of high performance controllers. Today, many strong and new methods are used to design adaptive nonlinear robust controllers with acceptable performance. The Sliding mode controller (SMC) is one of the best nonlinear robust controllers that can be used in nonlinear systems that suffer from parameters uncertainty, **Utkin, 2009**. The sliding mode controller was first proposed in the 1950. It is consists of two phases; reaching and sliding phases. In reaching phase, the sliding mode control drives the state trajectory, from any initial point, toward the sliding surface in the state space by using a discontinuous control action. In sliding phase, it will force the state trajectory to stay on this sliding surface and to slide along this surface until reaching the origin. In this method, the control action was smoothed to reduce the chattering. The ultimate advantage of using sliding mode controller is achieved when the sliding surface becomes insensitive to parameters uncertainty or external disturbances inside a plant, **AL-Samarraie 2011.** The chattering phenomenon that results from the discontinuous control action is, however, a severe problem in SMC. In a method called modified sliding controller, the boundary layer was employed in order to reduce the chattering phenomenon, **Hamoudi, 2014** and **Piltan, et al., 2011.** The disadvantages of using pure sliding mode controller were resolved after adopting a modified sliding mode controller scheme. Some authors used Genetic algorithms to improve the classical sliding mode controller, **Wong, et al., 2001 and Lin, 2003.** Others combined fuzzy logic controller (FLC) with the sliding mode control method (SMC) to overpass the disadvantages of the pure sliding mode controllers, **Rahmdel, and Bairami, 2012.** Fuzzy logic controller is, however, weaker in testing the stability. Nevertheless, the stability can be ensured by combining together fuzzy and sliding mode controllers to get a new; more practical, structure called sliding mode fuzzy controller (SMFC). In the current study, a sliding mode fuzzy controller (SMFC) was used in order to reduce the chattering phenomenon; usually appears with pure sliding mode controllers.

2. SLIDING MODE CONTROL (SMC)

For nonlinear systems control, the most challenging problem in designing a control algorithm is to design a linear controller for nonlinear systems. This method, however, needs some stringent setup in which the controller must work near the system operating point. This is very difficult for large variations in dynamic system parameters and high nonlinearities **Lin, and Chen, 1994**. To solve the above problems in nonlinear systems, most researches went toward designing a nonlinear controller. SMC is one of the most powerful nonlinear techniques; first proposed in the 1950 and was used later in wide range applications due to its acceptable control performance. This controller ensures insensitive control systems to unpredicted disturbance and parameters uncertainty.

The sliding surface can be represented as;

$s(x,t) = \lambda x + \dot{x} = 0$; Where λ is constant with positive value. (1)

Let us define that $x_1 = x \; and \; x_2 = \dot{x}$, so the sliding surface will be re-written as:

$$s = \lambda x_1 + x_2$$

And for $\lambda = 1$ the sliding surface will be as:

$$s = x_1 + x_2 \tag{2}$$

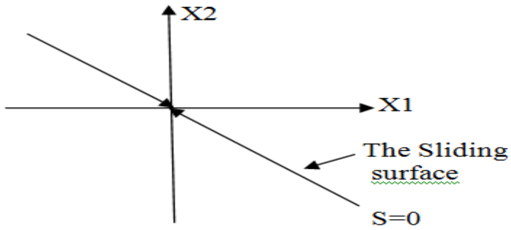

Figure 1. The sliding surface in state space for $\lambda = 1$.

The idea is to keep $s(x,t)$ near zero, in the phase plane, and to derive the system's state trajectory to sliding surface, $s(x,t) = 0$, if it is outside the sliding surface.

The control law of sliding mode controller can be described as:

$$u = u_{eq} + u_{dis} \tag{3}$$

Where, u_{eq} represent the equivalent part of SMC and u_{dis} is the discontinuous part.

The u_{dis} is defined as;

$$u_{dis} = -k.\ sign(s) \tag{4}$$

Where k is constant and its value is $k > 0$, where the $sign(s)$ function can be described and defined as;

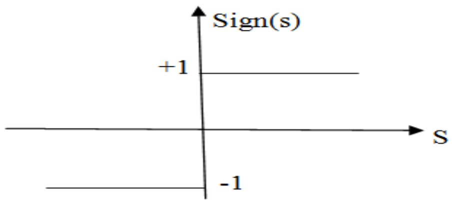

Figure 2. Sign(s) function.

$$sign(s) = \begin{cases} +1 & s > 0 \\ -1 & s < 0 \\ 0 & s = 0 \end{cases} \tag{5}$$

Therefore equation (3) can be re- written as

$$u = u_{eq} - k.\ sign(s) \tag{6}$$

3. MODIFIED SLIDING MODE CONTROL

To reduce the chattering phenomenon, the modified sliding mode controller will be used. The new controller is achieved when using the boundary layer function $sat(s)$ instead of the $sign(s)$ function. The $sat(s)$ function is described as;

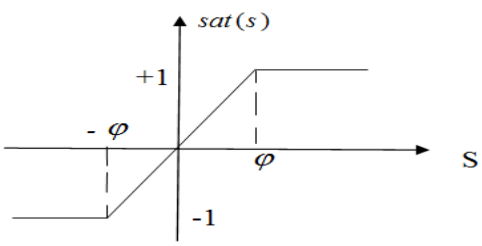

Figure 3. The $sat(s)$ **function**.

$$sat(s/\varphi) = \begin{cases} +1 & (s/\varphi > 0) \\ s/\varphi & (-1 < s/\varphi < 1) \\ -1 & (s/\varphi < 0) \end{cases} \tag{7}$$

Where φ is the thickness of the boundary layer

$$u_{dis} = u_{sat} = -k.\ sat(s/\varphi) \tag{8}$$

By substituting **Eq. (8)** in **Eq. (3),** the total control will be described as;

$$u = u_{eq} + u_{sat} \tag{9}$$

$$\therefore u = u_{eq} - k.sat(s/\varphi) \tag{10}$$

4. FUZZY LOGIC CONTROL

In 1960, the control science made use of the fuzzy logic theory to design a powerful fuzzy logic controller to control nonlinear systems which suffer from parameters uncertainty and nonlinearity**.** In many applications, when using pure fuzzy controller, the stability cannot be guarantee and the performance may be unacceptable. The fuzzy logic controller (FLC), used in this work, is based on Mamdani's method and consists of many stages as described below;

4.1 Fuzzification: In this stage the inputs and outputs must be determined firstly and then selecting the suitable membership function (MF) according to this input and output.

4.2 Fuzzy rule base: The rules in this stage consist from two parts, the antecedent and the consequent. The antecedent contains inequality or suitable relation that must be satisfied. Satisfying the antecedent will give the consequent. This point is exemplified as follows. If A is satisfied, then the output is B. Where; (A) and (B) are the antecedent and the consequent respectively.

4.3 Aggregation of the rules: It is the process of obtaining the total conclusion from the consequents that come from each rule.

4.4 Defuzzification: This is the final stage, where, the fuzzy output set is converted to crisp output value. There have been many defuzzification methods introduced; one such was used in this work, and is called the center of area (COA).

5. SLIDING MODE FUZZY CONTROL (SMFC)

SMC is a strong mathematical tool which can be considered as a robust nonlinear controller with acceptable performance. This controller can be used in nonlinear systems with parameters uncertainty. However, pure SMC is suffering from chattering problem which is undesired properties. For this reason, the present work focuses on combining fuzzy logic with sliding mode controllers to obtain a new structure; called SMFC of better performance (small settling time, fast response, and with no oscillation). Our main task is to find a suitable control law, for system's output, capable of tracking reference trajectories. The structure of the SMFC is consisting of two parts as explained bellow:

1: The SMC: This part has error (e) as its input and u_s as its output.

2: The fuzzy controller: This part has one input (s) and one output (u_{fuzzy}). The input, s , is come from the output of the sliding mode controller. The membership functions of the fuzzy controller are illustrated in **Fig. 4** bellow:

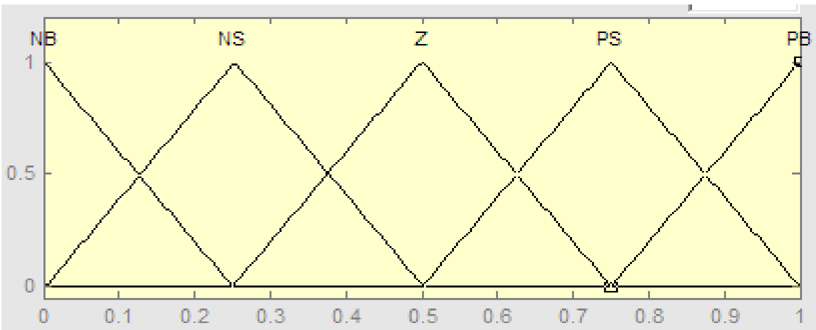

Figure 4. The membership function of the fuzzy controller

Where; *NB*, *NS*, *Z*, *PS*, *PB* are linguistic terms of antecedent fuzzy set. They mean negative big, negative small, zero, positive small, and positive big, respectively. A general form can be used to describe the fuzzy rules as it shown below:

$$if\ \ S\ is\ A_i,\ then\ U_f\ \ is\ B_i,\ i=1,\dots\dots\dots,5 \qquad (11)$$

Where A_i represent the fuzzy triangle-shaped number and B_i represents the fuzzy singleton.

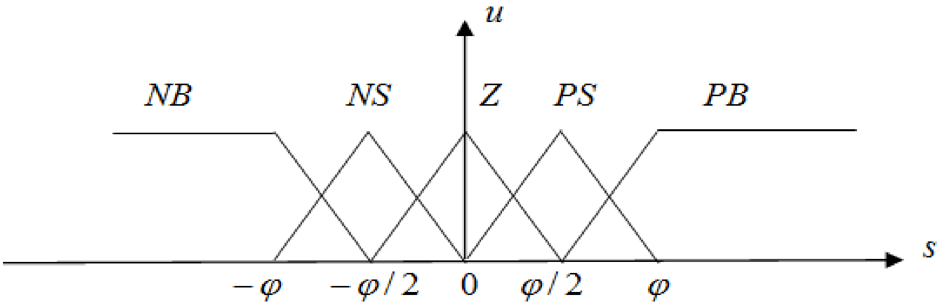

Figure 5. The input membership function of the sliding mode fuzzy controller

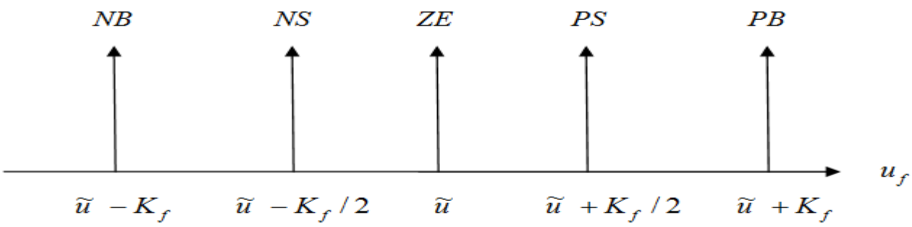

Figure 6. The output membership function of sliding mode fuzzy controller

From **Fig. 5 and Fig. 6,** it can be concluded that for the sliding mode fuzzy controller

$$u=\tilde{u}-k_f.sig(s/\varphi) \qquad (12)$$

$$sig(a)=\begin{cases}+1\ if\ \ a\geq 1\\ a\ \ if\ -1\langle a\langle 1\\ -1\ if\ a\leq -1\end{cases} \qquad (13)$$

From above, it can be concluded that the control signal in the sliding mode fuzzy controller in **Eq. (12)** and the modified sliding mode controller in **Eq. (10)** are completely the same. In the design of SMFC, the membership function for the input and output of the fuzzy controller part can be found after making use of the modified sliding mode controller. In **Eq. (12)** for the SMFC, the center of the fuzzy output $\tilde{u}$ and the gain k_f can be substituted by u_{eq} and k respectively of **Eq. (10)** for the modified sliding mode controller. So, completely stability and robust can be ensured for the fuzzy controller part in SMFC. The total controller of the SMFC will, therefore, be described as:

$$u_{total} = u_{sliding} + u_{fuzzy} \tag{14}$$

Where $u_{sliding}$ is defined in **Eq. (10).** So **Eq. (14)** can be re-written as:

$$u_{total} = u_{eq} - k.sat(s/\varphi) + u_{fuzzy} \tag{15}$$

6. SINGLE INVERTED PENDULUM

The proposed Sliding Mode Fuzzy Control was implemented to single inverted pendulum systems. The position of such system is widely used in engineering systems. The main advantage of using this system is its ability for high tracking, fast response, no overshoot, and high robustness. The dynamic equation of single inverted pendulum can be given as in **Wang, Wu, 2009**.

$$\dot{x}_1 = x_2$$

$$\dot{x}_2 = -\frac{g\sin x_1 - mlx_2^2\cos x_1 \sin x_1/(m_c+m)}{l(4/3 - m\cos^2 x_1/(m_c+m))} + \frac{\cos x_1/(m_c+m)}{l(4/3 - m\cos^2 x_1/(m_c+m))}u(t) + d(t)$$

Where x_1 is the angular position, x_2 is the velocity, $g = 9.81 m/s^2$, m_c is the mass and $m = 0.1kg$, $l = 0.5m$ is a half length, u is the control input and $d(t)$ is the external disturbance.

In this work, it is assumed that $d(t) = 0,$ and the initial condition is $x(0) = [pi/8 \quad 0]^T$

7. SIMULATION RESULTS

In this section two sets of results are obtained. The first is obtained by using the classical sliding mode controller described in **Eq. (6).** The second set is obtained by using the proposed approach "the sliding mode fuzzy controller" described in **Eq. (15).** In both cases, it is assumed that $k = 10$. The figures from **Fig. 7** to **Fig. 11** are belonging to the classical SMC, where the figures from **Fig. 12** to **Fig. 16** are belonging to the proposed SMFC. The results in SMFC are found by assuming $\varphi = 1.$

8. DISCUSSION

In this paper, two controllers are used for testing the single inverted pendulum. The first is the classical sliding mode controller; described in **Eq. (6)** and the second is the sliding mode fuzzy controller described by **Eq. (15)**; to reduce the chattering associating the classical SMC.

Fig. 9 shows the undesired chattering which appears clearly in the classical SMC. This undesired chattering was highly reduced after using the proposed SMFC method as it is shown clearly in **Fig. 14.** In classical SMC the chattering is illustrated because the system state hits the sliding surface vertically as it is shown in **Fig. 11**. When using the proposed method SMFC, the system state hits the sliding surface approximately in an arc shape as shown in **Fig. 16.** As a result, the chattering was reduced. Also in classical SMC, it is noticed clearly that the error in **Fig. 7** and the derivative of error in **Fig. 8** are reached zero value in steady state. This is also appeared clearly when plot the phase plane between x_1 and x_2 in **Fig. 11.** These zero values in error and derivative of error means that the system is asymptotically stable, and this is considered as important properties of the SMC. The same result is illustrated when using the proposed method SMFC as it is shown clearly in **Fig. 12, Fig. 13,** and **Fig. 16.** These results of both the classical SMC, and the proposed method SMFC, lead us to conclude the ability of both types of controllers to force the system to be asymptotically stable when they are used with it.

9. CONCLUSION

The obtained results show an improvement in the response of the proposed SMFC. The chattering usually appear in the classical SMC has been reduced as it is seen clearly when comparing between **Fig. 9 and Fig. 14.** Also from the above results, it can be seen clearly the ability of both controllers, the classical SMC and the proposed SMFC, to make the system in asymptotically stable case by making the error and the derivative of error at zero value as it shown clearly in **Fig. 7, Fig. 8,** and **Fig. 11** in classical SMC and **Fig. 12, Fig. 13,** and **Fig. 16** in proposed SMFC**.** This is an important property that is associated with the SMC and SMFC.

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Table 1. Table of fuzzy rules for **Fig. 5 and Fig. 6** in SMFC system

S	*NB*	*NS*	*Z*	*PS*	*PB*
U_f	*PB*	*PS*	*ZE*	*NS*	*NB*

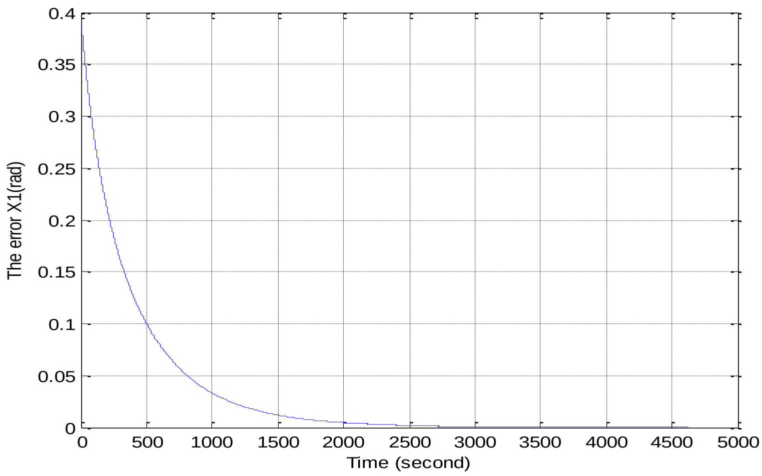

Figure 7. The error x_1 vs. time in classical SMC.

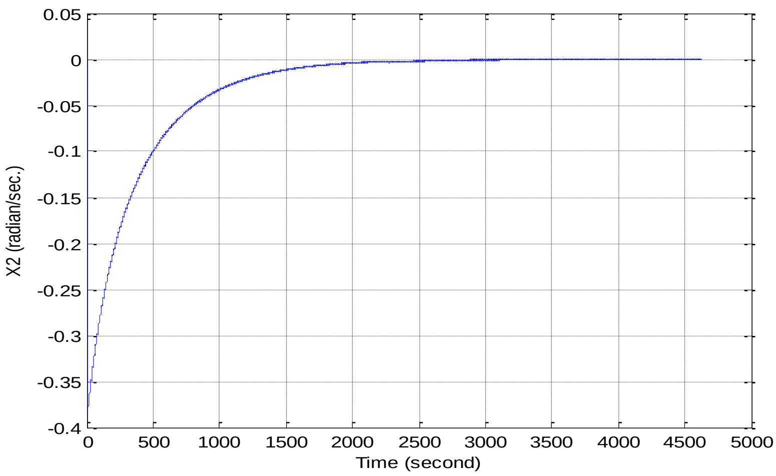

Figure 8. Plot of x_2 vs. time in classical SMC.

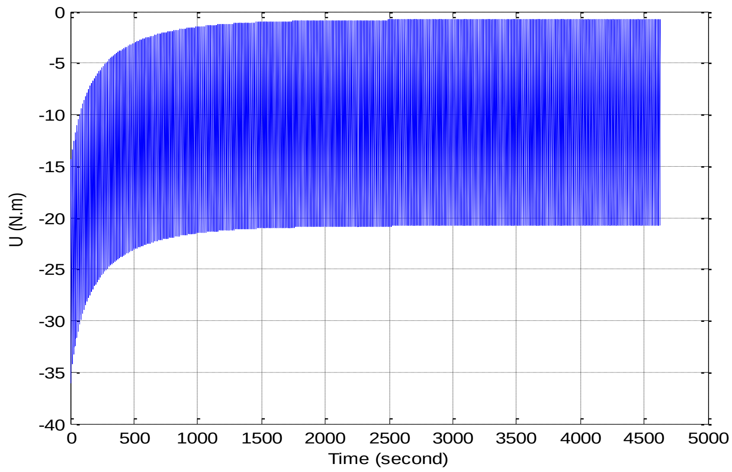

Figure 9. The control action U vs. time in classical SMC**.**

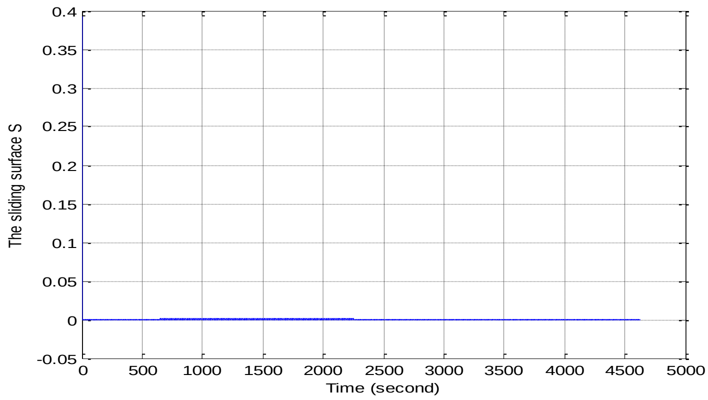

Figure 10. The sliding surface S vs. time in classical SMC**.**

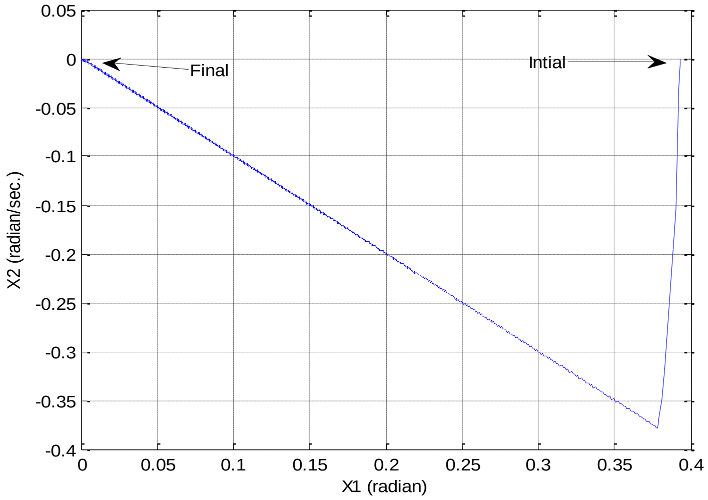

Figure 11. The phase plane between x_2 and x_1 in classical SMC.

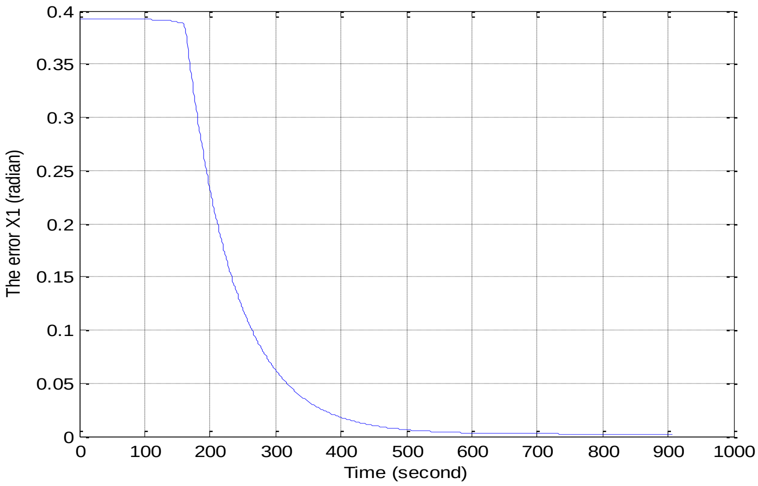

Figure 12. Plot of the error x_1 vs. time in SMFC.

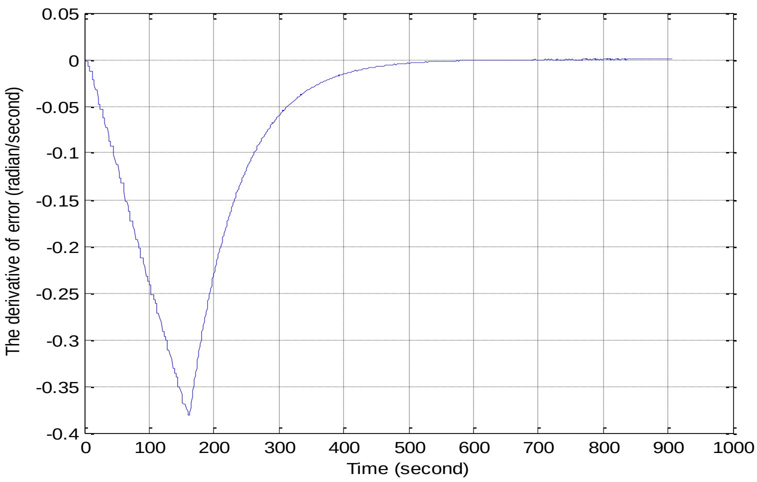

Figure 13. Plot of x_2 vs. time in SMFC.

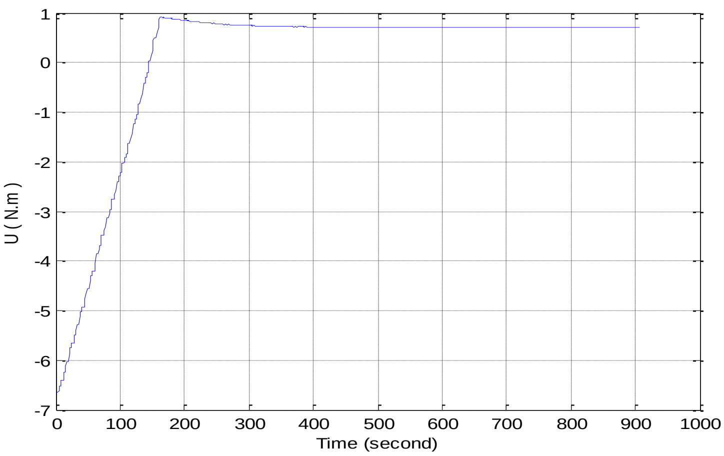

Figure 14. The control action U vs. time in SMFC.

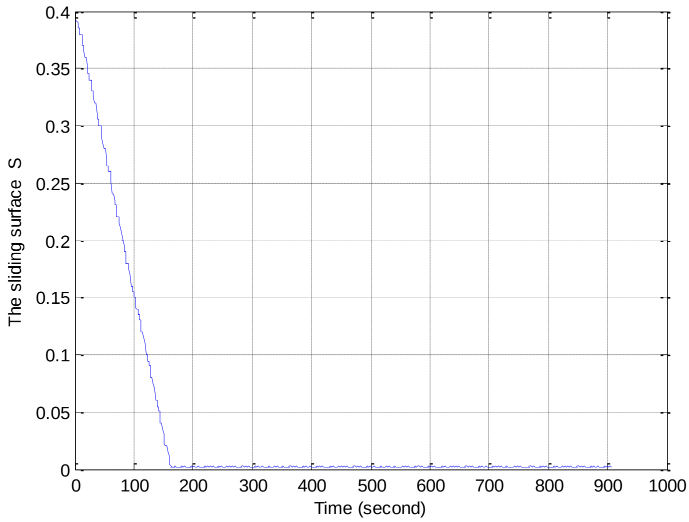

Figure 15. The sliding surface S vs. time in SMFC.

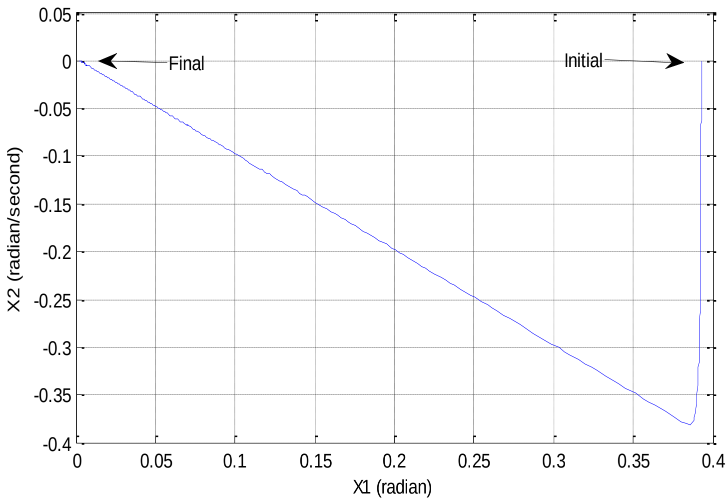

Figure 16. The phase plane between x_2 and x_1 in SMFC.

Energy Dissipation on the Ogee Spillways by Using Direction Diverting Blocks

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ABSTRACT

The purpose of this study is to evaluate the hydraulic performance and efficiency of using direction diverting blocks, DDBs, fixed on the surface on an Ogee spillway in reducing the acceleration and dissipating the energy of the incoming supercritical flow. Fifteen types of DDB models were made from wood with a triangulate shape and different sizes were used. Investigation tests on pressure distribution at the DDBs boundaries were curried out to insure there is no negative pressures is developed that cause cavitation. In these tests, thirty six test runs were accomplished by using six types of blocks with the same size but differ in apex angle. Results of these test showed no negative pressures developed at the boundaries of these blocks. A physical model for a part of Mandili Dam spillway system was constructed with a scale ratio of 1:50. Thirteen runs were carried out to obtain the rating curve of the ogee weir of Mandili Dam Model. Four hundred and seventy test runs were carried out to investigate the performance of the DDBs in reducing the energy of the flow. In these test runs, nine types of blocks with different sizes and different apex angles installed with different configurations on the spillway surface. Thirteen configurations of DDBs were tested. The Froude Number and the location of the hydraulic jump were used as indicators for the efficiency of these DDBs. Results indicated that when using the DDBs on a spillway surface, less Froude Number downstream the spillway is obtained and the hydraulic jump occurs at a much shorter distance from the spillway toe compared to same spillway without DDBs. Depending on the DDBs type, configuration, and the applied discharge, the obtained reduction in Froude Number varied between 4.4 to 19.3% and the reduction in the hydraulic jump distance measured from the spillway toe varied between 54% and 76% compared with that of the standard design of Mandili Dam.

Key words: energy dissipation, ogee spillway, stilting basin.

تبديد الطاقة على المطافح نوع اوجي باستخدام كتل تغيير الاتجاه

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الخلاصة

هدفت هذه الدراسة الى اختبار اداء وكفاءة استخدام كتل تغيير الإتجاه مثبتة على سطح مطفح مائي نوع اوجي في تقليل تعجيل وتشتيت طاقة المياه ذات الجريان فوق الحرج. تم اختبار خمسة عشر نموذجا من هذه ألكتل مصنعة من الخشب ذات اشكال مثلثة وباحجام مختلفة. اختبر توزيع الضغوط على جوانب هذه ألكتل لاختبار فيما اذا كان هنالك ضغوط سالبة متولدة يمكن أن تؤدي إلى حدوث ظاهرة التكهف. اجري ستة وثلاثون اختبارا بتصاريف مختلفة وباستخدام ستة أنواع من كتل تغيير ألاتجاه ذات حجم ثابت وتختلف بمقدار ألزاوية ألراسية. بينت نتائج هذه ألاختبارات عدم تولد ضغوط سالبة على جوانب هذه الكتل. انشئ نموذج فيزيائي للتصميم الأساسي لسد مندلي وبمقياس 50:1 وثبت في قناة مختبريه وحددت علاقة التصاريف المارة فوق الهدار بمنسوب الماء على اساس نتائج ثلاثة عشر اختبارا. اجري أربعمائة وسبعين اختبارا لتحديد اداء

كتل تغيير اتجاه الجريان باستخدام تسعة أنواع من ألكتل بأحجام وزوايا رأسية مختلفة وتم توزيعها و تثبيتها على سطح ألمسيل ألمائي بتسعة انماط مختلفة. اعتمد رقم فرود مؤخر المطفح ومقدرا بعد مسافة تولد القفزة الهيدروليكية عن اسفل المطفح كمؤشرات لتحديد كفائة الاداء. بينت نتائج الاختبارات المختبرية كفاءة هذه ألكتل في تقليل رقم فرود للجريان أسفل ألمسيل ألمائي وتقليل طول حوض ألتسكين. اعتمادا على نوع الكتل وطريقة توزيعها على سطح المطفح فان نسبة التقليل في رقم فرود تراوحت بين 4.5 و 19.3% ولمسافة تولد القفزة الهيدروليكية تراوحت بين 54 و76% مقارنة بالتصميم الاساس لمنظومة مطفح سد مندلي.

1. INTRODUCTION

High kinetic energy of water flowing over a spillway should be dissipated in stilling basins before reaching the downstream channel to eliminate scour of downstream river bed. Different common designs of stilling basins are available. These basins are usually equipped by a combination of chute blocks, baffle blocks, and end sills. Spillway surface was used to dissipate the energy in the ancient past by constructing a stepped spillway. This study attempts to make use of the ogee spillway surface by fixing energy dissipaters on it to reduce the acceleration and energy of the flow over a spillway. A new type of blocks was used as energy dissipaters that are known by direction diverting blocks, DDBs, **Fig. 1**. These blocks have a triangular shape with a different apex angle. The direction of incoming flow over the spillway of high kinetic energy is diverted by triangular shape DDBs to both sides. The diverted flow of two adjacent blocks having an opposite velocity component across the flow direction will meet at a point downstream the blocks. If more than one row of DDBs were used on the spillway surface, then the diverted flow from the previous row hits the side of the blocks at the next row. This causes a reduction in the acceleration of the incoming flow along the spillway and a high turbulence increases the energy dissipation. This study attempts to evaluate the hydraulic performance and efficiency of using DDBs in reducing dissipating the energy downstream ogee spillways.

2. PHYSICAL MODELS OF THE DDBS AND THE SPILLWAY

Fifteen type of triangular shape DDB models were used with different shapes and sizes. The main details of these blocks models are shown in **Fig. 2** and their dimensions are presented in **Table 1**. These models were made from wood and coated with varnish to protect them from damage by water. The DDBs were fixed by using special glue. The first six of these blocks were used for pressure distribution tests, and the last nine were used for energy dissipation tests.

To make comparisons between the energy dissipation with and without using DDBs, the system of Mandili Dam Spillway was selected to be modeled. Mandili Dam has the following characteristics, **General Directorate for Dams and Reservoirs, 2006**:

- Dam Height: 14*m*.
- Dam length = 1150*m*.
- Dam crest level =184*m.a.m.s.l.*
- Maximum water level=182.5*m*.
- Maximum Discharge =1724m^3/s.
- Spillway length =250*m*.
- Maximum head over spillway=2.5*m*.
- Maximum design discharge is 1724m^3/s
- Spillway crest elevation=180 *m.a.m.s.l.*

Mandili spillway was designed as an uncontrolled ogee weir. Its stilling basin floor level was set to 165*m.a.m.s.l* with a length of 21.5*m*. Chute blocks and dentated sills were provided in the stilling basin. The chute blocks have a width of 0.5*m* and height of 0.5*m*; the dentate sill has a height of 1*m*, a top width of 0.1*m*, distance between teeth is 0.75*m*, and an out slope of 2:1. A slopping hump was located at the end of the stilling basin at an elevation 169.00*m.a.m.s.l*. This hump is of 7*m* in length with an inclination of 1.5V:5H.

The hydraulic model of Mandili Dam Spillway system was constructed with a scale of 1:50. Based on the Laboratory channel width of 30*cm*, a part of the weir of 15*m* was modeled and tested. **Fig. 3** shows the longitudinal section in the physical model of Mandili Dam Spillway. The spillway model was constructed from wood, and was coated with plies of varnish.

3. CONFIGURATIONS OF THE DDBS

Laboratory tests were carried out to investigate any development of negative pressures at the boundary of the DDBS and the efficiency of these blocks in dissipation of the flow energy. In negative pressures investigation tests, DDBs were fixed in one row perpendicular to the flow direction of a flume of 30*cm* in width. Six types of DDBs, blocks of type 1, 2, 3, 4, 5, and 6, were used in these tests. The blocks were fixed on a wooden plate installed in the flume with a longitudinal slope of 1:30 in the direction of the flow. Eight piezometers were installed with their openings are located at the base of the blocks as shown in **Fig. 4**.

The energy dissipation tests were carried out with DDBs of type 7, 8, 9, 10, 11, 12, 13, 14, and 15, arranged in thirteen different configurations that are shown in **Figs. 5** to **13**. In these configurations, blocks were used in one or multi rows on the spillway surface with varying distances between the blocks and rows, with and without a stilling basin. In addition, these tests were carried with a modified length of the stilling basin of Mandili Dam Spillway or without a stilling basin. **Tables 2** and **3** present the details of these thirteen configuration and the types of DDBs used in each configuration, respectively.

4. RESULTS AND DISCUSSION

The piezometers readings were recorded in each pressure investigation test when using the six types of DDBs and discharges varied between of 2.5 and 8.8*l/s*. **Fig. 14** shows the variation of pressure head readings of the piezometers with discharge for each type of DDBs. At the upper limit of the applied discharge of 8.8*l/s*, the maximum value of pressure head varied between 4.2 and 4.6*cm* that was obtained when using DDB of type 6 and the minimum value of pressure head varied between 3.4 and 3.7*cm* that was obtained when using DDBs of types 1 and 2. At the lower limit of the applied discharge of 2.5*l/s*, the maximum value of pressure head varied between 1.5 and 3*cm* that was obtained when DDB type 6 was used, and the the minimum value of pressure head ranged between 1 and 1.7*cm* that was obtained DDB types 1 was used. It was found that the measured pressures at these eight points were positive for all the range of the used discharges and for all block types.

The rating curve of Mandili Dam Weir model was obtained and was used to obtain the discharge during other the tests. **Fig. 15** shows a comparison between the obtained rating curve in this research, design, the rating curve of the hydraulic model of Mandili Dam, **Rafidain State Company for Dams Construction, 2008**, and that obtained according to Chow's charts, **Chow, 1959**. Discharges reading using the obtained rating curve are higher than other rating curves. This may be referred to the accuracy working in lab conditions and to high smoothness of model surface.

To show the effectiveness of the DDBs in dissipation of energy, the energy dissipation in the standard design of Mandili Dam was investigated then the DDBs of type 1 to 12 were installed at its spillway with configurations Number 1, 2, and 3. In these tests, the applied discharges varied between 200 and 1725m^3/s (0.68 and 6*l/s* in the model) and in each test, the flow depths at 20*cm* upstream the weir model and at a distance of 100*cm* downstream of the spillway toe were measured to obtain the discharge and the Froude Number.

It is logical to adopt the downstream Froude Number as the dimensionless parameter as a criterion in assessing the hydraulic performance of stilling basins, **Eloubaidy et al., 1998.** The occurrence of the hydraulic jump, as well as the sequent depth ratio and the dimensionless energy loss, are functions of the approach Froude Number, **Sturm, 2001**.

Figs. 16 to **18** show the variation of the Froude Number with discharge obtained downstream the standard design of Mandili Dam when carrying out the investigation tests by using blocks type 7 to 12 and configuration 1, 2, and 3. **Table 4** summarizes the obtained extreme values of the Froude Number during these tests. The maximum value of Froude Number was 0.86 which was recorded at the maximum design discharge of 1724m^3/s with configuration number 1 and DDBs of type 7. This value of Froude Number is less by 10.4% than that obtained without using DDBs. At this design discharge, the minimum value of Froude Number was 0.77 which was recorded when using DDBs of type 9 and configuration number 2. This obtained value of Froude Number is less by 19.3% than that obtained without using and DDBs. For the applied minimum discharge of 200 m^3/s, the maximum value of Froude Number was approximately the same for all configurations with all type of blocks, it was about 0.68 and is the same when no DDBs were used. For the same discharge of 200m^3/s, the minimum value of Froude Number varied between 0.63-0.65 for all configurations with all blocks types, with a reduction of 7.4-4.4% than that obtained when no DDBs were used. Froude Number value for configuration number 3 was less than the Froude Number with configurations number 1 and 2. This indicates that the Froude Number decreases by increasing the number of blocks, number of blocks rows, and as the block apex angle decreases.

As a conclusion from results mentioned above, as the Froude Number is reduced when using the DDBs, the flowing water will reach the stilling basin with less kinetic energy. Accordingly, shorter stilling basin can be used at the downstream of the spillway. Modification was made by reducing the length of the stilling basin of the standard design of Mandili Dam and then effectiveness of the DDBs in dissipating energy was tested. The length of the stilling basin was reduced to half and one fourth the length of the stilling basin of the standard design of Mandili Dam. Tests runs were carried out with configurations number 4, 5, 6, 7, 8, and 9. Tests runs with configurations number 4, 5, and 6 were carried out with half the length of the stilling basin of the standard design of Mandili Dam. While, configurations number 7, 8 and 9 have one fourth of the length. Three types of DDBs with small apex angles were selected and used in these tests. DDBs type13 were tested with configurations number 4 and 7, blocks type 14 were tested with configurations number 5 and 8, and blocks type 15 were tested with configurations number 6 and 9. **Figs. 19** and **20** show the variation of the Froude Number with discharge for all configurations with the modified design of the stilling basin of Mandili Dam and the extreme values of the Froude Number are summarizes in **Table 5.** At the maximum design discharge of 1724m^3/s, the maximum value of Froude Number was 0.91 which was obtained with configuration number 8. It is 5.2% less than that obtained with standard design of Mandili Dam. At the same discharge, the minimum Froude Number of 0.86 was obtained with configurations number 5 and 6 with a reduction of 10.4% compared with standard design. At the minimum applied discharge of 200m^3/s, the maximum value of Froude Number was about 0.68 in configurations number 4 and 7, which is the same as in the standard design of Mandili Dam. For the same discharge, the minimum value of Froude Number was the same value of about 0.63 for configurations number 5, 6, and 8, with a reduction of 7.4% compared with standard design of Mandili Dam. In general, the Froude Number values for configurations with a half stilling basin were less than with one fourth length stilling basin. Also, the Froude Number values with these configurations were less than that obtained with standard design of Mandili Dam in all tests within the range of applied discharges.

Based on the above discussion the length of the stilling basin of the standard design of Mandili Dam can be reduced when using the DDBs, without effecting the energy loss and Froude Number values. To investigate the effects of using the DDBs on the Froude Number, and the location of the hydraulic jump, any other energy dissipaters were eliminated, ie. the stilling basin was removed. Experimental runs were carried out on configurations number 10, 11, 12 and 13. **Fig. 21** and **22** show the variation of Froude Number and the distance of hydraulic jump with discharge with configurations number 10, 11, 12, and 13. **Table 6** summarizes the Froude Number and the hydraulic jump distance from the toe of the spillway that were obtained at extreme discharges. the Froude Number values with configuration number 10 vary with a steep slope between discharge values of about $650m^3/s$ and $900m^3/s$ and the flow was supercritical over a discharge of $750m^3/s$. With configurations number 11, 12, and 13, the flow was sub critical with Froude Number less than unity. Under these configurations the flow has approximately the same Froude Number values for all the range of discharge. At the minimum applied discharge of $200m^3/s$, the free hydraulic jump was obtained with configuration number 10 at a distance of 5*m* from the spillway toe with a Froude Number of 0.36. While, a submerged hydraulic jump occurred at the toe of the spillway for configurations number 11, 12, and 13, with a Froude Number varies between 0.17 and 0.18, depending on the block type. The Froude Number reduction in configurations number 11, 12, and 13 is about 49% to 52% compared with configuration number 10. At the maximum applied discharge of $1724m^3/s$, the free hydraulic jump for configuration number 10 was at a distance of 105*m* from toe of the spillway and a high Froude Number of 4.21. The minimum Froude Number of 0.51 was recorded with configuration number 13, with a reduction of 700% compared with configuration number 10. The maximum value of Froude Number was 0.54 recorded with configuration number 11, with a reduction of 660% than configuration number 10. The hydraulic jump distance from the spillway toe was about 48*m*, 40.5*m*, and 25*m* for configurations number 11, 12, and 13, respectively. Compared with configuration number 10, the reduction in the hydraulic jump distance from the spillway toe was 54%, 61%, and 76% for configurations number 11, 12, and 13, respectively, which indicates that the hydraulic jump in test runs with configuration number 13 have the shortest distance from the spillway toe compared to configurations number 10, 11, 12, for all the applied range of discharge. This indicates that increasing the number of blocks rows leads to more dissipation of the energy of the flow.

5. CONCLUSIONS

The results of the laboratory investigation test runs that were carried in this study indicated that the DDBs fixed on the surface of an ogee slipway can be used effectively to reduce the energy of the flow downstream the spillway and accordingly, shorter stilling basin can be used. More energy is dissipated when increasing the number of blocks, number of blocks rows, and as the block apex angle decreases.

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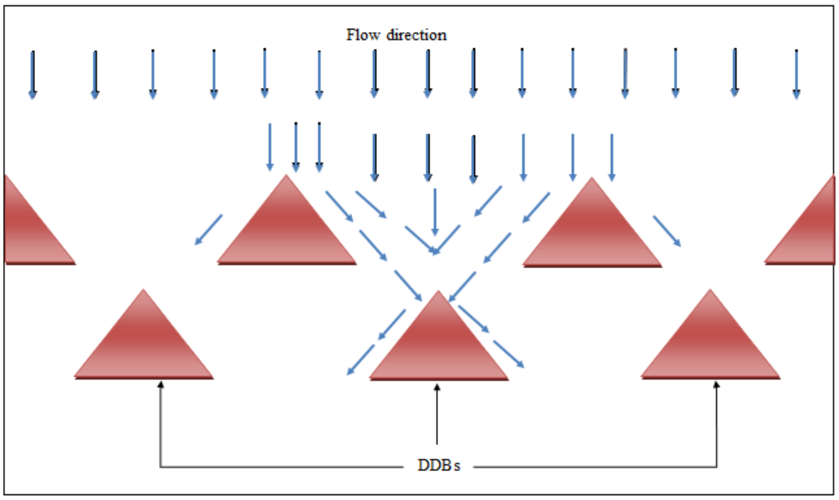


Figure 1. A schematic diagram showing a top view of the DDBs on an ogee spillway surface.

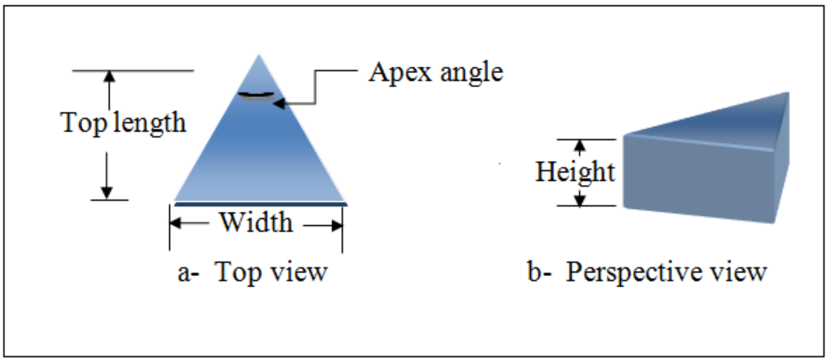


Figure 2. **D**etails of the triangular shape DDBs.

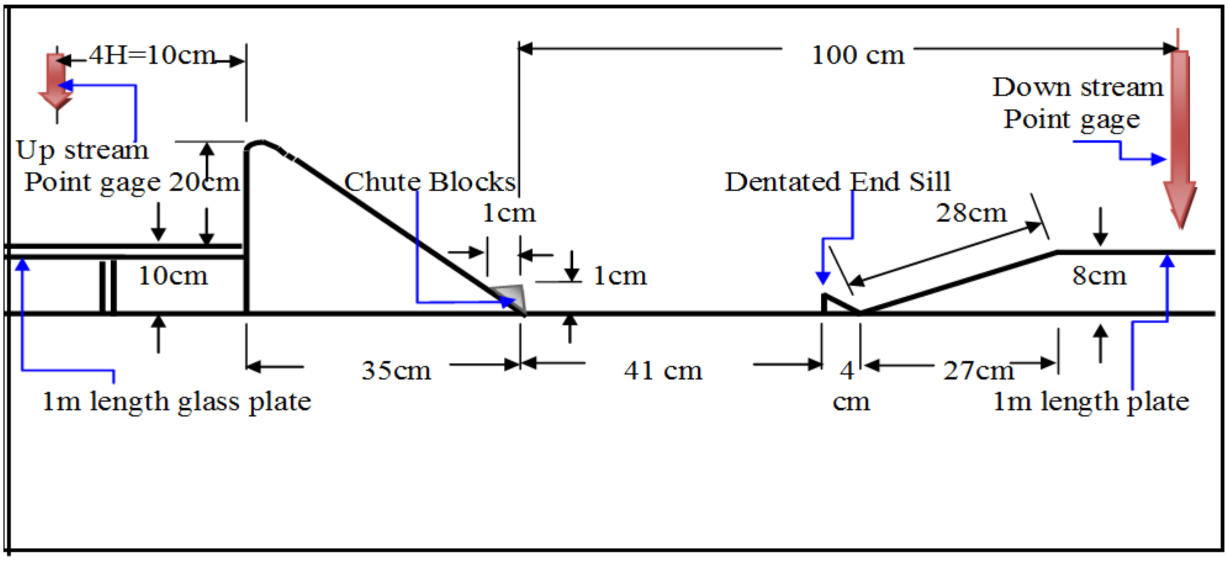
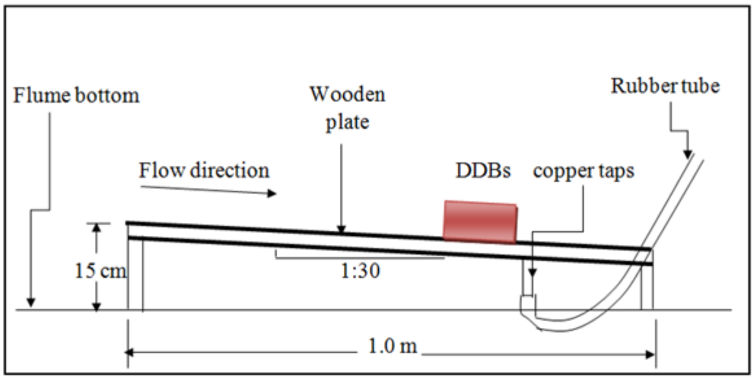
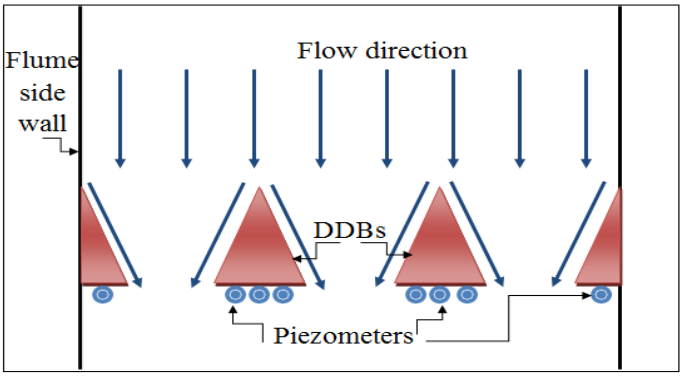


Figure 3. Longitudinal section in the physical model of Mandili Dam Spillway.



a- Side view



b- Top view

Figure 4. Schematic diagram showing the configuration of the pressure tests.

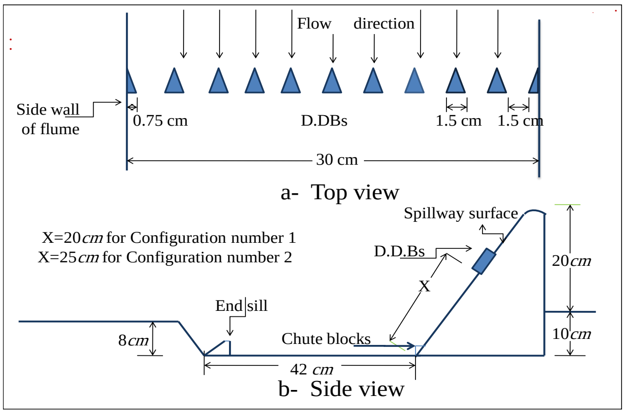


Figure 5. Configurations number 1 and 2.

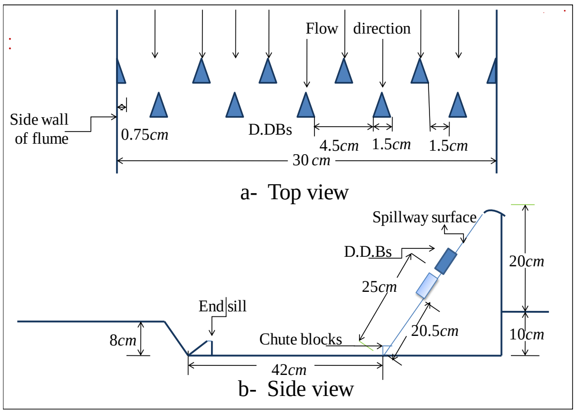


Figure 6. Configurations number 3.

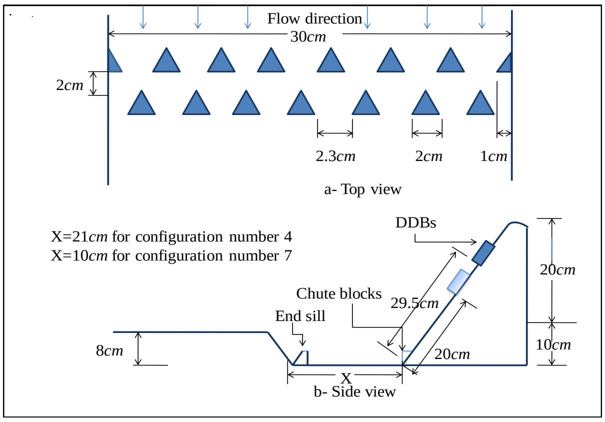


Figure 7. Configurations number 4 and 7.

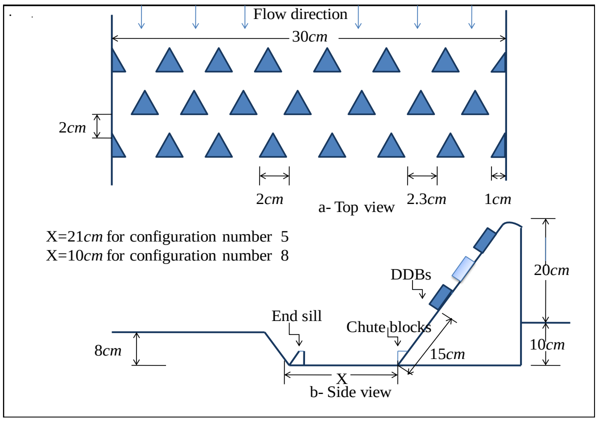


Figure 8. Configurations number 5 and 8.

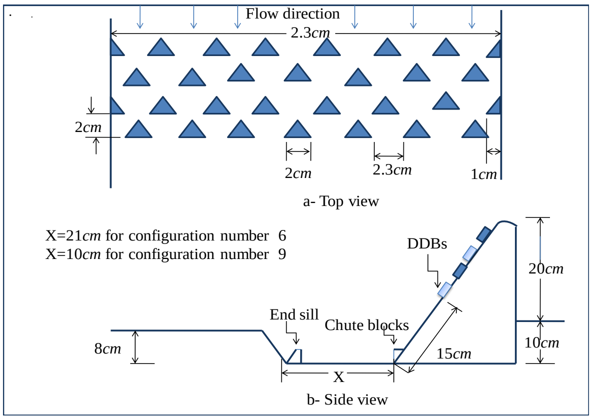


Figure 9. Configurations number 6 and 9.

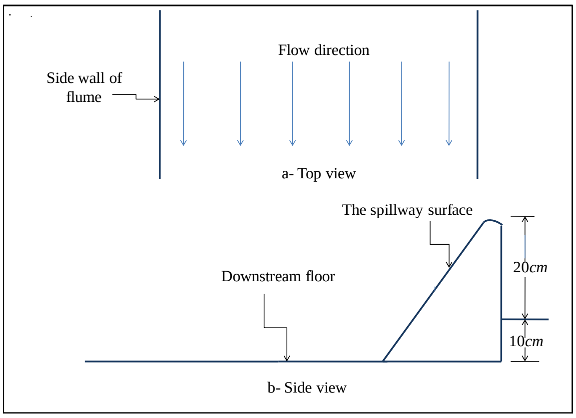


Figure 10. Configuration number 10.

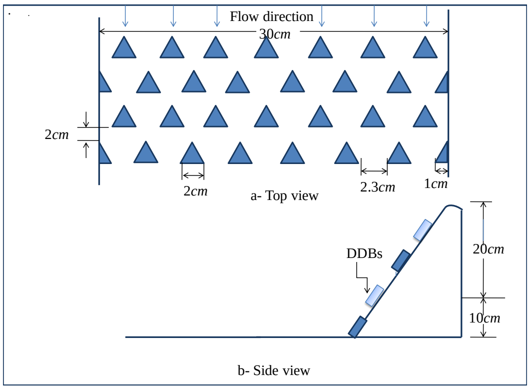


Figure 11. Configuration number 11.

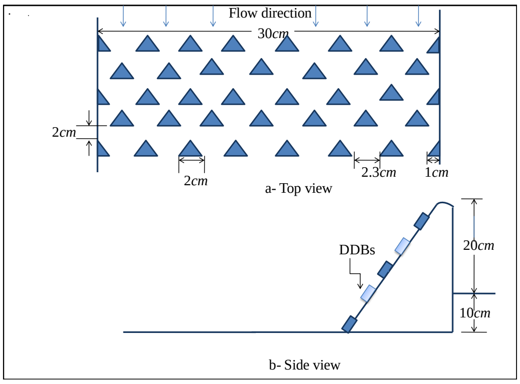


Figure 12. Configuration number 12.

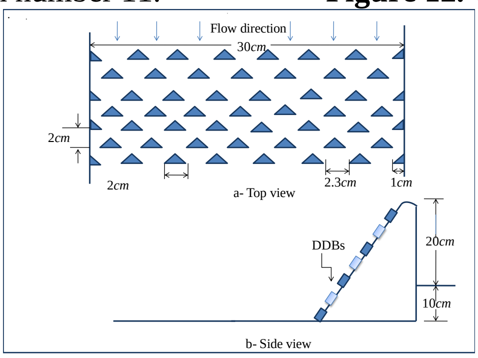


Figure 13. Configuration number 13.

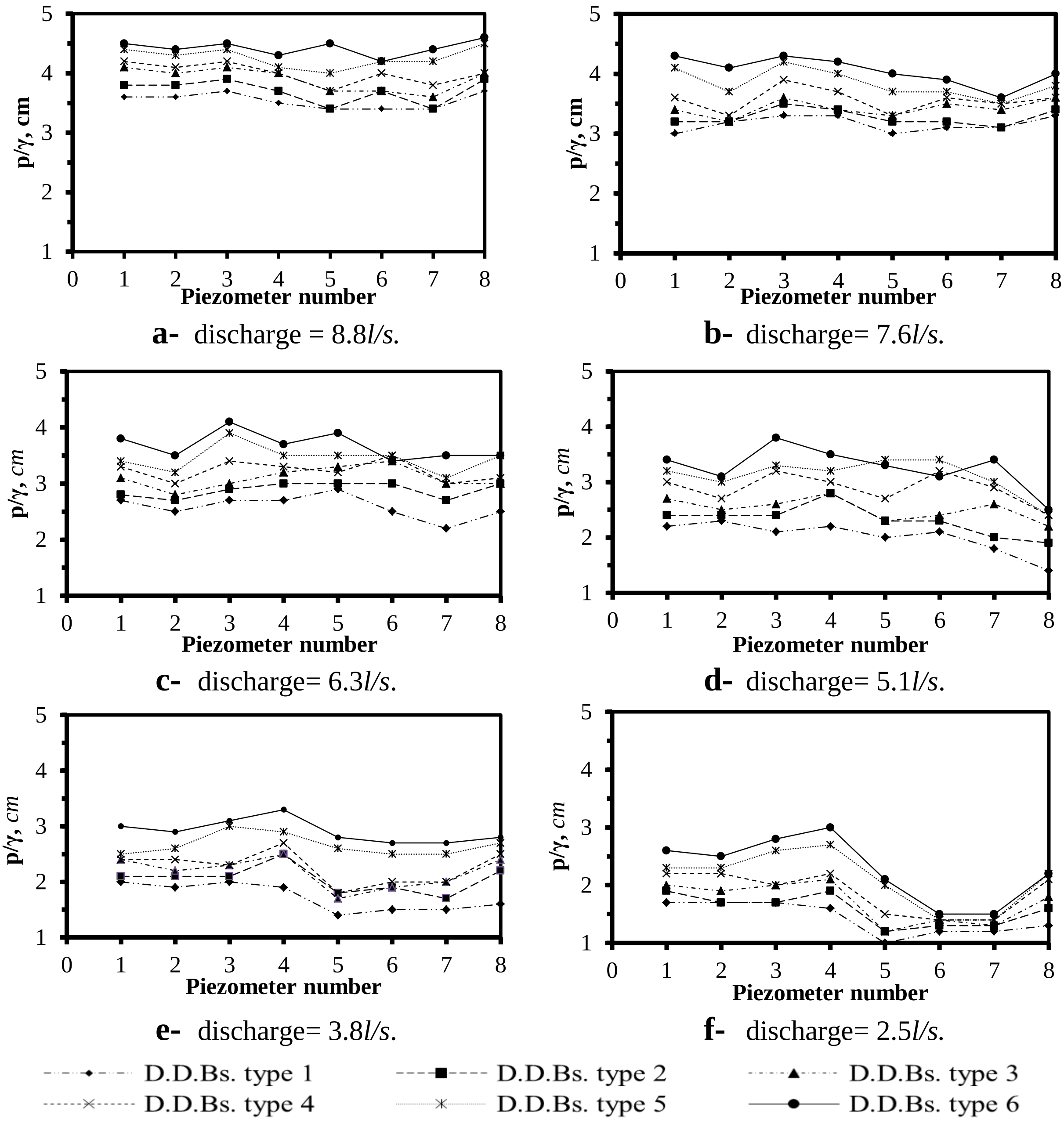


Figure 14. Variation of pressure heads with the applied discharges for each type of blocks.

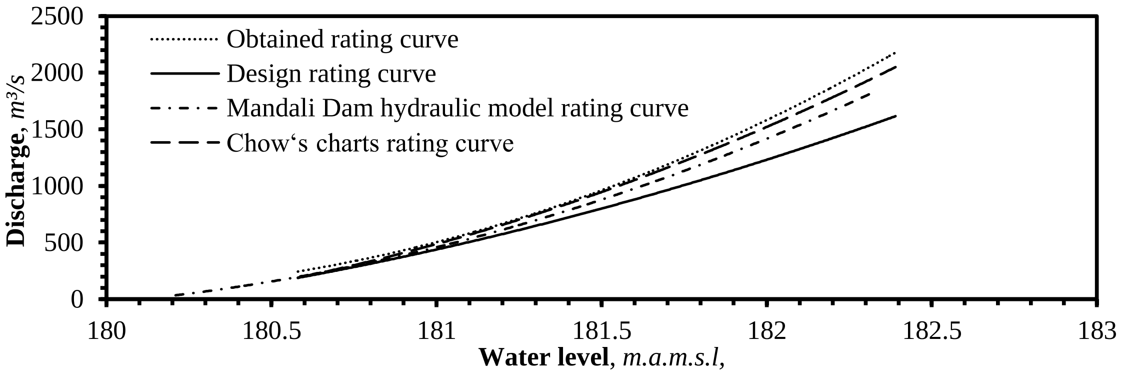


Figure 15. The rating curve of Mandili Dam Weir.

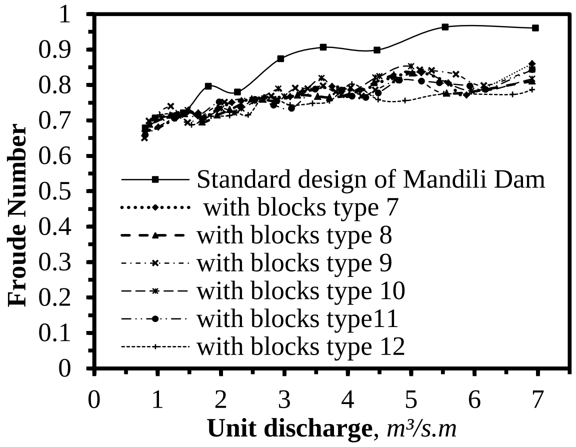


Figure 16. Variation of the Froude Number with the applied discharges for configuration number 1.

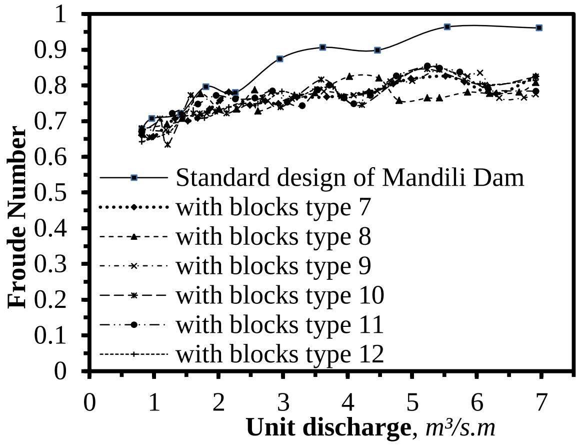


Figure 17. Variation of the Froude Number the applied discharges for configuration number 2.

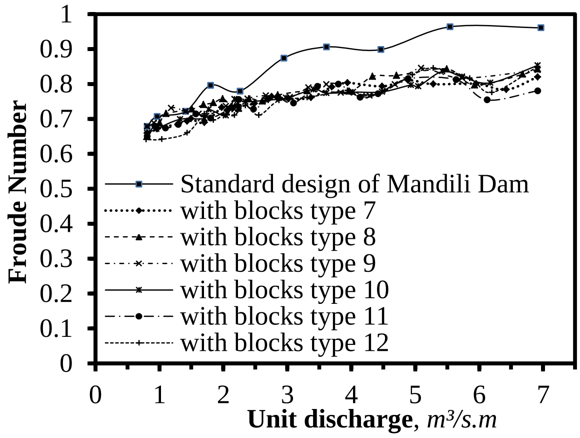


Figure 18. Variation of the Froude Number with the applied discharges configuration number 3

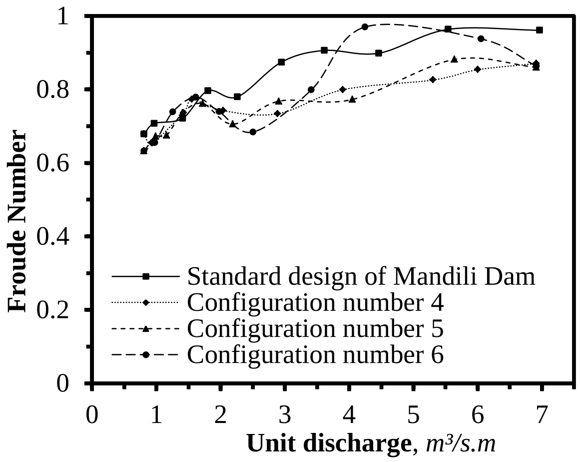


Figure 19. Variation of the Froude Number with the applied discharges, half the length of the stilling basin.

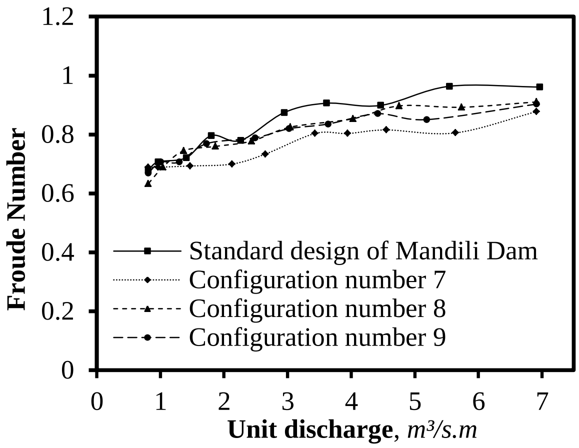


Figure 20. Variation of the Froude Number with the applied discharges, one fourth the length of the stilling basin.

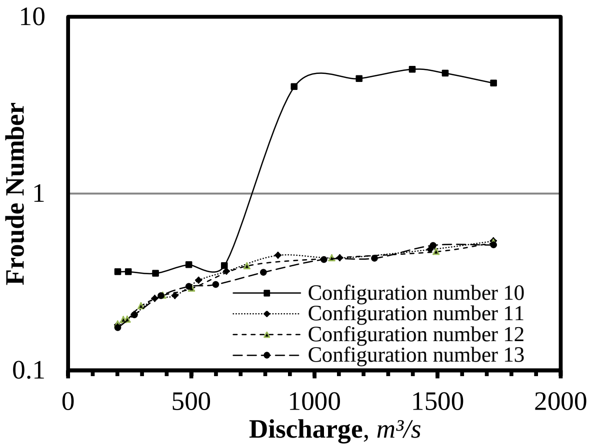


Figure 21. Variation of Froude Number with the applied discharges, no stilling basin.

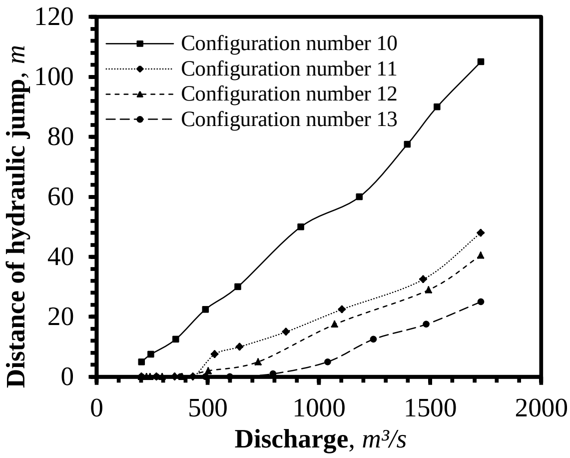


Figure 22. Variation of the distance of hydraulic jump with the applied discharges, no stilling basin.

Table 1. Dimensions of the used DDBs models.

Type of DDBs	DDBs dimensions			
	Width *cm*	**Height** *cm*	**Apex angle** *degree*	**Top length** *cm*
1	5	3.9	30	9.3
2	5	3.9	45	6
3	5	3.9	60	4.3
4	5	3.9	90	2.5
5	5	3.9	120	1.4
6	5	3.9	180	5
7	1.5	1.5	20	4.25
8	1.5	1.5	30	2.8
9	1.5	1.5	45	1.8
10	1.5	1.5	60	1.3
11	1.5	1.5	90	0.75
12	1.5	1.5	180	1.5
13	2	2	15	7.6
14	2	2	20	5.7
15	2	2	30	3.7

Table 2. Details of the configurations used for the energy dissipation test.

	Configuration Number												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Number of rows	1	1	2	2	3	4	2	3	4	-	4	5	7
Spacing between blocks, *cm*	1.5	1.5	4.5	2.3							2.3		
Distance of 1st row from weir toe, *cm*	20	25	20.5	20	15		20	15		-	0		
Distance of 2nd row from weir toe, *cm*	-	-	25	29.	-		29.5				-		
spacing between rows for more than two rows, *cm*	-	-	Variable*	2						-	2		
Number of blocks in each row	10	10	5	7						-	7		
Length of stilling basin, *cm*	42			21			10			No stilling			

*depends on the block dimensions.

Table 3. The types of DDBs that were used in each configuration.

	Configuration Number												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Type of blocks	7, 8, 9, 10, 11, 12			13	14	15	13	14	15	Without blocks	13	14	15

Table 4. The extreme values of the Froude Number, standard design of Mandili Dam Spillway.

	Discharge *m³/s*	**Froude Number**	
		Max.	**Min.**
Configuration number 1	200	0.68, with block type 8,10, and 12	0.65, with blocks type 9
	1724	0.86, with blocks type 7	0.79, with blocks type12
Configuration number 2	200	0.68, with blocks types 8, and 9.	0.64, with blocks type 12
	1724	0.825, with blocks type 7	0.77, with blocks type 9
Configuration number 3	200	0.67, with blocks type 9	0.64, with blocks type12
	1724	0.85, with blocks type10	0.78, with blocks type11

Table 5. The extreme values of the Froude Number, modified design of Mandili Dam Spillway.

	Discharge *m³/s*	**Froude Number**	
		Max.	**Min.**
Configuration number 4, 5, and 6.	200	0.68, configuration number 4	0.63, configuration number 5 and 6
	1724	0.87, configuration number 4	0.86, configuration number 5and 6
Configuration number 7, 8, and 9.	200	0.68, configuration number 7	0.63, configuration number 8
	1724	0.91, configuration number 8	0.88, configuration number 7

Table 6. The extreme values Froude Number and the distance of the hydraulic jump, no stilling basin.

Configuration number	**Discharge** *m³/s*	**Froude Number**	**distance of hydraulic jump** *m*
10	200	0.36	5
	1724	4.21	105
11	200	0.18	0
	1724	0.54	48
12	200	0.18	0
	1724	0.53	40.5
13	200	0.17	0
	1724	0.51	25

Analysis of Recorded Inflow Data of Ataturk Reservoir

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ABSTRACT

Since the beginning of the last century, the competition for water resources has intensified dramatically, especially between countries that have no agreements in place for water resources that they share. Such is the situation with the Euphrates River which flows through three countries (Turkey, Syria, and Iraq) and represents the main water resource for these countries. Therefore, the comprehensive hydrologic investigation needed to derive optimal operations requires reliable forecasts. This study aims to analysis and create a forecasting model for data generation from Turkey perspective by using the recorded inflow data of Ataturk reservoir for the period (Oct. 1961 - Sep. 2009). Based on 49 years of real inflow data from the Euphrates River recorded at Ataturk, a spilt-sample approach was adopted for testing homogeneity. The autoregressive model of order one [AR(1)] was found to be the best for the forecasting as it accurately reproduced the means, standard deviations, and skewness coefficients observed in the generated records forecast at the Ataturk reservoir. Ten sets of 100 years data have been forecasted.

In Iraq, optimization of the operation of all reservoirs is necessary after operating new reservoirs in Turkey.

Keywords: Time series, Reservoir operation, Euphrates River, Ataturk Dam, and Forecasting.

تحليل معلومات الجريان الداخل الى خزان أتاترك

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الخلاصة :

منذ بداية القرن الماضي ازداد الصراع على الموارد المائية , وخاصة بين الدول المتشاطئة لعدم وجود اتفاقيات بينهم, كما هو الحال مع نهر الفرات الذي يجري بثلاث دول (تركيا , سوريا , العراق), ويمثل المصدر الرئيسي للمياه لتلك الدول, لذالك أصبح من الضروري التكهن بالمتغيرات الهيدرولوجية لمشاريع الموارد المائية من أجل الادارة المثلى لتلك المشاريع.

ان الهدف من هذه الدراسة هو تحليل بيانات التدفق الداخلة لسد أتاترك والتكهن بها من وجهة النظر التركية, وذلك اعتمادا على التصاريف المرصوده لنهر الفرات عند سد أتاترك خلال 49 سنة مائية للفترة من تشرين الاول 1961 ولغاية ايلول 2009. حيث وجد بان نموذج (AR(1)) Autoregressive يعد الأفضل في هذا المجال لانها أنتجت قيم كل من المعدل والانحراف المعياري ومعامل الالتواء للبيانات المرصودة نفسها او قريبة جدا منها للبيانات الصنيعة .وعليه تم استخدام هذا النموذج للتنبؤ بعشر سلاسل من التصاريف الصنيعة الداخلة لخزان سد أتاترك ولفترة 100 عام لكل منها.

ان التشغيل الامثل لكل الخزانات في العراق ضروري جدا وخاصة بعد تشغيل تركيا لخزاناتها الجديدة .

الكلمات الرئيسية :
البيانات المتسلسلة مع الزمن , تشغيل الخزانات , نهر الفرات , سد اتاترك , التكهن بالبيانات.

1. INTRODUCTION

The Euphrates has its source in eastern Turkey. Euphrates brings water to the Mesopotamian lowlands of Iraq as well as hydropower and irrigation to parts of southeastern Turkey and much of northern and eastern Syria. It is the longest river (2,700 km) in southwest Asia west of the Indus, although its maximum average annual volume (35.9×10^9 m³ at Hit, Iraq) is less than that of the Tigris (70.4×10^9 m³ at Baghdad) or the Karun (48.8×10^9 m³ at Ahwaz), **Cressey, 1958**. The Euphrates River enters Iraq border at Hussaiba town. Because its waters comes from melting snows, maximum flows are in April and May, while minimum flows are in September and October. Many researchers have studied the Euphrates and Tigris rivers basins and the Turkish Great Anatolia Project (GAP). **Mujumdar and Kumar, 1990** investigated 10 candidate models from the autoregressive moving average model (ARMA) family for representing and forecasting monthly and 10-day stream flow in three Indian rivers.

Kolars and Mitchell, 1991 introduced a chart for projected sequential depletion of the Euphrates River for the period 1990-2040.

Al-Tikriti, 2001 used single site multivariate autoregressive models, AR(1), to model seven parameters of average weekly water quality data and discharges at two stations on the Euphrates River (Al-Hindiya and Al-Samawa stations) for the period 1984-1997.

El-Obaidy, 2006 studied the effect of future Turkish projects on the Tigris River. In order to consider the uncertain conditions affecting the future performance of the system, a multisite ARMA (1, 1) model was used to generate a monthly time series over 70 years of inflows to various reservoir sites on the Tigris River in Turkey.

2. AREA OF STUDY

The Ataturk Dam, power station, and irrigation project is located near town of Bozova, 70 km northeast of Urfa and 181 km downstream from Karakaya. It will be the largest dam in Turkey, its filled reservoir capacity as well as its embankment volume will make it the fifth-largest dam in the world, **TDN, 1988**. Constructed in the 1980s on the Euphrates River in semi-arid Southeastern Turkey, it forms the central component of a large-scale regional GAP development project. The dam and its associated hydroelectric power plant went into service in 1992 and today plays an important role in the development of Turkey's energy and agriculture sectors, **Ozcana et al., 2012.** The dam is located at 37˚28`54‵N 38˚ 19` 03‵ E / 37.48167˚ N and 38.31750˚ E, www.marefa,org> **index.php**. It is the third dam built on the Euphrates River with an active capacity of 19×10^9 m^3, within a total capacity of 50×10^9 m^3 and installed power of 2,400 MW. Its height from the river bed is 169 m with a crest length of 1,664 m and a catchment area of 92,240 km^2**, Demir et al., 2009**.

3.THEORIES

3.1 Hydrologic Time Series

A hydrologic time series is defined as a continuous set of sequential observations, usually expressed as an average value over specified intervals of time such as mean daily, mean monthly, or mean annual flows. Hydrologic time series may consist of four components depending on the type of variable and the average time interval**, Yevjevich , 1972**. In seasonal stream flow series four components exist as shown in Eq. (1):-

$$Q = J_e + T_e + P_e + E_e \tag{1}$$

where:

Q is the time series value (actual data) at period t,

J_e is the jump component at period t,

T_e is the trend-cycle component at period t,

P_e is the periodic or cyclic component at period t, and
E_e is the stochastic (or random) component at period t.

The first three components represent the deterministic part of the process while the fourth component represents the non-deterministic part.

3.1.1 Test and Removal of Non-Homogeneity

This test is performed to check the homogeneity of the historical data in the stream flow series. In order to construct a model of a stream flow that remains valid for the future, the hydrologic data series which are used in generating the model should be homogenous. By definition, homogeneity requires at least two conditions, **Yevjevich, 1972**:

1. The hydrological data series must not contain any systematic error.
2. All the hydrological conditions should be constant.

If these conditions are satisfied then the series may be considered homogeneous. These two conditions imply that a homogenous series should be free from both trend and jump components; therefore, homogeneity is enforced at the beginning of an analysis by detection and removal of these components.

A jump component is defined as a sudden slippage (either negative or positive) in the parameters of the historical data, such as in the means or standard deviations of the stream flow data. A sudden increase is termed a positive jump, whereas a sudden decrease is termed a negative jump. The jump component usually results from human activities; for example; the construction of a dam, a reservoir, or an outflow canal upstream of the observation station.

A trend component is defined as a systematic and continuous change over an entire sample in any parameter of the series. A trend can be negative or positive. It may be traced to human causes (such as diversions of flow for irrigation), to natural causes (such as climate changes), or to methodological causes (such as measurement inconsistencies or other systematic errors).

To check for the existence of these components, statistical test methods such as the (t-test or F-test) may be used to detect significant changes in means or standard deviations of two samples at a desired percent probability level of significance. If those tests indicate significant changes, an analyst concludes that the two samples are from different populations and a jump and/or trend component exists. Trend components may also be detected by regression analysis and described mathematically by means of polynomial functions. **Yevjevich, 1972** maintains that the most powerful method for testing homogeneity is carried out by using the split-sample approach. Here, the entire sample is divided into two subsamples, and then means and standard deviations for each subsample are calculated. These are then tested to ascertain whether their differences are significantly nonzero at a 95% confidence level.

3.2 Analysis and Forecasting of ATATURK Recorded Data

Tests for homogeneity require that the data sample be divided into two subsamples. The recorded inflow data at Ataturk dam from Oct.1961 to Sep.2009 were thus divided into two subsamples; the first was 24 years long, spanning Oct.1961 to Sep.1984, while the second was 25 years long, spanning Oct.1985 to Sep.2009.

To remove non-homogeneity, **Yevjevich, 1972** suggests fitting linear regression equations to both annual averages and annual standard deviations according to the following equation:

$$Y_{(j,t)} = Sd_2\,[\,X_{(j,t)} - M_{(j)}\,]\,/S_{(j)} + Av_2 \qquad (2)$$

where:

j,t = the annual and seasonal positions of observations, respectively,
Y = transformed series (homogeneous),
X= historical non-homogeneous series,

Av_2 , Sd_2= the average and standard deviation of the second subsample, respectively,
$M_{(j)}$, $S_{(j)}$ = linear regression of annual historical mean and standard deviation against years (The equations in the upper right corner in **Figs. 1 and 2**).
The trend component of the considered historical data is removed by applying Eq.(3):

$$Y(j,t) = \frac{Y(j,t) - 912.595 + 2.8655 * (i + j/12)}{810.332 - 3.7177 * (i + j/12)} * 199.1 + 813.3 \quad \textbf{(3)}$$

where:

j,t = the annual and seasonal positions of observations, respectively; the constants (813.3 and 199.1) m^3/s are the overall mean and standard deviation of the second subseries, respectively over the 25 years Oct.1985- Sep.2009.

The test is now repeated to check the existence of trend component by using [Y(j,t)] as the new series for the whole dataset.

3.2.1 Detection and Removal of the Periodic Component

The correlogram is useful for the detection of the periodic component. If it reflects periodicity, that means there is a periodic component in the series, otherwise there is not. The serial correlation coefficients of the flow at Ataturk are calculated for lags (1 to 24), using the expression given by Eq.(4).

$$r(k) = \frac{\sum_{j=1}^{N-k} Y(j)\,Y(j+k) - \frac{1}{N-k}\left(\sum_{j=1}^{N-k} Y(j)\right)\left(\sum_{j=1}^{N-k} Y(j+k)\right)}{\left[\sum_{j=1}^{N-k} Y^2(j) - \frac{1}{N-k}\left(\sum_{j=1}^{N-k} Y(j)\right)^2\right]^{\frac{1}{2}} \left[\sum_{j=1}^{N-k} Y^2(j+k) - \frac{1}{N-k}\left(\sum_{j=1}^{N-k} Y(j+k)\right)^2\right]^{\frac{1}{2}}} \quad \textbf{(4)}$$

where:

r(k) = the lag (k) serial correlation coefficient,
N = sample size,
k = lag in time units, and
Y(j) = the homogeneous series value at time t.

For k=0, r (k) =1. In practice, k is limited by [N/4].

The non-parametric method may be used to remove the periodic component from the hydrological time series as follows:

$$Z_{(j,t)} = (Y_{(j,t)} - Avy_{(t)}) / Sdy_{(t)} \quad \textbf{(5)}$$

where:

$Z_{(j,t)}$= the series free from periodic component at year (j) and month (t)
$Y_{(j,t)}$= the homogeneous series
$Avy_{(t)}$ = the sample average of Y(j,t) at month (t)
$Sdy_{(t)}$= the sample standard deviation of Y(j,t) at month (t).

The resulting series, Z(j,t) is called a stochastic series. The application of Eq.(5) is also called standardization as it gives a series [Z(j,t)] with zero mean and unit variance . This series contains a dependent part which may be represented by an autoregressive model ,AR(p), moving average model , MA(q), or an autoregressive moving average model of higher order , ARMA(p, q), and an independent part that can only be described by some probability distribution function.

3.2.2 Data Normalization

Box and Cox transformation has been used to transform the series by applying Eqs. (6) and (7).

$$Z^* = (Z^{\lambda} - 1)/\lambda \qquad \text{when} \quad \lambda \neq 0 \tag{6}$$

and $$Z^* = \log(Z) \qquad \text{when} \quad \lambda = 0 \tag{7}$$

where (λ) is the transformation coefficient.

The value of the parameter (λ) is found by choosing random values between (-1 to 1) with steps 0.1 and computing the corresponding Cs and Ck values of the transformed series. For normally-distributed data, Cs=0 and Ck≈3.

Where Cs = coefficient of skewness.
Ck = coefficient of kurtosis.

3.3 The Univariate Stochastic Model

The basis of the Box-Jenkins approach for modeling time series consists of three phases: identification, estimation and testing, and application. These three basic stages have been adopted for univariate model building. The input of this analysis is the stochastic series [Z^*(j,t)] and the output is the independent stochastic component (ζ p,t).

3.4 Model Identification

The principal tools of model identification are the behavior of the autocorrelation function (ACF) coupled with that of the partial autocorrelation function (PACF).
Values of ACF that fall outside the 95% confidence level were significantly different from zero at the 5% level; the lower and upper limits were found by:

$$\text{Lower Confidence Limit} = \frac{-1-1.96[Nj-k-2]^{0.5}}{Nj-k-1} \tag{8}$$

$$\text{Upper Confidence Limit} = \frac{-1+1.96[Nj-k-2]^{0.5}}{Nj-k-1} \tag{9}$$

Where the value 1.96 is the z-tabulated under the normal curve and Nj is the sample size.

3.5 Autoregressive Model [AR(p)]

The general form of this linear model is:

$$E_{p,t} = \sum_{k=1}^{p} a_{k,t} \,.\, E_{p,t-k} + \sigma_{\zeta,t} \,.\, \zeta_{p,t} \tag{10}$$

where:
p = the degree of model.
$\mathbf{E_{p,t}}$ = the dependent stochastic component.

$\zeta_{p,t}$ = the independent stochastic component at year (t) and month (p).
$\mathbf{a_{k,t}}$ and $\sigma_{\zeta,t}$ the model parameters.

Yevjevich, 1972 suggests a simplified practical method to express the goodness of fit of an autoregressive model by the determination coefficients (D_i, i=1,2,3,...), which represent the percentage of the total variance of ($\mathbf{E_{p,t}}$) explained by the ith order term of an autoregressive equation. The remaining portion of this variance is explained by the ($\sigma_{\zeta,t}$, $\zeta_{p,t}$) term. The criterion used is as follows: the explanatory power of the (i+1)th order term must exceed that of the ith order term by at least a chosen threshold ΔD for the higher order model to be favored. Said another way, if the difference between the percentage of variance explained by the (i+1)th and ith order terms of the model, i.e.,($D_{i+1} - D_i$), is less than ΔD , then the model order (p) taken equal to (i). ΔD is usually set at 0.01, i.e., one percent of the total variance of ($\mathbf{E_{p,t}}$).It is expected that the degree of the model (p) will not exceed three; therefore, the determination coefficients D_1, D_2, and D_3, are typically the only ones calculated. The equations of **Yevjevich, 1972** used are:

$$D_1 = r_1^2 \tag{11}$$

$$D_2 = \frac{r_1^2 + r_2^2 - 2 r_1^2 r_2}{1 - r_1^2} \tag{12}$$

$$D_3 = \frac{r_1^2 + r_2^2 + r_3^2 + 2 r_1^3 r_3 + 2 r_1^2 r_2^2 + 2 r_1 r_2^2 r_3 - 2 r_1^2 r_2 - 4 r_1 r_2 r_3 - r_1^4 - r_2^4 - r_1^2 r_3^2}{1 - 2 r_1^2 - r_2^2 + 2 r_1^2 r_2} \tag{13}$$

and the order of the model may be found through using the following steps:

1. if $D_2 - D_1 < \Delta D$ and $D_3 - D_1 < 2\Delta D$ then p=1
2. if $D_2 - D_1 \geq \Delta D$ and $D_3 - D_2 < \Delta D$ then p=2
3. if $D_2 - D_1 \geq \Delta D$ and $D_3 - D_2 > \Delta D$ then p=3

where r_1, r_2, and r_3 are the serial correlation coefficients for lags 1, 2, and 3, respectively. From these results, it can be seen that a first order autoregressive model, AR(1), fits the series, since higher degree models do not account for an increase of the explained variance of 1% or more over that explained by the first order model.

3.6 MARKOV Model (Autoregressive Model) [AR(P)]

This model describes the dependence in a hydrologic stochastic series ($\mathbf{E_{p,t}}$) by assuming that each value ($\mathbf{E_{p,t}}$) is the combined effect of previous values plus an independent stochastic component ($\zeta_{p,t}$), which occurs at the same time of occurrence of ($\mathbf{E_{p,t}}$) . The independent stochastic series ($\zeta_{p,t}$) is a series of random numbers usually with zero mean and unit variance . The formulation of this model is given as, **Makridakis et al., 1998**:

$$E_{p,t} = a_1 E_{p,t-1} + \sigma \zeta_{p,t} \tag{14}$$

Where

$$a_1 = r_{1,t} \text{ or } a_1 = r_1 \quad \textbf{(15)}$$

$$s = \sqrt{1 - r_1^2} \quad \textbf{(16)}$$

3.7 Diagnostic Checking

Diagnostic checking means statistically verifying the adequacy of the formulated model. For this checking, the residual series is examined for any lack of randomness.

The effect of using AR (1) may be tested by finding whether the model satisfactorily removes the dependence from the stochastic variables (**$E_{p,t}$**), i.e., whether the resulting (**$\zeta_{p,t}$**) can be considered independent at a 95% confidence level. The independent stochastic series (**$\zeta_{p,t}$**) is found from Eq.(17) with $a_1=r_1=0.63$ as follows:

$$\zeta_{p,t} = (E_{p,t} - a_1 E_{p,t-1}) / \sqrt{1 - a_1^2} \quad \textbf{(17)}$$

To test the independence of the resulting (**$\zeta_{p,t}$**) series, the ACF and PACF of this component are computed up to lag (24).

3. 8 Verification of the Model

To verify the model, 10 new sets of time series were generated. The generation procedure for the first order autoregressive model, AR(1), can be regarded as reversing the analysis procedure with slight differences, as shown by the following steps**:**

1. Generate the independent stochastic component (**$\zeta_{j,t}$**) using a pseudo-random number generator.
2. Generate the dependent stochastic component ($E_{(j,t)}$) using:

$$E_{(j,t)} = a_1 E_{(j,t-1)} + \sqrt{1 - a_1^2}\, \zeta_{(j,t)} \quad \textbf{(18)}$$

3. Apply the inverse power transformation:

$$Y(j,t) = (\lambda * E(j,t) + 1)^{1/\lambda} \quad \textbf{(19)}$$

4. Standardize the new series using the monthly mean $MY_{(t)}$ and monthly standard deviation $SY_{(t)}$ at month (t):

$$\boldsymbol{Yt_{(i,j)} = (Y_{(i,j)} - MY_{(t)}) / Sy_{(t)}} \quad \textbf{(20)}$$

5. Calculate the normalized flow series X(j,t) using:

$$\boldsymbol{X_{(j,t)} = My_{(t)} + Yt_{(j,t)} * Sy_{(t)}} \quad \textbf{(21)}$$

Where **$X_{(j,t)}$** = the generated flow of month (t) and year (j).

Each time series generated covers 50 years. A comparison between the properties of the observed data and generated data is presented.

3.9 Generation of the Model

The generation procedure for the first order autoregressive model follows the same steps (1 to 5) used above in generating the verification models.

4. CALCULATIONS AND RESULTS

In creating the forecasting model for data generation, a split-sample approach – the most powerful method for testing homogeneity – was adopted**. Figs. 1 and 2** show the annual means and annual standard deviations of these time-series. The lines crossing the data points in these figures represent the averages of the annual means and standard deviations of the series. These figures show that there is no jump in the annual flow data; however, the determination coefficients reveal a trend component indicating non-homogeneity. **Table 1** presents the results of this split sample test for the recorded inflow data at the Ataturk dam. The result of testing the jump by splitting the data are shown in **Figs. 3 and 4**, which present the annual mean and standard deviations of the split data, showing that a jump component does not exist. The trend component of the considered historical data is removed by applying Eq.(3).

The test is now repeated using [Y(j,t)] as the new series for the whole dataset; the results are shown in **Figs. 5 and 6** for the annual means and standard deviations, respectively. The determination coefficients are very small for linear trends, indicating the absence of a trend component. The slopes of the lines representing the linear regression fit are small enough to be attributed to sample fluctuations. Therefore, the series may now be considered homogeneous, i.e., free of jump and trend components .The results of a split-sample test of the data after removing the jump and trend components are shown in **Table 2**.

For the detection of the periodic component, the correlogram is useful. By using Eq.(4) the serial correlation coefficients of the flow at Ataturk reservoir were calculated for lags (1 to 24). The existence of an annual cycle is evident from the occurrence of peaks in the correlogram as shown in **Fig. 7.** The high magnitude of the peak values shows that the deterministic periodic components form a dominant part of the structure of monthly flow time series at Ataturk.

The non-parametric method is used to remove the periodic component from the hydrological time series by using Eq.(5). The resulting series, Z(j,t), which is shown in **Fig. 8,** is called a stochastic series. The application of Eq.(5) is also called standardization as it gives a series [Z(j,t)] with zero mean and unit variance.

Transformation has been done to transform the series of Ataturk monthly inflows by applying Eqs. (6) and (7). **Table 3** shows the value of (λ) at which the series is normally distributed together with other parameters. **Fig. 9** shows the transformed series (or normalized series). As the flow data after removing the periodic component included negative and positive values, a value equal to 3 was added to all of the data to make the computation process easier.

The behavior of the autocorrelation function (ACF) coupled with that of the partial autocorrelation function (PACF) are the principal tools of model identification.

Figs. 10 and 11 illustrate the behavior of the ACF and the PACF of the stochastic component (or normalized flow data), [Z*(j,t)]. The lower and upper limits were found by using Eqs. (8) and (9).

From **Figs. 10 and 11,** it may be concluded that the autoregressive model [AR(1)] shows the best fit for this data set, since the ACF shows an exponential decrease and the PACF shows a cutoff after the first lag at [$\alpha_{1,1} \neq 0$] and [$a\, k,t = 0$ for $k = 2, 3, 4, \ldots$].

The determination coefficients D_1, D_2, and D_3 which express the fit of an autoregressive model were found by using, **Yevjevich, 1972** method. The Eqs. used are (11),(12), and (13) with three steps to find the order of the model. The results of the application of the equations and steps are shown below:

$r_1 = 0.63$ $r_2 = 0.41$ $r_3 = 0.37$

$D_1 = 0.39$ $D_2 = 0.39$ $D_3 = 0.41$

$D_2 - D_1 = 0.0004 < 0.01$

$D3 - D1 = 0.0179 < 0.02$

$D_3 - D_2 = 0.0175 > 0.01$

Diagnostic checking means statistically verifying the adequacy of the formulated model. For this checking, the residual series is examined for any lack of randomness. The independent stochastic series ($\zeta_{p,t}$) is found from Eq. (17) with $a_1=r_1=0.63$.

To test the independence of the resulting ($\zeta_{p,t}$) series, the ACF and PACF of this component are computed up to lag (24) as shown in **Figs. 12 and 13**. The results show that all computed values lie inside the 95% confidence range; therefore, the series can be considered to exhibit a white noise term. Hence the diagnostic check on the AR(1)model indicates that it is verifiably adequate.

For the verification of the model, 10 new sets of time series were generated. The generation procedure for the first order autoregressive model, AR(1), can be regarded as reversing the analysis procedure with slight differences by using the five steps and the Eqs. (18) through (21).

Each time series generated covers 50 years. A comparison between the properties of the observed and generated data is presented in **Table 4**. It can be seen that the total mean flow and total standard deviation in the generated data are the same as those in the observed data. It can also be seen that maximum values in the generated flow data are larger than those in the observed data, while the minimum values in the generated data are less than those in the observed data.

Fig. 14 shows a comparison between the monthly mean flow of observed and generated data. As the two coincide, the conclusion can be made that the AR(1) model is perfectly fitted to the observed data.

The generation procedure for the first order autoregressive model follows the same steps (1 to 5) used above in generating the verification models. Ten sets of data were generated for stream flow at Ataturk using the autoregressive model AR(1). Each set was 100 years long. The properties of the generated monthly stream flow series were compared with those of the observed series.

Table 5 shows the general properties of the generated sequences. The model is capable of preserving the general means characteristics of the original series (Av), and standard deviation (S.D.).The skewness coefficient (Cs) and the kurtosis coefficient (Ck) are almost preserved.

Table 6 shows the monthly means of the generated monthly stream flow data series. The tabulated results clearly indicate that the AR(1) model preserved with a high degree of accuracy the basic statistical characteristics of the recorded data. All the monthly means of the generated data pass the (t-test) at the 95% confidence level. **Fig. 16** shows that the monthly means of the generated and observed data are the same.

Table 7 and **Fig. 17** show the monthly standard deviation of the generated data and observed data.

5. CONCLUSIONS

The negative trend in the historical monthly inflow data may due to natural reasons such as dry seasons or to man made reasons such as construction of a new dam on the river or another hydraulic structure .

From **Tables 4** through **7** it can be concluded that the univariate autoregressive model of order one [AR (1)] with constant parameters model accurately reproduced the means, standard deviations, and skewness coefficients observed in the generated records forecast at Ataturk reservoir.

6. RECOMONDATIONS

- Handling of the uncertain behavior of hydrologic variables. Soft computing systems like artificial neural networks (ANNs) or fuzzy inference system (FIS) models could be applied to the historical inflow data used herein to produce alternative reservoir inflow forecasts. The results using those forecasts could then be compared to the results of this study.
- New researches that focus on the operation of Turkish and Syrian future projects implementation on Tigris, Euphrates, Greater Zab and Less Zab River will be required to determine the future inflow and salinity at Iraqi borders.
- Optimization of the operation of all reservoirs in Iraq is necessary after operating new reservoirs in Turkey.

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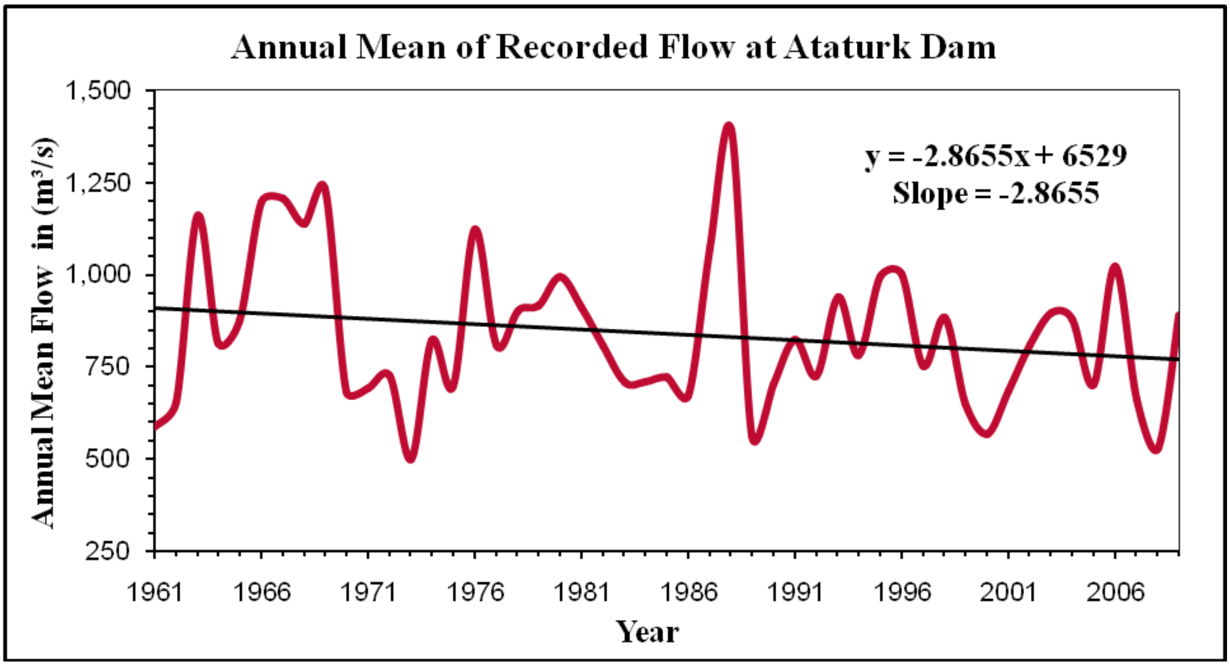

Figure 1. Annual mean flow at Ataturk dam (Oct.1961- Sep.2009), for detecting trend component.

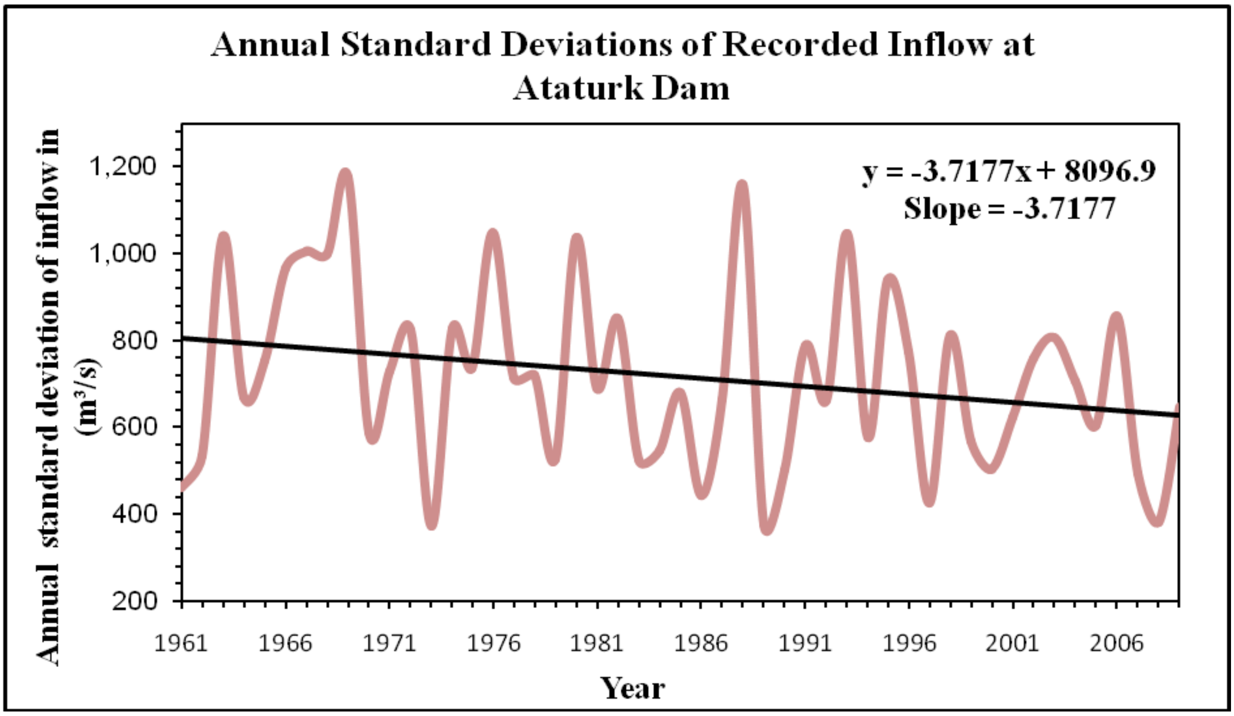

Figure 2. Annual standard deviations of the recorded inflow at Ataturk dam for (Oct.1961- Sep. 2009), for detecting trend component.

Table 1. Result of split-sample test of the Ataturk Dam's monthly recorded inflow (Oct.1961- Sep.2009).

	Statistical Parameters	Annual Average (m^3/s)	Annual standard deviation (m^3/s)
1st Period (Oct.1961- Sep.1984)	Number of years	24	24
	Average (m^3/s)	870	764
	Standard deviation (m^3/s)	213	217
2nd Period (Oct.1985- Sep.2009)	Number of years	25	25
	Average (m^3/s)	813	672
	Standard deviation (m^3/s)	192	199
	t-calculate	0.975	1.546
	t-table at 5% significance level	2.013	2.013
	F- calculate	1.229	1.187
	F-table at 5% significance level	2.014	2.003
	Jump component (t-test)	Not exist	Not exist
	Jump component (F- test)	Not exist	Not exist

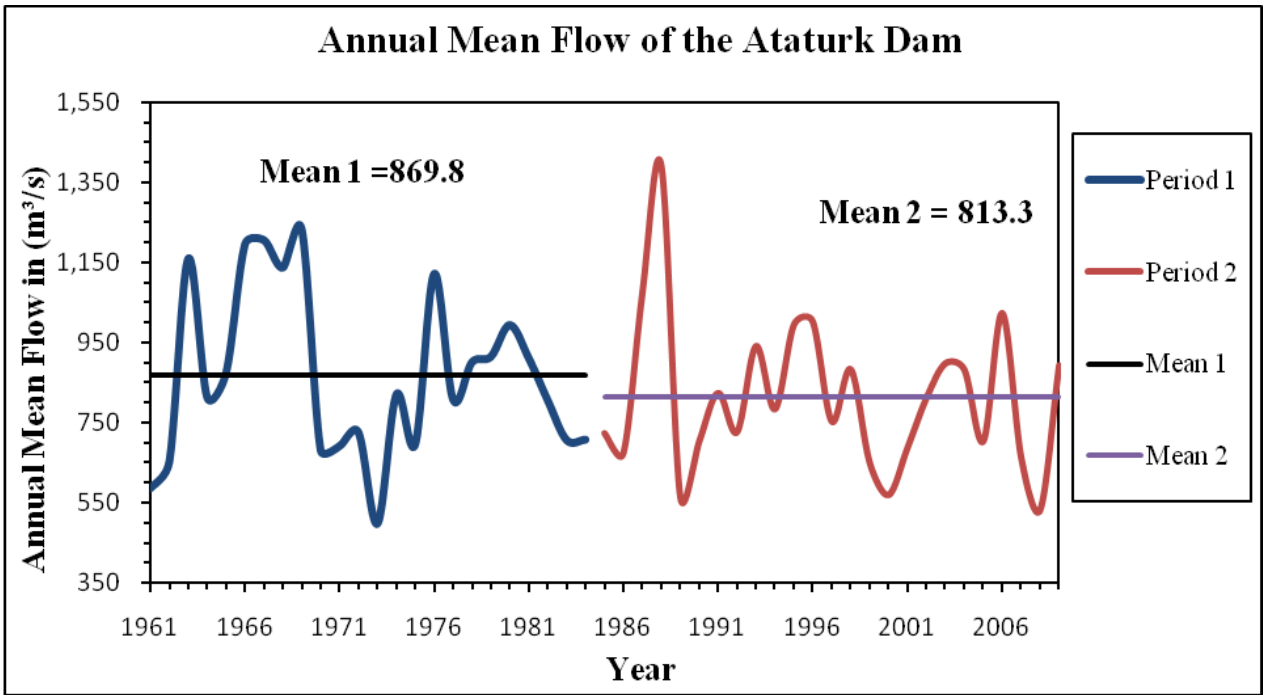

Figure 3. Annual means inflow at the Ataturk Dam (Oct.1961- Sep.2009).

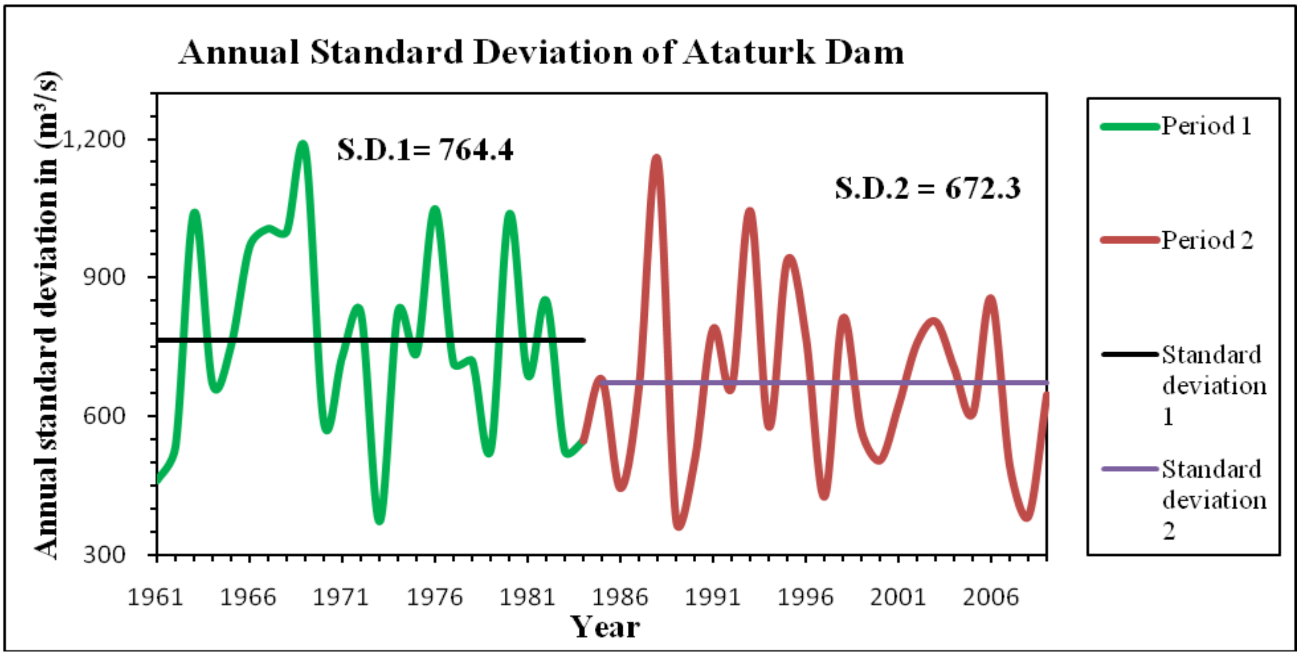

Figure 4. Annual standard deviation of the monthly recorded inflow at Ataturk Dam (Oct.1961- Sep.2009).

Table 2. Result of split-sample test of Ataturk dam's monthly recorded inflow after removing trend component.

	Statistical Parameters	Annual Average (m^3/s)	Annual standard deviation (m^3/s)
1st Period (Oct.1961-Sep.1984)	Number of years	24	24
	Average (m^3/s)	812	200
	Standard deviation (m^3/s)	54	56
2nd Period (Oct.1985-Sep.2009)	Number of years	25	25
	Average (m^3/s)	816	199
	Standard deviation(m^3/s)	55	58
	t-calculate	0.240	0.012
	t-table at 5% significance level	2.013	2.013
	F- calculate	1.041	1.070
	F-table at 5% significance level	2.014	2.003
	Jump component (t - test)	Not exist	Not exist
	Jump component (F- test)	Not exist	Not exist

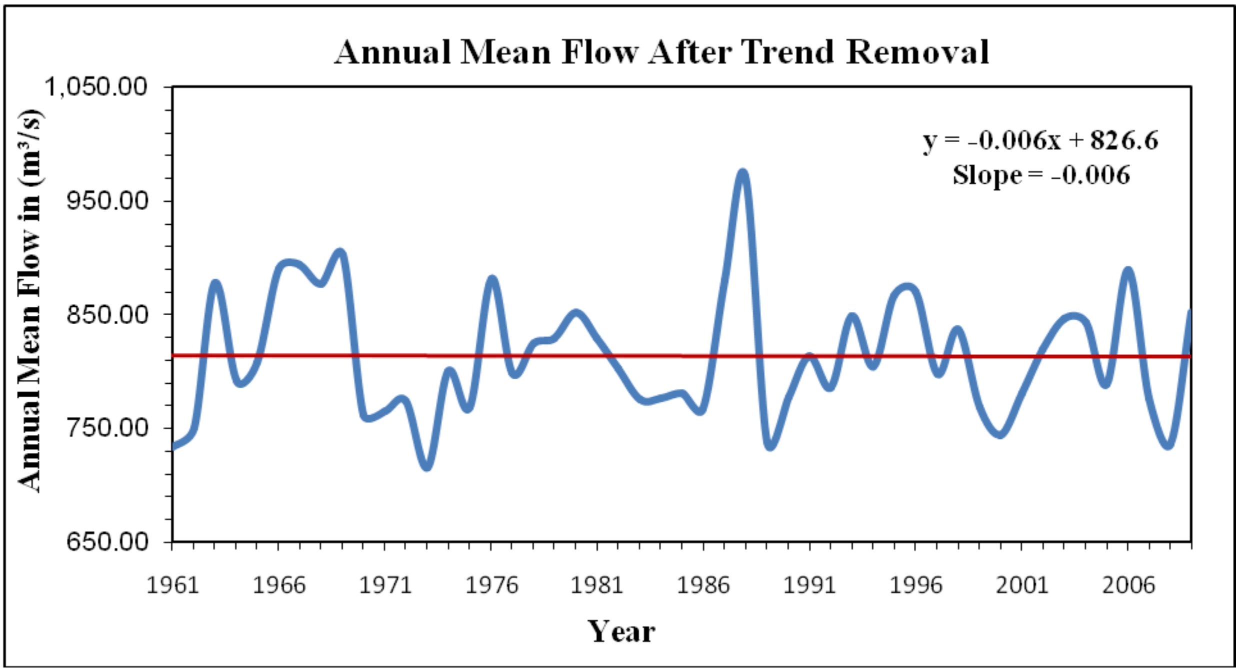

Figure 5 . Annual mean of recorded inflow at Ataturk Dam for Oct.1961- Sep.2009 after removing the trend component.

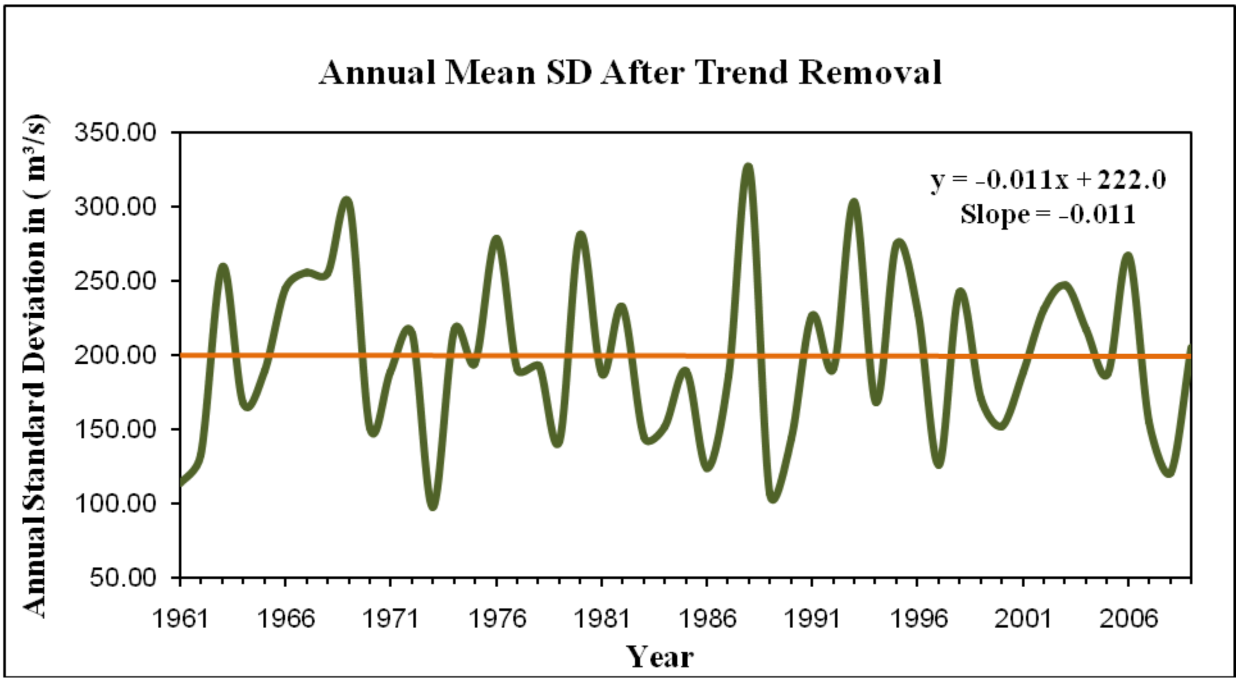

Figure 6 . Annual flow standard deviations of recorded inflow at the Ataturk Dam for Oct.1961- Sep.2009 after removing the trend component.

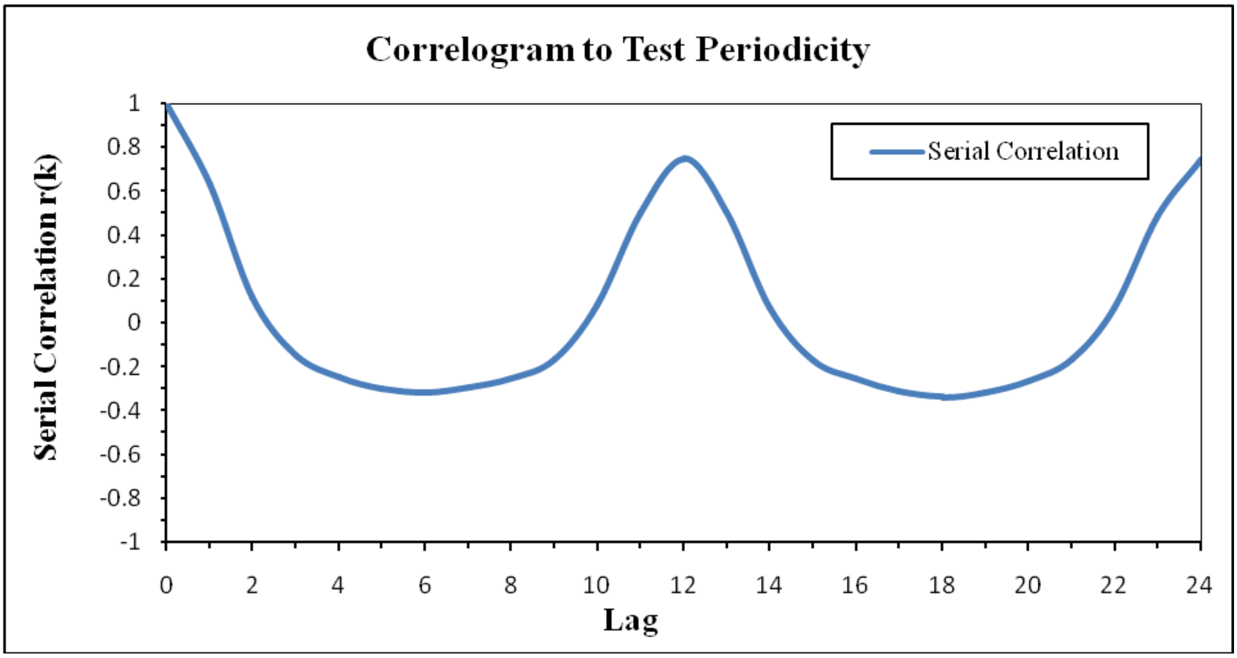

Figure 7. Serial correlation for Ataturk Dam's time series for monthly data after removing jump and trend components.

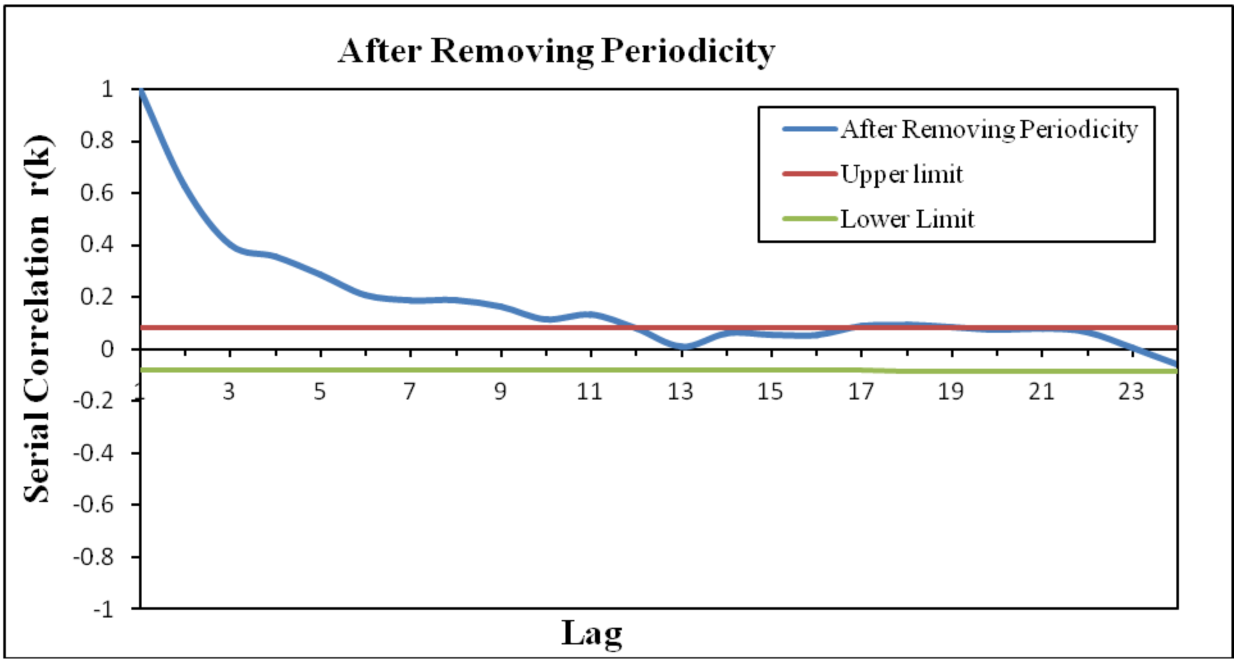

Figure 8. Ataturk correlogram for the mean monthly flow data after removing periodic component.

Table 3. Values of the statistical parameters of the recorded data and transformed data series.

Series	λ	Av.	S.D.	Cs	Ck
Recorded data	-	814	206	1.66	5.24
Transformed data	0.28	1.23	0.44	0.01	3.93

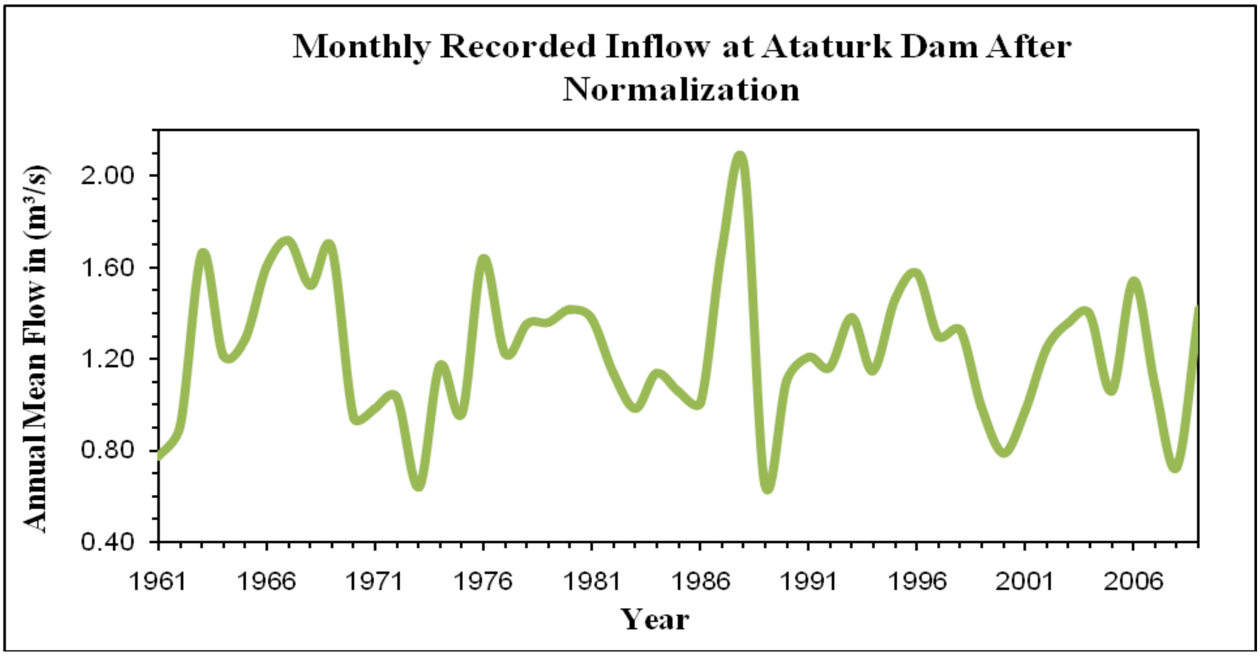

Figure 9. Annual mean flow at the Ataturk Dam after normalization.

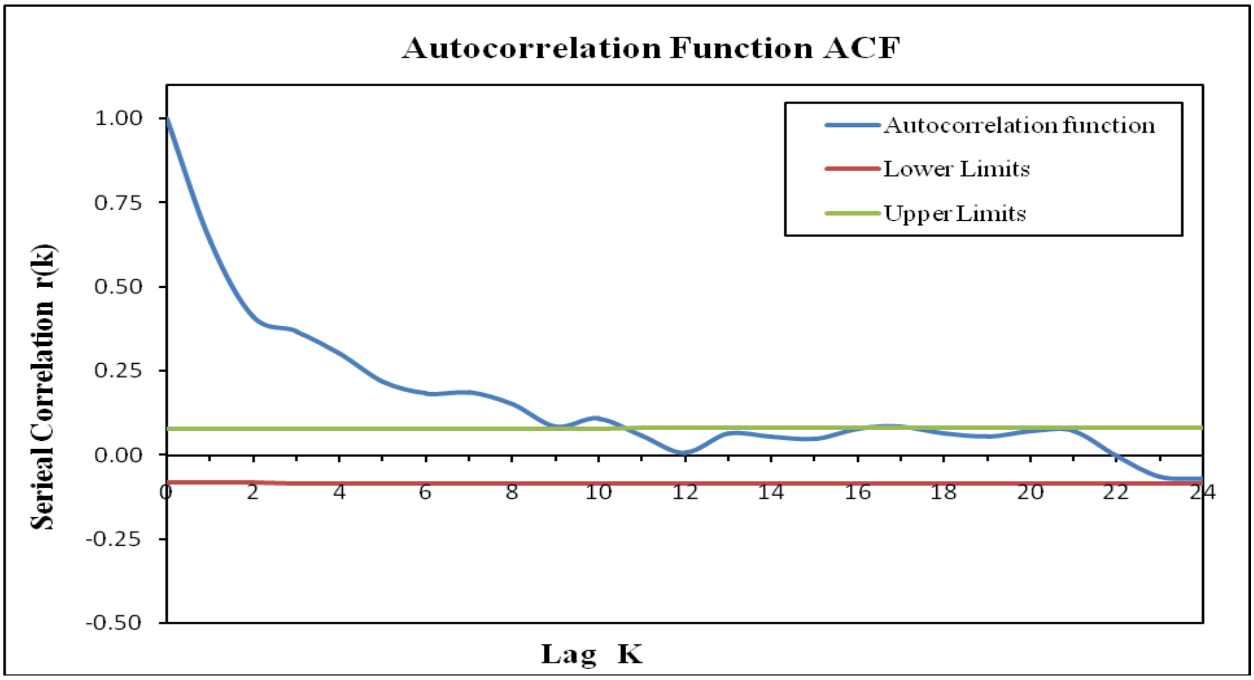

Figure 10. The Autocorrelation Function of monthly recorded inflow at the Ataturk Dam after normalization.

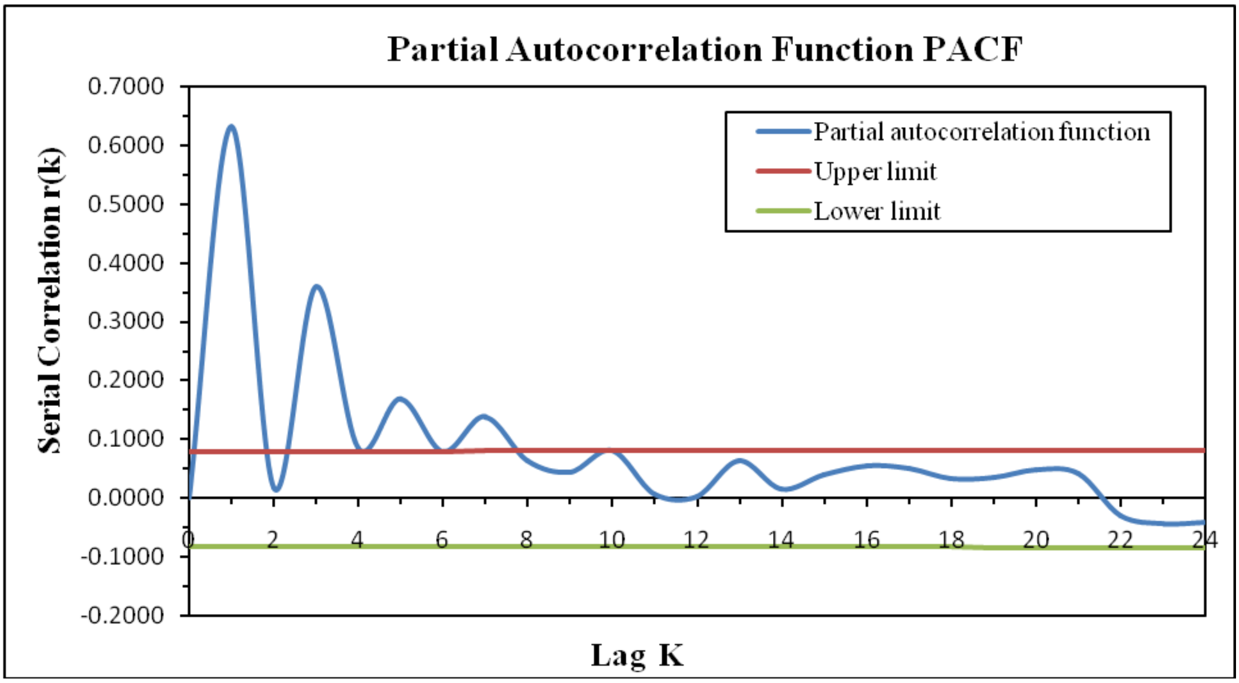

Figure 11. The Partial Autocorrelation Function of monthly recorded inflow of Ataturk Dam after normalization.

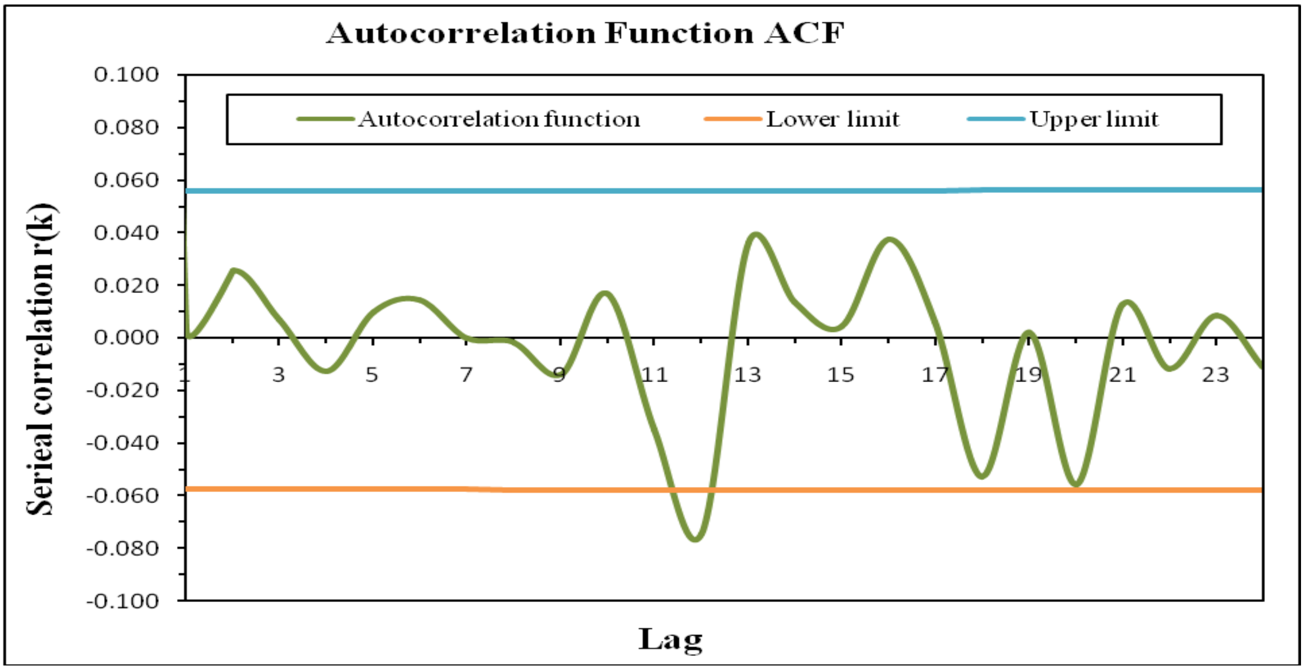

Figure 12. Autocorrelation Function of Ataturk dam for the independent stochastic component obtained by AR(1) model.

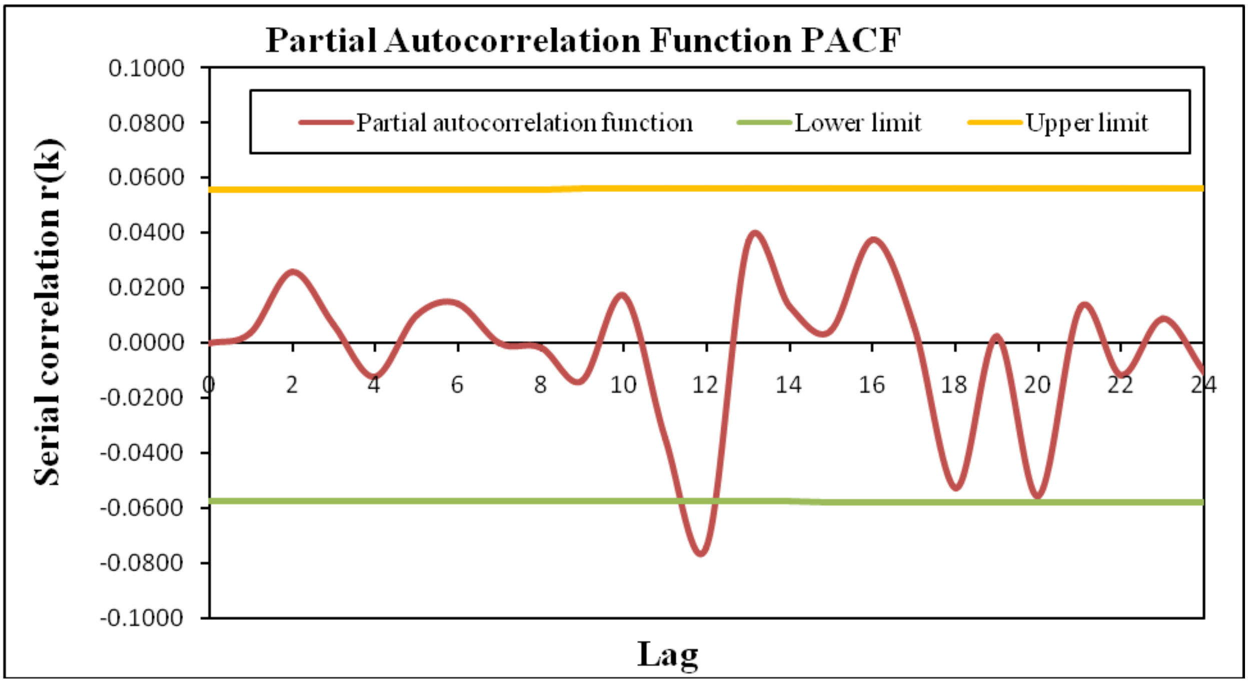

Figure 13. Partial Autocorrelation Function of Ataturk dam for the independent stochastic component obtained by AR(1) model

Table 4. Comparison between the general properties of the observed data and the generated data by AR(1) model for verification.

Series	Set	Meanm³/s	S.D. m³/s	C_s	C_k	Max. m³/s	Min. m³/s
Observed	---	813.61	205.58	1.66	5.24	1621.56	637.88
Generated	1	813.61	205.59	1.77	6.16	1766.82	620.12
Generated	2	813.61	205.59	1.78	6.26	1784.71	615.57
Generated	3	813.61	205.59	1.79	6.27	1844.67	608.82
Generated	4	813.61	205.59	1.78	6.09	1761.47	626.54
Generated	5	813.61	205.59	1.81	6.64	1954.09	603.88
Generated	6	813.61	205.59	1.71	5.69	1688.39	604.54
Generated	7	813.61	205.59	1.86	7.03	2030.68	633.04
Generated	8	813.61	205.59	1.83	6.65	1891.71	604.57
Generated	9	813.61	205.59	1.80	6.32	1806.60	613.84
Generated	10	813.61	205.59	1.95	8.01	2109.59	616.23

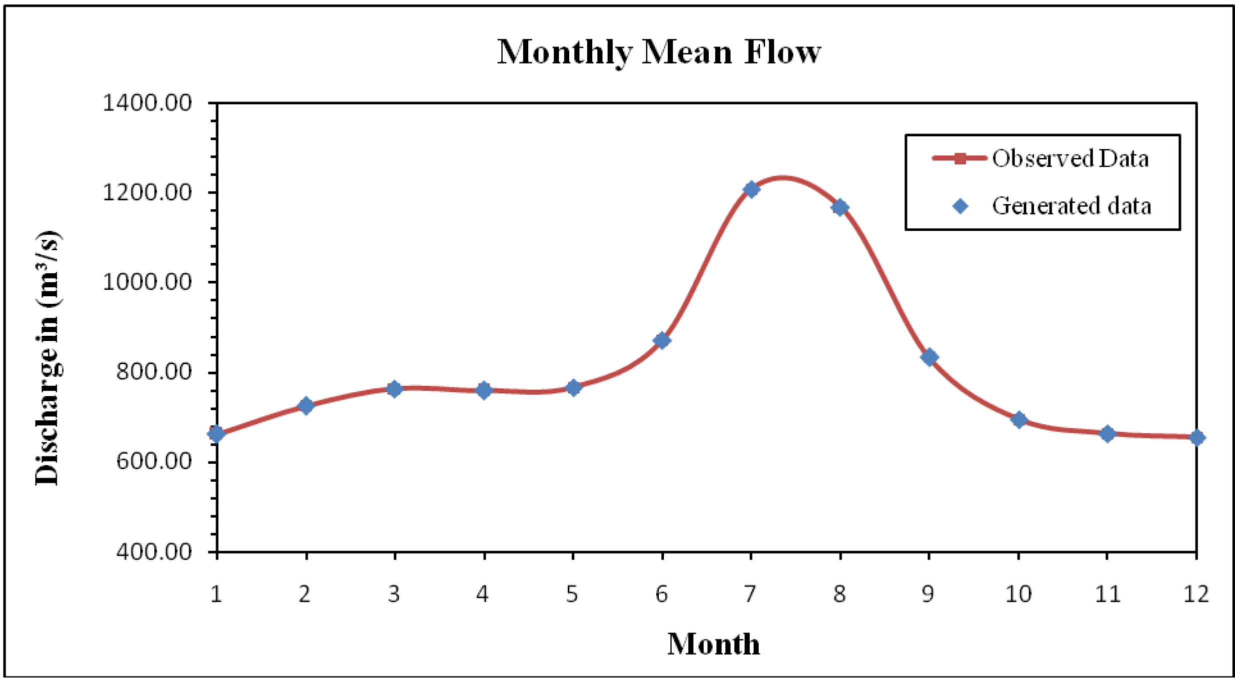

Figure 14. Comparison between the monthly averages of the observed data and the data generated by AR (1) model for verification

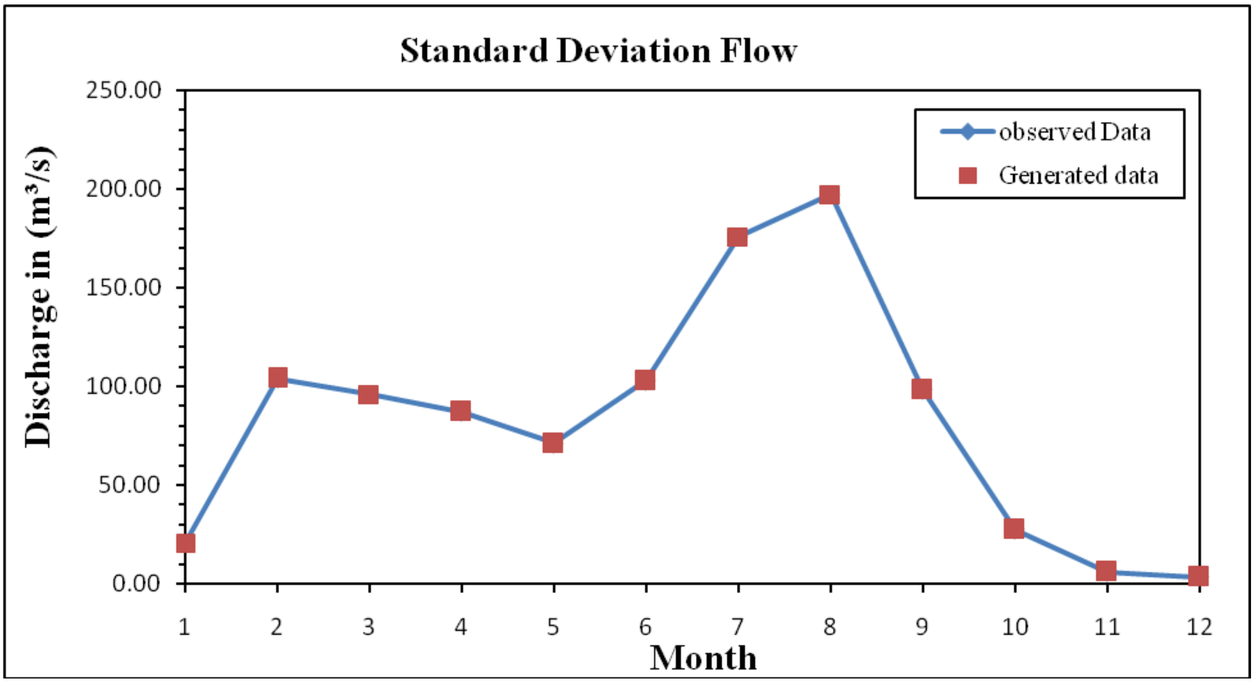

Figure 15. Comparison between the monthly standard deviations of observed and generated data by model AR (1) for verification.

Table 5. Comparison between the general properties of the observed data and the generated data by AR(1) model.

Series	Set	Meanm³/s	S.D.m³/s	C_s	C_k	Max. m³/s	Min. m³/s
Observed	---	813.62	205.58	1.66	5.24	1621.56	637.88
Generated	1	813.62	205.75	1.86	6.82	2017.45	615.12
Generated	2	813.62	205.75	1.89	7.26	2029.42	614.70
Generated	3	813.62	205.75	1.83	6.64	1912.29	612.04
Generated	4	813.62	205.75	1.82	6.55	1935.01	613.31
Generated	5	813.62	205.75	1.81	6.42	1816.65	614.63
Generated	6	813.62	205.75	1.80	6.45	1881.28	605.78
Generated	7	813.62	205.75	1.85	6.88	1993.83	623.58
Generated	8	813.62	205.75	1.78	6.23	1845.81	601.33
Generated	9	813.62	205.75	1.75	5.93	1767.78	619.12
Generated	10	813.62	205.75	1.83	6.77	2051.41	611.11

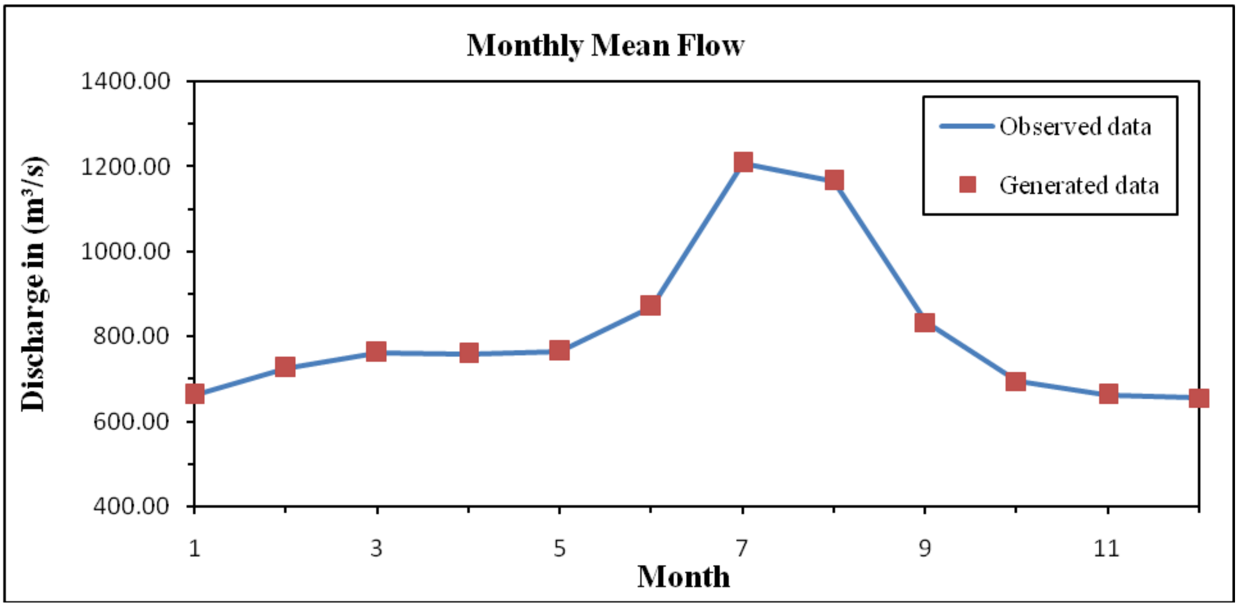

Figure 16. Comparison between the monthly averages of the observed data and the data generated by AR(1) model.

Table 6. Comparison between the monthly averages of the observed data and the data generated by AR(1) model (m^3/s).

Series	Oct	Nov	Dec	Jan	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep
Obse.	661.75	724.86	762.52	758.64	765.31	870.79	1207.67	1166.83	832.92	694.42	662.98	654.66
Gen.1	661.75	724.86	762.52	758.64	765.31	870.79	1207.67	1166.83	832.92	694.42	662.98	654.66
Gen.2	661.75	724.86	762.52	758.64	765.31	870.79	1207.67	1166.83	832.92	694.42	662.98	654.66
Gen.3	661.75	724.86	762.52	758.64	765.31	870.79	1207.67	1166.83	832.92	694.42	662.98	654.66
Gen.4	661.75	724.86	762.52	758.64	765.31	870.79	1207.67	1166.83	832.92	694.42	662.98	654.66
Gen.5	661.75	724.86	762.52	758.64	765.31	870.79	1207.67	1166.83	832.92	694.42	662.98	654.66
Gen.6	661.75	724.86	762.52	758.64	765.31	870.79	1207.67	1166.83	832.92	694.42	662.98	654.66
Gen.7	661.75	724.86	762.52	758.64	765.31	870.79	1207.67	1166.83	832.92	694.42	662.98	654.66
Gen.8	661.75	724.86	762.52	758.64	765.31	870.79	1207.67	1166.83	832.92	694.42	662.98	654.66
Gen.9	661.75	724.86	762.52	758.64	765.31	870.79	1207.67	1166.83	832.92	694.42	662.98	654.66
Gen.10	661.75	724.86	762.52	758.64	765.31	870.79	1207.67	1166.83	832.92	694.42	662.98	654.66

Table 7. Comparison between the monthly standard deviations of the observed data and the data generated by AR(1) model (m^3/s).

Series	Oct	Nov	Dec	Jan	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep
Obse.	20.88	104.20	95.93	87.42	71.24	103.03	175.76	197.22	98.25	27.52	6.22	3.59
Gen.1	20.88	104.20	95.93	87.42	71.24	103.03	175.76	197.22	98.25	27.52	6.22	3.59
Gen.2	20.88	104.20	95.93	87.42	71.24	103.03	175.76	197.22	98.25	27.52	6.22	3.59
Gen.3	20.88	104.20	95.93	87.42	71.24	103.03	175.76	197.22	98.25	27.52	6.22	3.59
Gen.4	20.88	104.20	95.93	87.42	71.24	103.03	175.76	197.22	98.25	27.52	6.22	3.59
Gen.5	20.88	104.20	95.93	87.42	71.24	103.03	175.76	197.22	98.25	27.52	6.22	3.59
Gen.6	20.88	104.20	95.93	87.42	71.24	103.03	175.76	197.22	98.25	27.52	6.22	3.59
Gen.7	20.88	104.20	95.93	87.42	71.24	103.03	175.76	197.22	98.25	27.52	6.22	3.59
Gen.8	20.88	104.20	95.93	87.42	71.24	103.03	175.76	197.22	98.25	27.52	6.22	3.59
Gen.9	20.88	104.20	95.93	87.42	71.24	103.03	175.76	197.22	98.25	27.52	6.22	3.59
Gen.10	20.88	104.20	95.93	87.42	71.24	103.03	175.76	197.22	98.25	27.52	6.22	3.59

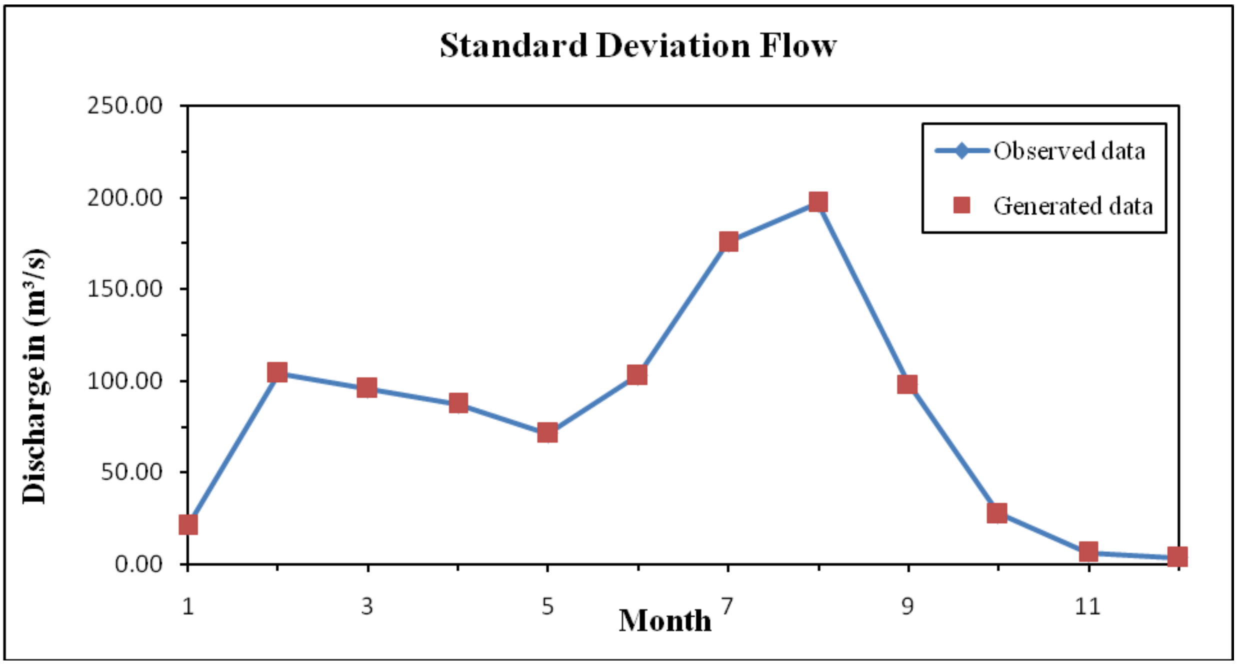

Figure 17. Comparison between the monthly standard deviations of the observed data and the data generated by AR(1) model.

Analytical and Numerical Tooth Contact Analysis (TCA) of Standard and Modified Involute Profile Spur Gear

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ABSTRACT

Among all the common mechanical transmission elements, gears still playing the most dominant role especially in the heavy duty works offering extraordinary performance under extreme conditions and that the cause behind the extensive researches concentrating on the enhancement of its durability to do its job as well as possible. Contact stress distribution within the teeth domain is considered as one of the most effective parameters characterizing gear life, performance, efficiency, and application so that it has been well sought for formal gear profiles and paid a lot of attention for moderate tooth shapes. The aim of this work is to investigate the effect of pressure angle, speed ratio, and correction factor on the maximum contact and bending stress value and principal stresses distribution for symmetric and asymmetric spur gear. The analytical investigation adopted Hertz equations to find the contact stress value, distribution, and the contact zone width while the numerical part depends on Ansys software version 15, as a FE solver with Lagrange and penalty contact algorithm. The most fruitful points to be noticed are that the increasing of pressure angle and speed ratio trends to minimize all the induced stresses for the classical gears and the altered teeth shape with larger loaded side pressure angle than the unloaded side one behave better than the symmetric teeth concerning the stress reduction.

Key words: symmetric and asymmetric spur gear, contact stress.

تحليل تلامس الأسنان نظرياً وعددياً للتروس الصماء التقليدية والمعدلة ذات الجانبية الالتفافية

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الخلاصة

من بين كل عناصر النقل الميكانيكية المعروفة لاتزال المسننات تلعب دوراً مهيمناً خاصةً في الاعمال الثقيلة مقدمةً اداءً استثنائياً تحت الظروف المتطرفة وهو سبب كثرة الابحاث المركزة على تحسين مقاومتها لآداء دورها على اكمل وجه. يعتبر توزيع إجهادات التلامس في الاسنان واحداً من اهم العوامل المحددة لحياة المسنن وآداؤه وكفائته ومجال تطبيقه لذلك تم تحريه بعناية للمسننات ذات الجانبية المنهجية ومنح الكثير من الاهتمام لأشكال الاسنان المعدلة. الهدف من هذا العمل هو تحري تأثير زاوية الضغط ونسبة التحويل و معامل التصحيح على القيمة العظمى لإجهاد التلامس والحناية وتوزيع الإجهادات الرئيسية للمسننات الصماء المتناظرة وغير المتناظرة. اعتمد التحليل النظري معادلات (Hertz) لحساب إجهاد التلامس وتوزيعه وعرض منطقة التلامس بينما اعتمد الحل العددي برنامج Ansys النسخة الخامسة عشر لايجاد الاجهادات باستخدام خوارزمية (Lagrange- penalty). أهم النقاط المثمرة التي ينبغي ملاحظتها ان زيادة زاوية الضغط ونسبة السرع تميل لتقليل كل إجهادات المسننات التقليدية و إن الاسنان معدلة الشكل ذات زاوية تحميل اكبر من نظيرتها غير المحملة تتصرف بشكل افضل من الاسنان المتناظرة فيما يخص تقليل الإجهادات.

الكلمات الرئيسية: المسننات الصماء المتناظرة وغير المتناظرة, إجهاد التلامس.

1. INTRODUCTION

Gears have been focused on as the prime power transmission mechanical elements regarding durable and superior stress and vibration related performance. The confidence of any mechanical system is austerely related to the survival of its components under the working environment conditions such as contact, bending, and thermal stresses, vibration, fatigue and so on. The requirements placed on gear design technology are constantly increasing and need new technical solutions which are mainly related to the gear teeth shape altering aiming to reach the optimum geometrical combination that reduces the induced teeth contact and bending stresses o that, spur gear has an extensive studies regarding mathematical representation, manufacturing, transmission errors, stress analysis, wear, dynamic behavior, efficiency , and performance etc.

The most well known formulations addressing the problem of gear stresses ,Lewis equation for fillet stresses and Hertz equation for contact stresses, are derived for standard tooth profiles and show some shortage to come up with the nowadays gear design tools and manufacturing facilities which enable designer to innovate gears like never known before. Aiming to fit modern industry needs researchers, societies and companies still developing these formulations, and the latest formula for bending stress is M.Q. Abdullah equation, **Abdullah, 2012,** and AGMA equation for contact stress, **Slogén, 2013.**

It has been found that the contact stress and wear rate are expressing each other because of the intensity of contact stress play an important role in quantifying the amount of wear and vice versa the amount of wear change the involute profile by a certain distribution and lead to increase the induced contact stress with some improvements on the transmission smoothness **Farhan Muhammad et.al, 2015**. This study is focusing on the contact stress and the induced principal stresses within the tooth subsurface as the base of tooth shape optimization and simulates the studied cases numerically to compare with the mathematical results and then adopted to verify the nonstandard teeth profile results.

2. SLIDING BEHAVIOR

Pinion and gear push each other and transmit power depending on the sliding and rolling actions during the period of engagement. The maximum sliding action occurs at the tip and base of tooth regions and accompanied by heat generation, wear development, and power loss but it is unavoidable action and necessary to sustain the successive engagement of teeth. Rolling action is dominant at pitch point and accompanied by high pressure intensity without heat generation or wear setup. In general the larger sliding distance the greater wear rate and the lower vibration. It is often required to find the amount of the sliding velocity which has got a direct bearing on the amount of wear, **Maitra, 2001**. The relative sliding velocity is expressed as follows.

$$s_v = s_d \times (\omega_1 - \omega_2) \qquad (1)$$

Where $\omega_1$and ω_2 are the angular speed of pinion and gear respectively, s_d is the relative sliding distance.

$$s_{d\,max} = \sqrt{{Ra_1}^2 - {Rb_1}^2} + \sqrt{{Ra_2}^2 - {Rb_2}^2} - (R_{p1} + R_{p2}) \times \sin\alpha \qquad (2)$$

Where $Ra_{1,2}$ are the gear and pinion addendum radii, $Rb_{1,2}$ are the gear and pinion base radii, $R_{p1,2}$ are gear and pinion pitch radii, and α is the pressure angle.

The distribution of sliding distance and velocity is linear and identical for the flank and face portions of uncorrected tooth profiles unlike its counterpart, it is linear but with larger value for addendum than the dedendum part.

The load share between the successive teeth indicates the gear load carrying capacity which could be expressed in terms of contact ratio (CR). Higher contact ratio means larger number of gear teeth contributing power transmission leading to elongate gear life and generally it is ranging from 1.2 to 1.6 for standard applications. Working contact ratio is less than the design one due to mounting and assembly errors and that increases the vibration and coarsens the transmission process, **Tharmakulasingam, 2009.**

$$CR = \frac{S_{d\,max}}{\pi m} \qquad (3)$$

Where CR is the contact ratio and m is the module.

3. HERTZ CONTACT STRESS

Due to its high intensity value compared to other stresses induced in gear teeth, contact stress has been paid a lot of attention in the design process to be the deciding factor for the determination of the requisite dimensions of gears aiming to minimize its maximum value as possible to be less than the allowable value and rearrange its distribution. In 1881 Heinrich Hertz derived his famous equation to calculate the induced contact stress between two elastic cylinders. Hertz theory assumed that the surfaces are continuous, smooth, nonconforming, frictionless, the size of the contact area is small compared to the size of the bodies, i.e., the strains associated with the deformations are small, each solid can be considered to behave as an elastic half-space in the vicinity of the contact zone, **Bhushan, 2001.**

The main shortages of this equation in gearing field are that the radius of tooth profile is not constant and it is a permanent calculation error, and the contact stress becomes infinite at the base of the profile so that it is not applicable at this point. This equation is the most dependable and accurate ever known approach simulates contact mechanism realistically and has been dealt with as the dominant equation over 100 years, where the contacting zone half width is see **Fig.1**, **Johnson 1985**

$$a = \sqrt{\frac{4F(\frac{1-v1^2}{E_1}+\frac{1-v2^2}{E_2}}{\pi b\left(\frac{1}{r_1}+\frac{1}{r_2}\right)}} \qquad (4)$$

And the maximum contact pressure is

$$P_{max.} = \frac{2F}{\pi ab} = \sigma_c \quad (5)$$

Sub. Eq. (4) in Eq. (5) the maximum contact stress will be

$$\sigma_c = \sqrt{\frac{1}{\pi} * \frac{F}{b} \frac{\left(\frac{1}{\rho_1}+\frac{1}{\rho_2}\right)}{\left(\frac{1-\nu_1^2}{E_1}+\frac{1-\nu_2^2}{E_2}\right)}} \quad (6)$$

And spreads over the contacting zone as follow

$$P = \sigma_c \sqrt{1 - \frac{x^2}{a^2}} \quad (7)$$

The principal stresses under the contacting surfaces is expressed by

$$\sigma_1 = \sigma_y = a\, P_{max}(a^2 + y^2)^{-0.5} \quad (8)$$

$$\sigma_2 = \sigma_x = \frac{P_{max}}{a} \, [(a^2 + 2y^2)(a^2 + y^2)^{-0.5} - 2y \quad (9)$$

$$\sigma_3 = \nu\, (\sigma_1 + \sigma_2) \quad (10)$$

any discontinuity within the contacting surfaces or sharp edges rising up the interacting pressure rapidly which is existed in case of undercut, if the teeth number is lower than the minimum number as in Eq.(11), and at the tip of any tooth without tip modification.

$$z_{min} = \frac{2}{(sin\alpha)^2} \quad (11)$$

4. INTERFERING AND TOOTH CORRECTION

The transmitted power and available space are the functional criteria for choosing gear system size which is characterized by module and tooth number. Beyond the minimum teeth number the tip of cutting tool will Remove the material from the tooth fillet region, layer after layer during the reciprocating process between the cuter and gear blank modifying the manufactured gears to have jam free engagement action, making the gear fillet and involute shape no more in tangency but intersect each other, **Litvin, 2004**. This material removal has some disadvantages such as weakening the tooth bending strength, defeat the involute profile to be shorter than its normal length, and the intersecting point of involute profile with the trochoidal fillet shape produces a sharp edge along the face width produce a high stress concentration zone. One of the most beneficial solutions to overcome the undercut problem is addendum modification by some correction factor leading to some geometrical improvements like increasing weakest section tooth width, preventing the sudden change in tooth profile and emergence of sharp edge, enlarging the pressure angle, and increasing load carrying capacity see **Fig. 2**. The amount of addendum correction factor is obeyed to

$$x = \frac{z_{min} - z}{z_{\mathrm{m}}} \tag{12}$$

5. CASE STUDY

The effect of pressure angle for symmetric and asymmetric spur gear on the induced contact stress is sought numerically and analytically. The FEM has been adopted to build up the 3-D model and analyzed the contact stress using Ansys software version 15. Hertz equation is modified to take into account the correction factor, the adjusted radius of curvature, and the working pressure angle affected by the correction are;

$$\tan\alpha_c - \alpha_c = \frac{2(x_1 + x_2)}{z_1 + z_2}\ \tan\alpha + \tan\alpha - \alpha \tag{13}$$

$$r_{pc} = r_p \frac{\cos\alpha}{\cos\alpha_c} \tag{14}$$

Eq.(7) must be solved numerically to get the working pressure angle equivalent to the summation of pinion and gear correction factors to evaluate the corrected pitch radius so that Eq.(4) will be

$$\sigma_c = \sqrt{0.35 * \frac{F_n}{b} \frac{\left(\frac{1}{R_{1c}\sin\alpha_c} + \frac{1}{R_{2c}\sin\alpha_c}\right)}{\left(\frac{1}{E_1} + \frac{1}{E_2}\right)}} \tag{15}$$

The general dimensions and properties of the sought models are shown in **Table 1**, the range of pressure angles are shown in **Table 2**, the applied normal load have been chosen to be 100 N and contact position is the pitch point.

7. RESULTS AND DISCUSSIONS

7.1 Analytical Results

Hertz contact stress equation have been applied directly to the proposed studied cases of 20^o and 25^opressure angles but the 14.5^o pressure angle needs some addition calculation because the minimum teeth number for such pressure angle is 32 tooth according to Eq. (11) while the current teeth number is 14 tooth i.e. gear suffers of large undercut depending upon Eq. (12) the correction factor is (0.56 m_o) **Fig.2** shows the corrected and uncorrected spur gear teeth. The radius of curvature at the pitch point equal to (49 *sin α) but in the case of corrected gear the pitch point radius and the working pressure will change and could be calculated according to Eq. (13) and Eq. (14). **Table 3** represents the correction amount with its working pressure angles and corrected pitch radii.

Fig.3 relates the change in the contact zone half width distance to the variation of the pressure angle and the speed ratio. It is distinct that the increasing of the pressure angle and speed ratio plays a good role on the increasing of the contact area, because both increase the radius of curvature.

Fig.4 shows the effect of pressure angle on the contact stress, for different speed ratios, it is clear that the increasing of the pressure angle, by 20^o, reduced the contact stress by about 34%, while tripling the speed ratio decreases the contact stress by about 22%, and the cause of that is the larger angle and speed ratio means a larger contact radius of curvature leading to increase the contact zone width, i.e. the same load spread over a larger area. The other remark to be noticed is that the pressure angle sustains its effect on the contact stress but the speed ratio effect diminishes or becomes worthless after number 5 especially it is not an optional choice to enlarge the gear size by this magnitude.

Figs. 5.6,7 and 8 clarify how such high intensity contact stress flow or distributed within the tooth subsurface along the contacting teeth normal for 14.5^o, 20^o, 25^o, and 30^o pressure angle gear teeth respectively. The three principal stresses and the resulting von mises stresses have been converted to be dimensionless values, divided by the max. contact stress of the 14.5^o gear tooth i.e. 771 MPa.

Results emphasized the following facts

- The stress falls down or dissipated within (1 mm) beneath the tooth surface to be lower than one tenth of its max value, for the max. principal stresses and lower for the others.
- The first and second principal stresses equal to the maximum contact stress at the surface but the von mises stress is 0.6 of its value.
- The results confirm that the increasing of the pressure angle play a positive role on the reduction of all the induced stresses.

7.2 Finite Element Results

The different gear pairs have been modeled by Ansys software version 15 to investigate the induced static stresses and the pressure distribution within the contact area, along the contact zone half width distance and the gear face width. The models have been meshed using solid elements type brick with 20 nodes and contact elements 170 for the contact surface and 174 for the target surface, the material was chosen to be isotropic with linear behavior.

Fig.9.a, b show the contact stress distribution along the contact zone width and face width, it is obvious that the stress distribution matching that of Eq. (7) along the minor contact axis i.e. along the half contact zone distance a, but it refuted the assumption of Hertz theory about the contact stress distribution constancy along the contacting surfaces face width, such behavior is interpreted by the free end deformation trend which works as a stress relief regions. Despite this positive effect of these regions but it resize the face width to withstand against the external loads by about 0.8 of its real value and this is the counterpart negative effect, an evidence of such phenomenon is the pitting failure accurse faraway the tooth ends.

Fig. 10 represents the max. principal stress value and distribution for 14.5^o pressure angel teeth corrected by $0.1m_o$ and **Fig.10,b** corrected by $0.5m_o$, the max contact stress has been (771MPa) for the uncorrected gear as shown in **Fig.9** and reduced by about 21% due to correction factor, the modification of tooth profile by $0.56m_o$ for gear and pinion increase the pressure angle to be 23.97^o instead of 14.5^o and the pitch radius to be 51.9 mm instead of 49 mm and that lead to increasing the curvature radius, which is (R_p*sin α), to be 21.1 mm instead of 12.27 mm and that leads to increase the contact area by about 30% according to Eq.(4) so that the contact stress reduced.

Fig. 11 shows the bending stress distribution in the tension side bending zone affected by the pressure angle for symmetric spur gear. **Fig. 12** demonstrates the bending stress distribution in the tension side bending zone for asymmetric spur gear with loaded side pressure angle of 14.5^o pressure angle.

Fig.13 implies the effect of the unloaded side pressure angle variation on the max. contact stress of 14.5^o, 20^o, and $25^{o\ pressure}$ angle. It is evident that

- The increasing of the unloaded side pressure angle badly affected the max. induced contact stress
- The loaded side pressure angle must be greater than the unloaded side one for lower contact stress levels.
- The worst effect occurs for the gear of 14.5^o loaded side pressure angle.
- The unloaded pressure angle role diminishes after some value for the different three cases.

The larger unloaded pressure angle means a larger mass added to the spur gear teeth to be stiffer, leading to lower profile deformation at the contact point i.e. small contact zone area or high load intensity.

Fig. 14 relates the max. bending stresses for loaded and unloaded side of 14.5^o, 20^o, 25^o loaded side pressure angle with the variation of the unloaded side pressure angle. The following remarks could be concluded

- The lower loaded pressure angle accompanied by the larger bending stress, due to the increasing of the horizontal component of the applied load and decreasing of the tooth weakest section thickness.
- In general the compression side bending stress is higher than its counterpart of the tension side, due to the magnification of the bending compression side force by the vertical component of the applied load.
- The unloaded side pressure angle has a significant role regarding the bending stress reduction by control the weakest tooth thickness.

Fig.15 compares the analytical and numerical max. contact stress results for symmetric teeth of different pressure angles and shows a small discrepancy ranging between zero for 35^o pressure angle to 2.8% for 14.5^o which refers to the reliable FE model and boundary conditions.

8. CONCLUSIONS

Based on the whole presented theoretical and numerical results and explanation the following remarks could be concluded;

1. The use of asymmetric spur gears, with lower unloaded side pressure angle than its counterpart loaded side one, ensures low contact stress.
2. The higher pressure angle leads to lower contact and bending stress, with preservation of the first conclusion content.
3. The max. 1^{st} and 2^{nd} principal stresses have the same value of the max. contact stress at the contacting surfaces.
4. The unloaded side bending stress always prevails on that of the tension side.

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NOMENCLATURES

a= Contact zone half width, mm.

b= Face width, mm.

CR= Contact ratio.

$E_{1,2}$= Gear and pinion modulus of elasticity, MPa.

F=Applied normal force, N.

m= Module, mm.

P=Contact pressure, MPa.

$r_{1,2}$= Gear and pinion profile radii at any contact point, mm.

$Ra_{1,2}$= Gear and pinion addendum radii, mm.

$Rb_{1,2}$= Gear and pinion base radii, mm.

$R_{p1,2}$= Gear and pinion pitch radii, mm.

s_v= Sliding velocity, mm/s.

s_d= Sliding distance, mm.

$x_{1,2}$= Gear and pinion correction factor, mm.

z_{min}=Min teeth number.

α= Pressure angle, degree

α_c= Corrected pressure angle, degree.

$v_{1,2}$= Gear and pinion Poisson's ratio.

$\rho_{1,2}$= Gear and pinion radii of curvature, mm.

$\sigma_{1,2,3}$= Maxrincipal stress, MPa.

σ_c= Max. contact stress, MPa.

Table 1. Dimensions and material properties, of studied models.

	Pinion	**Gear**
Teeth number	14	14
Module (mm)	7	
Correction factor (mm)	0.5*m	
Face width (mm)	1	
Height (mm)	2.25*m	
Fillet radius (mm)	0.25*m	

Modulus of elasticity GN/m^2	200
Poison's ratio	0.3

Table 2. Rang of pressure angles.

Loaded side pressure angle (degree)	14.5	20	25
Unloaded side pressure angle (degree)	14.5	14.5	14.5
	18	18	18
	20	20	20
	22	22	22
	25	25	25
	28	28	28

Table 3. Corrected profile pressure angle and pitch radius for 14.5^o pressure angle gear.

Correction factor (x)	0	0.1	0.2	0.3	0.4	0.5	0.56
Working pressure angle	14.5	17.13052	19.10514	20.71728	22.09404	23.30346	23.9666
Corrected pitch radius	49	49.64152	50.20452	50.71885	51.19888	51.65295	51.91523

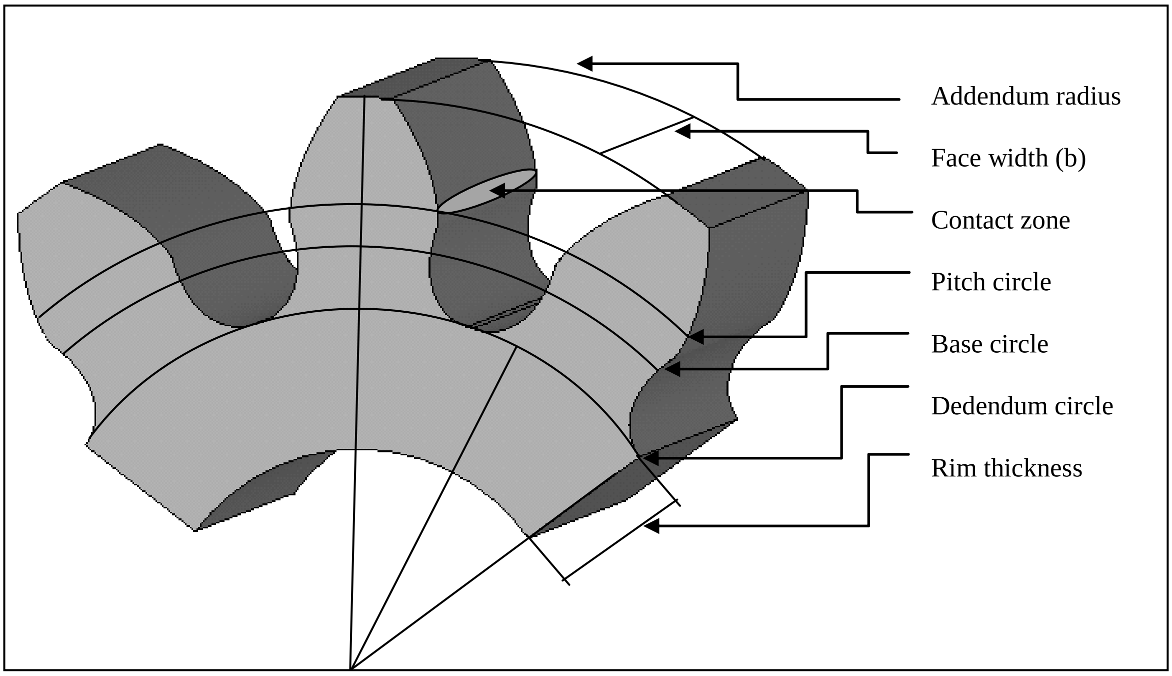

Figure 1. Geometry and main dimensions of spur gear teeth, α=20^o, m_o=7 mm, Z=10 teeth.

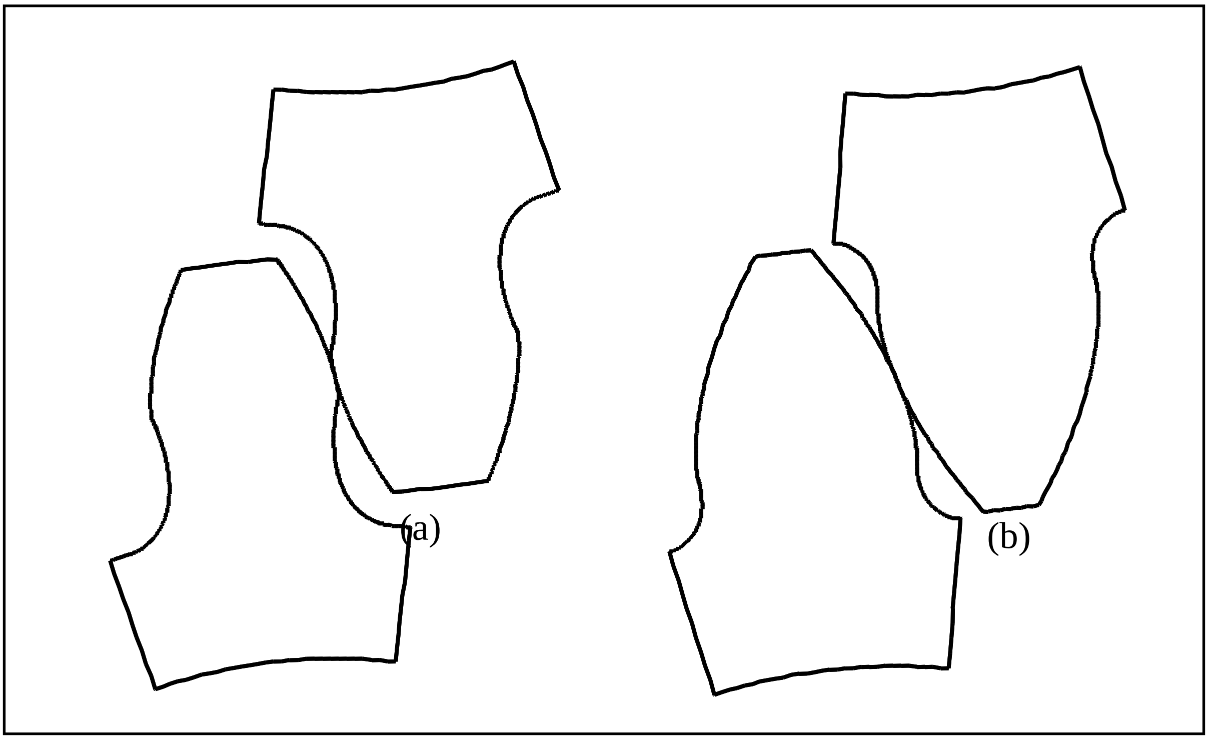

Figure 2. The effect of correction factor on the tooth shape, both have 7mm module and 14 teeth for gear and pinion . (a) Uncorrected teeth, (b) Corrected teeth by 0.5 correction factor.

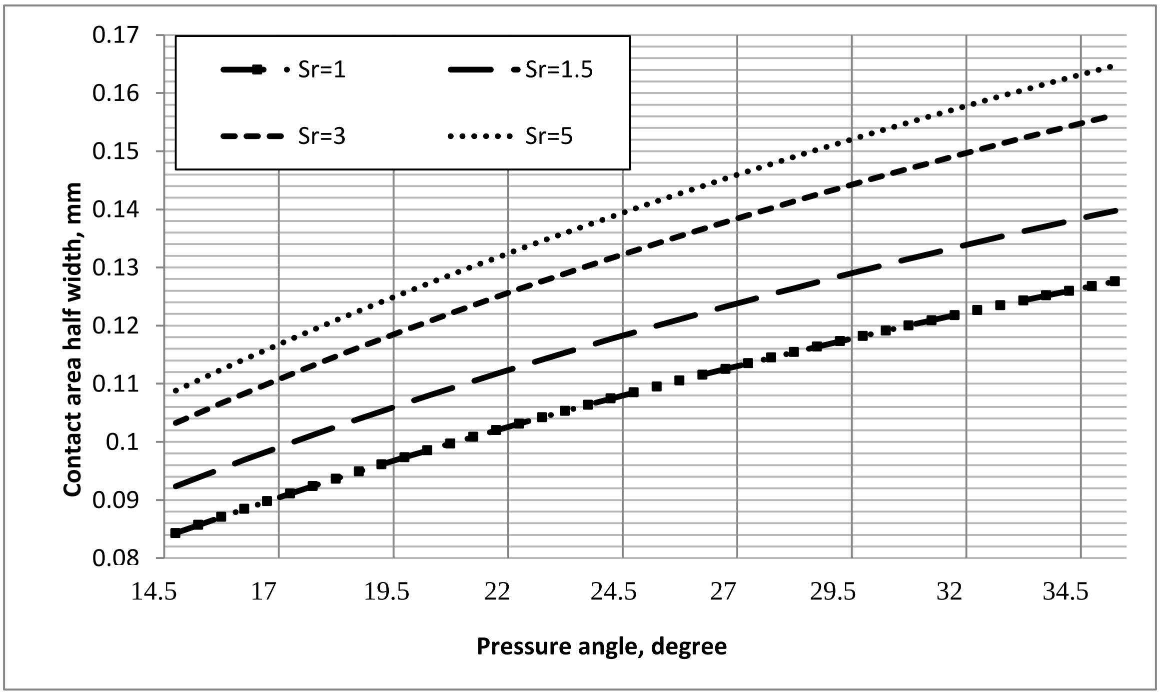

Figure 3. The effect of the pressure angle and speed ratio variation on the contact half width distance.

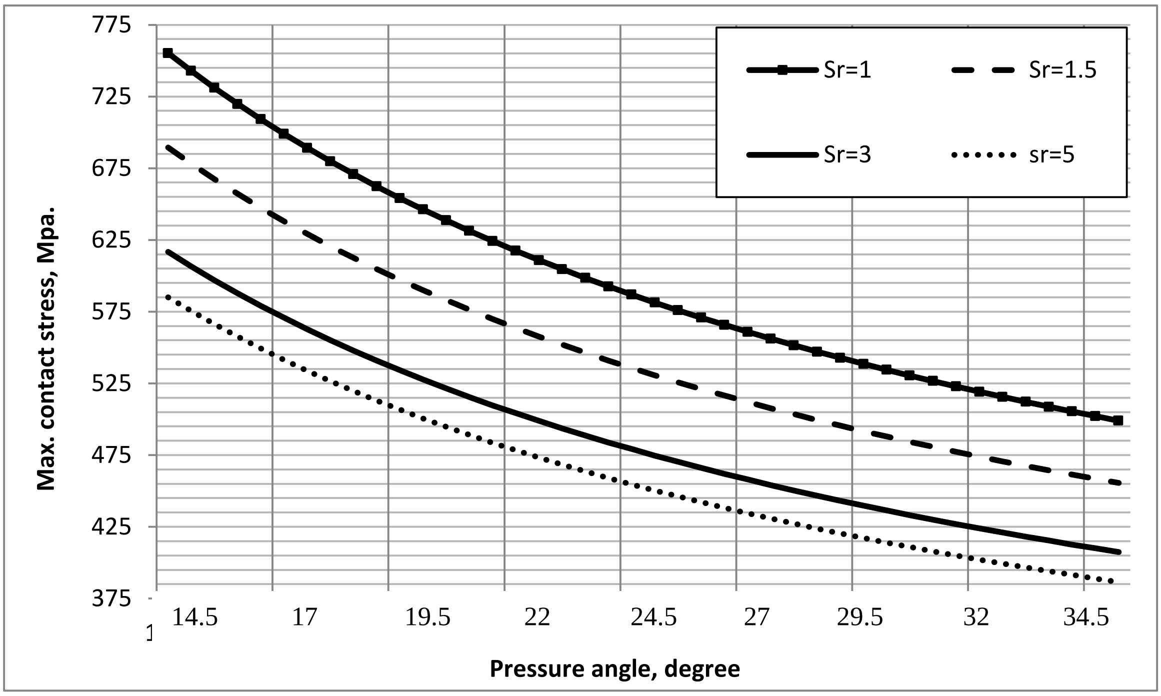

Figure 4. The Role of the pressure angle variation on the max. contact stress for different speed ratios.

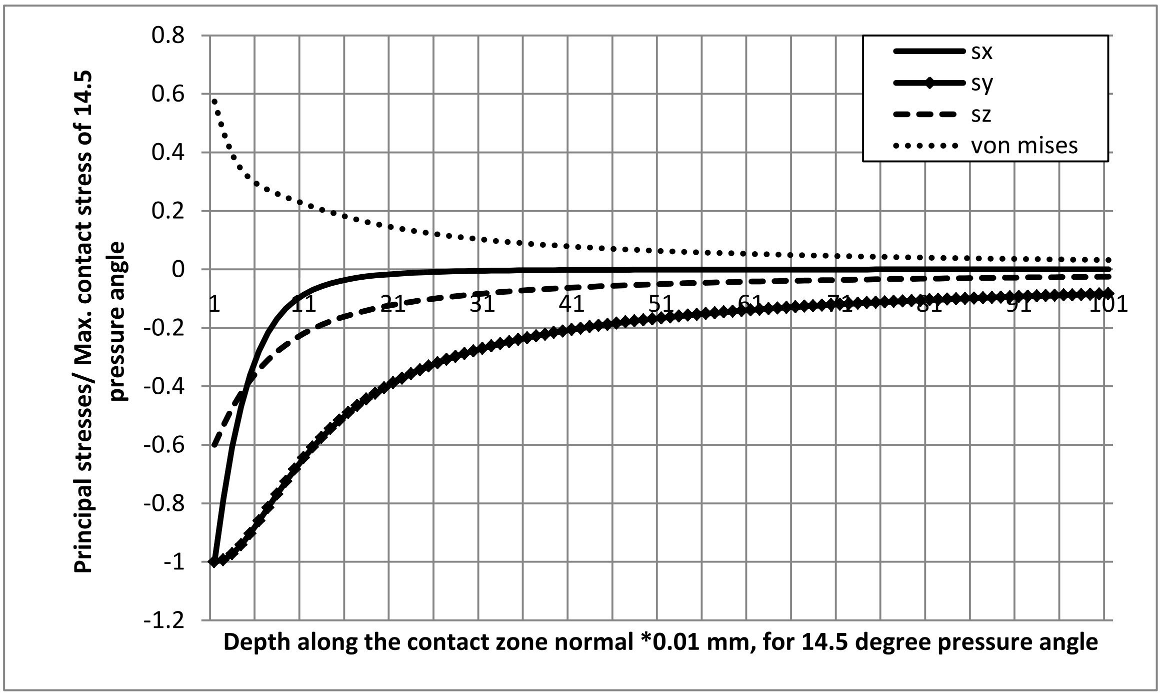

Figure 5. The dimensionless different stresses distribution along the contacting surfaces normal, the pressure angle is 14.5°.

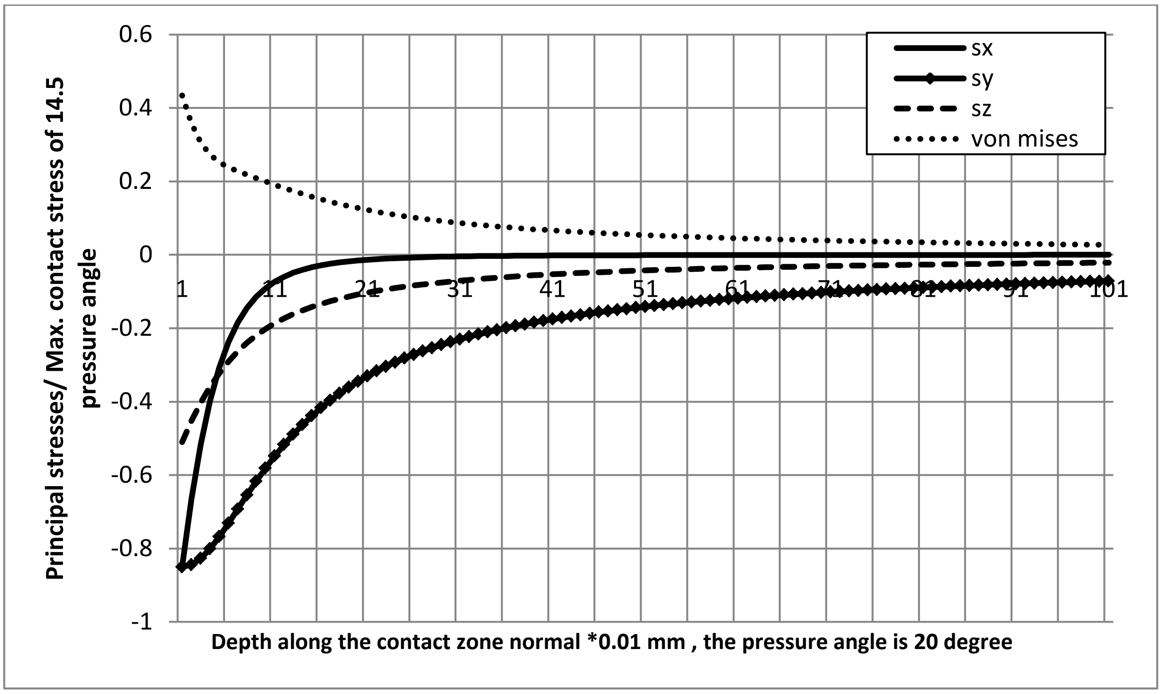

Figure 6. The dimensionless different stresses distribution along the contacting surfaces normal, the pressure angle is 20^o.

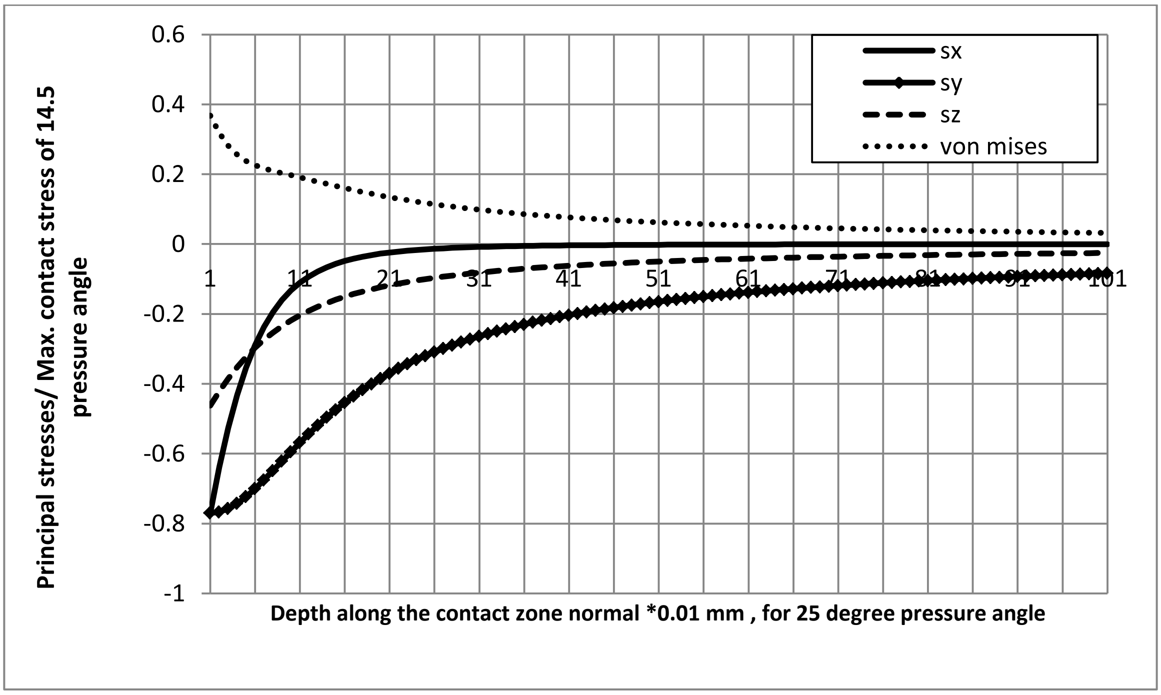

Figure 7. The dimensionless different stresses distribution along the contacting surfaces normal, the pressure angle is 25^o.

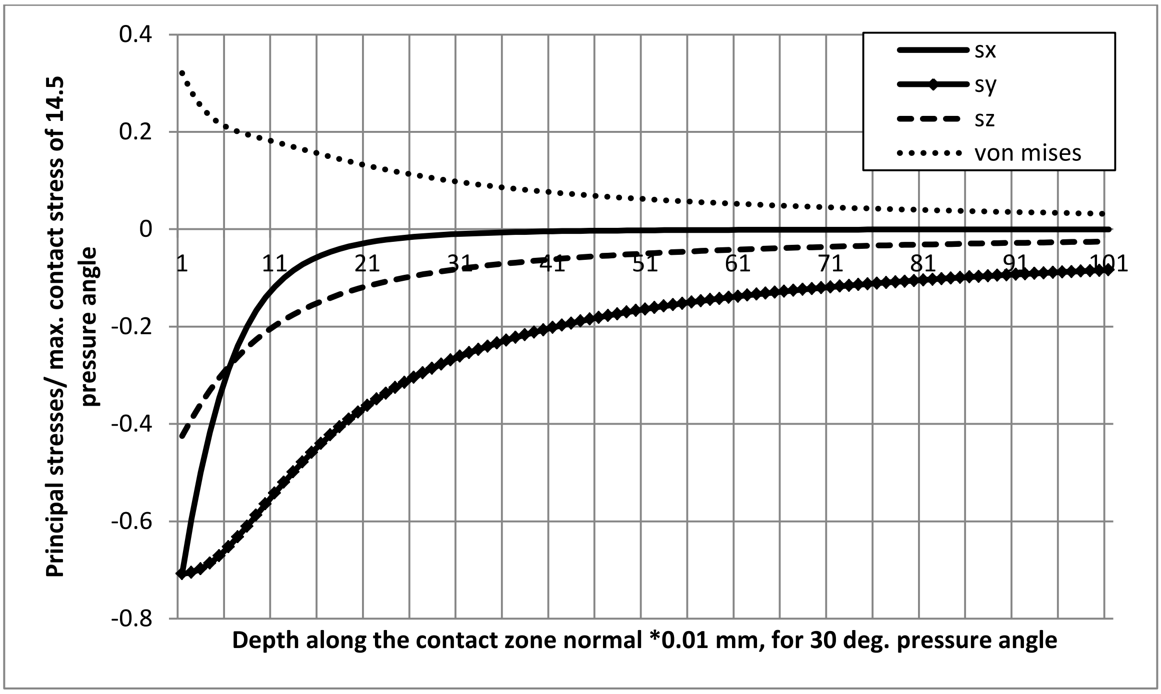

Figure 8. The dimensionless different stresses distribution along the contacting surfaces normal, the pressure angle is 30^o.

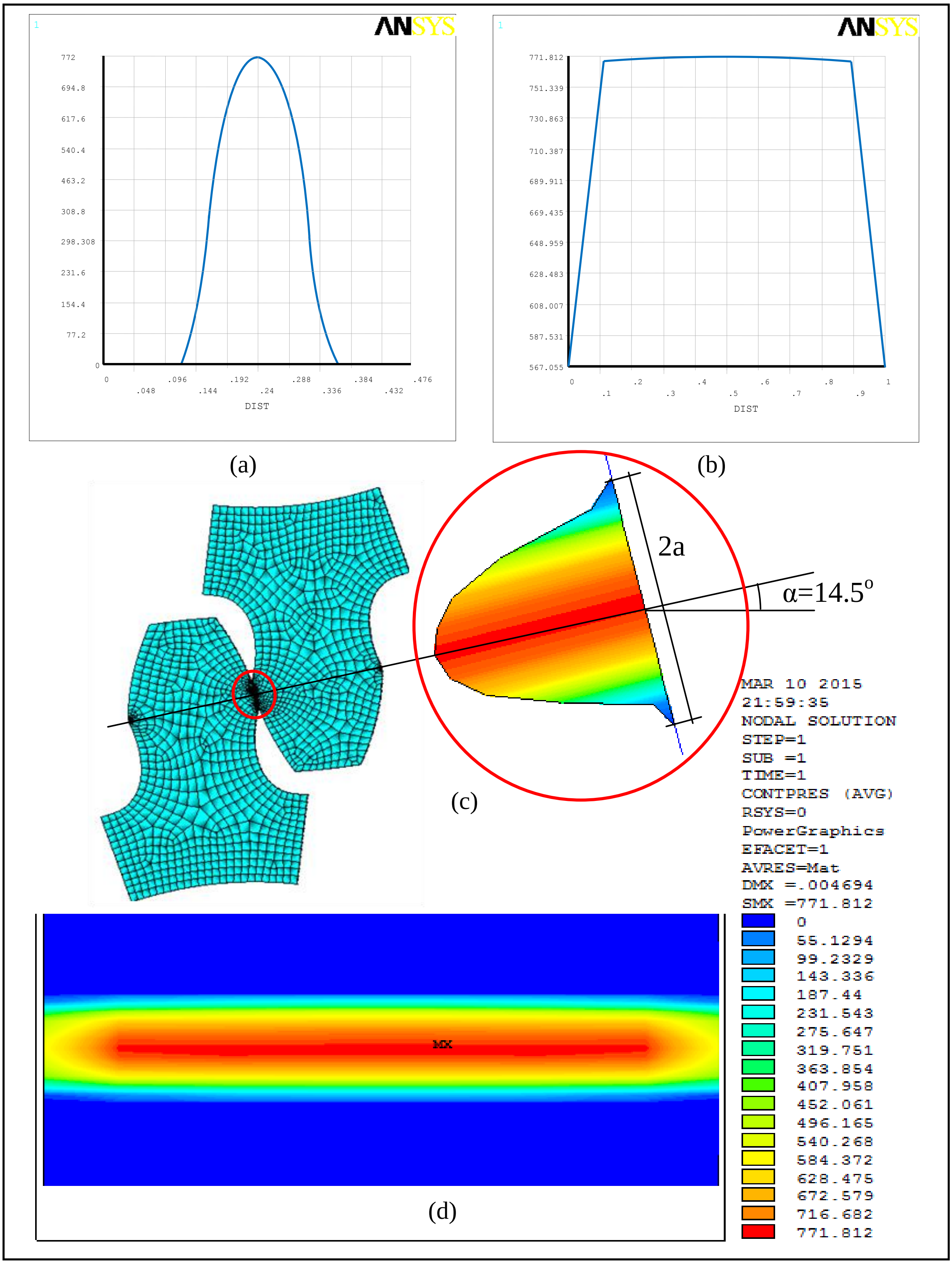

Figure 9. Contact stress distribution of symmetric spur gear of 14.5° pressure angle, (a) Along contact zone minor axis (a), (b) Along major axis (face width), (c) Teeth in mesh at pitch point, (d) Contact stress pattern in the contact zone.

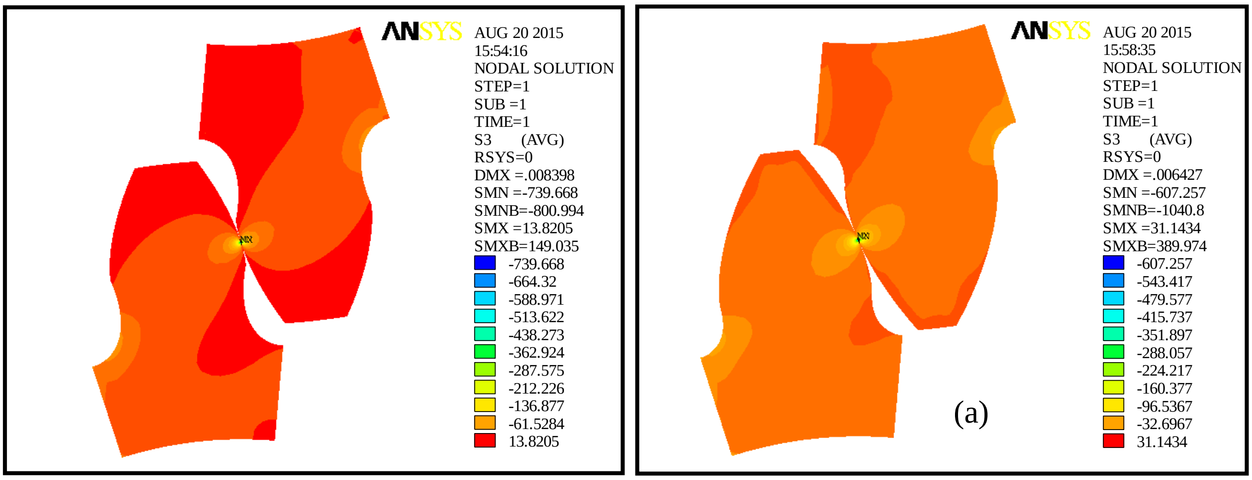

Figure 10. Max. principal stress for 14.5^o pressure angle involute profile.
(a) Corrected by 0.1 m_o. (b) corrected by 0.5 m_o.

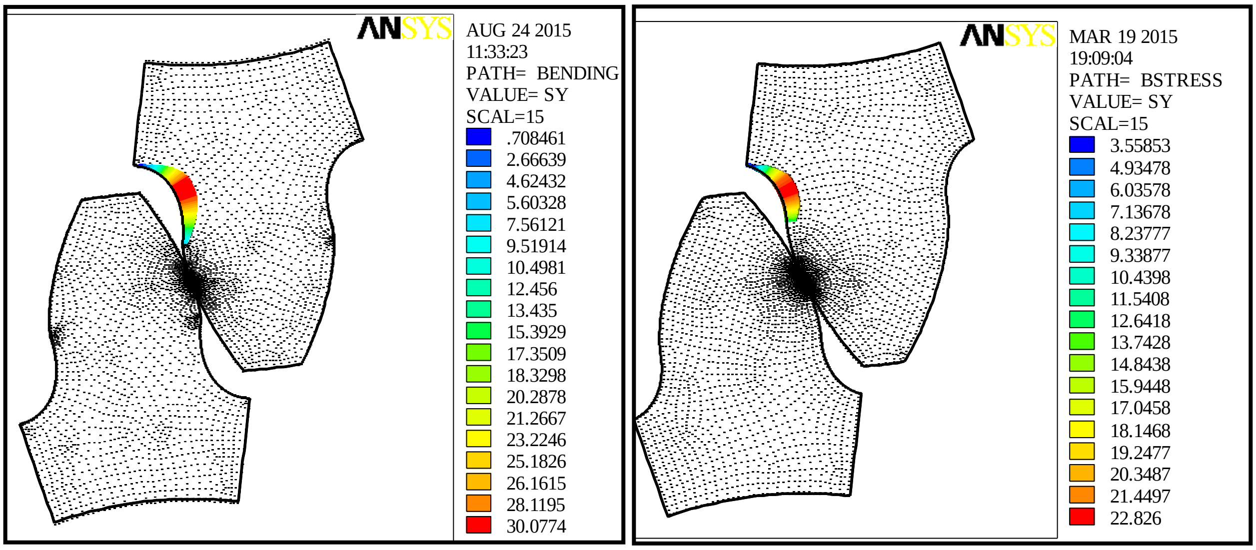

Figure 11 Max. bending stress for symmetric spur gear with (a) 20^o pressure angle (b) 25^o pressure angle

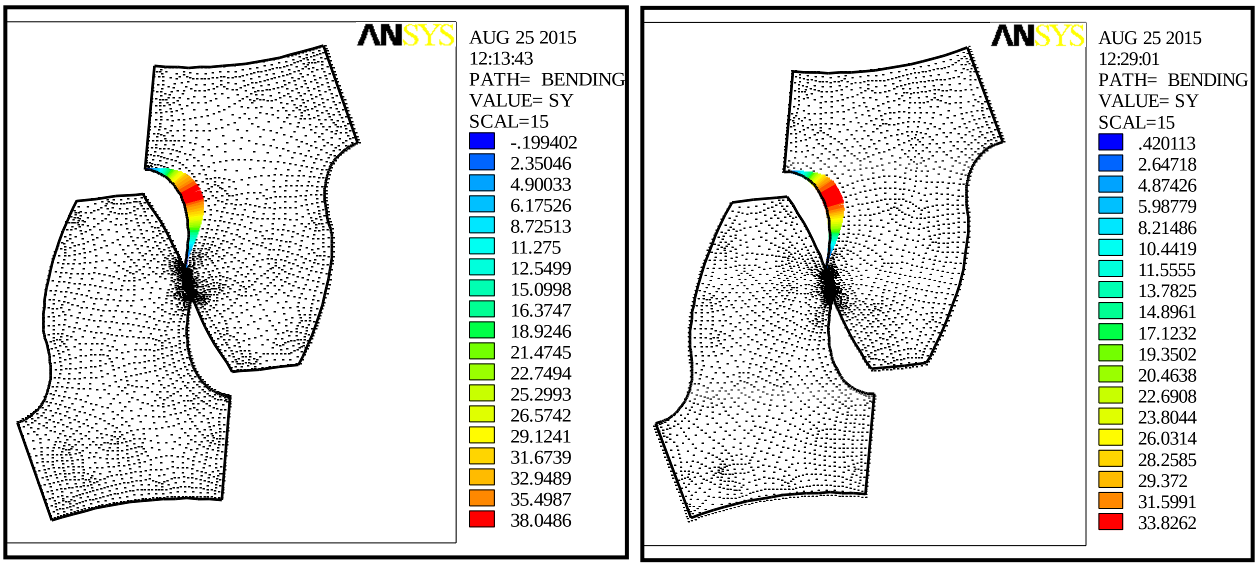

Figure 12. Max. bending stress for asymmetric spur gear with 14.5^o loaded side and (a) 20^o unloaded pressure angle (b) 25^o unloaded pressure angle.

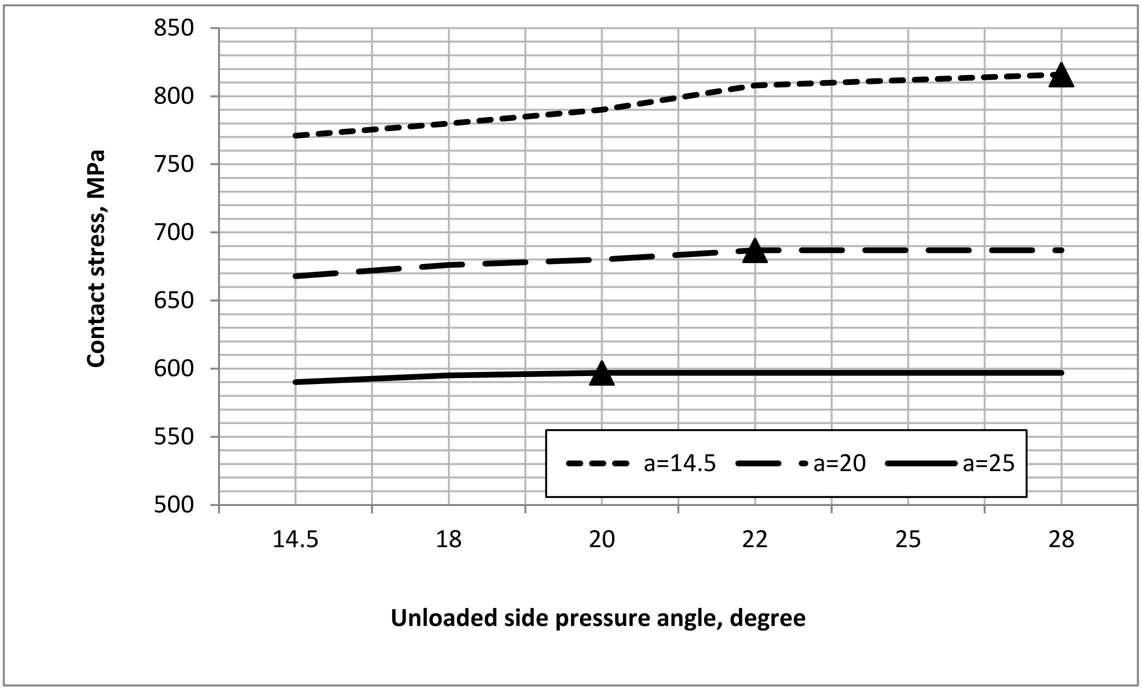

Figure 13. Max. contact stress for asymmetric spur gear with unloaded pressure side angle variation.

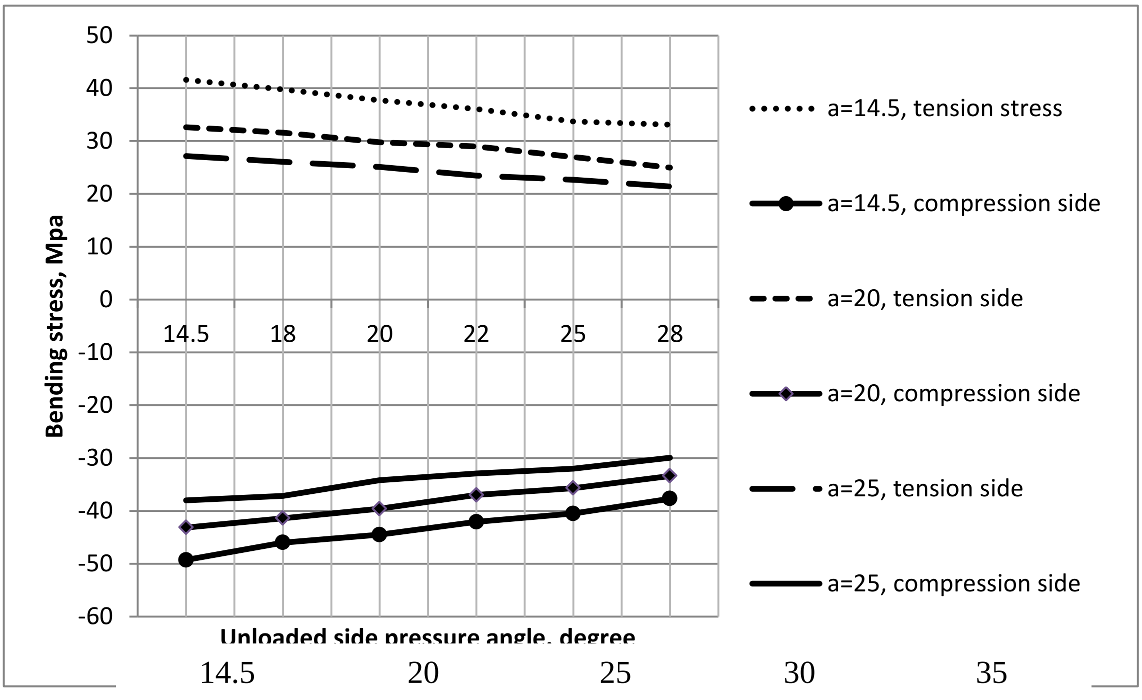

Figure 14. Max. bending stress for asymmetric spur gear with unloaded side pressure angle variation.

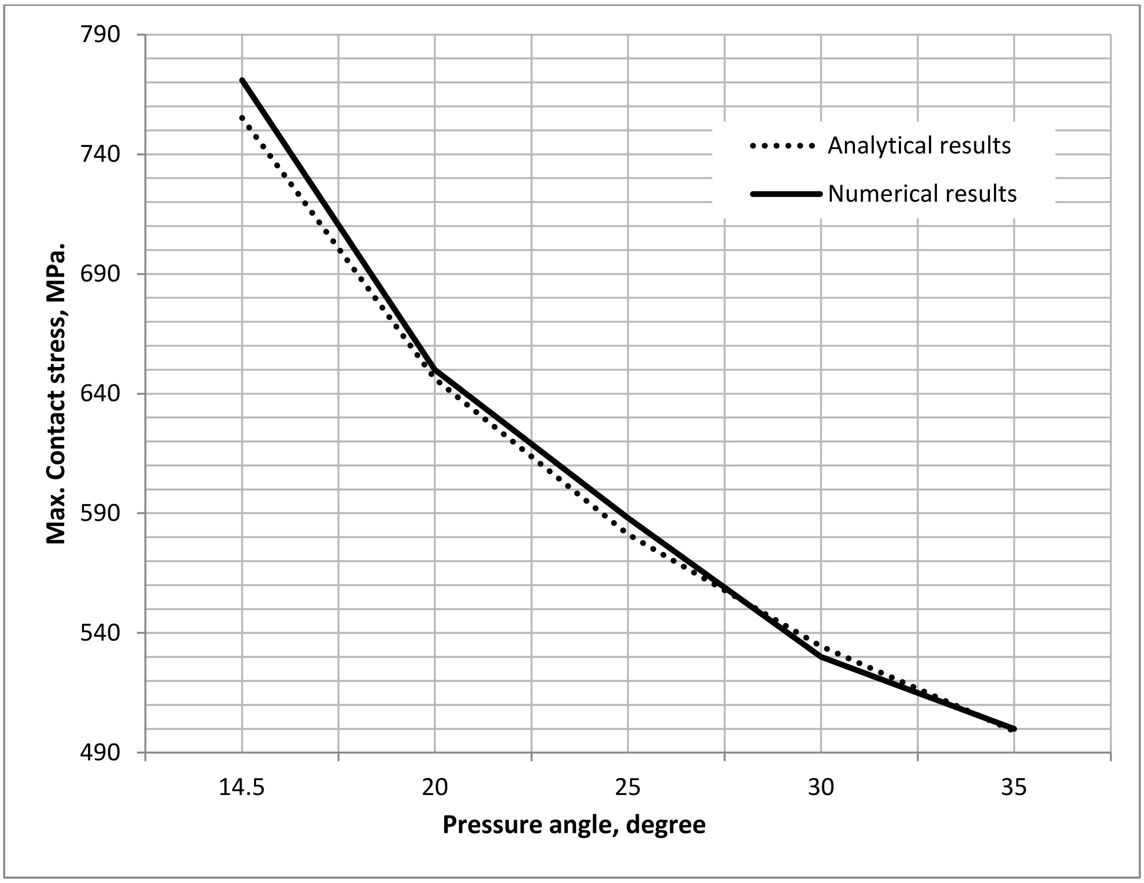

Figure 15. Analytical and numerical max. contact stress results for symmetric teeth.

Critical Success Factors in Construction Projects (Governmental Projects as a Case Study)

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ABSTRACT

The importance of the construction sector and its Great role in the provision of services and infrastructure, reduce poverty, improve living conditions and improve the economic situation in the country, impose attention to the way in which the projects implemented for its improvement and to get successful projects. The objective of this research was to determine the criteria for success as well as critical success and failure factors that have a significant impact on project success. A selected 75 engineer (department managers, project managers and engineers) are asked to fill the questionnaire form, Sixty-seven valid questionnaire forms were analyzed statistically to get search results, which were as follows : Twelve critical success factors, the most important factors of it were ("contractor financial efficiency ", " security ,political , economic stability ", "the project manager competence" and " Integration and clarity of contract documents ") , thirteen critical failure factors, the most important factors of it were ("corruption " , " external circumstances ", "Financial difficulties of owner)", and ten success criteria , the most important criteria of it were ("within allocated budget" , " within time period" , "Quality").

Key word: critical success factors, critical failure factors, success criteria and project .

عوامل النجاح الحرجة في المشاريع الانشائية (المشاريع الحكومية حالة دراسية)

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الخلاصة

ان اهمية قطاع الانشاءات و دوره الكبير في توفير الخدمات و البنى التحتية ، تقليل الفقر و تحسين الحالة المعيشية و الحالة الاقتصادية في البلد ، تفرض الاهتمام بالطريقة التي تنفذ فيها المشاريع لتحسينها لغرض الحصول على مشاريع ناجحة. كان الهدف من هذا البحث تحديد معايير النجاح اضافة الى عوامل النجاح و الفشل الحرجة التي لها تاثير كبير على نجاح المشروع . لتحقيق اهداف البحث . تم اختيار 75 مهندس (مدير قسم , مدير مشروع و مهندس) لغرض ملئ استمارة الاستبيان . تم استرجاع سبعة و ستون استمارة صالحة تم تحليلها احصائيا للحصول على نتائج البحث ، التي كانت كماياتي : اثنى عشر عامل نجاح حرج اهمها (الكفاءة المالية للمقاول ، الاستقرار السياسي ، الامني و الاقتصادي في البلد ، كفاءة مدير المشروع و تكامل وثائق المقاولة) , ثلاثةعشر من عوامل الفشل الحرجة , اهمها ("الفساد"، "الظروف الخارجية"، "الصعوبات المالية للمالك) اضافة الى عشرة معايير للنجاح، اهمها ("ضمن الميزانية المخصصة "،" ضمن الفترة الزمنية "،" الاستدامة "و" الجودة ") .

الكلمات الرئيسية : عوامل النجاح , عوامل الفشل الحرجة , معايير النجاح و المشروع .

1. INTRODUCTION

The construction sector is one of the most important sectors in any country , it plays a major role in providing buildings , public institutions, infrastructure, reduce poverty, improve the pension status of the citizens, job creation, improve the environment, improve the economic sector and other important matters offered by this sector . Despite the availability of all the possibilities, experiences, factors and other things that lead to the success of construction sector and projects that it offers, but the proportion of the failed projects is relatively large in Iraq , project failure is common in all countries of the world, even developed ones but in varying proportions, This failures proportion requires identification of problems and imbalances suffered by this industry in addition to identification of factors that will raise the success rate of Iraqi construction industry projects, if the project is completed within the agreed budget , on time and according to the desired quality, "the 'golden triangle'", the project considered successful , this is Far from reality. The construction industry participants have to notice the critical success factors, along with 'golden triangle', to ensure its continuity, **Toor and Ogunlana, 2009**. The work of the companies in the construction sector is project-oriented, i.e., it is unique and has a known start and finish, Zwikael**, 2012**. The difficulties and the obstacles facing the departments of organizations in this sector could be minimizing the negative effects through the use of tools and construction project management techniques. The proper usage of the project management tools in all phases of the project, will ensures the smooth execution of project activities. Generally research is divided into two parts, the first part is theoretical part and the second side is the practical side, the theoretical part reviews projects and project management, failure and success of the construction projects in addition to the critical factors for success and failure and success criteria in the construction sector , The practical side In it, will identify critical factors and criteria for success through case studies and direct meetings with specialists in the field of construction in addition to the closed and open questionnaire and also extract a mathematical model to calculate the the project success index .

2. PROJECT AND PROJECT MANAGEMENT

The project definition must be general to include examples of the organizational activities wide variety of which the managers consider to be "the project functions." and, it should be narrow enough It is allows distinguish it from other projects , describe as "project-oriented." There are many definitions for the project, including:

1- The project is a human and nonhuman resources combination Integrates together in a temporary organization for the purposes of achieve a specified objective, **Kerzner ,2001** .

2- The project is a temporary endeavor undertaken to meet a unique objectives and goals within a defined time frame, budget and scope, **PMI, 2008**.

3- The project is a succession of complex, unique, and connected activities having a goal or purpose must be completed according to specification, within budget, and by a specific time.

The project management can defined as, " the techniques, skills, tools, and knowledge application to the project activities in order to meet the project requirements , **PMI, 2008** and **turner ,1996**, defined the project management " the competencies of different individuals and grouping them together to facilitate access to achieve the project objectives and ensure the project success". The project life cycle, is a logical sequence of the activities to fulfillment the project's goals, consist of five phases namely; (the *Project Initiation*, the *Project Planning*, the *Project Execution*, the *Monitoring and Controlling* stage, and the *Project Closure)* phases .The attention to details, proper documentation at each stage and the involvement of the key stakeholders ensures the success of the project. For example, the setting of the scope and specifications of the project in the Initiation phase enables the project manager and sponsor to be clear with the purpose, budget, expected outcomes, time frame and deliverables of the project. And also, the experience shows that getting the things right at the Planning phase is very critical for project success and the project outcomes sustainability. The Planning phase ties into the project Execution phase during which there should be a constant Monitoring and Controlling of all of the project aspects. The good monitoring, control and evaluation of the projects during its execution enhance the project success rate. The project's success is achieved by the integration of the role of all parties in all phases of the project from the idea stage to the operating and Maintenance stage.

3. PROJECT SUCCESS

Success can be defined as "the degree to which the project objectives and expectations are met" It always viewed from different perspectives. Indeed, the measuring of the project success is a complex task since the success is intangible and hardly be agreed upon. In the project management literature the project success concept had not been well-defined properly. **Shenhar and Wideman, 2000**, Indicated that there is no integrated understanding on the idea of success in either the business or project management literature. **DeWit, 1988**, distinguished between the project success, which measured against the overall goals of the project, and the project management success which measured against the traditional and widespread measures of performance against quality, time and cost. There are still too many examples of projects exceeding their budgets, running late, or failing to meet other objectives. it is very important, before any discussion of the factors leading to a successful project, to describe exactly what is a "successful, in its simplest terms, the project success can be thought of as the incorporating of four basic facets, if it :

1- Comes in on-budget (monetary criterion).

2- Comes in on-schedule (time criterion).

3- Is used and accepted by the clients and users for whom the project was intended (Client satisfaction criterion).

4- Achieves basically all the objectives originally set for it (effectiveness criterion). **Baccarini, 1999**, introduced five maxims to measure project success regardless of the project duration, size or scope which are; delivering of the product according to the customer needs; delivering the quality that consistent with the price; delivering the project within the agreed timeframe; delivering of the desired that the customer wishes; existing a system of conflict resolution that is fair to the development team and the customer. The project usually targeted for use by the client, either external or internal to the organization, its reasonable; therefore, that any project implementation success assessment should include these five metrics.

3.1 Critical Success Factors

The certain factors that are more critical to the project success than others , are called "critical success factors (CSFs)". term "critical success factors," in the projects and the management of projects, was used firstly by **Rockart ,1981** , defined as " those factors predicting success on projects ".the critical success factors are a group of project areas or variables that are correlated to the project success strongly, and whose maximization or minimization, will lead to project success. According to **Russell and Jaselskis, 1992**, the critical success factors are a limited number of variables in which the satisfactory results will ensure the successful competitive performance of the organization, department, or individual. And they are the few important areas where things must go right for the business to be flourishing. If the results in these areas are not good, then the organization's efforts will be less than desired. **Pinto and Slevin, 1987 ,** found a project model of ten CSFs they are: training, scheduling, communications, feedbacks and reports, user reception, user consultant, technical tasks, personnel (requirement, employment), senior manager support, fault detection and Project mission. **Frese and Sauter,2003,** conclude that generally, the (Schedule Control, Communications, good accountability, , Good Planning , Project leadership and Governance, and Clear Responsibility) are key areas of successful projects. Which means that, the commitment and support from stakeholders, the clear project plan, and a plan for risk management are the critical success factors for project management .**Mbugua et al., 1999** and **Chan and Chan, 2004**, identified five primary CSFs they are " project management actions, external environment, project-related factors, human-related factors and project procedures ". **Abraham, 2003**, identified seven CSFs they are " political environment, employee/organizational enhancement, competitive strategy, economic environment, process benchmarking, market analysis and technical application ". In 2004 Nguyen et al. identified five CSFs among twenty factors of the projects success: (Access to resources, providing adequate financial resources, competent project manager, Commitment to the project and competent project team).

3.2 Success Criteria

Criterion can be defined as "the principle or standard by which something can be judged or decided", Moreover, the success criteria should be measureable and observable. There is a clear difference between success criteria and success factors, the success criteria are measures in comparison with it the project success or failure can be judge; while the success factors can be defined as " those entered to the management systems result in directly or indirectly project success, time, quality and cost "The Iron Triangle" perceived as the major criteria to evaluate the success and performance of construction projects for a long time. Because of the great development of knowledge and the change in the projects and project management, these criteria is no longer sufficient to measure the success of the project, as in the project success literature, the project success criteria also hardly agreed upon in literature. **Lim and Mohamed, 1999**, modeled the project success measurement into a 'micro viewpoint: completion quality, completion safety, completion time, completion performance, completion cost; and the macro-viewpoints: completion operation, completion satisfaction, completion utility, completion time. **Patanakul and Milosevic, 2009,** grouped the success criteria into three: (i) organizational perspective criteria: organizational learning and resource productivity (ii) project perspective criteria: time-to-market and customer satisfaction and (iii) personal perspective criteria: personal growth and personal satisfaction. **Sadeh et al.,2000** , measure the project success from four dimensions:

1) The meeting of design goals,
2) The benefits to the user,
3) The developing organization benefit, and
4) The technological infrastructure benefit **Shenhar et al., 1997**, suggested four distinct dimensions for project success measure: the project efficiency; preparing for the future; business and direct success .Project consists of the integration efforts of a number of various parties, each of these parties has its own criteria for the success of the project as follows :

1-Owner's criteria for measuring success: function for intended use (satisfy the users and customers); on budget; on schedule; quality (workmanship, products); end result as envisioned; return on investment (responsiveness to the audiences); aesthetically pleasing;

minimize aggravation in producing a building and building must be marketable (image and financial).

2-Designer's criteria for measuring success: quality architectural product; satisfied client (develop the potential to obtain repeated work); professional staff fulfillment (learn new skills, gain experience); met design fee and profit goal; met the project schedule and budget; marketable product/ process; easy to operate, constructible design; no "ghosts," liability, claims; socially accepted; well defined scope of work; and client pays (reliability).

3-Contractor's criteria for measuring success: profit; under estimated budget (savings obtained for the owner and/or contractor); meet the schedule of (preconstruction, construction, design); no claims (owners, subcontractors); safety; quality specification met or exceeded; good sub-contractor buy out; client satisfaction (personal relationships); and minimal or no surprises during the project executing.

3.3 Critical Failure Factors

The study of the failure factors is very significant because; the prevention is better than remedial actions , and the elimination or reduction of the failure rate and a significant increase in civil engineering projects' successful level will result in provision of good infrastructures ;housing, bridges, roads, dams, railways and other. Contribute to providing employment opportunities for youth and experts. a reduction in waste of materials, human and fund, enhanced the socio-economic and physical development in the country. Project failure may be defined as "the project which did not meet the cost, time, quality and scope goals. Also, the project is a failure when it fails to persuading or meet the customer's requirements and when it cannot get its planned targets. **Chitkara, 2006**, asserted that it is common to see a project failing to achieve its mission, a very few projects get completed within the original costs and in time. According to **Chitkara 2006**, 49% faced a time overrun from 1 to 157 months and out of 351 projects, 56% had cost overrun (totally 20% cost), sometimes projects like Boston’s Big Dig go 50, 60, 90, or more than 100 percent over budget. The various causes of delays in Construction projects in Thailand were (unclear and incomplete drawing, deficiencies between consultant and contractor, improper planning of the sub-contractors and lack of sufficient sources.). **Noulmanee, et al., 2004** , found that the (supervision, unforeseen ground conditions, Poor site management, client initiated variations and low speed of decision making) were the five various failure reasons in construction projects of Hong-Kong, , the " factors relate to the designers, site conditions, weather, user changes, increase in quantity, economic conditions and late deliveries" , are the main project delay factor as indicated by **Ayman, 2000**, in addition to the other endless reasons for non-fulfillment of the project goals. The Failures can be by the unforeseen natural calamities like natural disasters, floods and earthquakes. It can also result come from the deliberate attempts made by the manipulators during the feasibility study stage by incorporating inaccurate cost and time estimates with a view of secure business or start a project. These incorrect actions in the feasibility study phase may lead to unrealistic objectives and thus to significant problems during implementation.

4. RESEARCH METHODOLOGY

The success of the project cannot be achieved without identifying the critical success factors, the critical failure factors in addition to the success criteria , Determine the criteria for success is the first element in maximizing the the proportion of the project's success, these criteria are the main goals that the management of organization and project have to ensure the achievement of it , After that , the identifying of the factors that lead to of gain such criteria and make use of them in raising the the proportion of the project's success and the factors that would prevent the achievement of these criteria to prevent their occurrence or minimize the negative effects on the success of the project .In order to get these criteria and factors and after studying the related literature, it has been extracted a number of factors and criteria and divided into seven groups. a meetings and interviews were held with a number of project managers, engineers and experts in the field of research who have the technical and scientific expertise to find out the reasons, problems, obstacles and other things that lead to the failure of projects in addition to identifying anything that might reduce or remove their adverse effects, and to determine the criteria for success and the factors that lead to getting these criteria. After the completion of this open questionnaire, a closed form questionnaire have been prepared and presented to a number of experts to evaluate, straightened and improve to the final form for submission it to the sample , Questionnaire was divided into two parts, the first is comprised background questions about the respondents and In the second section the experts were asked to rank the success factors groups and success factors in each group , failure factors and criteria according to their importance by a five-point Likert scale where 5: totally agree, 4: partially agree, 3: indifferent, 2: partially disagree and 1: totally disagree, Seventy-five questionnaire were distributed to the sample, sixty seven of them are valid and are in below description of of the members of sample, followed by statistical analysis of the answers by using the (SPSS) program

4.1 Respondents Background: The sample included a number of head of departments, project managers and engineers who have an experience in the area of government construction sector**, Table 1** shows the respondents background.

4.2 Identification of Critical Success and Failure Factors and Success Criteria

4.2.1 Success factors

In the beginning, the respondents have been asked to identify the ten most important factors for the success of the project, then and from the careful study of the previous literature, the ten most important factors from the respondents and the open questionnaire of the CSFs were grouped under eight main categories. These include: (1) Procurement-related Factors; (2) Project Management Factors;(3) Design team-related Factors; (4) Client-related Factors; (5) Contractor-related factors; (6) external Environment-related Factors ; (7) Project Manager-related Factors and (8) Project Manager-related Factors. **Table 2** Reviews the success factors, groups to which they belong, mean and standard deviation.

If the reliability coefficient above 0.7 it is considered acceptable **Nunnally and Bernstein, 1994**, the higher the Cronbach’s Alpha the better the reliability of the set of variables. The Cronbach’s Alpha of success factors was computed at 0.865, **Table 3.** which indicates a high level of internal consistency. As for the second condition, Kaiser-Meyer-Olkin (KMO) was used to measure sampling adequacy in the use of factor analysis **Sadeh et el., 2000.** The literature recommends that the KMO value should be greater than 0.50 if the sample size is adequate **Child, 1990.** From the above result; the Kaiser-Meyer-Olkin Measure of Sampling Adequacy has a value of more than 0.50 which is 0.575, this means that the sample size is adequate for analysis. **Table 4** shows the KMO analysis.

4.2.2 Failure factors: **Table 5** reviews the failure factors, mean and standard deviation, **Table 6** reviews the failure factors reliability analysis and **Table 7** reviews the failure factors KMO and Barlett's Test.

4.2.3 Success criteria: **Table 8** reviews the failure factors, mean and standard deviation, **Table 9** reviews the failure factors reliability analysis and **Table 10** reviews the failure factors KMO and Barlett's Test.

5. MATHEMATICAL EQUATION

Which can calculate the degree of success of the project, the closer one of the project the largest success, measuring the degree of success of the project can be divided into two main sections, the first section using the effect of each of the factors of success and failure in the design and implementation phases, the second section by using the criteria for success after implementation phase as follows:

5.1 Design and Implementation Phase:

The Mathematical equation consists from the integration of the impact of critical success and failure factors, as in Eq. (1):

$$PSI = \sum \sum (Wcsn * Wcfn)\, cSn * cFn \quad \text{.......(1)}$$

Where:
PSI: project success index.
Sn: CSF_n efficiency. F_n: CFF_n efficiency.
Wcsn: relative weight of CSF_n. Wcfn: relative weight of CFF_n.

5.2 Post Implementation Phase:

At this stage, after the completion of the project work is successful index calculation will based on the efficiency of getting the criteria for success as shown in Eq.(2) :

$$PSI = \sum (WCn * Cn) \quad \text{........ (2)}$$

Where:
Cn: success criteria n efficiency.
WCn: success criteria n relative weight.

6. ANALYSIS OF THE RESULTS

6.1 Success Factors: Critical success factors and its relative weights have been shown in the **Table 11**. The extraction of relative weights of the factors was done by calculating the total sum of the critical factors averages and then divides the average value of each factor on the total to find out relative importance of each factor, and so on for success criteria and critical failure factors.

6.2 Success Criteria: Success criteria and its relative weights have been shown in the **Table 12**.

6.3 Critical Failure Factors: Critical failure factors and its relative weights have been shown in the **Table 13**.

7. CONCLUSIONS

Conclusions could summarize as follows:

1. The construction sector in Iraq suffers from many problems and obvious defect performance and a large part of this weakness is due to poor management performance and

the lack of knowledge of the ethics of the construction project management application and the right to it.

2- Most of the feasibility studies for government projects incorrect or non-existent originally leading to the project or the building does not offer the purpose for which was established.

3- Recent experience of the engineers and designers which will reflect negatively on the performance.

4-Contracting methods characterized by a major corruption cases in terms of high prices and lack of clarity in many of the paragraphs in addition to the fact that designs and contract documents is not integrated which leads to a huge number of parts orders in government projects which will reflect negatively on the administration and the costs of the projects.

5- Contracting is forwarded the basis of the lower cost tender which leads to that we contract with inefficient companies and is a solid which will reflect negatively on the performance.

6- The absence of proper planning for the implementation and funding of projects which leads to hold the government huge sums of money (The project is implemented with funding from more than one government department, leading to obtain a conflict of powers, which reflects negatively on the performance) in addition to the lack of planning for cost operation and future maintenance and requirements, which could lead to get a project cost of implementation and sessile but the cost of maintenance and operation of high.

7- Identifying CSF's is important as it allows firms to focus their efforts on building their capabilities to meet the CSF's, assist in taking proactive measures for successful project management of construction project and The finding will also be useful for effective management for all type of construction projects (With the exception of some specialized projects such as oil projects), thus helping to raise the overall level of productivity in construction industry.

8-Success criteria that have been identified allows manager of departments and their staff to focus on the factors that lead to raise the proportion of access to these standards as well as the exclusion of the factors that impede access to these standards to achieve high success rates for projects.

9- It is not the use of modern principles (or sustainability) in design, but in rare cases leading to great wastage of money in addition to the lack of access to buildings do not fit with the global development of civilization.

10- Weak in the experience of the committees overseeing the projects or restrict their powers, especially the project manager and who has a very big role in the success of the project structural as well as the nature of the Iraqi citizen and employee and all reflect negatively on the performance in construction projects.

11- Non- transparency and corruption. The Sizable financial resources combined with slow progress in strengthening the rule of law in Iraq have led to widespread corruption in both the public and private economic sectors. These corrupt practices are substantially undermining public confidence and support for a still fragile democratic government and diverting the provision of resources to the poor and the most disadvantaged social groups.

8. RECOMMENDATIONS

1- Introduction of modern technology and patterns turnkey construction and modern materials and the development of project management systems and the expansion of the production of basic building materials to labs list Accordingly, as the new plants so as to ensure the need With the actual development of the domestic market in quantity and quality and to link the import of construction materials policies in terms of quantity and quality and the prices are not inconsistent with the development of domestic production and support plans and the need The actual local market

2- A comprehensive review of the laws currently in place as the General Conditions of Contract for Works of Civil Engineering two sections I and II and other laws suffer from a clear imbalance has a negative marking on the implementation of the projects in all stages

3- Adoption of the scientific basis of correct and accurate and fair in the classification of contractors and their potential financial knowledge and adoption at the assignment, which is reflected positively on the success of large construction projects

4- It is recommended to develop abilities and characteristics of project managers and Engineers through proper and continuous training programs about effective project Manager Abilities and characteristics with focus on the leadership area.

5- It is recommended for colleges and universities to make their curriculums more responsive to the leadership and management needs for modern engineers through education courses during college. Also, it is recommended to develop leading characteristics and abilities by education courses since college or seminars for project managers and engineers.

6- Carry out detailed studies to determine the most appropriate time to measure the factors and see its impact on the success of the project.

7- The legislation of laws which bear the person (project manager, contractor, designer, director, consultant or others) all the legal and financial responsibilities and to reduce the frequency of administrative error committed.

8-Managers and superintendents within organizations should address Communication needs. Systems for distributing information and data base management should be evaluated with feedback from managerial personnel. This was by far the most consistent attribute of concern between both groups over multiple surveys.

9-Focus on research and development in addition to interest the evolution of a development staff qualitatively because of its positive impact on the success of projects.

9. FUTURE STUDIES

1-Prepare for future research to determine the critical success factors in the Specialized departments of institutions (Such as the Ministry of Oil Projects and the Ministry of Electricity).

2-Identify the critical success factors affecting the success of the construction companies in Iraq.

3- Identify the critical success factors affecting the success of the governmental organization in Iraq.

4-Preparation of studies to see the applicability of the requirements of (the ISO in construction) and sustainability requirements and specifications relating thereto as well as the principles of the (TQM) to see the difficulties facing the application and the benefits that we get it in the success of projects in Iraq.

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Table 1 Respondent's background.

Respondents	Frequency (percentage) %
Gender	
Male	70
Female	30
	100
Type of respondents position	
1. Project Manager	44
2. Architecture	20
3. Engineer	16
5. Consultant	20
Educational attainment	
B.Sc.	73
High diploma	20
M.Sc.	6
Ph.D.	1
Working experience	
6-10 years	33
11-15 years	28
16-20 years	35
Above 20 years	14
Engineering Specialization	
Civil	43
Mechanic	20
Electric	24
Architectural	13

Table 2. Statistical analysis of success factors.

Item	Success factors group	Success factors	Mean	Sd.
1	Project Management Factors	Training the HR. in the skill demanded by project	3.94	0.910
2		Constructability program	3.75	0.774
3		Motivation/ Incentives Formal dispute resolution process	2.01	0.887
4		Risk identification and allocation	2.62	0.790
5		Prior project management experience	3.14	0.785
6		Control of sub-contractors' work	3.56	0.707
7		Implementing an effective quality assurance program	3.56	0.785
8		Implementing an effective safety program	3.18	0.767
9		Developing an appropriate organization structure	2.90	1.134
10		Top management support	4.16	0.833
11		Decision making effectiveness	3.21	1.022
12		Coordination effectiveness	3.16	1.100

Item	Success factors group	Success factors	Mean	Sd.
13	Project Management Factors	Planning effort	2.28	0.767
14		Troubleshooting	3.13	0.833
15		Feedback capabilities	3.16	1.134
16		Control mechanism	3.53	1.255
17		Communication system	3.16	1.165
18		Formal dispute resolution process	3.01	1.118
		Involvement of Stakeholders	3.14	0.950
19	Procurement Related Factors	Project delivery system (e.g. design-bid-build, design build)	3.1	1.177
		Awarding bids to the right project manager/contractor	3.74	1.077
20		Project bidding method (e.g. price based competitive bidding, negotiated bidding, best value bidding)	3.31	0.974
21		Project contract mechanism (e.g. lump sum, unit price, cost plus, etc.)	2.62	0.995
		Comprehensive contract documentation	3.21	0.876
22	Client Related Factors	Client's ability to define roles	3.18	0.775
23		Client's ability to make decision	3.92	1.118
24		Client's ability to brief	3.06	0.974
25		Client's project management	2.28	0.887
26		Client's emphasis of quick construction	2.62	0.785
27		Client's emphasis on high quality of construction	2.67	1.177
28		Client's emphasis on low construction cost	3.56	0.774
29		Owner's risk attitude (willingness to take risk)		0.707
30		Timely decision by owner/ owner's representative	2.90	0.887
31		Owner's clear and precise definition of project scope & Objectives	3.16	1.166
32		Owner's construction sophistication	2.85	0.785
33		Client's confidence in construction team	2.76	0.774
34		Client's knowledge of construction project organization	2.99	1.030
35		Size of client's organization	3.53	1.166
36		Nature of client (privately funded vs. publicly funded)	3.18	0.887
37		Client's experience	3.48	0.950
38		Influence of client/ client's representative	3.05	1.177
39	Design Team-Related Factors	Design team experience	4.05	0.876
40		Project design complexity	2.99	1.177
41		Mistakes/ delays in producing design documents	4.09	0.974

42		Design team's contribution to construction	3.04	1.077
43		Adequacy of plans and specifications	2.85	1.177
44	Contractor- Related Factors	Contractor experience	4.11	0.775
45		Speed of information flow	3.26	1.118
46		Effectiveness of cost control system	3.05	1.165
47		Contractor's cash flow	4.27	0.767
48		Extent (Involvement) of Subcontracting	3.05	1.022
49		Supervision	3.13	0.833
50		Site and work management	3.95	1.100
51	Project Manager Related Factors	Construction control meetings	2.85	0.879
52		Project manager's ability to delegate authority	3.74	1.043
53		Project manager's adaptability to changes in project Plan	3.19	.984
54		Project manager's early & continued involvement in project	3.16	1.043
55		Project manager's commitment to meet quality, cost &time	3.04	.945
56		Coordinating ability and rapport of project manager with owner/ owner representatives Motivating skills of project manager	2.67	.661
57		Coordinating ability and rapport of project manager with contractors/ subcontractors	2.28	.773
58		Organizing skills of project manager	3.56	.637
59		Leadership skills of project manager	3.19	.595
60		Technical capability of project manager	3.56	.550
61		Project Manager's authority to take financial decision, selecting key team members, etc	3.16	042
62		Project Manager's authority to take day-to-day decisions	3.05	.581
63		Project Manager's experience	4.27	.768
64		Project Manager's competence	3.05	.754
65	Business and Work Environment Related Factors	Human Skill availability	3.26	1.060
66		Technology availability	3.13	.550
67		Adequacy of funding	3.08	.945
68		Commitment of all parties to the project	3.01	.984
69		Administrative approvals environment	3.26	1.043
70		Industrial relations environment	3.05	.945
72		Political environment	4.26	.773
73		Social environment	4.90	.803
item	Success factors group	Success factors	mean	Sd.
74	Work Environment Rel	Economic environment	4.16	.661
75		level of technology advanced	2.85	.796

76		Availability of resources	3.7	.515
77	Project related factors	Human skill availability	3.56	.675
78		Clear objectives	2.85	.661
79		Project size	3.04	.614
80		Project location	2.76	.683
81		project complex	2.99	.614
82		Project importance	3.16	.650
83		Clear understanding of project environment	3.19	.803

Table 3. Success factors reliability analysis.

Cronbach′s Alpha	Cronbach′s Alpha Based on Standardized Items	N of Items
.865	.873	83

Table 4. Success factors KMO and Barlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.575
Bartlett′s Test of Sphericity	Approx. Chi-Square	627.107
	Significant	.007

Table 5. Statistical analysis of failure factors.

Item	Failure factors	Mean	SD.
1	Ineffective project planning and control	2.9	0.910
2	underestimation of time and cost	4.04	0.887
3	Poor monitoring and quality control by regulatory agencies	2.94	0.774
4	Poor design capacity and the frequent design changes	4.44	0.790
5	Lack of available skilled personnel and technical experts	3.29	0.785
6	Vulnerability to and ravaging environmental degradation and devastation due to wrong location.	2.85	0.833
7	Designers and contractors inability to do the work	2.29	0.767
8	Frequent changes and inconsistence in government policy and priority	2.89	0.790
9	Scarcity and lack of original materials requirement	3.06	1.134
10	Prequalification procedure and corrupt government officials.	2.96	1.022
11	Colossal waste of resources in project implementation due to unacceptable design errors and mistakes	3.04	0.833
12	Project contract sum indirectly used to compensate political party big-wigs.	3.28	0.767
13	Youth restiveness, and land ownership disputes	3.19	1.022
14	Litigations and court injunctions	3.15	1.100
15	Inaccessibility and geo hazardous impassable terrain to the	3.09	1.165

	project site		
16	Financial and administrative corruption	3.94	1.255
17	Project scope creep with massive amount of change or variation orders	3.16	0.775
18	Capacity constraints in terms of construction equipment	2.50	0.974
19	Mode of financing and payment for completed work	2.92	1.177
21	Delay in approving major changes in the scope of work by consultant	3.42	1.165
22	Rework due to error by contractor	3.32	1.100
23	Delay due to sub-contractor work	3.24	0.833
24	Inadequate experience of consultant	3.65	0.767
25	Financial difficulties of contractor	4.57	0.785
26	Changes in government regulations and laws	2.21	1.022
27	Delays in producing design documents	3.30	1.100
29	Delaying delivering the site to consultant and contractor	2.67	1.022
30	Financial difficulties of owner (Delays in progress payments by owner)	4.32	1.100
31	Delay in material delivery from the supplier	3.26	1.165
32	Frequent equipment breakdown	2.90	0.833
33	Delay from obtaining sanctions from various authorities	3.30	1.134
34	Inadequate legal framework	2.58	0.785
35	Lack of capable owners Improper planning and Scheduling	2.57	0.790
36	Insufficient data collection and Survey before design	3.24	1.177
37	Obsolete or unsuitable construction methods	3.5	0.807
38	Poor site management and supervision	2.2	1.028
39	Incompetence of project team	4.17	0.967
40	Shortage of manpower (skilled, semi-skilled, unskilled labor)	3.74	0.774
41	Slow payment of completed works	2.5	1.030
42	Bureaucratic administrative system	3.4	0.774
43	Lack of accurate historical information	3.0	1.177
44	Interest and inflation rates	2.94	0.876

Table 6. Failure factors Reliability analysis.

Cronbach′s Alpha	Cronbach′s Alpha Based on Standardized Items	N of Items
.795	.642	44

Table 7. Failure factors KMO and Barlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.743
Bartlett′s Test of Sphericity	Approx. Chi-Square	942.43
	Significant	.054

Table 8. Statistical analysis of Success criteria.

Item	Success criteria	Mean	SD
1	Complete within time period	4.52	.848
2	Sales of the product	2.58	.768
3	Developer-contractor relation	3.5	.754
4	Project safety	4.1	.581
5	Improvement of the management	3.61	1.119
6	Durability	3.5	1.060
7	Complete within allocated budget	4.75	042
8	Developer's reputation	3.4	.550
9	Sustainability	4.42	.754
10	Life cycle cost	3.3	1.119
11	Experience/Knowledge gain from the project	4.14	.637
12	Personnel training	2.58	.595
13	Environmental effect	2.75	.570
14	Company growth	2.57	.654
15	Quality	4.24	.791
16	Capital gain	3.27	.984
17	Project profitability	3.05	1.043
18	Customer's Satisfaction	3.68	.945
19	Customer's confidence on the product of the company	3.53	.803
20	Stakeholders' satisfaction	2.62	.773
21	Project management process	3.19	.661
22	Team creativity	3.04	.946
23	Meeting the regulatory requirements of the new product	2.85	.963
24	Financial	3.56	.945
25	Competency gains	3.77	.850
26	Meeting the market shares	2.85	.930
27	Direct and business success	2.99	.570
28	Impact on the customer	3.43	.637
29	Utility	3.48	042
30	Operation	3.00	1.119
31	technical success	3.95	.581
32	Efficiency	3.26	1.042
33	performance	2.85	.595

Table 9. Success criteria reliability analysis.

Cronbach′s Alpha	Cronbach′s Alpha Based on Standardized Items	No. of Items
.78	.873	33

Table 10. Success criteria KMO and Barlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.651
Bartlett′s Test of Sphericity	Approx. Chi-Square	742.31
	Significant	.012

Table 11. Critical success factors and its relative weights.

Item	Critical success factors	Weight%	Group
1	Contractor's cash flow	12.48	Contractor factors
2	Political ,security and economical stable environment	11.89	External environment factors
3	Project manager's experience	10.7	Project manager factors
4	Contractor experience	10.3	Contractor-related
5	Top management support	9.85	Project management factors
Item	Success factors	weight	group
6	Mistakes/ delays in producing design documents	9.3	Design team related factors
7	Site and work management	8.15	Contractor-related Factors
8	Client's ability to make decision	6.32	Client-related Factors.
9	Awarding bids to the right project manager/contractor	6.1	Procurement related factors
10	Design team experience	5.84	Design team related factors
11	Project manager's authority to take day-to-day decisions	4.7	Project manager factors
12	Availability of resources	4.3	External environment factors

Table 12. Success criteria and its relative weights.

Item	Success criteria	Weight%	item	Success criteria	Weight%
1	Complete within allocated budget	14.3	6	Project safety	9.54
2	Complete within time period	13.02	7	technical success	8.75
3	Sustainability	10.85	8	Competency gains	8.34
4	Quality	10.15	9	Customer's Satisfaction	7.85
5	Experience/Knowledge gain from the project	9.74	10	Improvement of the management	7.55

Table 13. Critical failure factors and its relative weights.

Item	Critical failure factors	Weight %
1	Financial difficulties of contractor	``````````
2	Poor design capacity and the frequent design changes	10.1
3	Financial difficulties of owner (delays in progress payments by owner)	8.4
4	Incompetence of project team	8.2
5	underestimation of time and cost	7.75
6	Financial and administrative corruption	6.75
7	Shortage of manpower (skilled, semi-skilled, unskilled labor)	6.45
8	Insufficient data collection and survey before design	6.45
9	Inadequate experience of consultant	5.86
10	Delay in approving major changes in the scope of work by consultant	5.7

Dynamic Stability Analysis and Critical Speed of Rotor supported by a Worn Fluid film Journal Bearings

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ABSTRACT

In this paper, the effect of wear in the fluid film journal bearings on the dynamic stability of rotor bearing system has been studied depending on the development of new analytical equations for motion, instability threshold speed and steady state harmonic response for rotor with offset disc supported by worn journal bearings. Finite element method had been used for modeling the rotor bearing system. The analytical model is verified by comparing its results with that obtained numerically for a rotor supported on the short bearings. The analytical and numerical results showed good agreement with about 8.5% percentage error in the value of critical speed and about 3.5% percentage error in the value of harmonic response. The results obtained show that the wear in journal bearing decrease the instability threshold speed by 2.5% for wear depth 0.02 mm and 12.5% for wear depth 0.04 mm as well as decrease critical speed by 4.2% and steady state harmonic response amplitude by 4.3% for wear depth 0.02 mm and decrease the critical speed by 7.1% and steady state harmonic response amplitude by 13.9% for wear depth 0.04 mm.

Key words: rotor, journal bearing, wear, instability, critical speed,

تحليل الاستقرارية الديناميكية والسرعة الحرجة لدوار مسنود بواسطة كراسي تحميل متآكلة

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الخلاصة

تم في هذا البحث دراسة تأثير ألتآكل في كراسي ألتحميل المقعدية ذات التزييت الهيدروديناميكي على ألاستقرار ألديناميكي لمحور دوار يستند على كراسي تحميل متاكلة بالاعتماد على تطوير معادلات جديدة للحركة واللااستقرارية والاستجابة التوافقية في حالة الاستقرار لمحور دوار مع قرص غير متمركز في الوسط. تم مقارنة النتائج النظرية والعددية لمحور دوار مستند على كراسي تحميل قصيرة. اظهرت النتائج التحليلية والعددية تطابقا جيدا مع نسبة خطا بحدود 8.5% بالنسبة للسرعة الحرجة و 3.5% بالنسبة للاستجابة التوافقية. أظهرت النتائج ان التآكل في كراسي التحميل يقلل سرعة اللااستقرارية بنسبة 2.5% لحالة التاكل بعمق 0.02 ملم و بنسبة 12.5% لحالة التاكل بعمق 0.04 ملم ويقلل كذلك السرعة الحرجة بنسبة 4.2% وسعة الاستجابة التوافقية العظمى بنسبة 4.3% لحالة التاكل بعمق 0.02 ملم اما لحالة التاكل بعمق 0.04 ملم فان السرعة الحرجة تنخفض بنسبة 7.1% وسعة الاستجابة التوافقية العظمى بنسبة 13.9%.

الكلمات ألرئيسية : ألدوار, كرسي تحميل, التآكل, اللااستقرارية, السرعة الحرجة

1. INTRODUCTION

Hydrodynamic fluid film journal bearings are frequently used in applications requiring high loads and high speeds. They usually exhibit lower friction and more damping compared to ball bearings. Hydrodynamic bearings, however, are susceptible to self excited instability known as oil whirl giving rise to large amplitude lateral vibrations and possibly a early wear. The prediction of the instability boundaries is an important step in the dynamic analysis of hydrodynamic bearings. Also the instability is of particular importance to the manufacturers and users of modern turbomachinery particularly with the present tend towards high speed and loading conditions.

Gunter, 1971, presented a survey of the various mechanisms that cause instability in rotor bearing system and the stability data on plain and multilobed journal bearings. He shows the effect of unbalance and external loading on the nonlinear rotor whirl .**Lund, 1975**, presented a method for calculating the threshold speed of instability and the damped critical speeds of a general flexible rotor in fluid film journal bearings. **Chauvin, 2003,** experimentally investigated the effect of lubricant temperature on the presence of whirl instability in journal bearings. Lubricant temperature, bearing temperature, frequency and amplitude of vibration, and rotational speed are monitored and analyzed in relation to presence of whirl instability. **Alsaeed, 2005**, studied the dynamic stability of an automotive turbocharger rotor-bearing system using both linear and nonlinear analyses. Several different hydrodynamic journal bearings were employed in the study of the turbocharger linearized dynamic stability. **Mancilla, et al., 2005**, presented new closed-form expressions for calculating the linear stability thresholds for rigid and flexible Jeffcott systems and the imbalance response for a rotor supported on a hybrid bearing. **Tuma and Bilos, 2007**, studied the instability of the rotor vibration in a journal bearing due to the oil whirl, they found that oil induced vibration, occurs when the rotor rotation speed crosses a certain threshold speed. **Miranda and Faria, 2014,** Presented a finite element procedure to perform the eigenvalue analysis of damped gyroscopic systems, represented by flexible rotors supported on fluid film journal bearings.

The present work focuses on the stability and unbalance response prediction for asymmetric rotor supported by two asymmetric fluid film bearings and one of them is worn

2. EQUATION OF MOTION OF ROTOR WITH NON CENTRAL DISK SUPORTED ON TWO ASYMMETRIC JOURNAL BEARINGS

For a one-mass flexible rotor with non central rigid disc (a ≠ b in this study) supported by two asymmetric bearings as shown in the **Fig 1**. A new equation of motion can be driven with the following assumptions

1- Small motion about equilibrium position of rotor bearing system
2- The difference between the eccentricity ratios of the two bearing is very small therefore it can be neglected.
3- Neglect the elastic coupling , the coupling between displacement and rotation because it has small effect on the system frequency , **Michael, et al., 2010**

There are three reference points were taken into consideration they were the journal's center, the bearings' center, and the rotor's center (which is located at the point of disc center). The first two equations of motion are found. **Rao, 1996**.

$$M\ddot{x}_r + K(x_r - x_j) = Mu\Omega^2 \cos \Omega t \text{ and } M\ddot{y}_r + K(y_r - y_j) = Mu\Omega^2 \sin \Omega t \quad (1)$$

Where the notation of (x_r) and (y_r) are the location of the rotor center, (x_j) and (y_j) are the location of the journal center and the terms $(\mathrm{Mu}\Omega^2 \cos \Omega\mathrm{t}\ and\ \mathrm{Mu} \sin \Omega\mathrm{t})$ are the unbalance forces due to unbalance mass in the *x* and *y* directions respectively The second two equations of motion are found by summing the forces on the fluid film journal bearing for a stable condition.

$$K(x_r - x_j) = F_{x1} + F_{x2} \quad \text{and} \quad K(y_r - y_j) = F_{y1} + F_{y2} \tag{2}$$

Where, subscript (1) and (2) are refer to bearing one and bearing two respectively, K is stiffness of shaft , F_{x1} , F_{x2} are the reaction forces of the bearing one and two in the x-direction and F_{y1}, F_{y2} are the reaction forces of the bearing one and two in the y- direction and the shaft damping is ignored because it has no effect on the unbalance response **Rao , 1996**. Also, the forces developed in the lubricating oil film of the bearings are

$$\begin{bmatrix} F_{x1} \\ F_{y1} \end{bmatrix} = \begin{bmatrix} K_{xx1} & K_{xy1} \\ K_{yx1} & K_{yy1} \end{bmatrix} \begin{Bmatrix} x_j \\ y_j \end{Bmatrix} + \begin{bmatrix} C_{xx1} & C_{xy1} \\ C_{yx1} & C_{yy1} \end{bmatrix} \begin{Bmatrix} \dot{x}_j \\ \dot{y}_j \end{Bmatrix} \tag{3}$$

$$\begin{bmatrix} F_{x2} \\ F_{y2} \end{bmatrix} = \begin{bmatrix} K_{xx2} & K_{xy2} \\ K_{yx2} & K_{yy2} \end{bmatrix} \begin{Bmatrix} x_j \\ y_j \end{Bmatrix} + \begin{bmatrix} C_{xx2} & C_{xy2} \\ C_{yx2} & C_{yy2} \end{bmatrix} \begin{Bmatrix} \dot{x}_j \\ \dot{y}_j \end{Bmatrix} \tag{4}$$

Substitute Eq. (3) and Eq. (4) into Eq. (2) get

$$\begin{bmatrix} K_{xx1} + K_{xx2} & K_{xy1} + K_{xy2} \\ K_{yx1} + K_{yx2} & K_{yy1} + K_{yy2} \end{bmatrix} \begin{Bmatrix} x_j \\ y_j \end{Bmatrix} + \begin{bmatrix} C_{xx1} + C_{xx2} & C_{xy1+}C_{xy2} \\ C_{yx1} + C_{yx2} & C_{yy1} + C_{yy2} \end{bmatrix} \begin{Bmatrix} \dot{x}_j \\ \dot{y}_j \end{Bmatrix} = \begin{bmatrix} K & 0 \\ 0 & K \end{bmatrix} \begin{Bmatrix} x_r - x_j \\ y_r - y_j \end{Bmatrix} \tag{5}$$

Where

M, is the mass of the rotor with offset disk and K the stiffness of the shaft with offset disk $K = 3EI\frac{a^3+b^3}{a^3b^3}$. , **Chen, et al., 2007**,

Above equations represent new equations of motion for rotor supported on asymmetric fluid film journal bearings (Asymmetry is a result of unequal load of bearings)

3. CRITICAL SPEED

Critical speeds are commonly defined as the rotational speeds at which vibration due to rotor unbalance is a local maximum. **Lee, 1993.** The critical speed of rotor supported on the fluid film journal bearings cannot be defined as in the case of a rigid bearing rotor, because the stiffness coefficients are functions of the speed of rotor. Consequently, it is always better to study the out-of- balance (unbalance) response to locate the critical speeds, **Rao, 1996.**

There are many types excitation forces that are encountered often in the rotating machinery, the mass unbalance is the most common source of excitation in the rotor bearing systems. The imbalance excitation is a harmonic excitation, which has an excitation frequency coincident with the rotor spin speed (rotational speed).

To find the critical speed, the harmonic steady state response due to unbalance mass can be calculated at disk location where the maximum response occurs and therefore the critical speed will be the rotor speed at the maximum response, **Rao , 1996**.. For harmonic motion Eq. (5) becomes

$$\begin{bmatrix} K_{xx} & K_{xy} \\ K_{yx} & K_{yy} \end{bmatrix} \begin{Bmatrix} x_j \\ y_j \end{Bmatrix} + \begin{bmatrix} C_{xx} & C_{xy} \\ C_{yx} & C_{yy} \end{bmatrix} \begin{Bmatrix} i\Omega x_j \\ i\Omega y_j \end{Bmatrix} + \begin{bmatrix} K & 0 \\ 0 & K \end{bmatrix} \begin{Bmatrix} x_j \\ y_j \end{Bmatrix} = \begin{bmatrix} K & 0 \\ 0 & K \end{bmatrix} \begin{Bmatrix} x_r \\ y_r \end{Bmatrix} \tag{6}$$

Where $x_j = Be^{i\Omega t}$, $\dot{x}_j = i\Omega Be^{i\Omega t} = i\Omega x_j$, $y_j = De^{i\Omega t}$, $\dot{y}_j = i\Omega De^{i\Omega t} = i\Omega y_j$

$K_{xx} = (K_{xx1} + K_{xx2}),\ K_{xy} = (K_{xy1} + K_{xy2}),\ K_{yy} = (K_{yy1} + K_{yy2}), K_{yx} = (K_{yx1} + K_{yx2})$

$C_{xy} = (C_{xy1} + C_{xy2}), v\ C_{xx} = (C_{xx1} + C_{xx2})\ ,\ C_{yy} = (C_{yy1} + C_{yy2}),\ C_{yx} = (C_{yx1} + C_{yx2})$

Eq. (6) can be rearranged as following

$$\begin{bmatrix} K_{xx} + K + i\Omega C_{xx} & K_{xy} + i\Omega C_{xy} \\ K_{yx} + i\Omega C_{yx} & K_{yy} + K + i\Omega C_{yy} \end{bmatrix} \begin{Bmatrix} x_j \\ y_j \end{Bmatrix} = \begin{bmatrix} Kx_r \\ Ky_r \end{bmatrix} \tag{7}$$

Solve Eq. (6) to find x_j and, y_j In terms of x_r, y_r , yields

$$x_j = \frac{K[(K_{yy}+K+i\Omega C_{yy})x_r-(K_{xy}+i\Omega C_{xy})y_r]}{(K_{xx}+K+i\Omega C_{xx})(K_{yy}+K+i\Omega C_{yy})-(K_{xy}+i\Omega C_{xy})(K_{yx}+i\Omega C_{yx})} \tag{8}$$

$$y_j = \frac{K[(K_{xx}+K+i\Omega C_{xx})x_r-(K_{yx}+i\Omega C_{yx})y_r]}{(K_{xx}+K+i\Omega C_{xx})(K_{yy}+K+i\Omega C_{yy})-(K_{xy}+i\Omega C_{xy})(K_{yx}+i\Omega C_{yx})} \tag{9}$$

Substitute Eq. (8) and Eq. (9) in Eq. (1) get

$$\begin{aligned} M\ddot{x}_r + K_1 x_r + K_{12} y_r &= Mu\Omega^2 \cos\Omega t \\ M\ddot{y}_r + K_2 y_r + K_{21} x_r &= Mu\Omega^2 \sin\Omega t \end{aligned} \tag{10}$$

Where

$$K_1 = \frac{K[(K_{xx}+i\Omega C_{xx})(K_{yy}+K+i\Omega C_{yy})-(K_{xy}+i\Omega C_{xy})(K_{yx}+i\Omega C_{yx})]}{(K_{xx}+K+i\Omega C_{xx})(K_{yy}+K+i\Omega C_{yy})-(K_{xy}+i\Omega C_{xy})(K_{yx}+i\Omega C_{yx})}$$

$$K_2 = \frac{K[(K_{yy}+i\Omega C_{yy})(K_{xx}+K+i\Omega C_{xx})-(K_{xy}+i\Omega C_{xy})(K_{yx}+i\Omega C_{yx})]}{(K_{xx}+K+i\Omega C_{xx})(K_{yy}+K+i\Omega C_{yy})-(K_{xy}+i\Omega C_{xy})(K_{yx}+i\Omega C_{yx})}$$

$$K_{12} = \frac{K^2(K_{xy}+i\Omega C_{xy})}{(K_{xx}+K+i\Omega C_{xx})(K_{yy}+K+i\Omega C_{yy})-(K_{xy}+i\Omega C_{xy})(K_{yx}+i\Omega C_{yx})}$$

$$K_{21} = \frac{K^2(K_{yx}+i\Omega C_{yx})}{(K_{xx}+K+i\Omega C_{xx})(K_{yy}+K+i\Omega C_{yy})-(K_{xy}+i\Omega C_{xy})(K_{yx}+i\Omega C_{yx})}$$

The solution of Eq. (10) can be directly written as following, **Rao, 2011**

$$x_r = x_r^+ e^{i\Omega t} + x_r^- e^{-i\Omega t}\quad , y_r = y_r^+ e^{i\Omega t} + y_r^- e^{-i\Omega t} \tag{11}$$

Where x_r^+ and y_r^+ are the whirl radius of the forward precession components which are in the same direction of the rotor rotational speed while x_r^- and y_r^- are that of the backward precession components which are in the opposite direction of the rotor spin speed.
Substitute Eq. (11) in Eq. (10) yields

$$x_r^+ = \frac{(Mu\Omega^2/2)[(K_2-M\Omega^2)+iK_{12}]}{(K_1-M\Omega^2)(K_2-M\Omega^2)-K_{12}K_{21}}\ , y_r^+ = \frac{(-iMu\Omega^2/2)[(K_1-M\Omega^2)+iK_{21}]}{(K_1-M\Omega^2)(K_2-M\Omega^2)-K_{12}K_{21}} \tag{12}$$

$$x_r^- = \frac{(Mu\Omega^2/2)[(K_2-M\Omega^2)+iK_{12}]}{(K_1-M\Omega^2)(K_2-M\Omega^2)-K_{12}K_{21}}\ , y_r^- = \frac{(-iMu\Omega^2/2)[(K_1-M\Omega^2)+iK_{21}]}{(K_1-M\Omega^2)(K_2-M\Omega^2)-K_{12}K_{21}} \tag{13}$$

The out of balance response (unbalance response) can be written as following, **Rao, 1996**

$$r = \frac{x_r + iy_r}{u} \tag{14}$$

Substitute Eq. (12) and Eq. (13) in the Eq. (11) then substitute the resultant equation in the Eq. (14) get the ***a new equation*** for harmonic response of rotor supported by asymmetric bearings

$$r = r_f e^{i\Omega t} + r_b e^{-i\Omega t} \tag{15}$$

Where

$$r_f = \frac{\Omega^2\{(\Omega_1^2+\Omega_2^2-2\Omega^2)-i(\mu_2\Omega_2^2-\mu_1\Omega_1^2)\}}{2[(\Omega_1^2-\Omega^2)(\Omega_2^2-\Omega^2)-\mu_1\mu_2\Omega_1^2\Omega_2^2]} \;,\; r_b = \frac{\Omega^2\,(\Omega_1^2-\Omega_2^2)+i(\mu_2\Omega_2^2+\mu_1\Omega_1^2)}{2[(\Omega_1^2-\Omega^2)(\Omega_2^2-\Omega^2)-\mu_1\mu_2\Omega_1^2\Omega_2^2]}$$

$$\Omega_1^2 = \frac{K_1}{M} \;,\; \Omega_2^2 = \frac{K_2}{M} \;,\; \mu_1 = \frac{K_{12}}{K_1} \;,\; \mu_2 = \frac{K_{21}}{K_2}$$

Where r_f and r_b are the forward and backward components of unbalance response **Childs, 1993.**

The major and minor radii of the elliptic orbit of rotor at disk are

$$|r|_{maj} = |r_f| + |r_b| \quad |r|_{min} = |r_f| - |r_b| \tag{16}$$

The critical speed of the rotor supported by a symmetric journal bearings is the rotor speed when the maximum harmonic response at disk is equal to, $|r|_{maj}$.

4. INSTABILITY THRESHOLD SPEED

The following forms can be assumed as a solution to the Eq. (1) and Eq. (5) **Kramer, 1993.**

$$x_r = Ae^{\lambda t} \;,\quad y_r = Be^{\lambda t} \;,\quad x_j = Be^{\lambda t} \;,\quad y_j = De^{\lambda t} \tag{17}$$

(The variable λ is the eigenvalue term) Substituting Eq. (17) into Eq. (1) and Eq. (5) and put unbalance forces equal to zero for free vibration yields,

$$M\lambda^2 A + K(A - B) = 0 \quad \text{and} \quad M\lambda^2 C + K(C - D) = 0 \tag{18}$$

$$K(A-B) - K_{xx}B - \lambda C_{xx}B - K_{xy}D - \lambda C_{xy}D = 0 \tag{19}$$

$$K(C-D) - K_{yx}B - \lambda C_{yx}B - K_{yy}D - \lambda C_{yy}D = 0 \tag{20}$$

The above system has four equations with four unknown constants. Putting these equations in matrix form and taking the determinant of the matrix and setting it equal to zero produces the values of A, B, C and D (the four unknowns) as following.

$$\begin{bmatrix} M\lambda^2+K & -K & 0 & 0 \\ 0 & 0 & M\lambda^2+K & -K \\ K & -(K+K_{xx}+\lambda C_{xx}) & 0 & -(K_{xy}+\lambda C_{xy}) \\ 0 & -(K_{yx}+\lambda C_{yx}) & K & -(K+K_{yy}+\lambda C_{yy}) \end{bmatrix} \begin{bmatrix} A \\ B \\ C \\ D \end{bmatrix} = 0 \tag{21}$$

The determinant of the matrix leads to the characteristic equation and when equating it to zero we get the non trivial solution. Making the characteristic equation dimensionless at this point will produce results of a general form. The dimensionless variables used to solve this problem are

$\bar{K} = K\frac{c}{Mg}$, $\bar{C} = C\frac{c\Omega}{Mg}$, $\bar{\lambda} = \lambda\sqrt{\frac{c}{g}}$, $\bar{\Omega} = \Omega\sqrt{\frac{c}{g}}$

The dimensionless characteristic equation will be as following.

$$\frac{G_1}{\bar{\Omega}^2}\bar{\lambda}^6 + \frac{G_2}{\bar{\Omega}}\bar{\lambda}^5 + (G_{31} + \frac{G_{32}}{\bar{\Omega}^2})\bar{\lambda}^4 + \frac{G_4}{\bar{\Omega}}\bar{\lambda}^3 + \left(G_{51} + \frac{G_{52}}{\bar{\Omega}^2}\right)\bar{\lambda}^2 + \frac{G_6}{\bar{\Omega}}\bar{\lambda} + G_7 = 0 \quad (22)$$

Where

$$G_1 = \left(\bar{C}_{xy1} + \bar{C}_{xy2}\right)\left(\bar{C}_{yx1} + \bar{C}_{yx2}\right) - (\bar{C}_{xx1} + \bar{C}_{xx2})\left(\bar{C}_{yy1} + \bar{C}_{yy2}\right)$$

$$G_2 = \left(\bar{K}_{xy1} + \bar{K}_{xy2}\right)\left(\bar{C}_{yx1} + \bar{C}_{yx2}\right) + \left(\bar{K}_{yx1} + \bar{K}_{yx2}\right)\left(\bar{C}_{xy1} + \bar{C}_{xy2}\right) - \bar{K}(\bar{C}_{xx1} + \bar{C}_{xx2}) - \bar{K}\left(\bar{C}_{yy1} + \bar{C}_{yy2}\right) - (\bar{K}_{xx1} + \bar{K}_{xx2})\left(\bar{C}_{yy1} + \bar{C}_{yy2}\right) - \left(\bar{K}_{yy1} + \bar{K}_{yy2}\right)(\bar{C}_{xx1} + \bar{C}_{xx2})$$

$$G_{31} = \left(\bar{K}_{xy1} + \bar{K}_{xy2}\right)\left(\bar{K}_{yx1} + \bar{K}_{yx2}\right) - (\bar{K}_{xx1} + \bar{K}_{xx2})\left(\bar{K}_{yy1} + \bar{K}_{yy2}\right) - \bar{K}(\bar{K}_{xx1} + \bar{K}_{xx2}) - \bar{K}\left(K_{yy1} + K_{yy2}\right) - \bar{K}^2$$

$$G_{32} = 2\bar{K}\{\left(\bar{C}_{xy1} + \bar{C}_{xy2}\right)\left(\bar{C}_{yx1} + \bar{C}_{yx2}\right) - (\bar{C}_{xx1} + \bar{C}_{xx2})\left(\bar{C}_{yy1} + \bar{C}_{yy2}\right)\}$$

$$G_4 = \bar{K}\{2\left(\bar{K}_{xy1} + \bar{K}_{xy2}\right)\left(\bar{C}_{yx1} + \bar{C}_{yx2}\right) + 2\left(\bar{K}_{yx1} + \bar{K}_{yx2}\right)\left(\bar{C}_{xy1} + \bar{C}_{xy2}\right) - \bar{K}(\bar{C}_{xx1} + \bar{C}_{xx2}) - \bar{K}\left(\bar{C}_{yy1} + \bar{C}_{yy2}\right)2(\bar{K}_{xx1} + \bar{K}_{xx2})\left(\bar{C}_{yy1} + \bar{C}_{yy2}\right) - 2\left(\bar{K}_{yy1} + \bar{K}_{yy2}\right)(\bar{C}_{xx1} + \bar{C}_{xx2})\}$$

$$G_{51} = 2\bar{K}\left(\bar{K}_{xy1} + \bar{K}_{xy2}\right)\left(\bar{K}_{yx1} + \bar{K}_{yx2}\right) - 2\bar{K}(\bar{K}_{xx1} + \bar{K}_{xx2})\left(\bar{K}_{yy1} + \bar{K}_{yy2}\right) - \bar{K}^2(\bar{K}_{xx1} + \bar{K}_{xx2}) - \bar{K}^2\left(\bar{K}_{yy1} + \bar{K}_{yy2}\right)$$

$$G_{52} = \bar{K}^2\{\left(\bar{C}_{xy1} + \bar{C}_{xy2}\right)\left(\bar{C}_{yx1} + \bar{C}_{yx2}\right) - (\bar{C}_{xx1} + \bar{C}_{xx2})\left(\bar{C}_{yy1} + \bar{C}_{yy2}\right)\}$$

$$G_6 = \bar{K}^2\left(\bar{K}_{xy1} + \bar{K}_{xy2}\right)\left(\bar{C}_{yx1} + \bar{C}_{yx2}\right) + \bar{K}^2\left(\bar{K}_{yx1} + \bar{K}_{yx2}\right)\left(\bar{C}_{xy1} + \bar{C}_{xy2}\right) - \bar{K}^2(\bar{K}_{xx1} + \bar{K}_{xx2})\left(\bar{C}_{yy1} + \bar{C}_{yy2}\right) - \bar{K}^2\left(\bar{K}_{yy1} + \bar{K}_{yy2}\right)(\bar{C}_{xx1} + \bar{C}_{xx2})$$

$$G_7 = \bar{K}^2\left(\bar{K}_{xy1} + \bar{K}_{xy2}\right)\left(\bar{K}_{yx1} + \bar{K}_{yx2}\right) - \bar{K}^2(\bar{K}_{xx1} + \bar{K}_{xx2})\left(\bar{K}_{yy1} + \bar{K}_{yy2}\right)$$

The dynamic coefficients for worn and intact journal bearings are taken from, **Jameel et al., 2015**.

To find a solution to the Eq. (22), firstly $\bar{\lambda}$ must be found. The general form of $\bar{\lambda}$ is a complex form. It may be written as

$$\bar{\lambda} = m + is$$

Where (m) and (s) are the real and imaginary parts of the eigenvalue respectively. Observe that the equation of motion has the following form of a solution

$$x = Ae^{(m+is)t} = Ae^{mt}e^{ist}$$

If the real part of the eigenvalue is positive, then *x* goes to infinity, and if the real part is negative, then *x* goes to negative infinity. So for the rotor to be at a state that neither declines nor inclines, (m) must be equal to zero. Thus, real part (m) equal zero is a major stability limit (threshold) criteria and the eigenvalue takes the following form

$$\bar{\lambda} = is$$

The dimensionless new characteristic equation can be rewritten just a function of the eigenvalue as following

$$-\frac{G_1}{\bar{\Omega}^2}s^6 + i\frac{G_2}{\bar{\Omega}}s^5 + \left(G_{31} + \frac{G_{32}}{\bar{\Omega}^2}\right)s^4 - i\frac{G_4}{\bar{\Omega}}s^3 - \left(G_{51} + \frac{G_{52}}{\bar{\Omega}^2}\right)s^2 + i\frac{G_6}{\bar{\Omega}}s + G_7 = 0 \qquad (23)$$

Since the characteristic equation, Eq. (23), equal zero, then the real part and the imaginary part must equal zero. Thus, there are two equations can be made as following.

$$-\frac{G_1}{\bar{\Omega}^2}s^6 + \left(G_{31} + \frac{G_{32}}{\bar{\Omega}^2}\right)s^4 - \left(G_{51} + \frac{G_{52}}{\bar{\Omega}^2}\right)s^2 + G_7 = 0 \qquad (24)$$

$$i\frac{G_2}{\bar{\Omega}}s^5 - i\frac{G_4}{\bar{\Omega}}s^3 + i\frac{G_6}{\bar{\Omega}}s = 0 \qquad (25)$$

Eq. (25) represents the imaginary part of the characteristic equation and it has the following solution.

$$s^2 = \frac{G_4 \pm \sqrt{(-G_4)^2 - 4G_2G_6}}{2G_2} \qquad (26)$$

Since the two solutions of Eq. (26) satisfy the imaginary part of the characteristic equation, substitute the value of (s^2) into the real part of the characteristic equation, Eq. (24), and solve it for the dimensionless speed.

The dimensionless speed has two results one of them is usually near zero. While another gives a logical value. So only the second is valid. This value is known as the instability threshold speed.

$$\bar{\Omega}_{th} = \sqrt{\frac{G_1 s^6 - G_{32}s^4 + G_{52}s^2}{G_{31}s^4 - G_{51}s^2 + G_7}} \qquad (27)$$

The instability threshold speed can be rewritten in term of Sommerfeld Number as following

$$\bar{\Omega}_{th} = S_s \frac{\pi M g c^2}{\mu \Omega L R^3} \sqrt{\frac{G_1 s^6 - G_{32}s^4 + G_{52}s^2}{G_{31}s^4 - G_{51}s^2 + G_7}} \qquad (28)$$

5. ROTOR BEARING SYSTEM ANALYSIS USING ANSYS

3-D Solid model rotor bearing system gives more accurate results than in the case of one dimensional beam model as well as there are many advantages in adopting this model **Rao and Sreenivas, 2003.** Therefore it is used in this work; Solid187 element (4452 elements) has been used to model shaft and disk as shown in the **Fig.2. (a),** as well as COMBI214 element used to model journal bearing. All steps to model rotor bearing system can be found with details in **ANSYS Guide, 2012**. The eight dynamic coefficients of journal bearing are depending on the rotational speed therefore when these coefficients represent in ANSYS must be changed with rotor speed. The dimensions of rotor and bearings which used in this work are shown in **Fig.2. (b),** and **Table.1.**

6. RESULTS AND DISCUSSION

6.1 Effect of Wear on the Steady State Harmonic Response Amplitude and Critical Speed

. The present analytical has been validated with **Rao, 1996**. It is observed well agreement as shown in the **Fig.3**. Different combinations of dynamic coefficients have been studied separately to observe their effect on the harmonic response and critical speed. All results compared with case when all dynamic coefficients used in analysis **Fig.4.a.** Ignoring damping of journal bearings led to decreasing harmonic response and critical speed in the case of non-worn and worn journal bearing but the decreasing in the harmonic response higher in the case of non-worn Compared with the case of worn journal bearing as well as the harmonic response amplitude in the case of wear depth 0.04 mm becomes higher than in the case of wear depth 0.02 mm about 3.6% as shown in the **Fig .4.b.**ignoring cross coupled damping in bearings led to Slight decrease in the response amplitude and critical speed as shown in the **Fig.4.c**. Neglected direct damping in the bearings showed that increasing in the response amplitude and decreasing in the critical speed as shown in the **Fig.4.d**.Neglected the cross coupled stiffness led to increasing in the response amplitude and critical speed for all cases (worn and non-worn) as shown in the **Fig.5.a**. The last case when the cross coupled damping coefficients have been neglected led to increasing in the response amplitude and critical speed but the increase in the response amplitude and critical speed in the state of wear depth 0.04 mm higher than in the state of wear depth 0.02 mm by about 6.6% because the cross coupled damping coefficients in the case of wear depth 0.04 mm greater than in the case of 0.02 mm and when neglected it led to this state see **Fig.5.b.** In the **Fig.6**, **Fig.7** and **F.g.8**, all dynamic coefficients combinations have been plotted together showed that the major effect on the steady state harmonic response and critical speed is to the cross coupling stiffness and when neglected it led to increase in the response amplitude by 23% and critical speed by 7% because the cross coupled stiffness increasing with the increase in the rotor speed. The rotor orbit has been plotted as shown in the **Fig.9** for different rotational speed whereas the real value of Eq.(15) represent the x- coordinate of orbit and imaginary value of Eq.(15) represent the y- coordinate of orbit . The orbit radii increasing with the increase in rotor speed and with wear depth at the maximum response amplitude. The shape of rotor orbit approaching the shape of the circle at 9000 rpm because the eccentricity ratio becomes very small and real and imagery value of Eq. (15) become approximately equal for non-worn and worn journal bearing. Verification were done between analytical and numerical using ANSYS showed good agreement with error percentage about 8.5% for critical speed and about 3.5% error percentage for harmonic response as shown in the **Figs.10. 11 and 12** and **Table.2.**

6.2 Effect of Wear on the Instability Threshold Speed

The stability threshold speed represents the important parameter in the rotor dynamic for designers and operators. The stability decreasing with increase in the wear depth when the Sommerfeld number more than one as shown in the **Fig.13.d**, because the dynamic coefficients decreasing with increase in the rotor speed for worn journal bearing when compared with the dynamic coefficients of non worn bearing except for direct stiffness in the y-direction **Jameel et al., 2015,** also the cross coupled stiffness has little effect on the stability threshold speed for worn and non-worn journal bearing as shown in the **Figs.13.a, 13.b** and **13.d.**

7. CONCLUSIONS

1. Wear in journal bearing is generally decreasing the steady state harmonic response amplitude by 4.3% and critical speed by 4.2% for wear depth 0.02 mm and decreasing the steady state harmonic response amplitude by 13.9% and critical speed by 7.1% for wear depth 0.04 mm

2. Increase in wear depth lead to decrease the orbit dimension at speed near critical speed by the same percentage of harmonic response in the first conclusion.
3. Orbit shape approaching the shape of the circle at high speed greater than critical speed.
4. The wear in journal bearing decrease the instability threshold speed by 2.5% for wear depth 0.02 mm and 12.5% for wear depth 0.04 mm
5. Increasing in the wear depth in journal bearing increases damping in rotor bearing system but decreasing the stability of system.

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NOMENCLATURE

Cd = direct damping, Ns/m
Cc = cross coupled damping, Ns/m
c = radial clearance, m
E = modulus of elasticity, N/m^2
F_{x1} , F_{x2} = reaction forces of the bearing one and two in the x- direction, N
F_{y1}, F_{y2} = reaction forces of the bearing one and two in the y- direction, N
K = stiffness of rotor, N/m
Kd = direct stiffness, N/m
Kc = cross coupled stiffness, N/m
L = bearing length, m
M = rotor mass, Kg
r_f , r_b = forward and backward components of unbalance response respectively, m
R = journal radius, m
(x_r) , (y_r) = location of the rotor center
(x_j) , (y_j) = location of the journal center
u = mass eccentricity, m
μ = viscosity pa s
Ω = rotational speed of rotor, rad/s
$\bar{\Omega}_{th}$ = dimensionless instability threshold speed
λ, $\bar{\lambda}$ = eigenvalue term and dimensionless eigenvalue term

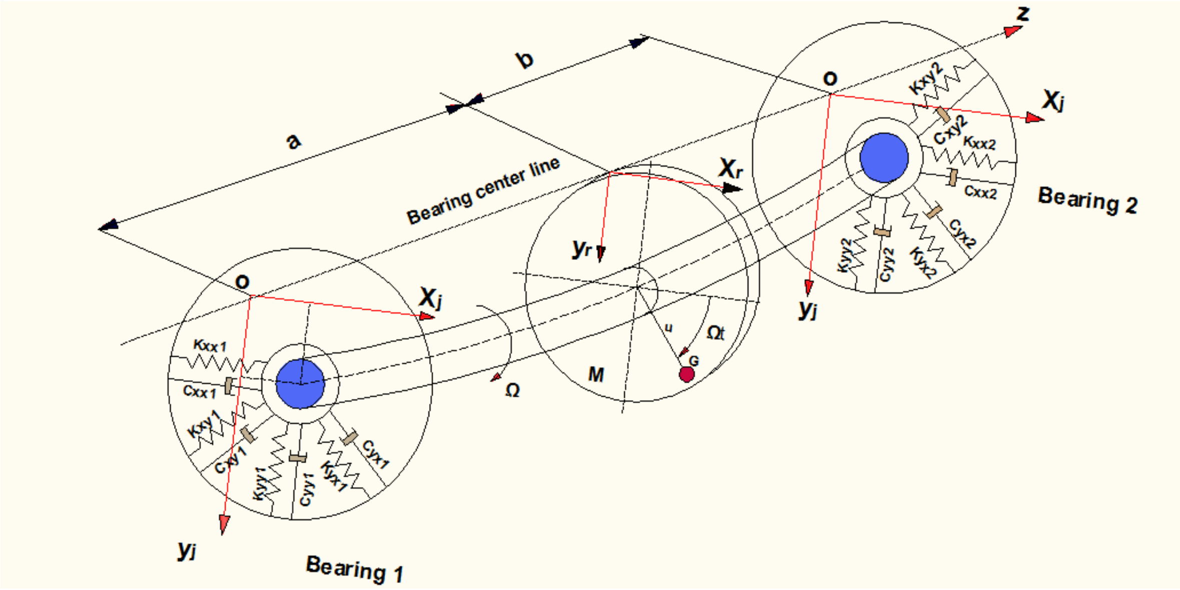


Figure 1. Rotor supported on the fluid film journal bearings.

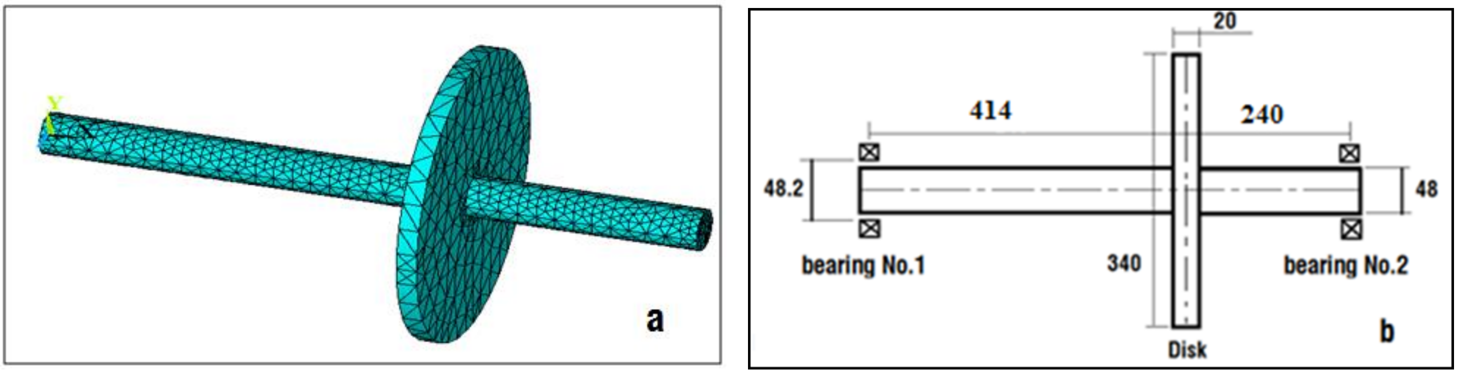


Figure 2. (a) Ansys rotor model (b) Mechanical drawing of present rotor bearing system.

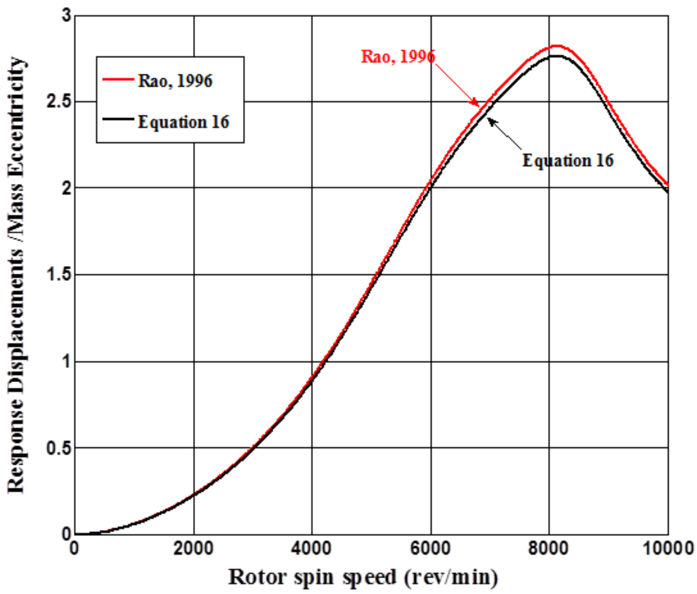


Figure 3. Steady state harmonic unbalance response.

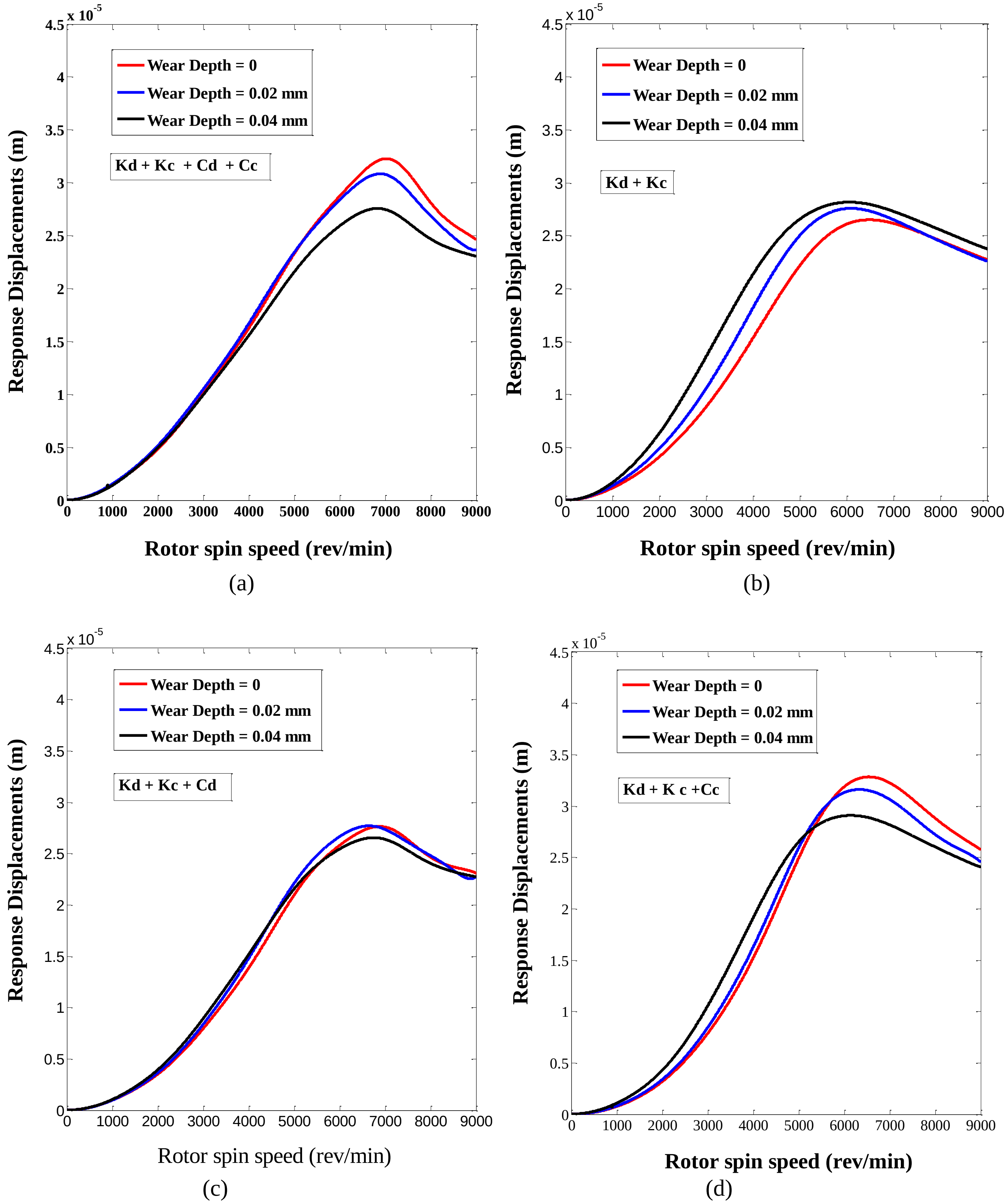
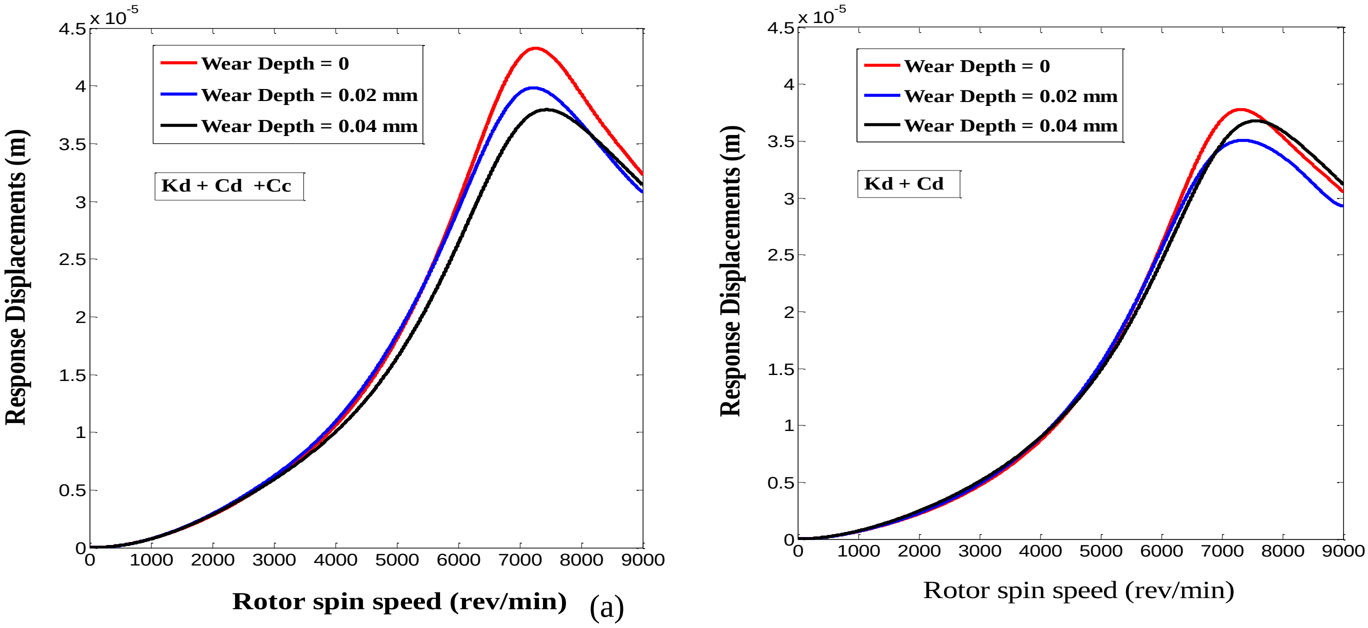


Figure 4. Effect of wear in journal bearing on the harmonic response of rotor bearing system (a): Using all coefficients, (b): Ignoring damping, (c): Ignoring cross coupled damping, (d): Ignoring direct damping.



(b)

Figure 5. Effect of wear in journal bearing on the harmonic response of rotor bearing system (a): Ignoring cross coupled stiffness, (b): Ignoring cross coupled stiffness and damping.

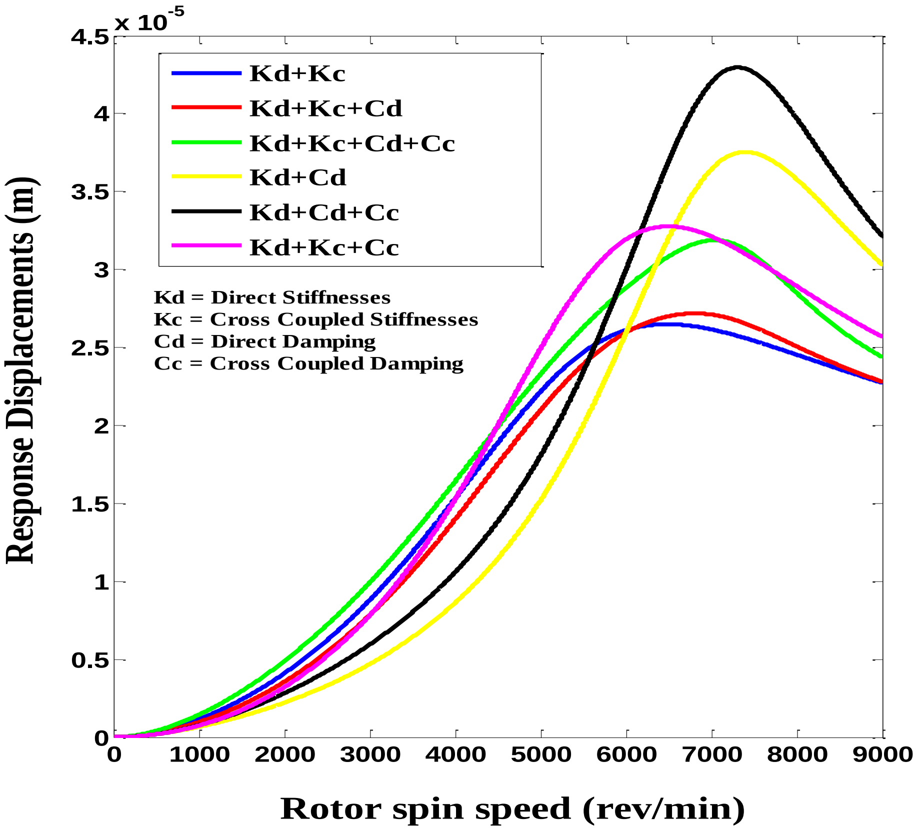


Figure 6. Harmonic unbalance response of rotor bearing system with different combinations of stiffnesses and damping of non-worn journal bearing.

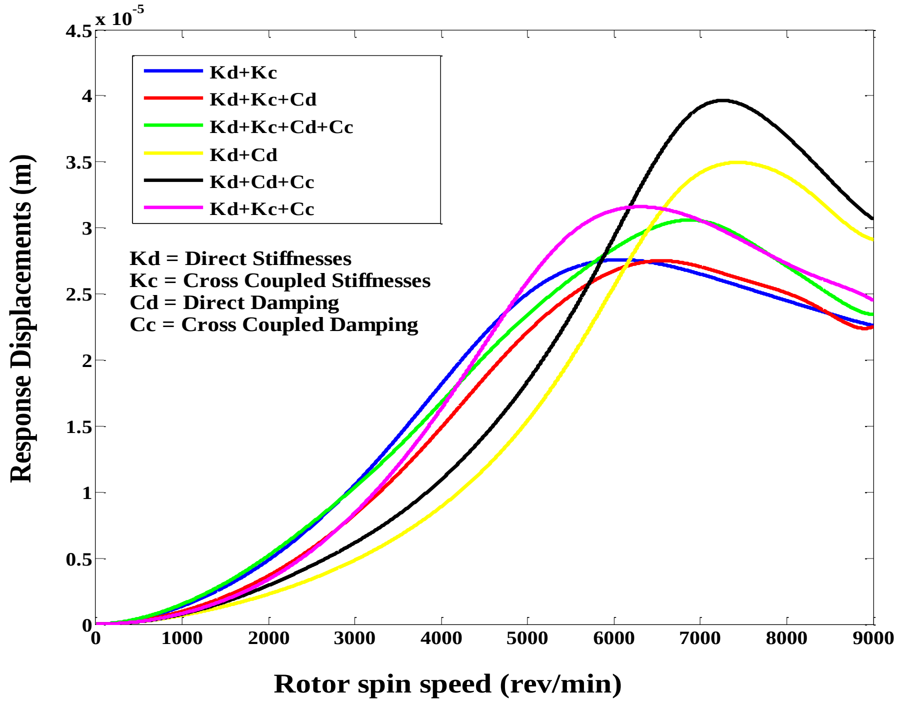


Figure 7. Harmonic unbalance response of rotor bearing system with different combinations of stiffnesses and damping of worn journal bearing ,wear depth = 0.02 mm.

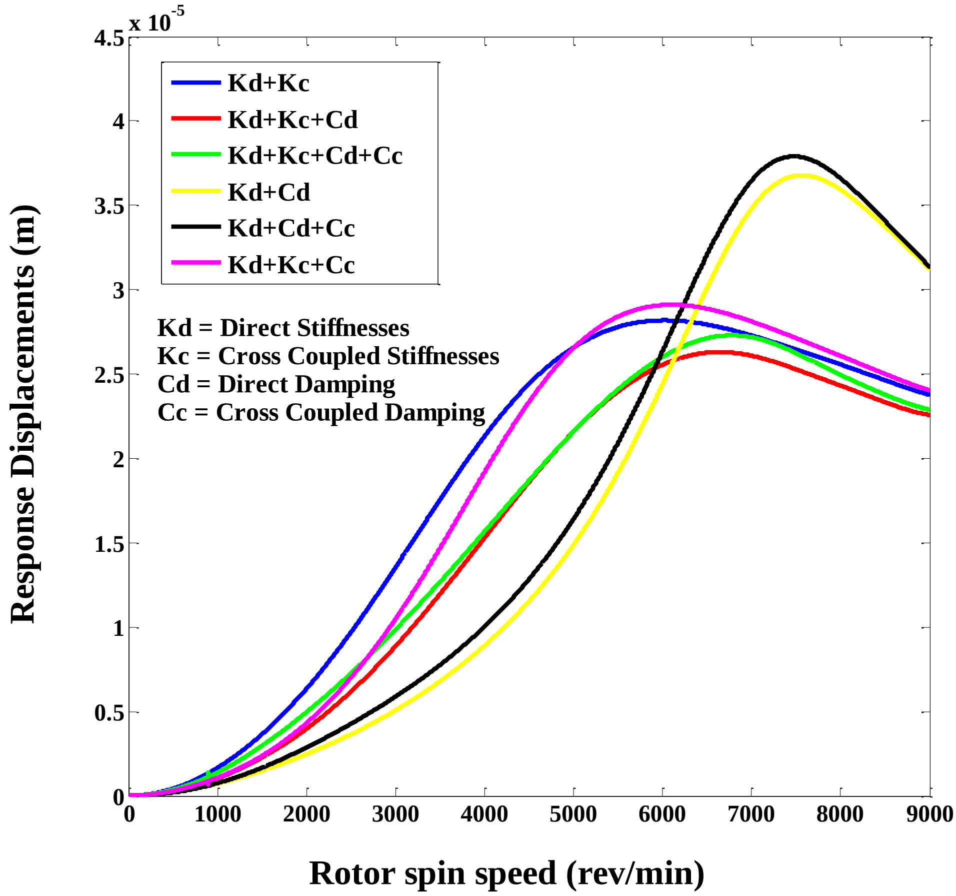


Figure 8. Harmonic unbalance response of rotor bearing system with different combinations of stiffnesses and damping of worn journal bearing ,wear depth = 0.04 mm.

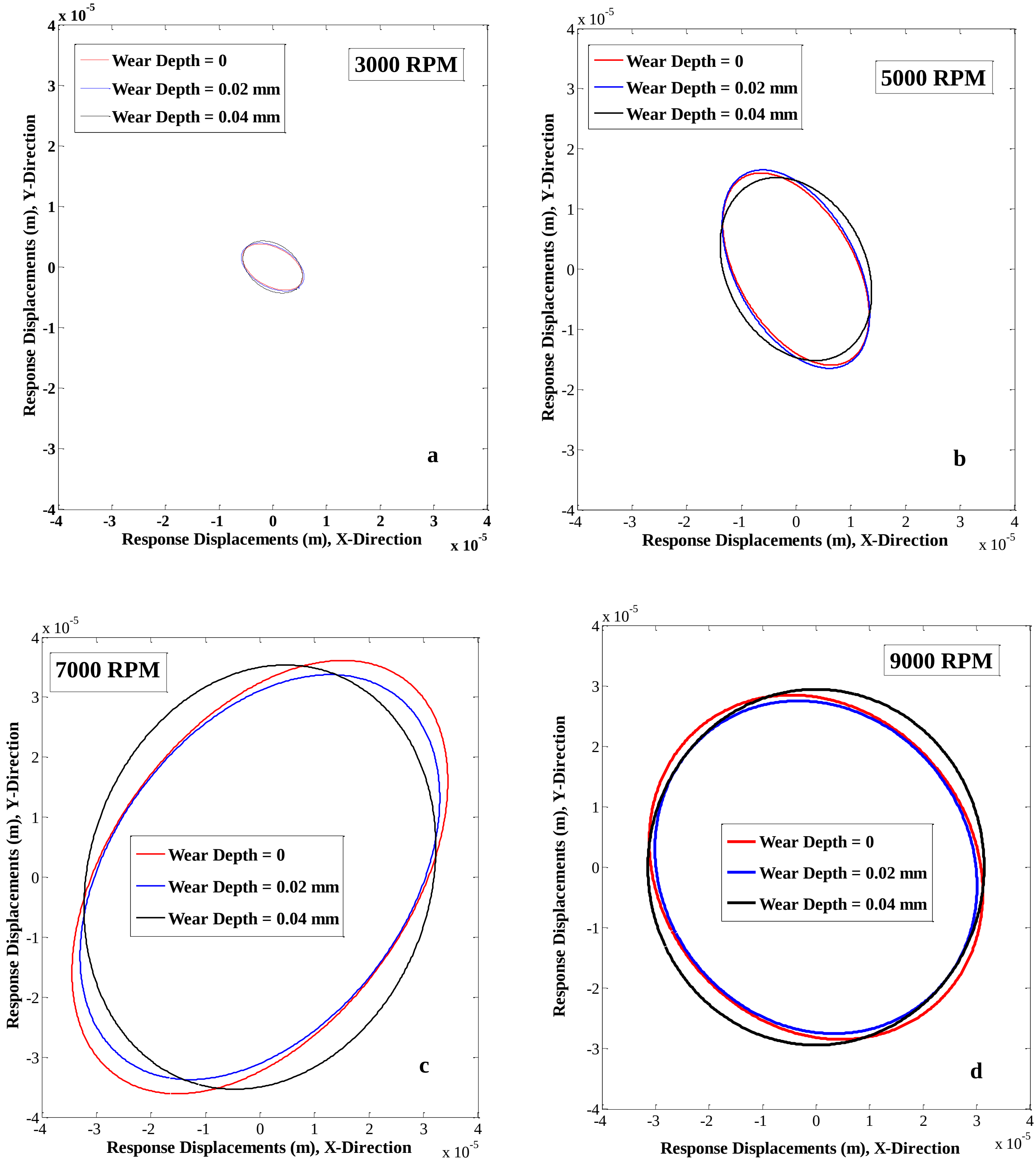


Figure 9. Effect of wear depth in journal bearing on the rotor whirl orbit at disk center, (a) At 3000 rpm, (b) At 5000 rpm, (c) At 7000 rpm and (d) At 9000 rpm.

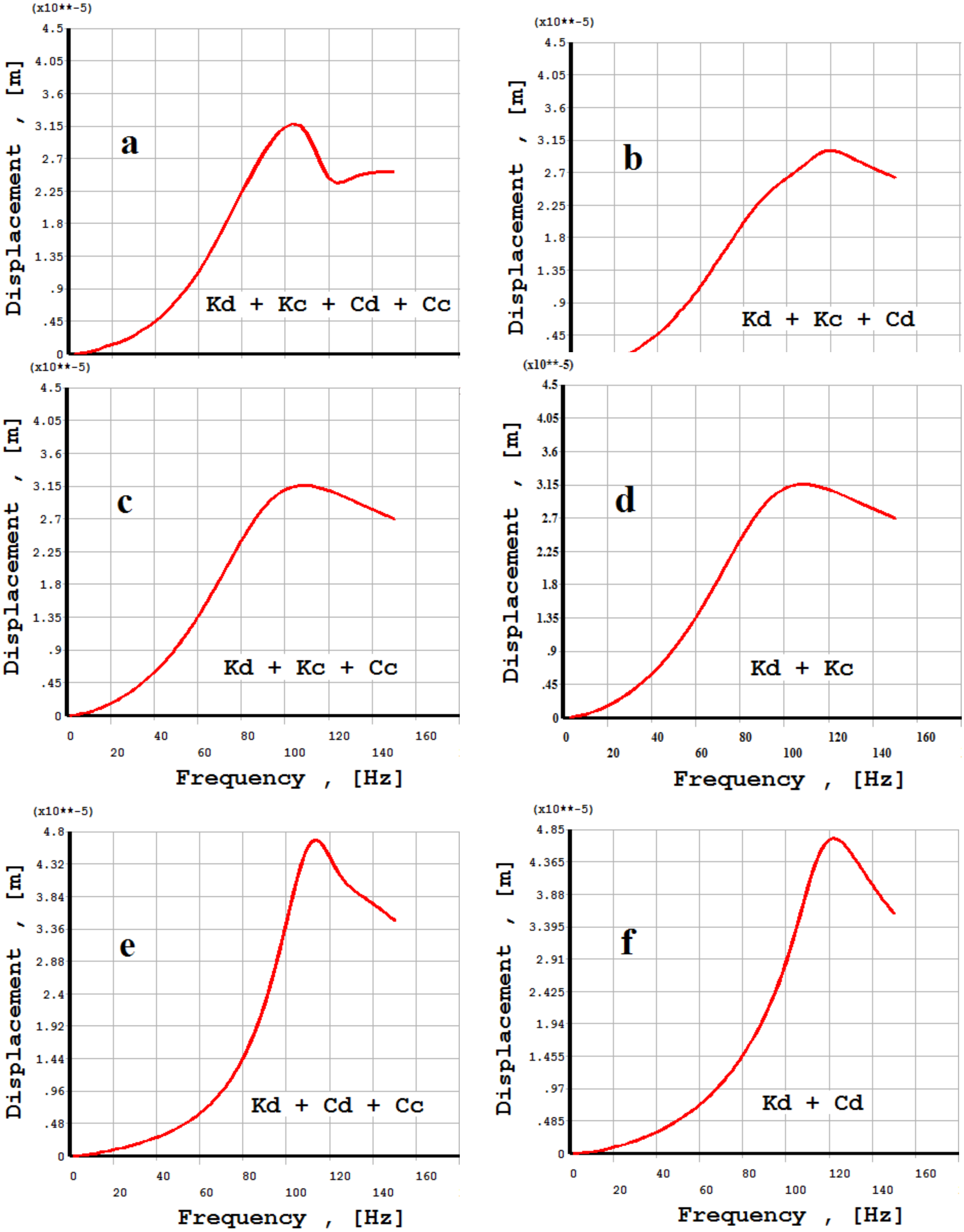


Figure 10. Steady state harmonic response of rotor mounted on non-worn fluid film journal bearing with different combinations of dynamic coefficients (ANSYS).

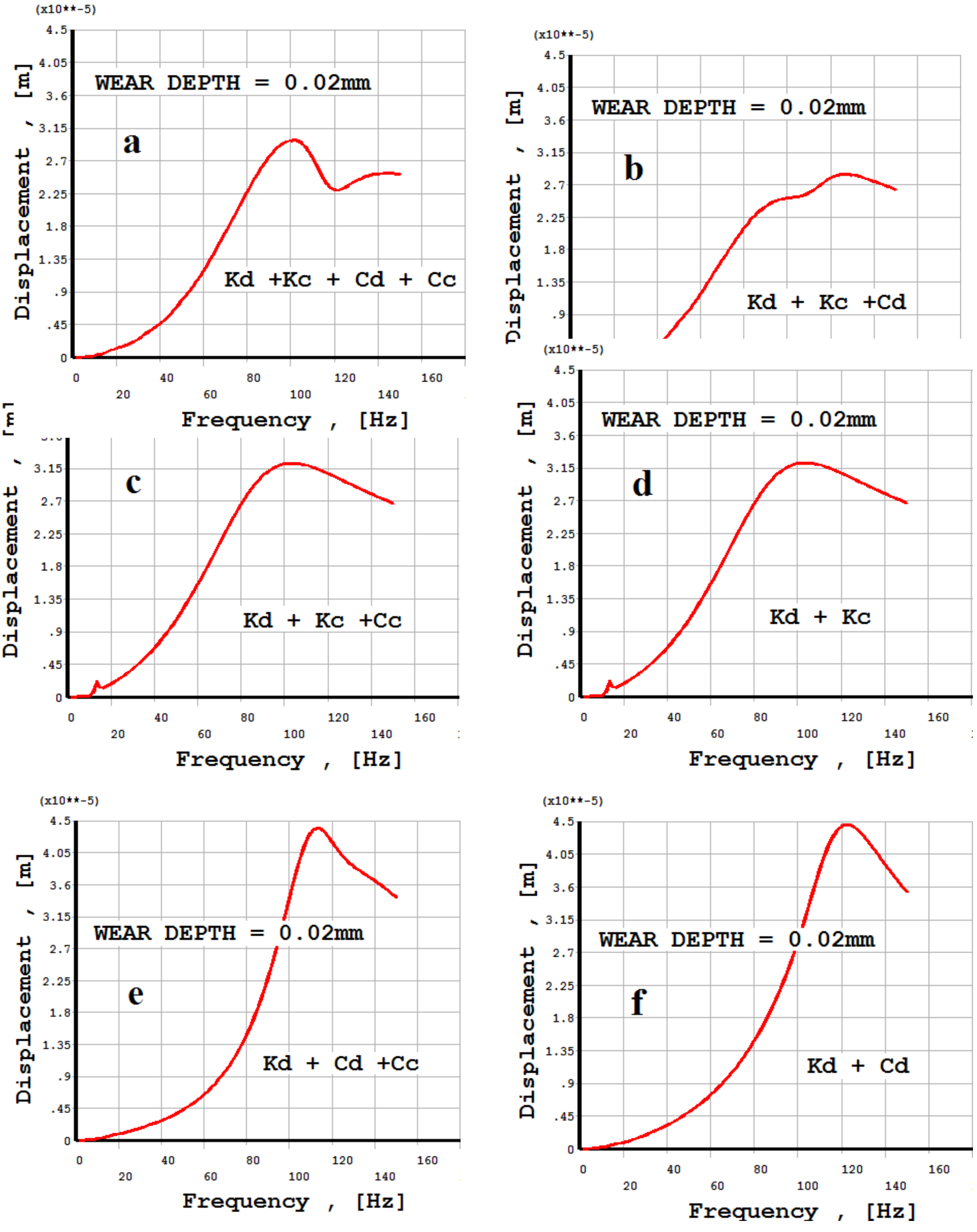


Figure 11. Steady state harmonic response of rotor mounted on worn fluid film journal bearing (wear depth = 0.02 mm) with different combinations of dynamic coefficients (ANSYS).

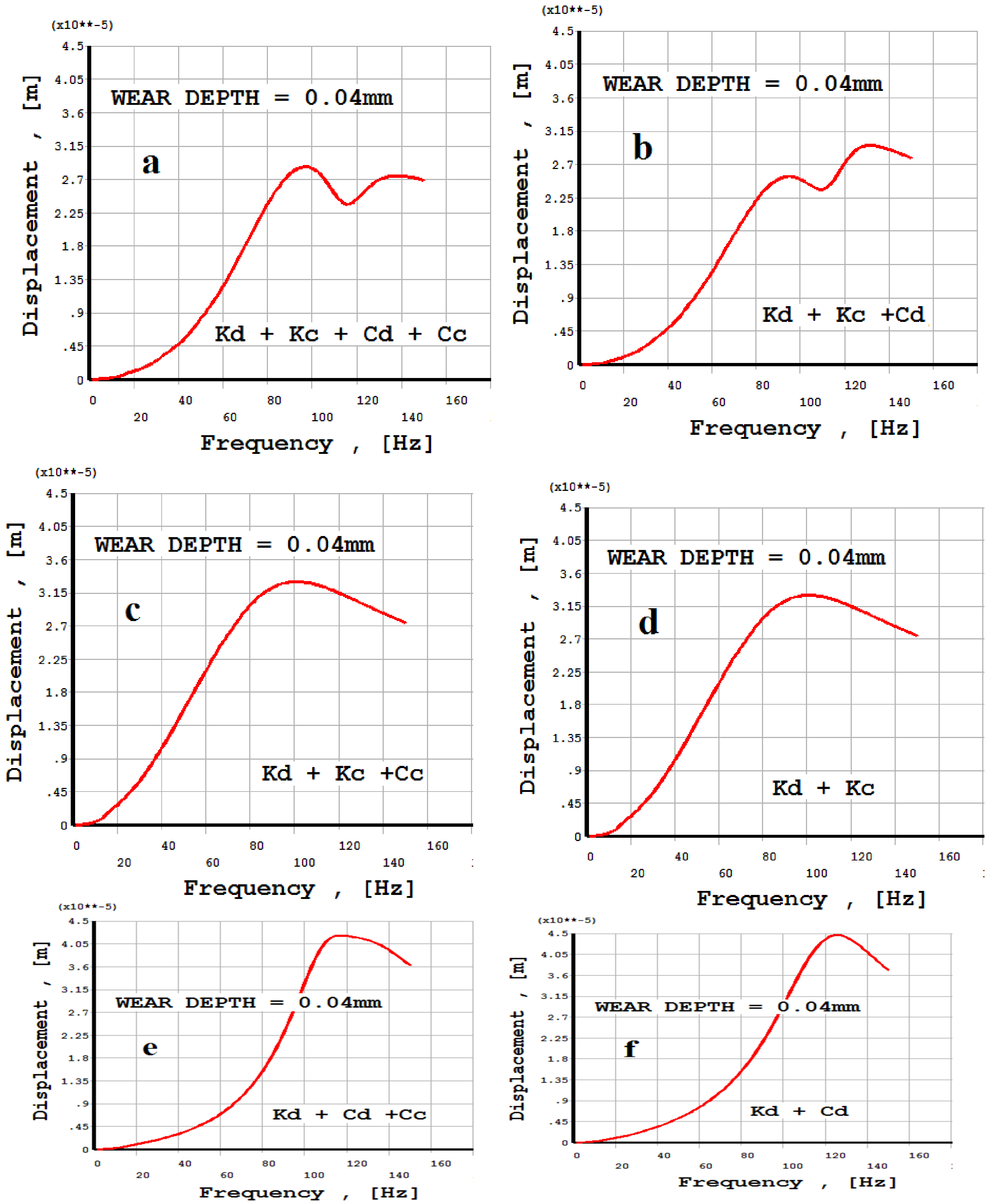


Figure 12. Steady state harmonic response of rotor mounted on worn fluid film journal bearing (wear depth = 0.04 mm) with different combinations of dynamic coefficients (ANSYS).

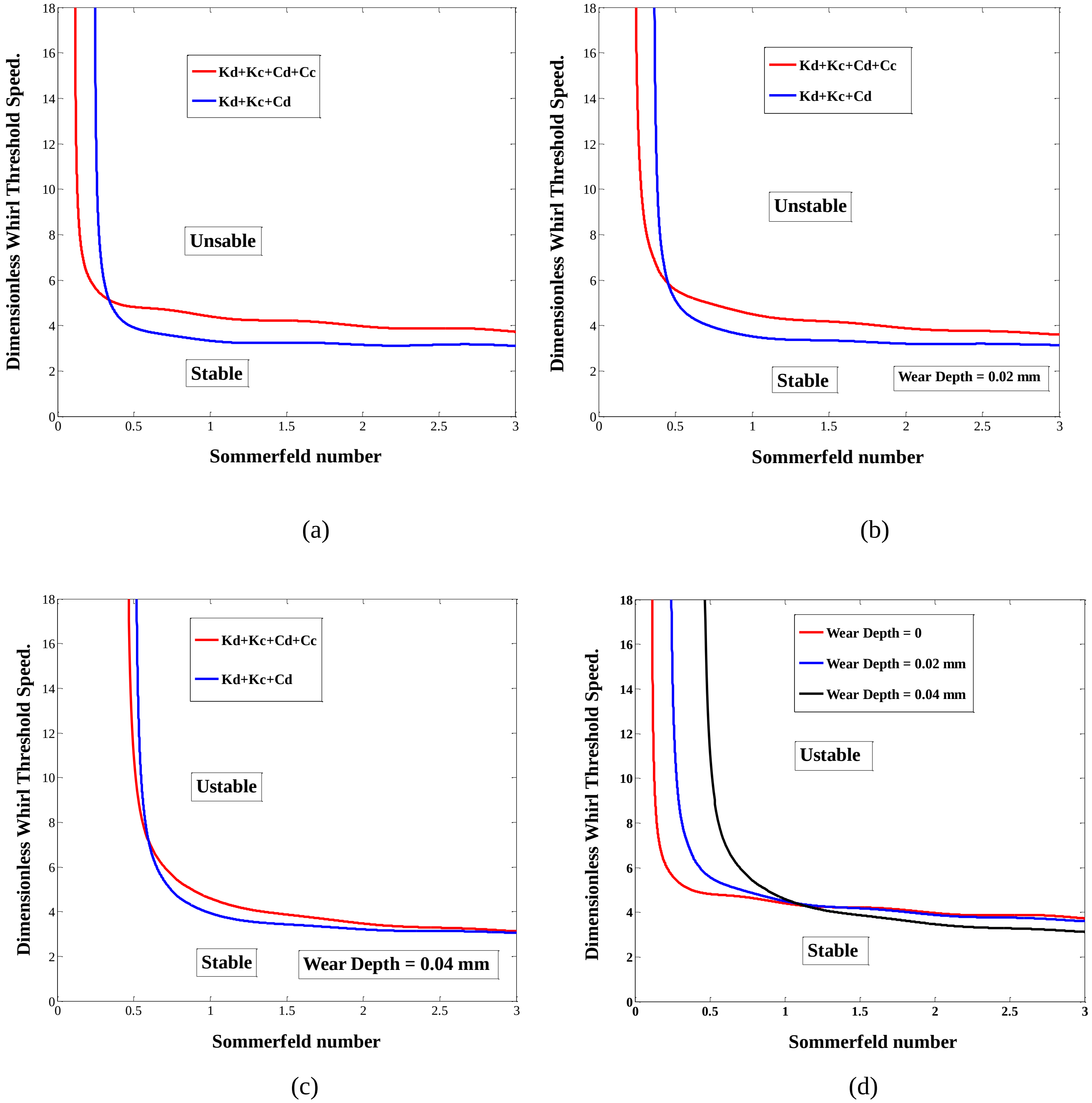


Figure 13. Instability threshold speed (a) Non-worn journal bearing, (b) Wear depth = 0.02 mm, (c) Wear depth = 0.04mm, (d) Comparison between three cases.

Table 1. Shows rotor dimensions and material properties and lubricant oil specifications.

Shaft length m	Shaft diam. m	Disc diam. m	Disc thickness m	Modulus of elasticity pa	Shaft and disk density Kg/m^3	Lubricant oil viscosity Pa s	Unbalance force Kg - m
o.654	0.048	0.34	0.02	$2.1x10^{11}$	7850	0.032	$0.323x10^{-3}$

Table 2. Effect of wear depth in the fluid film journal bearing on the steady state harmonic response amplitude and critical speed of rotor mounted on worn fluid film journal bearing.

Wear Depth mm	Analytical		ANSYS		% Error	
	Max Response Amplitude m	Critical Speed rpm	Max Response Amplitude m	Critical Speed rpm	Critical Speed	Response Amplitude
0	3.22×10^{-5}	7000	3.182×10^{-5}	6400	8.5	1.18
0.02	3.08×10^{-5}	6700	2.983×10^{-5}	6100	8.9	3.14
0.04	2.77×10^{-5}	6500	2.873×10^{-5}	5950	8.4	3.58

الكفاءة الإنشائية في عمارة الاهوار التقليدية

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الخلاصة

تعد الكفاءة الإنشائية في العمارة بشكل عام إحدى أهم معايير نجاح أي منشأ ومقياس لديمومته وملاءمته عبر الزمان والمكان، ونظراً لأهمية بيئة الأهوار وما تمتلكه من مقومات مكانية، وبيئية، واقتصادية، وإجتماعية، كان لها الأثر البارز في خلق أنماط العمارة بالشكل الذي خلق بيئة معمارية وإنشائية مميزة لها امتلكت العديد من الصفات والمقومات التي ساهمت في ديمومتها وحافظت على كيانها عبر السنين، من منطلق إن الإنسان وبيئته تعد الهدف الأساسي لأي نمط معماري ينحى للديمومة والبقاء، بالتالي ظهرت **المشكلة البحثية المتمثلة في قلة وضوح الأدبيات السابقة في طرحها لدور الأنماط المعمارية في الأهوار في تحقيقها للكفاءة الإنشائية،** فبالرغم من كثرة الطروحات والدراسات التي تناولت عمارة الأهوار إلا إنها إتسمت بعدم الوضوح وقلة الشمولية في التطرق للجوانب الإنشائية والتقنية، بالتالي تركز هدف البحث في الكشف عن طبيعة تأثير التقنيات المستخدمة في تشكيلات عمارة الأهوار التقليدية في الوصول إلى الكفاءة الإنشائية من مختلف جوانبها التقنية، والمادية، والاقتصادية، وحتى التعبيرية منها، مفترضاً تحقيق عمارة الأهوار التقليدية للكفاءة الإنشائية بما امتلكته تلك العمارة من خصائص ومقومات بالشكل الذي ساهم في ديمومة أنماطها عبر الزمن. وقد أعتمد البحث إسلوب الدراسة التحليلية لإنموذج العمارة التقليدية في الأهوار للوصول إلى تلك الأهداف، حيث إن دراسة هذه المفردات بشكل شمولي يهدف إلى تعميق فهم المصمم لمتطلبات كل مكون بغرض تحقيق تزاوجها وتكاملها معا. فهذه المكونات يجب ألا تتعارض مع بعضها البعض، بل يجب أن تتكامل أثناء وبعد العملية التصميمية حتى يخرج العمل مبدعاً من الوجهة المعمارية.

- **الكلمات الرئيسية: عمارة الأهوار–الكفاءة الإنشائية – الجوانب التقنية والمادية – التكامل الإنشائي.**

Constructional Efficiency in Al_Ahwaar Traditional Architecture

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ABSTRACT

Constructional Efficiency in architecture in general is one of the most important standard success for any structure and a measure of its continuity and relevance across time and space. Given the importance of Al−Ahwaar environment that owned the spatial, environmental, economic and social elements had a prominent impact in creation of architecture patterns form to create special architectural and structural environment, which had many qualities and ingredients that contributed to its continuity and existence over the years. From the premise that man and his environment is the main goal to any architectural style,

Thus the research problem focusing on the lack of clarity of the previous literatures in its studies for the role of architectural styles in Al-Ahwaar in achieving constructional efficiency, despite the large number of studies on Al-Ahwaar architecture but it is mostly marked by non-clarity and lack in the constructional and technical aspects,

Therefore, the research goal focusing on clarification of the impact of the techniques that used in formations Al_Ahwaar traditional architecture in order to reach to the constructional efficiency in various aspects such as technical, material, economical, and expressional. Assuming that achieving to the constructional efficiency at Al-Ahwaar traditional architecture depends on its characteristics and elements that contributed to the continuity of their patterns across time.

The research depended on analytical method of a model of traditional architecture in Al-Ahwaar to reach those goals, as the study of these items aims to deepen the understanding of the designer to the requirements of each component in order to achieve integration together. These components must not conflict with each other, but it must be integrated during and after the design process until it comes out as a creative of architectural destination.

- **Keywords:** al-ahwaar architecture, constructional efficiency, technical and material aspects, constructional integration.

المقدمة

يُعد الإنشاء هو النظام الذي يسلكه المبنى يتحقق فيه الاتزان عن طريق صورة معينة، حيث يكون الإنشاء هو الترتيب والنظام الذي تتجمع فيه الأجزاء المكونة للمبنى لغرض بقاء الشكل متزناً فضلاً عن الغرض الأساسي في مقاومة أي أحمال يتعرض لها المنشأ ونقلها إلى الأرض، أي إن الإنشاء هو نظام لمقاومة الأحمال وضمان بقاء الشكل متزناً فهو الجانب المادي من العملية التصميمية.

ولقد استخدم الإنسان العراقي لبناء عمارته "في مراحل حضارته المختلفة"، مواد أولية متنوعة مما يتوفر في بيئته من حجارة، أو قصب، وطابوق، وبما أن الهدف الأساسي للعمل المعماري هو الإنسان وبيئته، لذلك يجب وضع الإنسان واحتياجاته البيئية كأول وأهم مكونات العمارة المتكاملة. ويكون الجزء المهم هو أن يحقق للإنسان المنظومة البيئية والفراغية اللازمة لراحته والمحققة لكفاءة أداء العمل من نواحي الإنشاء والوظيفة والاقتصاد بغية الوصول للإبداع المادي. ومن ثم نصل للجزء الأخر للإبداع الإنشائي والمتمثل بالتكنولوجيا المناسبة محلياً لخلق الفراغات المطلوبة. بالتالي تبرز أهمية الكفاءة في أي إنجاز معماري سواءً كانت الكفاءة إبداعية التي تقرر الخواص والسمات المبدئية للعمل عن طريق المقارنة مع الحلول المتوفرة والسعي لإطلاقها. أو تكون تلك الكفاءة إدارية والتي تقرر شكل تجميع العلاقات الاقتصادية والإدارية بين المصمم والمنفذ.

لذلك أثرّت المواد الأولية في أبنية جنوب العراق على شكل الصورة المعمارية للوحدة البنائية، فعلى الرغم من استخدام الطابوق واللبن في الأبنية الخاصة بالمعابد والأسوار فقد ظل استخدام أهل جنوب العراق للقصب في تشييد أبنيتهم الخاصة مستمراً. وهو الأمر الشائع عند سكان مناطق الأهوار والمضايف العربية العراقية حتى اليوم عن طريق استغلال كل الإمكانيات المادية والتقنية والاقتصادية لتخرج عمارة تعبر عن مكانها ومكانتها (التعبيرية والإنشائية). بالتالي تتميز العمارة في أي مكان وزمان عن باقي الفنون بشكل يسمو بها لتكون بحق أم الفنون، وهو يرتفع بالعمل المعماري من مجرد خدمة انتفاعية إنشائية محددة ليصبح عملا يوجه الحياة الإنسانية بكاملها نحو التطور المستمر عبر العصور متأثرا بأهداف عصره، سواء كانت بيئية أم تقنية أم اجتماعية أم إقتصادية، وخالقاً لتراث فني وفكري للأجيال اللاحقة.

1) التخطيط المنشئي والتصميم المنشئي Structural planning & Structural design

التخطيط المنشئي: هو طريقة تحديد نوع الإنشاء المتبع في المبنى ويعنى ذلك إن المعماري محتاج إلى المعرفة التي تتعلق بالعلوم الإنشائية حتى يتمكن من تنمية قدراته الإنشائية.

التصميم المنشئي: هو تخصص المهندس الإنشائي ويختص بتحديد القطاعات والمواد الإنشائية، هذا يعنى إن المهندس المعماري يضع الخطة أو السلوك الإنشائي، ثم تأتي وظيفة الإنشائي الذي يحدد الأبعاد والكفاءة للنظام الإنشائي الذي صممه المعماري وهي إعطاء الأبعاد والصفات والتأكيد على الكفاءة وتسمى هذه المرحلة بمرحلة التصميم، إذ إن الفكرة الإنشائية في جميع المنشآت هي محاولة تجميع الأوزان وتركيزها في نقاط الأساسات. وتجميع الأوزان ونقلها وتركيزها يعنى إن هناك مسار يسير فيه حمل المادة حتى يصل إلى الأساسات بالأرض وذلك بفعل الجاذبية الأرضية، وهو المسار الطبيعي للوزن (أبراهيم ميخائيل، 2014، html).

2) المسار المادي والمسار الطبيعي للأحمال الإنشائية:

يعد مصطلح المسار الإنشائي الطريق الذي يسير فيه حمل المادة حتى يصل إلى الأرض بفعل الجاذبية الأرضية، إذن من البديهي أن يكون المسار الطبيعي للمادة هو الخط العمودي الواصل من مركز ثقل المادة إلى الأرض، أما المسار المادي فهو المسار الذي يصنعه الأنسان وفيها يغير المسار الطبيعي طريقه أو يسير في نفس اتجاهه حسب تصميم الأنسان له (أبراهيم ميخائيل، 2014، html) ونلاحظ هنا انه إذا انطبق المسار الطبيعي مع المسار المادي تكون المشكلة الإنشائية بسيطة وصولاً لأعلى كفاءة إنشائية ممكنة. إذ كلما زاد البعد بين المسار المادي والمسار الطبيعي كلما كانت المشكلة الإنشائية أكبر، ومن ذلك يمكن القول إن المنشأ تزداد كفاءته الإنشائية كلما تطابق المسار المادي مع المسار الطبيعي.

3) الكفاءة المنشئية Structural Efficiency:

تخضع أي فعالية تكنولوجية (ومن ضمنها الفعالية المنشئية) للتقييم والمسائلة على أساس الكفاءة (efficiency) لقياس ومقارنة مدى قدرة هذه الفعالية لتحقيق الهدف أو الغرض، حيث يسبق التقييم على أساس الكفاءة مفهوم الغرض.

وعلى هذا الأساس يمكن أن نعرف كفاءة المنشأ بعدة توجهات منها: أنها النسبة بين الحمل الكلي إلى الوزن الميت فكلما قل الوزن الميت ازدادت الكفاءة المنشئية (فراس عصام، 1996، ص:27). أو أنها النسبة بين المنفعة "النتاج" إلى الكلفة "المدخلات" (Holgate, 1986, p:14). ومن وجهة نظر المتطلبات المنشئية الأساسية فالمنشأ المبدع هو ذلك المنشأ الذي يكون الأكثر استقراراً وثباتاً، الأقوى والأمتن، الأكثر أدائية ووظيفية، الأكثر اقتصادية، والأكثر جمالية وتعبيرية. (Nervi, 1956, p:26).

وتواجه المهندسين الإنشائيين الكثير من التحديات المتمثلة في التصميم الإنشائي والتي يمكن لا تدعم وزن المنشأ فقط ولكن الأحمال الأخرى أيضاً، مثل القوى الناجمة عن المستخدمين، والأثاث، والثلوج والرياح والزلازل. لذلك ينبغي أن يتم تصميم النظام المنشئي لتحقيق هذه الأهداف وبطريقة فعالة. لأن غالباً ما تستند تكلفة المواد الإنشائية المستخدمة في بناء الهيكل الإنشائي على وزن المواد، فهي فعالة من حيث التكلفة من خلال استخدام أقل كمية من المواد اللازمة لتوفير المنشأ الذي يمكن أن يحمل الأحمال المسلطة بصورة آمنة. وعليه فأن المنشآت الأكثر كفاءة هي التي تكون قوية وخفيفة الوزن.

ويعد مقياس الكفاءة المنشئية أحد مقاييس فعالية تكلفة المنشأ. وعلى الرغم من إن الكفاءة المنشئية يمكن أن تُعرف بطرق عديدة، إلا انه يمكن توضيحها عن طريق معادلة رياضية تستند على نسبة الحمل المسلط مقسمة على وزن المنشأ نفسه. وكما يأتي: (Eric,2010, p:4).

$$\text{معدل الكفاءة المنشئية} = \frac{\text{الحد الأعلى للحمل المسلط على المنشأ}}{\text{وزن المنشأ}}$$

$$Structural\ Efficiency\ Rating = \frac{Maximum\ Design\ Load\ Applied\ to\ Structure}{Weight\ of\ Structure}$$

وعن طريق ذلك يمكننا أن نفهم أن الحد الأعلى لتصميم الحمل المسلط على المنشأ ليس بالضرورة أن يكون هو الحد الأعلى للأحمال التي يمكن أن يتحملها المنشأ.

لذلك من أجل توفير تصميم كفوء، يجب على المهندس الإنشائي أن يصمم منشأ لمقاومة الأحمال التي من المتوقع أن تحدث، والذي يدعى بحمل التصميم (*design load*). لذلك تستند الكفاءة على الحد الأعلى لحمل التصميم (*design load*)، وليس على التحميل الفعلي الذي يمكن أن يتحمله المنشأ، والتي قد تكون أعلى بكثير من حمل التصميم (*design load*). في كثير من الأحيان المنشأ الأكثر كفاءة هو الذي يملك أقصى قدرة تساوي الحد الأقصى لحمل التصميم (*design load*). (Eric, 2010, p: 5) .

وعلى هذا الأساس يقسم (Nervi) العملية الإبداعية وفقاً لتحقيق الكفاءة إلى مرحلتين:

الأولى: تمثل الملاءمة الموضوعية وتحقيق المتطلبات التقنية. **والثانية:** تتميز بكونها شخصية جدا ولا يمكن أن تكون تحت سيطرة القواعد والقوانين أو السببية الموضوعية المطلقة. حيث يرى بالنتيجة أن إمكانية الإبداع تكمن في تناوب هاتين المرحلتين بشكل ثابت في عقل المصمم أو عن طريق المناقشة بين الإنشائي والمعماري.

وبعد هذا الطرح تتجلى أهمية عاملي الإبداع والكفاءة كعناصر تؤثر وتتأثر بالشكل المنشئي حيث لا يكمن وجودها كعوامل أو عناصر تصميمية تمثل وتجسد النتيجة بل بكونها أحد أسباب ومسببات الشكلين المعماري والمنشئي معاً أن لم يكونا كياناً واحداً.

ومن المبادئ الأساسية التي من شأنها تحقيق أعلى كفاءة ممكنة تلك التي تتركز في كون الأشكال المنشئية تفضل أن تكون مشابهة لتلك الأشكال الموجودة في الطبيعة والعمل على تحليلها ودراستها وإستنباط النظم منها، لا سيما نظم نقل أحمالها وأوزانها إلى الأرض. ومن أجل إنجاز بعض الأشكال المنشئية بدرجة مماثلة من الكفاءة يفضل الإقتباس والإستلهام من بعض الأشكال الطبيعية. (Holgate, 1986, p:208).

ويمكن ملاحظة هذا المبدأ بأبسط أشكاله في منشأ (قصر العمل "Labour في Turin") للمهندس الإنشائي Nervi الشكل (1)، فالشكل مقارب لأغصان الشجرة التي تعمل على جمع الأحمال وتوجيهها نحو الدعائم كالجذع الذي يعمل عمل الأعمدة. ومن ثم تنتقل الأحمال بصورة طبيعية للأسفل بإتجاه الجذور التي تعكس صورة الأسس.

الأمر الآخر والمتعلق بمبدأ الكفاءة هو **تدرج كفاءة المنشأ تبعاً للقوى الأساسية** التي يعتمد عليها المنشأ. ففي المنشآت أو العناصر المنشئية المعتمدة على فعل الإنحناء تكون جزيئات المادّة القريبة من المحور المركزي المحايد تحت الإجهاد؛ شكل(2) في الواقع فإن جزيئات المادّة في قمة وقعر العنصر معرضة بالكامل للإجهاد. (Eric, 2010, p: 6).

<u>3-1) المبادئ الأساسية الواجب توفرها في أي مبنى للوصول للكفاءة المنشئية</u> (أبراهيم ميخائيل، 2014، html)

1- الثبات- الاستقرار Stability.

2- القوة والصلابة Rigidity-Strength.

3- ملاءمة الإنشاء لوظيفة المبنى Functionality.

4- الاقتصاد Economic.

5- الجمال Esthetic.

2-3) الكفاءة الإنشائية والجانب الإقتصادي:

تتغير عوامل الكفاءة الاقتصادية من مكان وزمان إلى آخر، فقد يكون أحد النظم الإنشائية أكثر كفاءة في استخدام المواد في منطقة بذاتها، بينما تكون التكاليف النهائية غير اقتصادية بالنسبة لأجور العمالة وتكاليف رأس المال الأساسي المطلوب على هيئة معدات وتشغيلها، وكذلك الوقت اللازم لإنهاء الأعمال المطلوبة.
لذا قد يكون أحد النظم الإنشائية اقتصادياً في ظروف مكانية وزمانية بعينها، بينما هو ذاته غير اقتصادي في ظروف أخرى مختلفة، ومن البديهي إن النظام الإنشائي المثالي اقتصادياً هو الذي يحقق الفضاء المطلوب بأكثر الطرق وفراً في مجموع تكاليف المواد وأجور العمالة ومعدات التشغيل وزمن التشغيل، وبالتالي يكون هو النظام الذي ينفي وجود أي بديل آخر اقل اقتصاداً. (علي رأفت، 1997، ص: 135).

ولموضوع الاقتصاد علاقة وثيقة بمبدأ الكفاءة، فمن الصعوبة تحقيق كفاءة منشئية بسبب التنوع الكبير للعوامل المتداخلة ضمناً من جانب والعدد الضخم للحلول الممكنة لكل مهمة معمارية من جانب آخر.
ويرى الكثير بأن عامل الكلفة هو المحدد الرئيس لاقتصادية أي عمل أو مشروع حين يعامل المال والكلفة مع عوامل أخرى تكون المحصلة إقتصادية جيدة مرغوب فيها، وهي: -

(1) التوزيع الواضح والصريح للإجهادات والأحمال المسلطة.
(2) التوازن المناسب بين الأحمال والمتانة (الأفعال وردود الأفعال).
(3) التوافق الكامل بين الخواص التقنية والجمالية، والتي تبرز بوضوح في الجسور.
(4) مبدأي القوة والأمان مع زيادة نسبية في الكلفة.
(5) القدرة على مقاومة الأحمال غير المتوقعة. (Torroja,1962, p:323)

3-3) الكفاءة المنشئية وشكل العنصر الإنشائي:

تحتل أشكال العناصر الإنشائية وخاصةً شكل محورها الطولي وعلاقته بالحمل المسلط أهمية كبيرة، خاصة في تعيين نوع القوى الداخلية التي تحدث عند تسليط الأحمال وقيمة هذه القوى.
حيث يؤثر هذان العاملان (نوع القوى الداخلية وقيمتها) والتي تتكون عند تسليط الأحمال بشكل كبير على مستوى كفاءة المنشأ خاصة في تعيين نوع المواد التي يجب توفيرها لتعطي تلك العناصر الإنشائية المقاومة والصلابة المناسبتين. بالتالي فتصنيف النظام الإنشائي وفق هذا المنظور يعتمد على العلاقة بين الشكل وكفاءة المنشأ. .(Angus,2001, p:37)

ويعد شكل العنصر الإنشائي مهماً جداً في مقاومة القوة. فعند ضمان وجود شكل يتبع الخط الطبيعي لمسار القوة سوف نضمن تعرض المادة إلى الإجهاد المباشر بالشكل الذي تستطيع المادة مقاومته بإستخدام أقل كمية منها وبذلك تزداد كفاءة النظام الإنشائي. وهذا نراه جلياً في شكل التقوس الموجود في العناصر الإنشائية المشكلة لمبنى الأهوار والتي تنبع أساساً من خواص المادة الأساسية (القصب). شكل (3).

حيث يسمى إجهاداً الشد والضغط بالإجهادين المباشرين لثبات الإجهاد خلال المقطع الإنشائي، وتمييزاً عن الإجهادات المركبة التي يتغير فيها الإجهاد خلال المقطع الإنشائي والذي يسمى بـ(الانحناء). وتستطيع جميع المواد الإنشائية تقريباً مقاومة الإجهاد المباشر بصورة افضل من إجهاد الانحناء، فقد أثبتت التجارب بأن إجهاد الانحناء

يسبب إنفعالاً أكبر من الانفعال الذي يسببه الضغط في جميع المواد البنائية ما بين (2000 _3000) مرة (Salvadori,1975, p:160).

كلما أزداد الإجهاد يجب زيادة كفاءة النظام الإنشائي المستخدم عن طريق تقليل كمية المادة البنائية المستخدمة وإتخاذ العناصر الإنشائية المسار الطبيعي لانتقال القوة. (Zuk,1975, p:7).

4) الأهوار العراقية

تعد منطقة الأهوار في جنوب العراق منطقة مستنقعات، غنية بالبحيرات الضحلة والبرك، فيها أبنية من القصب والبردي، تقع في المجاري الدنيا للفرات ودجلة، وشط العرب في مثلث العمارة . القرنة . الناصرية . سوق الشيوخ. وتغطي الأهوار نحو 13000–15000كم2 أكبرها هور الحَمَّار (5100كم2) وهور الحُوَيْزَة (3000كم2). وتطلق تسمية هور أيضاً على مستنقعات وبحيرات تقع خارج منطقة الأهوار منها: الثرثار والحبانية وأبو دبس والملح. (عادل عبد السلام، 2012، html). شكل (4).

يمكن وصف حال الأهوار اليوم بأنه سيء، خاصة بجوانبه الإنسانية، فالجفاف يدمر وسائل عيش العشرات من العوائل. لأن الماء هو العنصر الأوحد الذي يديم الحياة وينعشها في الأهوار، وقد أصبح شحيحاً وبصورة مفاجئة، وتمثل هذه الشحة تهديداً مباشراً لتجمعات سكانية وقرى يسكنها المواطنون، كما إن إيرادات نهر الفرات تقلصت إلى حد قد لا تؤمن معه مياه الشرب فضلاً عن صعوبة إسناد المسطحات المائية والأهوار التي تمثل لهم خط الحياة.

4–1) التجمعات الحضرية للأهوار:

الأهوار عبارة عن مسطحات مائية عذبة تغطي مساحات شاسعة في جنوب العراق عرفت حضارة بشرية مميزة تعود إلى نحو 6000 سنة، وتعيش فيها كائنات حية متنوعة، وتزرع في هذه الأهوار محاصيل زراعية مختلفة وتكثر فيها النباتات المائية بسبب تدفق مياه نهري دجلة والفرات إليها. (محمد داوود، 2013، ص:12).

وأهم ما تتميز به الأهوار هو نوع المدائن أو القرى التي بنيت كمجموعة من الجزر الطافية على الماء وسط مسطح "الهور المائي". ويتم التحضير للجزر باختيار الموقع المناسب في وسط مسطحات الماء القريب من مصادر الرزق. ويتم صنع الجزيرة الإصطناعية عن طريق عملية ليّ حزم القصب والبردي وإرقادها بحيث تتشكل في مجموعها مسطحاً على صفحة الماء تمتد جذورها في ارض البحيرة ثم يتم لاحقاً نقل الطمي والطين من قاع البحيرة وتكديسه مع طبقات البردي والقصب فوقها بأسلوب الدك، حتى تصل إلى الارتفاع المناسب والمقاومة المناسبة لتلك الجزيرة الصناعية العائمة بما يطلقون عليها (جبيشة) ومجموعها (جبايش) (ربما تكون قريبة من كبائس العربية). شكل (5). وعادة ما يتركون فيها حفراً مناسبة لإرساء دعائم البيت المنظور. ويبلغ بعد الحفرة عن الأخرى بين متر ومترين لكي تغرس فيها الأساطين لاحقاً بعد أن تجف أرضها. (محمد الأمير، 2013، html).

أن اختيار هذه البيئة مسكناً جاء بسبب سخائها، فالقصب والبردي هو مصدر لا ينضب من مواد البناء وأدوات الاستعمال اليومي. ويعد استعمال القصب والبردي في بناء ديارهم تقليداً موروثاً منذ سومر وربما قبلها ولم يكن وليد اليوم، فالقصب أستُعمل في بناء بيوت وقوارب السومريين منذ آلاف السنين، ووجدت رقم طينية من الحفريات تؤكد ذلك. وكان يتم إكساء السطح الخارجي لبعض هذه المباني القصبية بطبقة من الجص الطيني بما يعرف باسم الوتل. و(التطيين daub) وربما كان من بقايا مرحلة وسيطة من مراحل تطور بناء الأقبية. (محمد الأمير، 2013، html)

وهنا تطلق على التجمعات الحضرية لكونها تسور مثل البيت الواحد، و"صرياثا"، ويقال لها (صريفة) اليوم، ومعناها العشة أو الكوخ المبني من القصب، وهكذا أصبح المعنى (مدينة العشش أو الأكواخ المصنوعة من القصب).

2-4) عمارة الأهوار:

تناولت الطروحات طرق تحليل العمارة عموماً، محددة إياها بستة مفردات رئيسة متمثلة بالعلاقة بين الداخل والخارج، والبعد الثالث، والبعد الرابع، والضوء، واللون، وأخيراً التأثيث، ومشيرة إلى أهم مؤشرات العمارة المتمثل بالبعد الثالث وإمكانية اعتماده عن طريق عدد من المفردات التي تشمل تسلسل الفضاءات، وامتداد الفضاء بصورة أبعد من الاحتواء، وتداخل الشكل والفضاء، والتداخل الفضائي (Kurtich, 1993, p: 16-25)، وفيما يخص عمارة قصب الأهوار جنوب العراق فقد أشارت الأدبيات إلى الأهوار أو "الأجمة" أو "البطائح"، بأنها عالم من تجمعات شحيحة من البشر وسط خضرة البردي والقصب، حالة من التوفيق بين نمط البندقية، وروح الصحراء، لذا يطلق عليها المستشرقون تسمية "بندقية الشرق الأوسط أما النمط العمراني المحلي في الأهوار (عمارة القصب) فيتواجد هذا النمط في الأهوار بسبب توفر مادة القصب بشكل واسع وبهيأة شاسعة لا تترك بينها سوى ممرات مائية ضيقة. وينتمي نوع القصب الموجود في العراق إلى نوع (phragmites gramineae) الذي يتميز بإرتفاعاته التي تصل إلى 3-4م وقطره 2-2.5سم (Jacobson, 2004, p: 5)

وتكون النماذج البنائية من القصب في الأهوار أربعة أنواع هي:

أ- **الجزر الصناعية** (الجباشات) التي تعتمد بالأساس على إحاطة المساحة المطلوبة لبناء الجزيرة بسياج من القصب ترتفع أغصانه إلى مسافة تصل أحياناً 6 أمتار، ثم تملأ المساحة بأوراق وأغصان البردي القصب (المتهرئة)، وتكسر بعد ذلك أغصان السياج المرتفعة. شكل (5).

ب- **المضيف أو دار الضيافة:** وهو مكان التجمع الوحيد لأهالي القرية، ويكون بأحجام كبيرة. ويبنى عادة على جزر طبيعية موجودة، وتحفر خطوط متوازية، بعمق 75 سم، وعلى مسافة 1.5 م عن بعضها. وتوضع فيها حزم القصب بإرتفاع 5-6 م. تترك في البداية مائلة إلى الخارج بزاوية 70 درجة تقريباً إلى حين ربطها مع بعضها لتكوين الأقواس ويكون مدخل المضيف واطئاً ومواجهًا للقبلة، فضلاً عن الرمز الديني الذي يعطيه التوجه إلى القبلة، فهناك فائدة كبيرة في التهوية، وإن الرياح السائدة هي الشمالية الغربية، فيكون المضيف متعامداً معها، حيث تتم تهويته من الداخل بالإتجاه العرضي ومن الفتحات السفلية (Maxwell, 1962, p: 135). شكل (6).

ونظرا لأهمية هذا النمط البنائي، سيتم اعتماد نموذج دار الضيافة كنموذج لعمارة الأهوار التقليدية.

ج- **الربعة:** مساكن الأهوار الدائمة، وتكون أما طولية بشكل I ومقسمة من الداخل إلى قسمين أو بشكل T وهي الحالة الغالبة.

د- **الصرائف السكنية:** ويستخدم في هذا النوع السقوف الجملونية المثلثية التي تستخدم كفضاءات للنوم أو للطبخ لدى السكان ذوي الموارد المعيشية المحدودة أما لدى المتمكنين والتجار فتستخدم للخزن وقد تستخدم لدى رؤساء العشائر لإستقبال الزوار. شكل (7).

4-3) الخصائص الإنشائية للقصب:

القصب مادة نباتية غير نافذة للرطوبة والماء، يمتاز بالمرونة والقابلية على الإلتواء، فضلاً عن المتانة النسبية نظراً لوجود المفاصل العرضية الداخلية التي تكسبها صلابة ومقاومة، وإن أحسن أنواع القصب هو من نوع (القباره) وتوجد له مناطق يعرفها المحترفون من بنائي البيوت. وإن حزمة من القصب يمكنها أن تتحمل أثقال الشد المتوسط عليها والبناء هنا مميزات إنشائية يوظف بها القصب كمادة أساسية للبناء. ويتم إنشاء الهيكل من الأساطين أو الأعمدة أو الصواري التي تصنع هنا من مجموعة كبيرة من القصب، ويطلق عليها أسم (شَبّه) ومجموعها (شبّات) وتضطلع بنقل العزوم الرأسية، أما العزوم الأفقية الواردة من الرياح مثلاً فتضطلع بتحملها حزم القصب التي تسمى (الهطر)، التي تربط بين الأعمدة. شكل (8). (عادل عبد السلام، 2012، html). ثم يتم تغطية الهيكل الإنشائي بشكل يعطي الخصوصية للفضاء المتكون ويعزله، ويستخدم لذلك نسيج متكون من خامة القصب تسمى بالعربية (الحصر العراقية) وتسمى محليا (البارية) وهي ناتجة من عملية نسج وتقضيب للقصب المشظى إلى مجموعة من المساطر الرقيقة، ونسج الحصيرة بعد تقطيع القصبة بامتداد طولها إلى عدة شظايا. وتستعمل في تغليف البيوت القصبية والسقائف كعنصر بناء غير نفاذ للماء. وهي منسوجة لعدد من الأغراض والاستعمالات فهي أما جدران أو سياج أو فرش لتكسي أرضية الديار، أو تستعمل حتى في طبقات التسقيف في العمارة الطينية ووجدت في طبقات مباني العراقيين في سومر وبابل كمادة ماسكة لطبقات الطين أو مداميك الطوب كما في الزقورات. وما زالت تستعمل في العراق ولاسيما الجنوبي منه وقد أتسع نطاق استعمالها حتى في الأقاليم المتاخمة للعراق خلال العصور السابقة. واليوم نجد تلك الحصر وقد وضفت في صناعة الأثاث، وكخامة للديكور المنزلي. (محمد الأمير، 2013، html). شكل (8).

4-4) طريقة إنشاء مبنى الأهوار التقليدي:

بعد أن يتم التحضير للمبنى المزمع إنشاؤه، على الجزيرة يشرع الجميع بعملية حزم القصب بأقطار تتفاوت بحسب وسع المبنى وأهميته ولكن عادة ما يكون قطرها بين 15 و20 سم ويصل حتى إلى 30 سم في حالة "المضائف" الواسعة وهذه الحزم تشكل الهيكل الإنشائي للمبنى حيث تحزم بعد ذلك بقوة، وبمعونة أربطة مصنوعة من قصب ملوي مثل الحبال يدعى (بنود). وتكون هيئة تلك (الأعمدة) الأساطين سميكة في قاعدتها وأقل سمكاً وصلابة وأكثر لدانة في طرفها العلوي. وعند اكتمال العدد المطلوب الذي يكون عادة مكرر العدد 5 أو 7 وذلك بحسب السعه وتبعاً لما يرصد من أعمدة البيت التي تحدد سعة المبنى. وتغرس الأساطين في صفين محوريين متقابلين ومتناظرين. شكل (9)، ويمثل البعد فيما بينها عرض المبنى المزمع إنشاؤه ومجموع الأبعاد فيما بينها يشكل طول المبنى. ويمتد توجيه المبنى عادة من الشرق إلى الغرب ليتسنى لهم الاستفادة من الريح الغربي والشمالي الغربي البارد، فضلاً عن دخول الإشعاع الشمسي إلى أعماقه، (محمد داوود، 2013، ص:22). يرفع كل عمود وتغرز قاعدته السميكة في الحفرة المخصصة، وتملأ الحفرة بالتراب، وتدك دكاً قوياً بأعمدة من خشب لضمان عدم ميل العمود، ويكون وضعه مائلاً عادة إلى الوراء لأسباب ميكانيكية، حيث يتم ثنيها باتجاه الداخل وذلك لتسبيق تحميله جهد معاكس. وتربط رؤوسها مع بعضها مكونة أقواساً هيكلية تحضر لشكل القبو النهائي الذي تظهر به. شكل (10). وهذا المبدأ الإنشائي

(**التمفصل Articulation**) لربط حنايا الأعمدة من الوسط، استعملت في الأزمنة المتأخرة لتنفيذ البناءات ولاسيما في الهياكل المعدنية كما في "رواق المكائن" الباريسي (عادل عبد السلام، 2012، html).

وتجهز خلال هذا الوقت حزم القصب التي توصل أفقياً بين الأعمدة (الهطر) وطولها عادة بمقدار طول المبنى فتكون روابط للهيكل تمنعه من الحركة أفقياً. ويتم ربطها بالأعمدة على مسافة لا تزيد عن النصف متر بينها. والمهم أن تكون الحنايا متجانسة بارتفاع واحد عن سطح المبنى، وأن يكون أكثرها سمكاً وقوةً هو الذي يقع في منتصف تقويس الحنيات بحيث يكون متقاطعاً مع كافة الأعمدة لأن العزوم في هذا المكان تكاد تكون على أشدها. ثم تبدأ مرحلة التغليف أو (أعمال الإنهاء أو التشطيب) حيث يصنع الجداران لسد فتحتي البيت الجانبيتين ويطلق عليها اسم (الكواسر) ويكون الباب في الفتحة الجنوبية من المبنى لمواجهة الشمس الساطعة ساعات الصباح، وقد يعمل على جانبي الباب مشبك من القصب بشكل معينات تدعى (مشبچ) وتوحي كأنها (مشربية)، ثم يكسى هيكل الدار كله بالحصران (البواري)، فتلقى أولاً الحصر الجديدة فوق الهيكل بوجوهها اللّماعة إلى الجهة السفلى، وتلقى فوقها طبقه تالية من الحصر القديمة المستخدمة سابقاً والتي تشبعت بالرطوبة، ثم تكسى فوقها بطبقة ثالثة من الحصر الجديدة وتثبت كلها بالـ(هطر) الخارجية للصريفة، وتدفن أطراف الحصر السفلي الملامسة للأرض بالتراب لمنع دخول الهواء والمطر إلى داخلها. ثم يتم دفن أرضية البيت بالتراب الناعم النظيف، وتدك جيداً وتسيج بالطين أحياناً وتفرش بالحصر كذلك ثم تفرش بالبسط والسجاد وترمى فوقها الوسائد للاتكاء عليها. (محمد الأمير، 2013، html). شكل(11).

5) التحليل الإنشائي لشكل العناصر الأساسية لمبنى الأهوار:

يكون الشكل المقوّس هو الشكل الغالب للعناصر الإنشائية الأساسية في مبنى الأهوار التقليدي (كما تم توضيحه سلفاً)، والقوس بشكل عام هو العنصر الإنشائي المحني ذا القابلية على تحمل كميات كبيرة من الأحمال والعمل على توزيعها على الجانبين ونقلها بالتالي إلى الأرض. وقد وجد القوس شأنه شأن العمود والجسر منذ القدم في المنشآت كعناصر أساسية منشئية تتعاطى مع الأحمال المسلطة كل حسب خواصه ونقلها إلى الأسس والتربة بشكل يبرر وجوده الدائم حتى هذه اللحظة في مختلف طرز العمارة.

حيث يلعب القوس دوراً مماثلاً للعمود عن طريق تعامله مع الإجهادات ولا سيما عند نقطة إسناده لتلك القوى. فالعمود يعمل على تجميع الأحمال وجعلها تسري خلاله بصورة انضغاطية مباشرة وعمودية نحو الأرض، أما القوس فيعمل على نفس المبدأ وهو استلام الأحمال التي تضغط على قمته ليعمل على توزيعها على الجانبين ومن ثم إلى الأسس. الشكل (12). (Torroja,1962, p:80).

وعادة ما يكون القوس أحد العناصر المنشئية سهلة الإدراك عن طريق خواصه الفيزياوية، فعملية الإدراك هذه تعتمد على متجه قمته –محوره directrix– الذي يكون على شكل متجهة يتجه نحو وجهة مقاومة الأحمال المسلطة عليه عمودياً. إضافة إلى ذلك يمكن ملاحظة الاختلاف في السمك تبعاً لأجزائه المعرضة للحمل بصورة مباشرة وغير مباشرة. في هذه الحالة تتوافق كل من الحسابات (calculations) مع الرؤية الحدسية (intuitive vision) على أن يكون القوس أكثر سمكاً في جوانبه منه في قمته الشكل(13). وهذا ما لاحظناه جلياً في عناصر القصب الإنشائية المقوسة. (Torroja,1962, p:302)

حيث لا تفشل عناصر الشد بالانبعاج، ولهذا لا تحتاج إلى زيادة مفرطة في كمية المادة لمقاومة الإجهاد، أي أن عناصر الشد أكثر كفاءة من عناصر الضغط التي تفشل بالانبعاج. ولكن وجود الجاذبية الأرضية يجعل من المتعذر الحصول على نظام إنشائي يتألف من عناصر الشد فقط، بل يجب أن يحتوي النظام الإنشائي على عناصر الضغط التي تقلل كفاءته، ولذلك يُعد النظام الإنشائي الذي يحوي أكبر عدد من عناصر الشد واقل عدد من عناصر الضغط منشأ عالي الكفاءة ويمكن أن يستخدم في تغطية البحور الطويلة. **بالتالي تعد طريق تقوّس العناصر الإنشائية المشكّلة لمبنى الأهوار هي عناصر شد وضغط في نفس الوقت لذلك تقترب من تحقيق اقصى كفاءة إنشائية ممكنة.**

6) تأثير الشكل الإنشائي الفعّال على نوع القوى الداخلية لمبنى الأهوار:

أذا كان العنصر غير مستقيم (كما هو الحال في العناصر الإنشائية الأساسية لمبنى الأهوار) فأنه في الغالب سوف يتعرض إلى القوى المحورية، وقوة الثني الداخلية، عند تسليط الأحمال، والشكل الإنشائي يرسم بواسطة المحور الطولي وإنموذج الحمل وعندها يسمى بـ(الشكل الفعال)، (Angus,2001, p:39). ففي المنشآت الحقيقية تكون المواد ذات المرونة مثل أسلاك الحديد والمواد المرنة الأخرى كالقصب والتي تستخدم في تكوين بعض العناصر أنها تأخذ وبشكل أوتوماتيكي (الشكل الفعال) عند تطبيق الأحمال.

في الشكل (14) يبين الفرق بين الشكل الفعال والشكل غير الفعال على إنموذجين من الأحمال كما موضح بالحمل المنتشر على كل العنصر وقوتان مركزتان تطبقان بمسافات متساوية لكل حمل على ثلاث نماذج إنشائية تتخذ عدة أشكال وكما يأتي:

(a) هنا العنصر يتحمل قوة ثني داخلية صافية، وليس قوة محورية، لأنه لا توجد أي مركبات أفقية للحمل وكلا الحملين غير موازيه للمحور الطولي للعنصر.

(b) هنا العنصر يملك شكل مطابق للشكل الفعال في الأحمال ولذلك الشكل الفعال يتحمل قوة محورية داخلية فقط في الحالتين من العناصر والحمل القوى هي الانضغاط. **وهذا يوضح أهمية التقوس في مبنى الأهوار.**

(c) هنا العنصر لا يطابق الشكل الفعال للقوى وسوف لن يحمل قوى محورية داخلية صافية ولا قوى ثني صافية بل سوف يحمل حمل مركب من قوى الثني والقوى المحورية الداخلية وعليه فالشكل الذي على المحور الطولي والذي يخص العناصر الإنشائية يمكن تصنيفه إلى عناصر الشكل الفعال وعناصر الشكل غير الفعال والعناصر ذات الشكل الشبه فعال. وعناصر الشكل الفعال تلك التي تتطابق مع الشكل الفعال للأحمال التي تطبق عليها والتي تحتوي على قوى محورية داخلية فقط. الشكل الفعال يكون أكثر فعالية في كل أنواع العناصر الإنشائية والشكل الشبه فعال يعتمد بفعاليته على الاختلاف مع الشكل الفعال.

7) آليات تطبيق مبدأ الكفاءة المنشئية في مبنى الأهوار:

يمكن القول بأنّ القوى لابد أن تجمع سوية وتسري طبيعياً إلى الأرض بأكثر الطرق مباشرةً وإختصاراً عن طريق الأشكال والعناصر المنشئية ليكون حلاً منطقياً. وتم تحقيق ذلك في مبنى الأهوار التقليدي عن طريق:

(1) إستعمال كلّ المواد الإنشائية قريباً من خواصها وقدرتها. فلابد أن تكون **المواد المستعملة مستخدمة بموجب خواصها الطبيعية**. حيث تنص الفكرة الصحيحة والسليمة بأنّ الشكل الناتج الصحيح والسليم يمثل نتيجة حتمية لخواص المادّة عند شيوع إستخدامها.

(2) تحقيق أدنى حد من وزن المادة (تقليل الوزن الميت قدر الإمكان).

(3) كان الفعل المنشئي، تحسساً وإدراكاً، واضحاً للشخص غير المتخصّص قبل كل شيء.

8) استخلاص وسائل تحقيق الكفاءة المنشئية في مبنى الأهوار:

8-1) الكفاءة في استعمال المادة الإنشائية Efficiency of Material usage:

هي احدى المعايير في الاقتصاد الإنشائي النهائي وبالذات في المناطق التي تتوافر فيها العمالة الرخيصة كما هو الحال في مناطق الأهوار، وبالتالي تمثل تكلفة المواد نسبة كبيرة من التكلفة النهائية وهذا ينطبق على اغلب بلدان العالم الثالث، وهذه الكفاءة المادية هي احدى نتائج التطور التكنولوجي الإنشائي بالتالي تحقيق التوفير في المواد والعمالة ووقت الإنشاء.

من المعروف إن الكفاءة المادية الإنشائية تأتي نتيجة للتصميم الذي يعرض المادة لأقصى إجهاداتها التصميمية في كافة قطاعاتها. هذه الحالة لا تتوفر إلا في حالة الإجهاد المحوري بالانضغاط أو الشد. أما التحميل الذي ينتج عنه عزوم انحناء فيعرض القطاع الإنشائي لأقصى إجهاد في جوانبه الطرفية فقط بالشد والانضغاط. (علي رأفت، 1997، ص: 138) وهو ما عرفناه **بالشكل الفعال** لعناصر مبنى الأهوار الإنشائية الذي تتضاءل فيه هذه الإجهادات إلى أن تصل إلى العدم حول محور محايد (Neutral Axis)، وبالتالي فأن نسبة ضئيلة من القطاع هي التي تتعرض لأقصى إجهادات في حدود المسموح به. الأمر الذي يتحقق بما يُطلق عليه **الاستمرار الهندسي**، وعليه فأن الكفاءة المادية الإنشائية تتوفر بالتكوين الذي يحقق جساءة المنشأ، أي تضافر كل أجزاءه في مقاومة الأحمال الواقعة عليه ويحقق ما نطلق عليه الاستمرار المادي، أي أن يكون العنصر الإنشائي كله كتلة واحدة تساعد بعضها بعضاً بدلا من أن تكون حملاً على غيرها.

8-2) توافق متطلبات التنفيذ مع المواد والعمالة والتكنولوجيا المتوفرة.

إن اختيار المنظومة الإنشائية المبدعة لا بد وان يتوافق مع الإمكانيات المحلية المتاحة في العمالة والمعدات والتكنولوجيا في ذلك المكان، إذ لا مبرر لاستيراد إمكانيات غريبة تتطلب معها استيراد عمالة ومعدات تنفيذ، وبالذات بالنسبة للمشروعات الخاصة والعامة في منطقة الأهوار، ولو فرض وتحققت هذه الإمكانيات للتنفيذ ولمرحلة معينة فلن تتوفر على المدى الطويل في الصيانة وفي التشغيل.

8-3) اختصار وقت المشروع:

يلعب الوقت عاملاً مهماً في اقتصاديات أي عمل، حيث إن التجهيز المباشر والمتاح لعناصر القصب الإنشائية وبالشكل المنظم والمخطط سيعود على المشروع بوافر في وقت التنفيذ. وخاصة إذا كان هنالك معرفة جيدة لتشكيل وحدات جاهزة للتركيب والتنفيذ المباشر.

فسلم التماسك الإنشائي (أو ما يطلق عليه بالاستمرارية الإنشائية) يتدرج أيضاً في إمكانيات سبق تجهيز منتجاته، ومن البديهي إن سبق التجهيز يتدرج عكسياً مع تماسك مكونات المنشأ، فكلما تماسكت أجزاؤه في كتلة واحدة قلت احتمالات تصنيعها خارج الموقع والعكس صحيح، بمعنى إن الدرجات الأولى في التماسك هي أقربها إلى سبق التجهيز الكامل، وبالتالي إلى توفير وقت التنفيذ.

الاستنتاجات

1- تكمن أهمية الإنشاء في العمل المعماري في جانبين أساسيين هما تحقيق الصورة وضمان بقائها وتحقيق الثبات والاتزان.

2- تدخل الكفاءة الإنشائية ضمن نطاق الإبداع المادي الانتفاعي إذا ما حقق الراحة الفسيولوجية والنفسية والاجتماعية والأمن والأمان، وفى نطاق الإبداع الإنشائي إذا ما حقق الفراغات والكتل المطلوبة بكل كفاءة من نواحي المواد والعمالة.

3- يمكن تحقيق الكفاءة المادية بوجود التكوين الذي يحقق جسأة المنشأ من خلال تضافر أو تعاون كل جزء من أجزاء المبنى في مقاومة الأحمال الواقعة عليه وهو ما يطلق عليه بالاستمرار المادي.

4- الفكرة الإنشائية في جميع المنشآت هي محاولة تجميع الأوزان وتركيزها في نقاط الأساسات.

5- تكون المشكلة الإنشائية بسيطة إذا انطبق المسار الطبيعي مع المسار المادي وصولا لأعلى كفاءة إنشائية.

6- يمكن تعريف كفاءة المنشأ بعدة تعريفات منها النسبة بين الحمل الكلي إلى الوزن الميت فكلما قل الوزن الميت ازدادت الكفاءة المنشئية، أو أنها النسبة بين المنفعة "النتاج" إلى الكلفة "المدخلات"

7- من أجل توفير تصميم كفوء، يجب على المهندس الإنشائي أن يصمم منشأ لمقاومة الأحمال التي من المتوقع أن تحدث، والذي يدعى بحمل التصميم (*design load*). لذلك تستند الكفاءة على الحد الأعلى لحمل التصميم (*design load*).

8- إن النظام الإنشائي المثالي اقتصادياً هو الذي يحقق الفراغ المطلوب بأكثر الطرق وفراً في مجموع تكاليف المواد وأجور العمالة ومعدات التشغيل وزمن التشغيل.

9-شكل العنصر الإنشائي مهم جدا في مقاومة القوة. بالشكل الذي تستطيع المادة مقاومته بإستخدام أقل كمية منها وبذلك تزداد كفاءة النظام الإنشائي. وهذا نراه جلياً في شكل التقوس الموجود في العناصر الإنشائية المشكلة لمبنى الأهوار والتي تتبع أساساً من خواص المادة الأساسية (القصب).

10- يكون الشكل المقوّس هو الشكل الغالب للعناصر الإنشائية الأساسية في مبنى الأهوار التقليدي، والقوس بشكل عام هو العنصر الإنشائي المحني ذا القابلية على تحمل كميات كبيرة من الأحمال والعمل على توزيعها على الجانبين ونقلها بالتالي إلى الأرض. وعادة ما يكون القوس أحد العناصر المنشئية سهلة الإدراك عن طريق

خواصه الفيزياوية. بالتالي تعد طريق تقوّس العناصر الإنشائية المشكّلة لمبنى الأهوار هي عناصر شد وضغط في نفس الوقت لذلك تقترب من تحقيق اقصى كفاءة إنشائية ممكنة.

11- تحقيق أعلى كفاءة إنشائية مادية في مبنى الأهوار التقليدي من خلال إستعمال كلّ المواد الإنشائية قريباً من خواصها وقدرتها، وتحقيق أدنى حد من وزن المادة (تقليل الوزن الميت قدر الإمكان). فضلاً عن كون الفعل المنشئي "تحسساً وإدراكاً" كان واضحاً للعيان.

12- اشتملت وسائل تحقيق الكفاءة المنشئية في مبنى الأهوار على عدة جوانب أهمها الكفاءة في استعمال المادة الإنشائية وتوافق متطلبات التنفيذ والمنظومة الإنشائية مع المواد والعمالة والتكنولوجيا المتوفرة.

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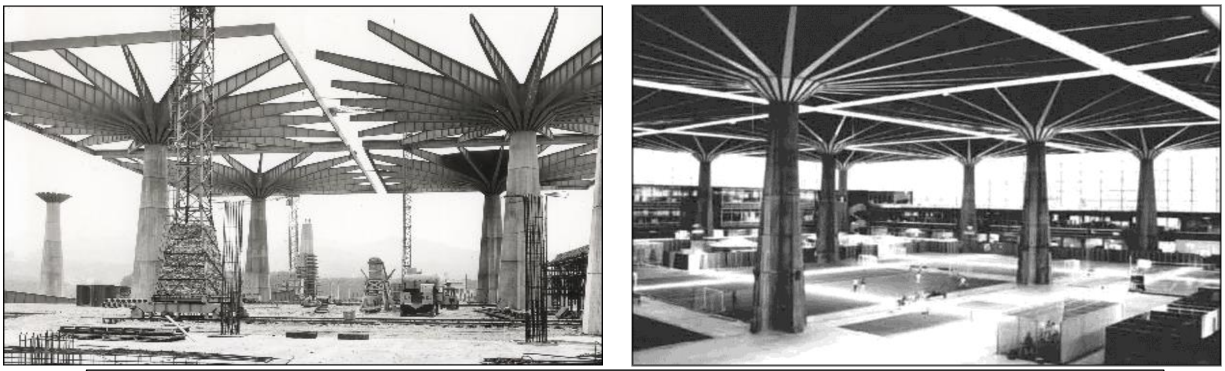
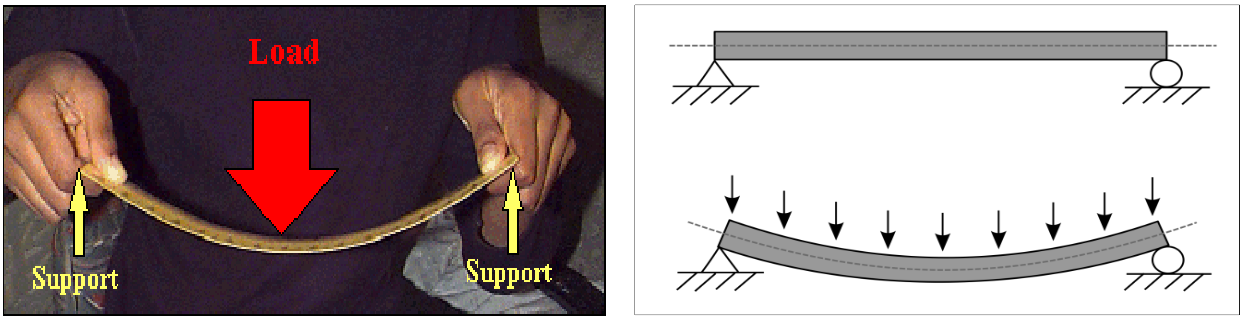
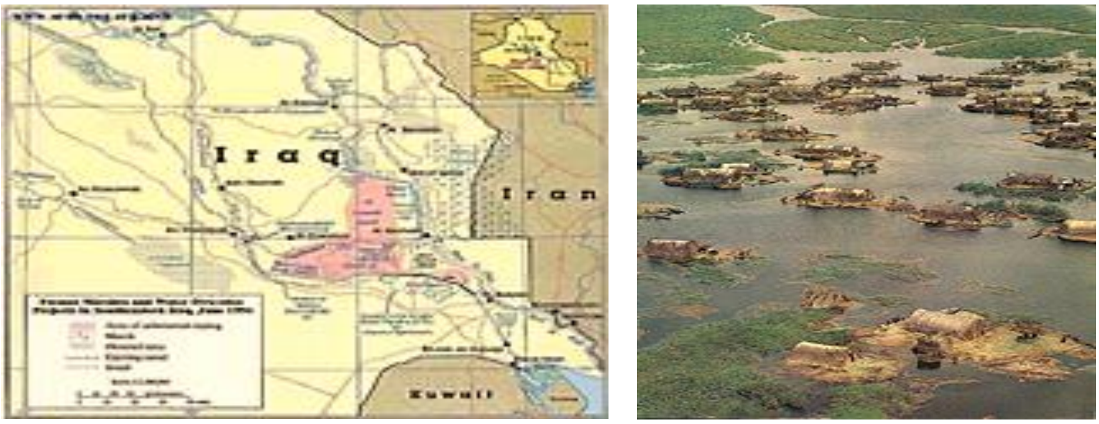


الشكل (1) منشأ قصر Labour في Turin للمعمار Nervi .(Holgate, 1986, p:208).



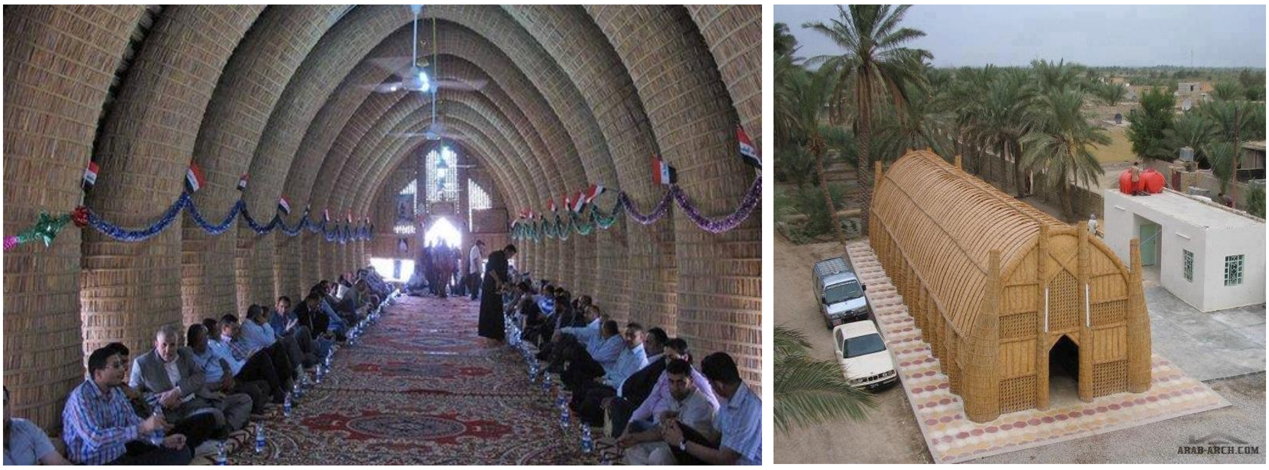
الشكل (2) مبدأ الانحناء الإنشائي
http://www.petervaldivia.com/eso/structures/imagen/bending.gif

الشكل (3) شكل العنصر الإنشائي المتمثل بشكل التقوس لمبنى الأهوار
http://www.aleqt.com/a/small/ec/ec1dccdd58f825c18f5e774528a4387d_w950_h950.jpg



الشكل (4) الأهوار في جنوب العراق
http://almajla.com/wp-content/uploads/2013/06/image-115100-galleryV9-ihpa.jpg

الشكل (5) الجزر الطافية على الماء وسط الأهوار
http://www.cinu-dn.com/upload/31143830u%20copy.gif



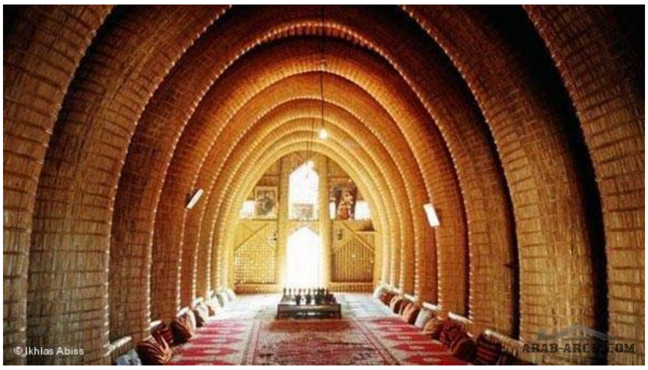
الشكل (6) المضيف أو دار الضيافة في الأهوار
http://www.waraqat.net/2009/07/swar_3eraq3.jpg

الشكل (7) الصرائف السكنية في الأهوار وفيها تستخدم السقوف الجملونية المثلثية
http://1.bp.blogspot.com/-siksee9HCZc/UG3Dx0ayKUI/z5Gb2Ji-8tY/s1600/DSC00463.jpg

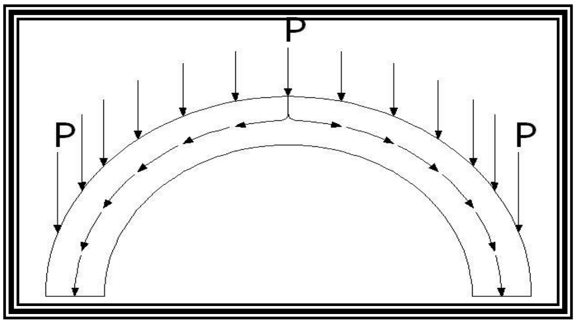
الشكل (8) إستخدامات القصب كمادة إنشاء أساسية في عمارة الأهوار
http://www.mriraq.com/vb/showthread.php?t=662302

الشكل (9) طريقة إنشاء العناصر الأساسية للهيكل الإنشائي في مبنى الأهوار التقليدي
https://fbcdn-sphotos-f-a.akamaihd.net/hphotos-ak-ash4/p480x480/1869215063_n.jpg

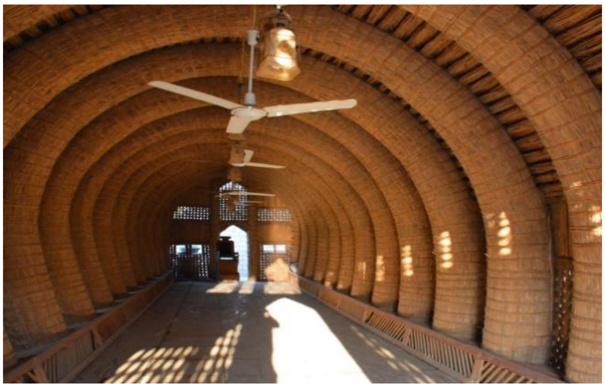
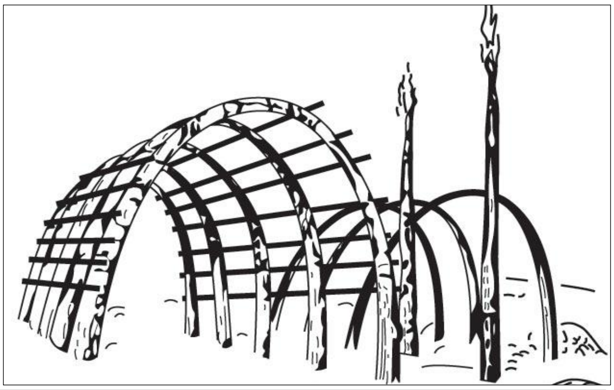
الشكل (10) الأقواس الهيكلية التي تعطي شكل القبو النهائي في مبنى الأهوار التقليدي
http://im36.gulfup.com/0cnd3.jpg



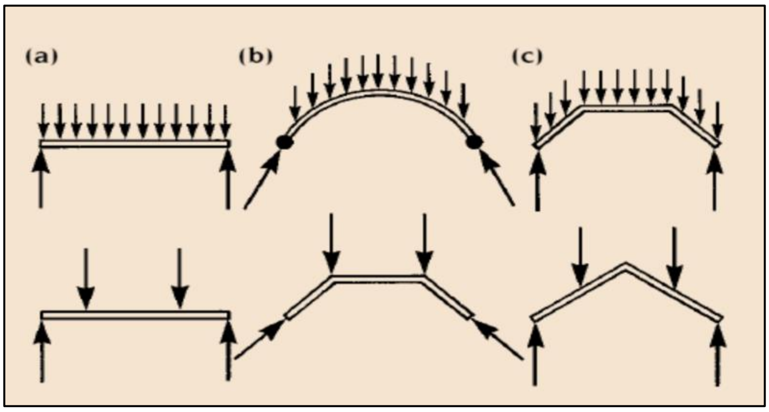

الشكل (11) إعطاء الشكل النهائي للهيكل الإنشائي في مبنى الأهوار التقليدي
http://im36.gulfup.com/0cnd3.jpg



الشكل: (12) استلام القوس للأحمال
(Torroja,1962, p:80)

الشكل (13) الاختلاف في سمك القوس الإنشائي تبعاً لأجزائه المعرضة للحمل بصورة مباشرة وغير مباشرة
http://www.dw.com/image/0,,5996431_1,00.jpg



الشكل (14) الفرق ما بين الشكل الفعال والشكل غير الفعال (Angus,2001, p:38)

دراسة تقويمية لمواضيع الادارة الانشائية في مناهج المرحلة الأولية للهندسة المدنية في بعض الجامعات العراقية

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الخلاصة

لاشك في ان ميدان التربية والتعليم في اي بلد من البلدان ومهما اختلف نظام الحكم فيه، يعد من اكثر الميادين دقة وحساسية لأنه يتعلق ببناء الانسان، ولما كان الانسان هو غاية ووسيلة في الوقت نفسه وهو رأس المال الستراتيجي فان طريقة تربيته وتعليمه وانتقاء المربي وطرائق العمل والمنهج والأهداف تعد من الأمور الخطيرة.

ان للعملية التربوية اهدافاً يحددها المجتمع لنفسه من خلال مؤسساته العاملة في هذا الميدان، وهي المؤسسات الرسمية او الشعبية وعند شعوره بقصور هذه المؤسسات عن القيام بدورها لايلبث ان يتدخل مباشرة بالوسائل التي يرتئيها لإصلاح الخلل. ونعني بأهداف العملية التربوية انها الصياغة المحددة للطرق التي نتوقع ان يتغير بها التلاميذ من خلال هذه العملية، اي الطرق التي سيبذلون بها تفكيرهم ومشاعرهم وافعالهم، والمناهج المتبعة تعد إحدى الوسائل لتحقيق الأهداف.

يهدف هذا البحث الى دراسة منهاج الادارة الإنشائية من حيث المفردات موزعة على السنوات والساعات للمرحلة الأولية لقسم الهندسة المدنية في جامعة بغداد وبعض الجامعات العراقية الاخرى ومفردات المناهج لبعض الجامعات العالمية الرصينة وعمل مقارنة بينها للتوصل الى صيغةمحددة لطريقة تدريس هذه المفردات وتوحيدها والنهوض بها والإسهام بتوضيح معالم الطريق أمام عضو الهيئة التدريسية الذي سيسلكه في مناهج تعليم الإدارة الهندسية في جامعاتنا مع التركيز على الوسائل التي تجعل القيام بهذه العملية المعقدة نظاماً حياً متفاعلاً.

A reformation Study about the Construction Management in the Primary Stage Curricula's for the Civil Engineering in Some of the Iraqi Universities

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ABSTRACT

There is no doubt that the field of education and teaching (in any country and whatever its ruling system varies "d") is considered one of the most specific and sensitive field, because it is related to the building of human. And as the human is a purpose (aim) and the means in the same

time and he is the strategist capital, so he way of his rearing, education, choosing the educator, methods of working and the aims are considered serious matters.

The educational process has aim determined by the society for him self through its working establishments in this field and these are the official and public establishments. And as he feels that the establishments have failed to achieve its duty, it, and without hesitation immediately interferes by the means that he choose to fix the defect. The educational process aims are meant to be the determined modification for the way which are expected to change the students through this process .i,e. the way of their thinking, feeling and actions. And the curricula's used (followed) are considered one of the means to achieve the aims.

This research aims at studying the program of the construction management wherefrom the items are distributed although the years and hours of primary stage in the civil engineering department in Baghdad university and some other Iraqi universities. The curricula's items of some sedate worldwide (universal) universities, and to make a comparison between them to reach a specific form to the method of teaching these items, unify them, revive them and to contribute in clarifying the features of the path way ahead of a teaching Corp member which is followed in the teaching curricula's of the construction on the means which make achieving this complicated process a living interactive system.

1. المقدمة:

كان الكثير من المسؤولين ينظرون الى المناهج في السابق على انها مجموعة المواد الدراسية التي تقدم الى الطلبة، اما حديثاً فهي مجموعة من العوامل المؤثرة في العملية التربوية والتعليمية التي تتمثل بأهدافها ومحتواها وطرق التدريس والتدريب والوسائل التعليمية واساليب التقويم والقياس المتبعة فيها(النعيمي، 1988).

ان عملبية تطوير المناهج تتطلب جهداً لايمكن توفيره في نهاية اليوم الدراسي ولايمكن تركه للعدد القليل من المدراء ورؤساء الاقسام، وانما هو مسؤولية المعلمين والمدرسين جميعاً فضلاً عن الخبراء والمستشارين والمفتشين والباحثين ومن هنا جاءت فكرة البحث بدراسة مفردات موضوع الادارة الهندسية لبعض الجامعات العراقية والاجنبية ومقارنتها مع بعضها فضلاً عن جمع آراء التدريسيين في الجامعات والعاملين في حقل العمل من خلال استمارات الاستبيان الموزعة اليهم والمعدة بهذا الخصوص ومن ثم تحليل اجاباتهم للتوصل الى الاستنتاج النهائي في مدى مواكبة هذه المفردات للصورة المستقبلية للخريج وللتطور الحاصل في العلوم الحديثة.

2. مشكلة البحث :

بالنظر لكون الخريج يتحمل مسؤولية كبيرة مباشرة بعد التخرج فإن ذلك يعرضه الى هزات كبيرة قد تنهي مستقبله المهني في بداية الطريق ويجعله ضعيفاً امام الفئات الاخرى ضمن الهرم الهندسي ولكون المناهج الهندسية تتكون من عدد كبير من المفردات الهندسية وان تطوير هذه المفردات يتطلب الأخذ بآراء الفئات التي لها علاقة بالتعليم الهندسي الا ان عملية تطوير المناهج تعتمد على الاسلوب التقليدي وذلك من خلال آراء الهيئة التدريسية فقط مع العلم ان البعض من اعضاءها الذين يشاركون في تطوير المناهج لاتتوفر لديهم الخبرة والدراية الكافية بالواقع العلمي من اجل ذلك كله تم إعداد هذا البحث، علماً بأن خلال فترة إعداده تم إصدار المنهاج الموحد بين الجامعات في القطر عدا الجامعة التكنلوجية ليتم تطبيقه اعتباراً من الفصل الاول للعام 2002 – 2003 الا ان ذلك لايمنع من مناقشة المنهاج الستبق وتأثيره على الخريجين للأعوام الماضية مع تفحص المنهاج الجديد وهذا ما سيتم في هذا البحث.

3. هدف البحث :

ان الهدف الرئيسي للبحث هو عمل دراسة للمفردات التي تتعلق بموضوع الادارة الهندسية في مناهج المرحلة الاولى من خلال معرفة الحاجة المحلية والمعرفة العالمية مع ملاحظة الحداثة من اجل تقديم هذه المفردات بما يخدم مصلحة الطالب ومن ثم مصلحة المجتمع بشكل عام.

4. منهجية البحث :

من اجل تحقيق هدف البحث فان منهجية اجراء تالحث قد اتخذت المراحل التالية :

4-1 الجانب النظري: كانت البداية مع الجانب النظري الذي تناول مراجعة الادبيات والمصادر والمجلات العلمية الواردة في هذا المجال.

4-2 الجانب العملي: لقد انجز الجانب العملي من خلال الاستبيان الميداني لمعرفة آراء المعنيين من التدريسيين في الجامعات العراقية والتي تمثلت بجامعة بغداد، الموصل، المستنصرية والجامعة التكنلوجية وآراء المسؤولين من المهندسين في حقل العمل. وبعد الاطلاع على نتائج الاستبيان وتحليلها تم التوصل الى الاستنتاجات المستندة الى واقع الحال وتطويراً للأساليب المطروحة في الدراسة النظرية والمتحققة من الدراسة الميدانية.

(الجانب النظري)

1- اختيار محتوى المناهج الدراسية :

المحتوى الدراسي هو نشاط علمي تربوي اجتماعي يفكر به الطالب ويتأمل ويجرب ويستنتج ويقوم نتائجه(الحسون، 1983).
ان المبادئ الاساسية لاختيار محتوى المنهج هي:

1-1 ان يتم اختياره بناءً على الاهداف التي تحاول المؤسسة التعليمية تحقيقها.

1-2 ان يتم اختياره بحيث يشمل جميع المعلومات والمفاهيم النظرية والتطبيقية والعملية التي من خلالها يمكن تحقيق الاهداف العلمية والتربوية.

1-3 ان يتم اختياره بالشكل الذي تنظم فيه الخبرات التعليمية لمادة دراسية معينة مع باقي المواد في المرحلة الواحدة والموضوع مع بقية المواضيع في المادة الواحدة بحيث يحدث هذا التنظيم تغييراً ايجابياً في سلوك المتعلم.

ان منهجية وضع المقررات الدراسية شأنها شأن اي عملية تطوير اساسها العنصر البشري تحتاج ايضاً لكي ينجح تطبيقها الى تغذية متكررة من الخبرة ة والحماس والنقد الفردي والجماعي(جريسون).

2- التقويم

ان اهمية التقويم من كونه الوسيلة التي يحكم بها على فاعلية المنهج، وهو ايضاً المصدر الاساس للتغيير او التطوير(عبد الموجود، 1979) وهناك جانبان رئيسيان في عملية التقويم هما الجانب المعرفي والجانب السلوكي. الاول يمكن تقويمه بوساطة الامتحانات والاختبارات التي تجري للطالب لمعرفة مدى نموه وتحصيله للمعلومات، اما الجانب السلوكي فان عملية تقويمه تكون معقدة جداً يشترك فيها الكثير من العوامل لأجل التعرف على النمو السلوكي للطلبة وتقويمه في ضوء الاهداف للمنهج(الوكيل، 1977).

ويفضل في التعليم الهندسي الاستعانة في تقويم المنهج بشكل عام او بخطواته التفصيلية بالخبراء المتخصصين في التعليم الهندسي ممن لديهم مؤهلات رفيعة المستوى من التخصصات الهندسية اضافة الى خبرات واسعة في الصناعة والبحث العلمي وذلك لتحديد نواحي الضعف والقوة في المناهج والوصول الى الطرق السليمة في اعداد وتطوير المناهج الدراسية (ناجار اجارد، 1978).

ويعتمد نجاح العملية على القدرة على التفاعل الحي مع حقل العمل والمتطلبات التي يعدها اساسية عند تسلم الخريج، وكذلك التطورات المستقبلية المتوقعة في حقل الاختصاص وامكانية استمرار الخريج على التطور لمستويات تعليمية اخرى.

(الجانب العملي)

1- جمع الموضوعات والمفردات الدراسية :

ان الخطوة الاولى في عملية تطوير المناهج هي جمع المفردات للموضوعات المختلفة والمتعلقة بموضوع الادارة الانشائية في قسم الهندسة المدنية للجامعات موضوع البحث في داخل القطر وخارجه واجراء مقارنة واعداد جداول مقارنة لآظهار مدى التطابق والاختلاف على مستوى الخطة الدراسية مع ملاحظة التباين بالمفردات الدراسية ومن ثم جمعها في جداول معينة (ملحق رقم (1)).

2- المقابلات الشخصية :

بغية التعرف الى وجهات النظر التي تخص المناهج الهندسية تمت مقابلة عدد من الشخصيات وتوجيه بعض الاسئلة (ملحق رقم (2)) ومن هذه الشخصيات:

2-1 المسؤولين عن التعليم الهندسي :

شملت هذه الفئة عميد الكلية ومعاون العميد ورئيس القسم المعني ونخبة من التدريسيين ذوي العلاقة بهذه الموضوعات لسماع آرائهم حول التباين بالخطة الدراسية لقسم الهندسة المدنية لهذه الجامعات والتباين والتطابق في المفردات وسماع تفسيراتهم لذلك.

2-2 المسؤولين في حقل العمل :

تم اختيار عدد من المسؤولين بآرائهم النقدية انتاج الجامعات وعرضت عليهم اسئلة تخص نوعية الخريج الجديد ودونت ملاحاظاتهم عنه وعن نواحي الخلل في إعداده ان وجدت ومدى كفاءته في أداء العمل ومدى قيام المؤسسات بتدريب عملي للخريج الجديد.

3- الاستبيان :

لغرض التعرف على وجهات النظر التي تخص المفردات الدراسية تم إعداد استمارتين، الاولى خاصة بأعضاء الهيئة التدريسية (ملحق رقم (3)) والتي تهدف الى معرفة وجهات نظرهم بمدى مواكبة مفردات المناهج الدراسية لموضوع الادارة الانشائية للتطورات العلمية والتكنلوجية الحاصلة في مجال العلوم والتطبيقات الهندسية. والاستمارة الثانية خاصة بالمسؤولين في حقل العمل (ملحق رقم (4)) لمعرفة وجهات نظرهم بمدى مواكبة مفردات هذه المناهج لمتطلبات الصورة المستقبلية للمهندس في اختصاص الهندسة المدنية.

4- اختيار نوع العينة وحجمها :

بغية لوصول الى الاهداف المرجوة من البحث تم اختيار العينة من اعضاء الهيئة التدريسية ممن أسهم في التدريس النظري والعملي لموضوعات الادارة الانشائية المباشرة وغير المباشرة التي تضمنها البحث، وعدد من المسؤولين في حقل العمل حيث يكون جزء كبير من واجبهم أو جله موجهاً الى قيادة زملاءهم من المهندسين عند تأديتهم لعملهم الهندسي التصميمي أو الاشرافي أو الصيانة أو التشغيل أو غيرها، وقد كانوا من ذوي الخبرة في مجال عملهم تزيد على (10) سنوات، وقد بلغ عددهم (28) مستبيناً وذلك اعتماداً على المواصفة الأمريكية (ASTM-E122-79) حيث تم اختيار فترة الثقة مساوية الى (%99,7).

5- تحليل النتائج ومناقشتها :

بعد الانتهاء من الجانب العملي تم جمع النتائج وكما يلي :

4-1 فيما يخص الاستبيان :

4-1-1 لقد تم جمع الاجابات على الاسئلة الواردة في استمارات الاستبيان. ولما كانت عملية تحليلها تستوجب التعامل مع عشرات الألوف من العمليات الحسابية والتي تعجز الأساليب الإحصائية الشائعة عن تحليل نتائج الاستبيان هذه (كالمتوسط الحسابي، والانحراف المعياري). ولأهمية اختيار الاسلوب الرياضي المناسب للحصول على دلالات واضحة تبين القيم المثلى التي تحصل عليها المفردات من خلال اجابات التدريسيين والمسؤولين في حقل العمل والذي يسهل عرض وتحليل النتائج بالشكل الذي يساعد متخذي القرار (القسم العملي) على اتخاذ القرارات المناسبة حول المفردات الدراسية على أسس علمية لذا تم استخدام طريقة الإرتباط التي تعطي صورة واضحة للقيم المثلى والخلل الذي تحصل عليه كل مفردة من المفردات الدراسية، حيث تم احتساب معامل الإرتباط بين مجموع المفردات الدراسية للموضوع والإرتباط بين إجابات التدريسيين والمسؤولين والذي تتراوح قيمته بين (+1) و (-1) (ملحق رقم (5)) وقد تم استخدام الحاسوب الالكتروني وتطبيق البرنامج الإحصائي (SPSS) لتحقيق ذلك.

تشير النتائج المستحصلة من الارتباطات بين اجابات اعضاء الهيئة التدريسية والمسؤولين في حقل العمل الى ان نسبة المفردات الدراسية التي حصلت على ارتباطات جيدة (معامل ارتباط اكبر من 0.5) بلغت (93%) من مجموع المفردات، في حين ان نسبة المفردات الدراسية التي حصلت على ارتباطات ضعيفة (معامل ارتباط اصغر من 0,5) بلغت (7%) من مجموع المفردات تركزت نسبة كبيرة منها في موضوع مبادئ علم الحاسبات وبرمجة الحاسبات والاقتصاد الهندسي وبدرجة اقل في موضوع مواد البناء. ان هذه النسبة تشير الى ضعف مواكبة هذه المفردات الى الصورة المستقبلية للمهندس المدني أو انها تشير الى اختلاف في وجهات النظر بين التدريسيين والمسؤولين حول مفهوم هذه المفردات ومدى تأثيرها على الصورة المستقبلية للخريج، ان الاحتمالين يمثلان مؤشراً سلبياً على مستقبله يستوجب إعادة النظر.

4-1-2 لقد لوحظ من خلال مقارنة المفردات الدراسية في الجامعات المختارة كنموذج للبحث بأن موضوع الادارة الانشائية خصص له فرع مستقل في الجامعة التكنلوجية بإسم (فرع البناء والادارة الانشائية) في حين يدرس هذا الموضوع ضمن المنهاج العام لقسم الهندسة المدنية في الجامعات النظرية (غير التقنية) وبذلك اصبح تدريس الجامعة التكنلوجية متخصصاً في الادارة الانشائية مقارنةً مع الجامعات النظرية برغم اختلاف مواصفات الخريج بينهما.

ان مواصفات الخريج في الجامعات النظرية ان يكون مهندساً مدنياً مخطط ومصمم لديه المعارف الأساسية ويكون قادراً على تنفيذ المشاريع المدنية الموكلة اليه اضافة الى قدرته على التصميم الخاص بأعمال الهندسة المدنية. ومن هنا جاءت اهمية البحث في التركيز حول موضوع الادارة الانشائية، حيث ان لخريج باعتباره مهندس عام يحتمل ان يمارس اي جزء من العملية الهندسية كأعمال التصاميم أو اعمال التنفيذ أو ان يتجه للاستمرار بالدراسة بالبحث العلمي. فاذا كان الاتجاه في الجانب الأول فأنه بالتأكيد سوف يحتاج الى الجانب الاداري بدرجة أو بأخرى، اما الاتجاه بالبحث العلمي فان هذا التوجه يستوجب دراسة موضوع الادارة الانشائية بشكل دقيق وكافي خصوصاً اذا كان البحث باختصاص الادارة انشائية.

4-1-3 كذلك لوحظ من مقارنة المفردات عدم تغطية مفردات بعض الواضيع لما يفيد الادارة الانشائية ومنها مفردات موضوع الاقتصاد الهندسي فانها في الجامعات النظرية لاتضم جميع المفردات التي تخدم الادارة الانشائية بالشكل المطلوب حيث انها تمثل مفردات اقتصاد بشكل رئيسي وليس اقتصاد هندسي، بينما نجد في منهاج الجامعة التكنلوجية تم تفصيل هذه المفردات بشكل علمي يفي بالغرض يمكن الطالب من تطبيق الادارة الانشائية بشكل فعلي بعد تخرجه، وبدلاً من معالجة هذا الأمر نجد في المنهاج الحديث للجامعات النظرية اعتبار موضوع (الادارة والاقتصاد الهندسي) موضوعاً اختيارياً الأمر الذي سيؤثر بشكل سلبي على الخريج لموضوع الادارة الانشائية وذلك لإحتمالية اختيار مواضيع اخرى بدلاً عنه في السنوات القادمة.

4-2 نتائج المقابلات الشخصية :

4-2-1 لقد تبين من المقابلات الشخصية مع بعض التدريسيين بمستوى العمداء ورؤساء الأقسام والمسؤولين في حقل العمل بأن هناك تأييداً لتصنيف البحث للمواضيع من حيث علاقتها بالادارة الانشائية (Construction Management) الى مواضيع ذات علاقة مباشرة وتشمل مواضيع (مواد البناء، انشاء المباني، تقنية الخرسانة، طرق الانشاء والنعدات والتخمين) وموضيع ذات علاقة غير مباشرة بالادارة الانشائية بينما لها علاقة مباشرة بموضوع الادارة الهندسية (Engineering Management) وتشمل مواضيع (الادارة الهندسية، الاقتصاد الهندسي، الاحصاء الهندسي)، وقد أكدت المقابلات بأن المواضيع غير المباشرة لازالت مشوشة ولاتتضمن جميع المواضيع غير المباشرة التي يجب أخذها بنظر الاعتبار في منهاج الادارة الانشائية.

4-2-2 أما فيما يخص موضوع علم الحاسبات فقد أشارت الاجابات الى المنهاج الحديث والذي ينقصه التطبيقات الحاسوبية لكل اختصاص في الهندسة المدنية لذا تم اقتراح استحداث موضوع آخر بإسم (تطبيقات الحاسوب في الهندسة الانشائية) لتحقيق ذلك.

وقد تم جمع الآراء حول امكانية استخدام التقنيات الحديثة كالبريد الالكتروني وشبكة المعلومات (الانترنت) كمراجع للطالب اضافة الى الكتاب المنهجي والمكتبة استناداً الى المؤشر المعتمد في مناقشات ورقة التربية والتعليم في (التأكيد على اعتبار الكتاب المنهجي يمتلك الحد الأدنى من المعلومات العلمية على ان يقوم الاستاذ والطالب باستخدام الكتب المساعدة أو اي مصادر اخرى للتوسع في العلوم والمعرفة)(مناقشات، 1981)، فقد كان هناك تأييداً لذلك وقد تم الاستعانة بمراكز شبكة المعلومات في بعض الكليات الهندسية وحسب الامكانيات المتوفرة للمعدات الحسبية (Hard ware) والطموح في التطور في هذا المجال في المستقبل القريب.

4-2-3 تجدر الاشارة هنا الى موضوع التدريب الصيفي الذي اشير اليه خلال المقابلات حيث ان الهدف من هذا الموضوع حدد بتعريف الطالب بالعمل والاحتكاك ما أمكن بقطاعات العاملين على اختلاف اصنافهم من اجل الربط بين المؤسسات

الانتاجية وبين الدراسة الجامعية (مناقشات، 1981)، حيث أيدت الآراء ضرورة تأكيد هذا الموضوع على تدريب الطالب على تطبيقات الادارة الانشائية وبدرجة اكبر على خريج الجامعة التكنلوجية مقارنة مع الجامعات النظرية.

4-2-4 إتضح من هذه المقابلات وفيما يتعلق بمفردات موضوع الادارة الانشائية بأنها مفردات عديدة ومهمة للمهندس المدني والانشائي الا انها مكبوسة في مادة واحدة وانها تمثل خليط غير منتظم في الجامعات النظرية في حين تم توزيع هذه المفردات بشكل أوفى للغرض في الجامعة التكنلوجية.

6- الاستنتاجات والتوصيات :

يمكن استعراض بعض الاستنتاجات التي توصل اليها البحث والتي من شأنها رفع مستوى التعليم الهندسي فيما يخص موضوع الادارة الانشائية :

6-1 عند تطوير المنهاج لابد من إعتماد آراء المهندسين العاملين في حقل العمل وقد تبين بأن المهندسين الذين تزيد مدة خدمتهم في حقل العمل على (10) سنوات هم أفضل فئة تستطيع تحديد الخلل في المناهج الدراسية وتبعاً لظاهرة تقادم المعرفة فقد لاينطبق هذا على مناهج الهندسة الكهربائية أو الحاسبات.

6-2 لابد من أن يتم التركيز على الميادين التي تشهد في العالم تطوراً علمياً وتكنلوجياً سريعاً كميدان الحاسبة الالكترونية وتطبيقاتها في الادارة الانشائية واختصاصات الهندسة المدنية الأخرى اضافة الى شبكة المعلومات، البريد الالكتروني وغيرها وتوظيفها لخدمة المناهج الدراسية ومنهامنهاج الادارة الانشائية واعتبارها مراجع اخرى للطالب اضافة الى الكتاب المنهجي والمكتبة التقليدية.

6-3 ان يتم وضع برامج تدريبية متكاملة لتدريب الطلبة ضمن موضوع التدريب الصيفي بالتسيق بين القسم العلمي والمؤسسات التدريبية فيما يتعلق بتطبيقات الادارة الانشائية بحيث يراعى فيها امكانية هذه المؤسسات والخبرات التعليمية التي يحتاج اليها الطالب من خلال هذا التدريب.

6-4 أوضحت نتيجة الاستبيان والمقابلات الشخصية ضرورة ان تتم دراسة مفردات موضوع مبادئ علم الحاسبات والبرمجة وموضوع الاقتصاد الهندسي بما يخدم الصورة المستقبلية للخريج كمهندس مدني، وبرغم تعديل المنهج الحديث فيما يخص علم الحاسبات الا انه لازال يفتقر الى تطبيقات الحاسوب في موضوع الادارة الانشائية والاختصاصات الاخرى.

كما اكدت ضرورة تفصيل مفردات الادارة الانشائية لكونها حالياً وبرغم صدور المنهاج الجديد فانها تمثل خليط غير متجانس من مفردات مكبوسة في مادة واحدة لاتخدم الغرض الرئيسي من موضوع الادارة الانشائية، هذا اضافة الى ضرورة جعل موضوع الادارة الهندسية أحد المواضيع الرئيسية في المنهاج وليس اختيارياً كونه موضوع يهم الخريج في قسم الهندسة المدنية والاقسام الهندسية الاخرى والأخذ بنظر الاعتبار منهاج الجامعة التكنلوجية ونظرة الجامعة الى مدى اهمية الادارة الانشائية في مستقبل المهندس الانشائي.

7- البحوث المستقبلية :

7-1 إكمال البحث اعلاه بدراسة المنهاج من خلال الساعات الاسبوعية والوحدات ونسبتها من الساعات والوحدات الكلية.

7-2 لقد تم في هذا البحث در اسة مفردات موضوع الادارة الانشائية للدراسات الاولية، يمكن اجراء الدراسة ذاتها بالنسبة للدراسات العليا.

7-3 وكمرحلة متممة لهذا البحث يمكن معرفة آراء المهندسين الجدد الذين تتراوح خدمتهم بين (1-5) سنوات لمعرفة مدى استفادتهم الفعلية من المفردات الدراسية لموضوع الادارة الانشائية.

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المصادر الاجنبية:

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ملحق رقم (1)

جدول المفردات الدراسية

اسم الموضوع :				
ت	المفردات الدراسية للموضوع	مواكبة	غير مواكبة	لا أعلم

ملحق رقم (2)

الاسئلة الخاصة بالمقابلات الشخصية لعمداء الكليات الهندسية ورؤساء الاقسام المعنية

1- (خاص بالسادة العمداء) : ماهي المواصفات المطلوبة في المهندس الخريج من تلك الجامعة؟

2- بالنسبة للمواضيع المدرجة ادناه ماهي برأيك المواضيع المباشرة والمواضيع غير المباشرة (الممهدة) لموضوع الادارة الهندسية ؟

- مواد البناء
- انشاء المباني
- تقنية الخرسانة
- طرق الانشاء والمعدات والتخمين
- الادارة الهندسية
- الاقتصاد الهندسي
- الاحصاء الهندسي
- مبادئ علم الحاسبات
- برمجة الحاسبات

3- بالنسبة الى موضوع علم الحاسبات، هل برأيك ضرورة تدريسه كلغة برمجة كما هو عليه الان أم كتطبيقات لبرامج الحاسوب في موضوع الادارة الانشائية وحسب متطلبات ذلك الفرع من الهندسة المدنية ؟

4-ماهي إمكانية استخدام التقنيات الحديثة : البريد الالكتروني، الانترنت وغيرها كمراجع حديثة يستعين بها الطالب اضافة الى الكتاب المنهجي والمكتبة التقليدية ويمكن الاشارة اليها ضمن مفردات موضوع الحاسبات أو ضمن مفردات الموضوع ذاته ؟

ملحق رقم (3)

الاستبيان الموجه الى التدريسيين في الكليات الهندسية

الأستاذ الفاضل ...

إن إسهامك في تطوير مفردات مواضيع الادارة الهندسية في الكليات الهندسية لجعلها اكثر فاعلية في عمليات التنمية الاقتصادية والاجتماعية للقطر يتم من خلال الأخذ بنظر الاعتبار الإجابات التي تتفضلون بها مشكورين على فقرات الاستبيان وتحليلها وذلك بتوضيح درجة مواكبة هذه المفردات للتطورات العلمية والتكنلوجية الحاصلة في مجال العلوم والتطبيقات الهندسية من وجهة نظرك والتي تتضمن مفردات المواضيع المشتركة وغير المشتركة بين الكليات الهندسية لموضوع الادارة الهندسية اضافة الى المواضيع الجديدة التي تدرس في بعض الكليات الهندسية في الجامعات المحلية والاجنبية ضمن موضوع الادارة الهندسية وذلك بوضع علامة (X) ازاء كل مفردة من مفردات الموضوع .

يرجى تدوين المعلومات الآتية :

1- اسم الكلية او الجامعة :

2- الشهادة والاختصاص :

3- مدة الخدمة في التدريس :

4- المواد التي تقوم بتدريسها :

ملحق رقم (4)

الاستبيان الموجه الى المسؤولين في حقل العمل

الاستاذ الفاضل ...

إن إسهامك في تطوير مفردات مواضيع الادارة الهندسية في الكليات الهندسية لجعلها اكثر فاعلية في عمليات التنمية الاقتصادية والاجتماعية للقطر يتم من خلال الأخذ بنظر الاعتبار الإجابات التي تتفضلون بها مشكورين على فقرات هذا الاستبيان وتحليلها وذلك بتوضيح درجة مواكبة هذه المفردات للتطورات العلمية والتكنلوجية الحاصلة في مجال العلوم والتطبيقات الهندسية من وجهة نظرك والتي تتضمن مفردات المواضيع المشتركة وغير المشتركة بين الكليات الهندسية لموضوع الادارة الهندسية اضافة الى المواضيع الجديدة التي تدرس في بعض الكليات الهندسية في الجامعات المحلية والاجنبية ضمن موضوع الادارة الهندسية وذلك بوضع علامة (X) ازاء كل مفردة من مفردات الموضوع .

يرجى تدوين المعلومات الآتية :

1- اسم الدائرة او المشروع :

2- العنوان الوظيفي :

3- الشهادة والاختصاص :

4- مدة الخدمة في حقل العمل :

جدول المفردات الدراسية المشتركة :

1- للمواضيع المباشرة :

ت	المفردات الدراسية للموضوع	مواكبة	غير مواكبة	لا أعلم
اسم الموضوع : مواد البناء				
1-	خواص مواد البناء			
2-	الطابوق الطيني والرملي			
3-	المونة			
4-	الخشب			
5-	الحجارة البنائية			
اسم الموضوع : انشاء المباني				
1-	اعمال الطابوق			

2-	اعمال الحجارة			
3-	السقوف والارضيات			
4-	اعمال الخرسانة			
5-	الابوبا والشبابيك			
6-	اعمال الانهاء			
7-	الاسس والركائز			
8-	السلالم			
اسم الموضوع : تقنية الخرسانة				
1-	الركام المستخدم في الخرسانة			
2-	تصميم الخلطات الخرسانية			
3-	خواص الخرسانة الطرية والمتصلدة			
4-	المضافات			
5-	صناعة السمنت وخواصه			
6-	انواع السمنت			
اسم الموضوع : طرق الانشاء والمعدات والتخمين				
1-	عملية الانشاء			
2-	الكوادر ضمن المشروع الانشائي			
3-	ادارة المشروع			
4-	دور المهندس والمقاول			
5-	برمجة العمالة			
6-	انواع المعدات			
7-	ادارة المعدات			
8-	الاعمال الترابية			
9-	صناعة الخرسانة			
10-	تقدير الكلفة			
11-	قياس الكميات			
12-	دراسة التسعير			
13-	المواصفات الفنية			
اسم الموضوع : الادارة الهندسية				
1-	انواع المقاولات			
2-	طرق برمجة المشاريع			

3-	تسارع او تقليص مدة المشروع			
4-	ادارة الموارد			

المواضيع غير المباشرة (الممهدة) :

اسم الموضوع : الاقتصاد الهندسي				
ت	**المفردات الدراسية للموضوع**	**مواكبة**	**غير مواكبة**	**لا أعلم**
1-	المدخل الى علم الاقتصاد			
2-	التكاليف			
3-	الميل والمرونة في الدول الاقتصادية			
4-	الريع وقوانينه			
5-	الاندثار			
اسم الموضوع : الاحصاء الهندسي				
1-	وصف وتصنيف البيانات			
2-	التوزيع التكراري			
3-	قياسات النزعة المركزية			
4-	التوزيع التكراري المتراكم			
5-	نظرية الاحتمالات			
6-	التوزيع الطبيعي			
اسم الموضوع : مبادئ علم الحاسبات **اسم الموضوع : برمجة الحاسبات**				
1-	نظرة تأريخية عن الحاسبات			
2-	المكونات الفيزيائية للحاسبة			
3-	الخوارزميات			
4-	المخططات الانسيابية			
5-	لغة بيسك			
6-	الثوابت والمتغيرات			
7-	الدوال المكتبية			
8-	عبارات الإدخال والإخراج			
9-	التفرع المشروط وغير المشروط			
10-	الدوال التكرارية			

11-	المصفوفات			
12-	البرامج الفرعية			
13-	لغة فورتران			
14-	الملفات			

جدول المفردات الدراسية غير المشتركة :

1- للمواضيع المباشرة :

اسم الموضوع : مواد البناء					
ت	**المفردات الدراسية للموضوع**	**تدرس في جامعة**	**مواكبة**	**غير مواكبة**	**لأعلم**
1-	فحص المعدات وقياس الاجهاد	بغداد			
2-	اختبار المقالع	=			
3-	البلاطات الفسيفسائية	=			
4-	الثرموستون	المستنصرية			
5-	الطابوق الخرساني	=			
6-	الكاشي الموزائيك	=			
7-	الكاشي انواعه ومواصفاته وفحوصه	الموصل			
8-	الجص وفحوصاته	=			
9-	تركيب المواد/التركيب الذري، انواع الروابط، آلية الفشل للمواد	تكنلوجيا/هندسة البناء وادارة المشاريع			
10-	حالات المادة/المواد المعدنية، المواد غير المعدنية، المواد السيراميكية	=			
11-	الفولاذ/التكوين والتصنيع، التصنيف، الخواص، الفحوصات، الخواص القياسية، الاستعمالات	=			
12-	اللدائن-المواد القيرية/مصدرها، خواصها واستعمالاتها	=			
13-	الخشب	المستنصرية/هندسة المواد			
14-	مواد الاكساء	=			
15-	الحديد	=			

16-	الزجاج	=			
17-	الانابيب/التصنيف، الخواص، الضغوط، النواع العيوب، الفحوصات القياسية، الحماية، المواصفات	تكنلوجيا/هندسة صحية			
اسم الموضوع : انشاء المباني					
1-	الاعمال الترابية	بغداد, الموصل, المستنصرية			
2-	منع الرطوبة والمعالجات	=			
3-	العتبات والعتبات المنحنية	=			
4-	الاعمدة	=			
5-	التفصيل الانشائي	=			
6-	المنشآت الحديدية والخشبية	=			
7-	الأقواس	المستنصرية			
8-	الدعامات	=			
9-	المفاصل	الموصل			
10-	طرق التحميل في البناء	تكنلوجيا/هـ.انشاءات			
11-	البناء بالبلوك	=			
12-	المواد الرابطة	=			
13-	مقدمة عن المشآت والهياكل المعدنية	=			
اسم الموضوع : تقنية الخرسانة					
1-	طرق متقدمة في فحص الخرسانة	بغداد			
2-	ديمومة الخرسانة : الانكماش، الزحف	المستنصرية، التكنلوجيا			
3-	الاحصاء والسيطرة النوعية	الموصل			
4-	السيطرة الحقلية (الموقعية، المواصفات)	تكنلوجيا			
5-	الخرسانة الخفيفة والعالية الكثافة	=			
اسم الموضوع : طرق الانشاء والمعدات والتخمين					
1-	عوامل نجاح تحقيق المشروع	بغداد، المستنصرية			
2-	ادارة المشروع	=			
3-	برمجة المشاريع الانشائية	بغداد			
4-	البناء الجاهز	=			

			بغداد، مستنصرية	التقرير الشامل	5-
			مستنصرية	مراحل التشييد	6-
			=	طرق التشييد	7-
			الموصل	ترسيخ وحدل التربة	8-
			=	اعمال الحقن للأسس	9-
				اسم الموضوع : ادارة المشاريع الانشائية	
			تكنلوجيا/هـ.بناء وادارة	مبادئ واهداف ادارة المشاريع	1-
			=	عناصر الادارة واهميتها	2-
			=	التخطيط واساليبه المختلفة	3-
			=	التنظيم والهياكل التنظيمية	4-
			=	الادارة والتوجيه	5-
			=	دراسات العمل والانتاجية	6-
			=	التدفقات النقدية تحليلها والتنبؤ بها	7-
			=	اساليب المتابعة والسيطرة على كلف الاعمال	8-
			=	ادارة المخازن والسيطرة على التخزين	9-
			=	مبادئ في حسابات الكلفة	10-
			=	تمويل المشاريع الانشائية	11-
			=	اتخاذ القرارات	12-
			University of Kansas/Civil and Environmental Engineering	شراء واستعمال المعدات	13-
				اسم الموضوع : طرق الانشاء	
			تكنلوجيا/هـ.انشاءات	الأسس الهندسية/مقاومة الحرجة، مقاومة الإنحدار ، القوالب للمنشآت الخرسانية	1-
			=	مكائن الضخ/الخباطات، الهزازات، صب الخرسانة	2-
				اسم الموضوع : الادارة	
			تكنلوجيا/هـ. صحية	التنبؤ بالتفقات النقدية	1-

2- للموضيع غير المباشرة (الممهدة) :

اسم الموضوع : الإقتصاد الهندسي					
ت	**المفردات الدراسية للموضوع**	**تدرس في جامعة**	**مواكبة**	**غير مواكبة**	**لاأعلم**
1-	اقتصاديات المؤسسات	بغداد			
2-	الايرادات	=			
3-	الاستهلاك	=			
4-	طرق احصائية واستخدامها في الاقتصاد الهندسي	=			
5-	التقويم والوصف	المستنصرية			
6-	دراسة الكلف الدنيا	=			
7-	Break-even cost analysis	=			
8-	واجبات المهندس في المراحل المختلفة للمشروع الانشائي	موصل			
9-	السلامة المهنية	=			
10-	الأسس والقوانين الاقتصادية	=			
11-	الإستبدال	=			
12-	التضخم	=			
13-	اسلوب صافي القيمة الحالية	تكنلوجيا/هـ.بناء وادارة			
14-	الإقراض والتمويل	=			
15-	الضرائب	=			
16-	الربحية والانتاجية	=			
17-	مؤشرات الكلف والأسعار	=			

اسم الموضوع :الاحصاء الهندسي					
1-	التوزيع التكراري المتراكم	بغداد			
2-	المدرج	=			
3-	المضلع التكراري، المضلع التكراري المتراكم	=			
4-	التوزيع ذو الحدين	=			
5-	الانحدار والارتباط البسيط	الموصل			

6-	نظرية التخمين، التخمين والمخمن، الكفاءة والكفاية والتواؤم، مستوى الثقة في التخمين، مستوى الثقة للأوساط والنسب والفروق والمجموع، اختيار حجم العينة	تكنلوجيا			
7-	نظرية العينات: طرق المعاينة، توزيع المعاينة، توزيع المعاينة للأوساط والفروق والمجموع	=			
8-	نظرية القرار الاحصائية: اختبار الفرضية وادلالة، الأخطاء الاحصائية	=			
9-	اختبار الفرضية للمتوسطات – للتباينات	المستنصرية/هندسة المواد			
10-	معامل الارتباط	المستنصرية/هندسة المواد، هندسة الطرق والنقل			
11-	الانحدار الخطي	المستنصرية/هندسة المواد، هندسة الطرق والنقل			
12-	علاقة الاحصاء الهندسية بالمواد	المستنصرية/هندسة المواد			
13-	طريقة المربعات الصغرى	المستنتصرية/ههندسة الطرق والنقل			
اسم الموضوع : مبادئ علم الحاسبات **اسم الموضوع : برمجة الحاسبات**					
1-	لغات البرمجة	المسنتصرية/الموصل			
2-	التغييرات الموسومة	الموصل			
3-	الحساب العددي	=			
4-	أسس عمل الحاسبة، وحدة المعالجة المركزية	تكنلوجيا			
5-	الخزن	=			
6-	الحساب والمنطق	=			
7-	السيطرة	=			

8-	كيف تتناقل المعلوماتبين الوحدات والاجزاء المختلفة	=			
9-	الماكنة	=			
10-	الرسم	بغداد والمستنصرية			
11-	Hidden lines & surface renewal algorithm	المستنصرية			
12-	طرق عددية	=			
13-	مخططات الانسيابية وتطبيقاتها لغة فورتران	موصل			
14-	تحليل المسائل	=			
15-	المبادئ العامة للتحليل العددي	=			
16-	حل المسائل بطريقة نيوتن رامتن	=			
17-	حل المعادلات التفاضلية بطريقة انج كوتا	=			
18-	تكامل	=			
19-	برمجة بلغة فورترتن	المستنصرية/هندسة المواد			
20-	التحليل العددي	=			
21-	المخططات الانسيابية	=			
22-	فورتران - 77	المستنصرية/هندسة الطرق والنقل			
23-	طرق عددية	=			

جدول المواضيع غير المشتركة :

اسم الموضوع	الجامعة التي يدرس فيها	مواكبة	غير مواكبة	لاأعلم
تصميم وادارة النظم الهندسية	تكنلوجيا/هندسة البناء وادارة المشاريع			
تنفيذ وادارة المشاريع الصحية	=			
السيطرة النوعية على عمليات الانشاء	=			
تطبيقات الحاسوب في هندسة البناء وادارة	=			

المشاريع				
السيطرة والتشغيل للمشاريع الصحية	تكنلوجيا/هندسة صحية			
مبادئ علم المواد	المستنصرية/هندسة المواد			
هندسة المعادن	=			
البوايمرات				
تكنلوجيا المواد الهندسية	=			
المواد شبه الموصلة	=			
فحص المواد والسيطر ة النوعية	=			
السيراميك	=			
المواد المركبة	=			
ادارة وصيانة الطرق	المستنصرية/هندسة الطرق والنقل			

جدول المواضيع غير المشتركة في الكليات الهندسية للجامعات الاجنبية :

اسم الموضوع	الجامعة التي يدرس فيها	مواكبة	غير مواكبة	لأعلم
Knowledge-Based Expert System	Civil and Environmental Engineering			
Cost Control Techniques	=			
Contract Administration & Claims Resolution	=			
Project &Company Management	=			
Construction Equipment	University Of Kansas and Environmental Engineering			
Work Management in Construction	=			
Financial Concept in Construction	=			

			=	Construction Management Techniques /Phased Contract, Value Engineering, Environmental and Political Construction
			=	Construction Project Controls
			=	Work Management in Construction
			University of Alberta	Advanced Project Planning and Control

ملاحظة :

هل من الضروري انضمام هذه المواضيع الى مواضيع الادارة الانشائية في كلياتنا الهندسية في القطر ؟ وماهي هذه المواضيع ؟ اذكرها رجاءً.

ملحق رقم (5) : معامل ارتباطات المفردات الدراسية موضوع طرق الانشاء والمعدات والتخمين