Studies on the melting of nano-enhanced phase change materials (NePCM) in rectangular, cylindrical and annular containers are performed experimentally and numerically. Containers of various shapes are subjected to a constant heat flux on an active wall and the other wall(s) are thermally insulated. The phase change material used is n-octadecane that is dispersed with CuO nanoparticles as the thermal conductivity enhancer (TCE). The experiments involved recording of temperatures at different locations inside the test cells, thus allowing for tracking the progress of the melting front in response to two controlled parameters which are the nanoparticle concentration (determines the enhancement in the effective thermal conductivity) and the Rayleigh number (measures the rate of supplied heat flux and natural convection). The finite element approach is utilized to solve the continuity, momentum and energy equations simultaneously. The computational model is validated and the results showed a good agreement with previous related works. Furthermore, good agreements are obtained between the experimental and simulated results. Regardless the shape of container, melting is dominated by conduction at early stages to absorb the initial subcooling and indicated by the solid–liquid interfaces being parallel to the heated wall. At later times, natural convection is augmented and this affects the shape of the melting front and consequently results in higher melting rate in the upper part of the container. The characteristics of the melting process are described by temperature of NePCM, progress of the shape of the solid–liquid interface, melting rate, melt fraction and charging time. For all enclosures, the experimental and numerical results reveal that there is an improvement in melting characteristics with the dispersion of more nanoparticles in PCM and raising the wall heat flux and the corresponding Rayleigh number which strengthens the role of natural convection. This enhancement in the melting process can be indicated by increasing the melting rate which leads to acceleration of the melting time. For example, dispersion 5 wt% of nanoparticles results in expediting the melting process by 14% for annular cavity with the Rayleigh number of 1.18x10^7. On the other hand, the rate of enhancement in the melting characteristics is higher at lower values of nano-additives loading, but this rate will decrease for higher values of nanoparticle concentration due to intensifying the effects of viscosity, agglomeration and sedimentation which override the impact of enhancement in thermal conductivity. In effect, lower concentration of nanoparticles offer a high energy storage capacity and less cost compared to higher concentrations. Therefore, the selection of a proper nanoparticle loading should consider these effects.

The magnitude and rate of expediting of the charging time
increases with augmenting the applied heat flux or increasing the Rayleigh number. For instance, the experimental maximum saving in time is about 11.7% due to using 5 wt% nanoparticles loading in rectangular enclosure for Rayleigh number of 2.79x10^8, while this saving is about 6.3% for the same loading of nanoparticle but for the Rayleigh number of 4.91x10^5 in cylindrical capsule. Furthermore, the impact of initial subcooling on the melting characteristics in all cavity shapes, ignoring the influence of natural convection in cylindrical capsule and eccentricity effect in annular vessel are examined.