International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 2 ǁ 2022 ǁ PP. 15-21

CFD Replication for Heat Transfer Improvement in Stage Vary Materials

1. Prof .Vipin Mehta
Asso prof in All Saints 'College of Technology Bhopal .MP

2 Dr Sanjay kateray **Prof SATI VIDISHA MP**
3 Dr P L Verma *Director in Govt Engg College Shahdol MP*

Abstract
In this research work, a two dimensional CFD approach was demonstrated to analyze the heat transfer phenomenon in phase transition materials (PCMs). In this research study a rectangular shell type heat exchanger filled with PCM was selected and rectangular tubes were inserted to allow the heat transfer fluid to flow. PCM is used as a thermal energy storage material to store thermal energy and CFD simulation is performed to analyze the melting process of PCM and to optimize the geometry of the rectangular tubes inside the shell. The two geometries of the rectangular tube, the incomplete tube and the four finned tube, are used to investigate the geometric effect on the heat transfer and melting of the PCM. In this research work, a CFD approach based on the enthalpy porous model is used to increase heat transfer and reduce the melting time of PCMs by inserting wings at the edges of rectangular tubes through which the hot temperature fluid flows. The goal of this research is to optimize the geometry to increase heat transfer in PCMs and analyze the results in a liquid context. 80c on rectangular tubes. The wings inserted in the tubes from the analysis increase the heat transfer to the PCM and shorten the melting time of the PCM.

Date of Submission: 06-02-2022 Date of acceptance: 19-02-2022

I. Introduction

Rectangular shell and tube heat exchangers (STEs) are non-contact type heat exchangers that have a rectangular shell and several rectangular tubes inside the shell that transfer heat energy from the fluid flowing inside the tube to another fluid. Located inside the shell. The fluids used in STHE for energy transfer can be in the same phase or change their phase. Materials that can change their phase and have a large latent heat capacity are used in heat exchangers to store energy and are called phase change materials (PCM) [1]. PCMs store latent heat during phase transition at a constant temperature and release this energy upon cooling. The phase change from liquid to gas involves a large increase in volume and high pressure [2]. Due to its high ability to store thermal energy, PCM in STHE is a new idea in research to fill the gap between energy availability and actual consumption of energy [3]. PCM and STHE have a huge range of research in the area of its application. Very limited research studies have been conducted over the last 15 years to improve the performance of PCMs in heat exchangers.

PCM can be mounted on the walls to store solar energy during the day and can be used at night when needed for space heating. An t. Et al. Al. [4] PCM developed a model for building walls in a coated heat pipe capable of repelling heat to cool the building during the summer. In this model, two concentric pipes are integrated into the wall of the building and a fluid flows through the inner pipe. PCM is inserted between the outer and inner pipes. PCM and the flowing fluid absorb heat from the building wall during the day and release this energy into the outer space with the help of gravity heat pipes during the night. Dears and. Al. [5] Regardless of the melting / freezing pattern that ignores thermal hysteresis, a PCM on the exterior wall exhibits a two-dimensional CFD simulation of the integrated building wall and separates the PCM with a specific thermal variation with temperature. Evaluated its suitability for use as stage material. Convection effect to reduce simulation time. At Kumaraswamy K. Al. [6] The CFD model was developed to analyze the behavior of PCMs covered with temperature hysteresis. To analyze the phase transition process using organic PCM n-octadecane using inorganic compound silica as a shell material, where more heat is transferred and the effects of encapsulation on the thermal behavior of the PCM are shown.

Eaten M. et al. Al. [7] The CFD numerical models of the system with PCM were developed and validated with experimental data. Two numerical simulation methods are used to analyze the sample. Analyzed from the results that similar results can be obtained from numerical simulations and experimental research, if the correct simulation method and appropriate thermo-physical properties are used. Yusuf [8] modeled, built and installed the PCM heat exchanger to run the heat pump using solar energy. Eight tubes are wired on its outer edge and the fluid flowing inside it for heat transfer is deposited in a shell containing PCM in a heat exchanger. Spiral wires are mounted on the edge of the tubes to increase the thermal conductivity of the PCM and to increase the heat transfer from the hot fluid flowing in the tubes to the PCM. Ahmed M et al. [9] Developed a special design that insulates refrigerated truck walls by integrating PCM into truck walls to prevent heat transfer through the walls into the refrigerated space. Experimental research has shown that PCM can store more heat by integrating PCM into truck walls, reducing heat transfer in the refrigerated space by 16%. Ping p. Et al. Al. [10] Developed a new system for cooling Li-ion batteries using PCM and Fin structures. A study will be conducted on Li-ion battery with PCM and fin structure between cells to improve cell cooling during discharge. It is taken from the results observed during 5 continuous charging-discharging cycles that the use of PCM improves the cooling of the cells, but is limited due to the low thermal conductivity of PCM. Using fin structure with PCM to improve heat transfer in PCM and improve cell cooling. Atui et al. [11] A prototype of a two-phase thermo-electric generator connected to a PCM was built and tested. In the initial stage, a thermo-electric generator is inserted between the electric heater and the PCM. In the next step, the temperature difference between the PCM and the 5 heat sink is maintained and analyzed to find that a two-phase thermo-electric generator produces 27% more net electricity than a conventional thermo-electric generator. Also if the heat source is turned off, the two-phase thermo-electric generator will supply voltage for about 7900 seconds, while the conventional thermo-electric generator will supply voltage for 2100 seconds. Bowl t. Et al. Al. [12] Conducted a 2D CFD study to analyze the melting of the PCM-shaped PCM and to optimize the geometry of the embedded heat source. A fixed temperature limiting condition was applied to the cylindrical heat source and heat source with four wings inserted into the cylindrical cavity filled with PCM, as well as the temperature profile and fluid fraction in terms of melting time. The study found that the four-wing configuration was effective in increasing the heat transfer in the PCM and that it shortened the melting time.

The above literature survey shows that very limited work has been done in the area of progression of heat transfer in the liquid-solid phase of PCM. This job Focuses on the melting process of PCM in STHE in which water flows through the tubes at a temperature higher than PCM and the effect of fin insertion at the edge of the rectangular tubes is observed in terms of PCM melting time and average temperature. . , This work was inspired to understand the freezing and thawing process of PCMs during natural convection under the influence of gravity. The aim of this research is to make efficient use of wing-filled STHE with or without PCM by proper geometry to store thermal energy.

Description of the physical model

In this research work, two-dimensional CFD numerical simulation is performed with STHE filled with solid PCM in a rectangular shell and water flowing in tubes at a temperature higher than the initial temperature of PCM. Wings are inserted at the edge of the tubes to increase the heat transfer rate and reduce the melting time of the PCM.

In this research study, PCH was investigated in the STHE shale area filled with pure gallium. Gallium was selected as PCM due to its high latent heat capacity and working temperature (29.8 C) suitable for use in solar water heating systems for domestic purposes. Other advantages of using gallium as PCM are its cost, inedibility and consistency over a large number of thermal cycles. Two different geometries of the heat exchanger are analyzed to investigate the heat transfer between water and PCM. The geometry of the heat exchanger consists of four finned rectangular tubes and tubes as shown in Fig. 1. The two configurations are used with a constant surface area to ensure mass protection between all components.

The dimensions of the geometry of the heat exchanger with and without wings are shown in Fig. 1. The structural triangular mesh finite element is used to construct the model and the final mesh contains 73,208 to 155,208 elements depending on the type of geometry used.

Shown in fig. 2. Based on the grid dependence test it was found that the number of elements used in the final mesh was sufficient to produce accurate simulation results.

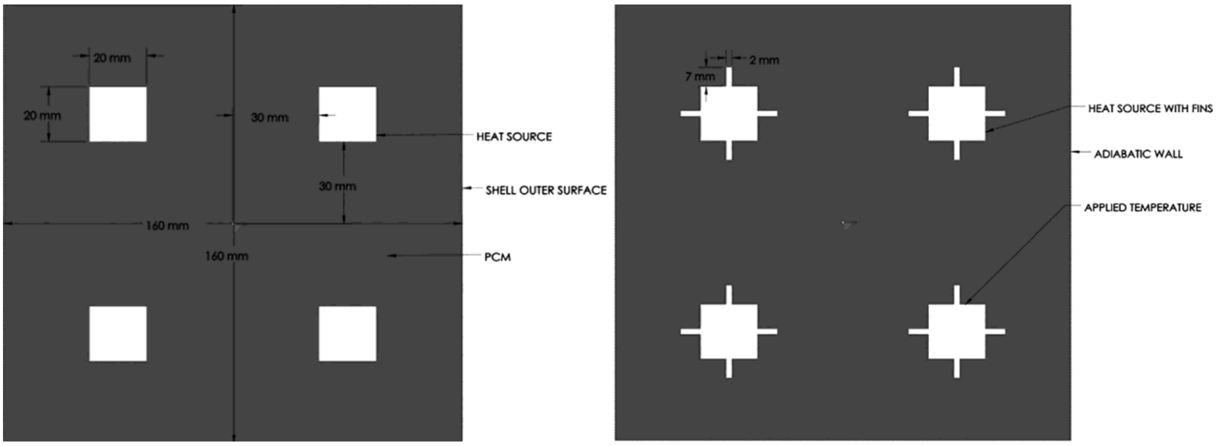


Fig. 1. Physical Modeling of the Geometries

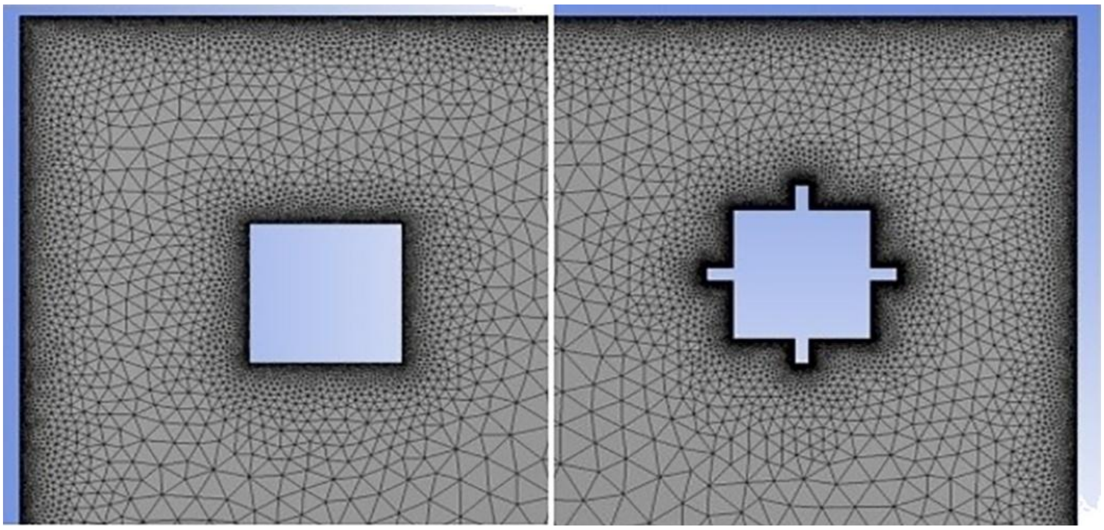


Fig. 2. Unstructured Triangular Mesh Grid.

. Mathematical formulation

The following assumptions are taken in STHE considering two dimensional unsteady model [10].The fluid is considered as incompressible. The physical properties of Gallium are taken as constant. Density variation with temperature is considered using Boussi- nesq approximation due to the field of buoyancy driven flow. Motion of fluid in melting zone is laminar and two dimensional Continuity, momentum and energy equations are used to inves- tigate the two dimensional transient flow field and thermal field of heat exchanger geometries during melting process of PCM. Consider-

Continuity equation

$$A_1V_1 = A_2V_2$$

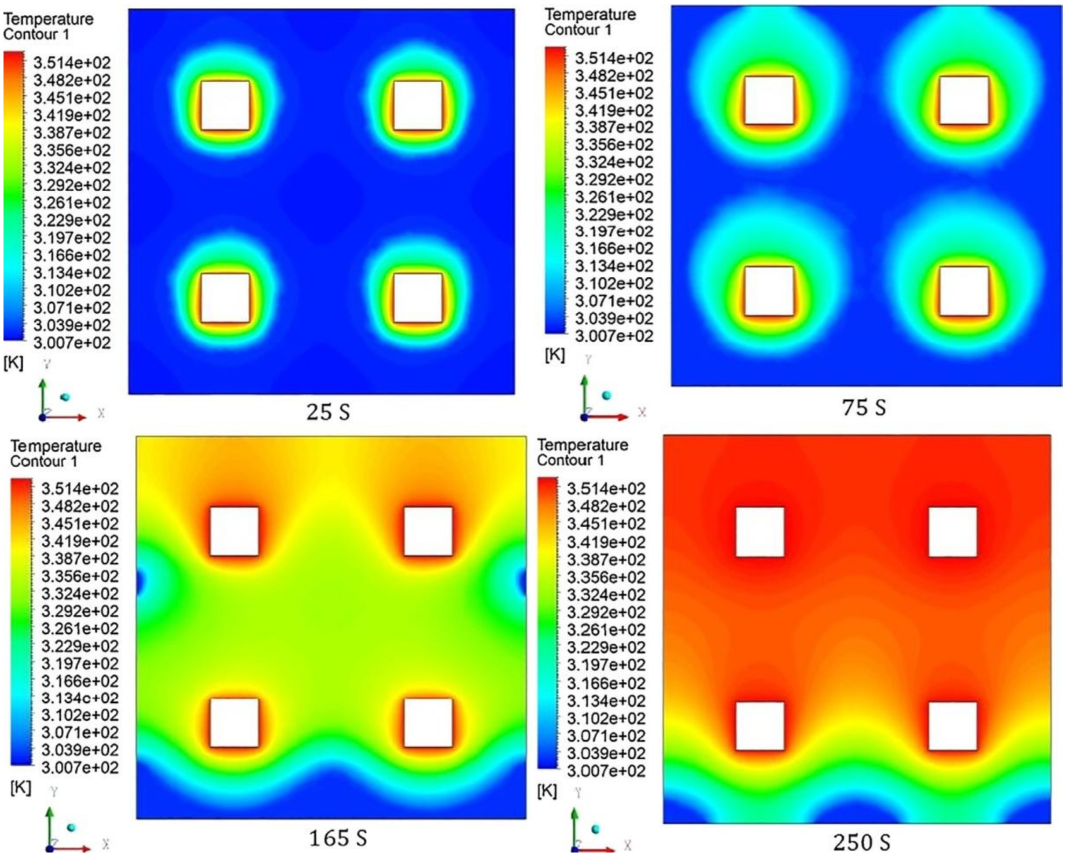


Fig. 3. Contours of Temperature Evolution for Configuration without Fins.

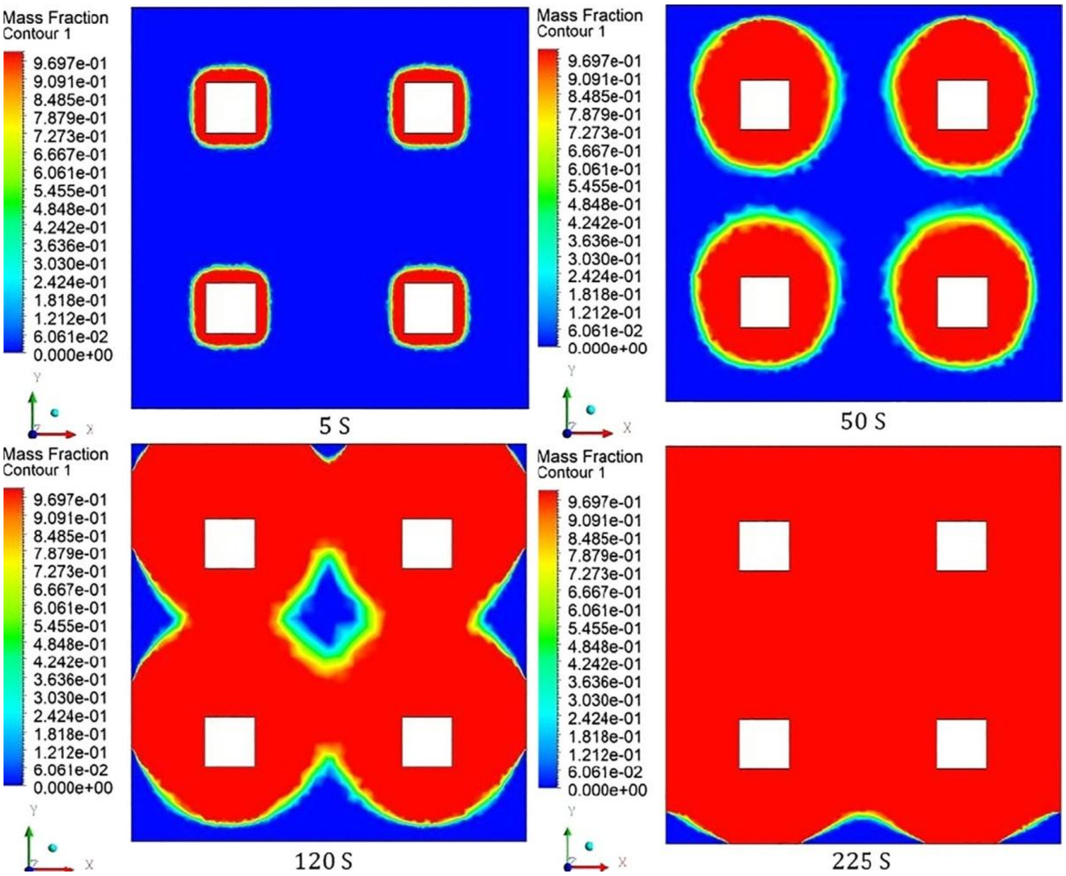


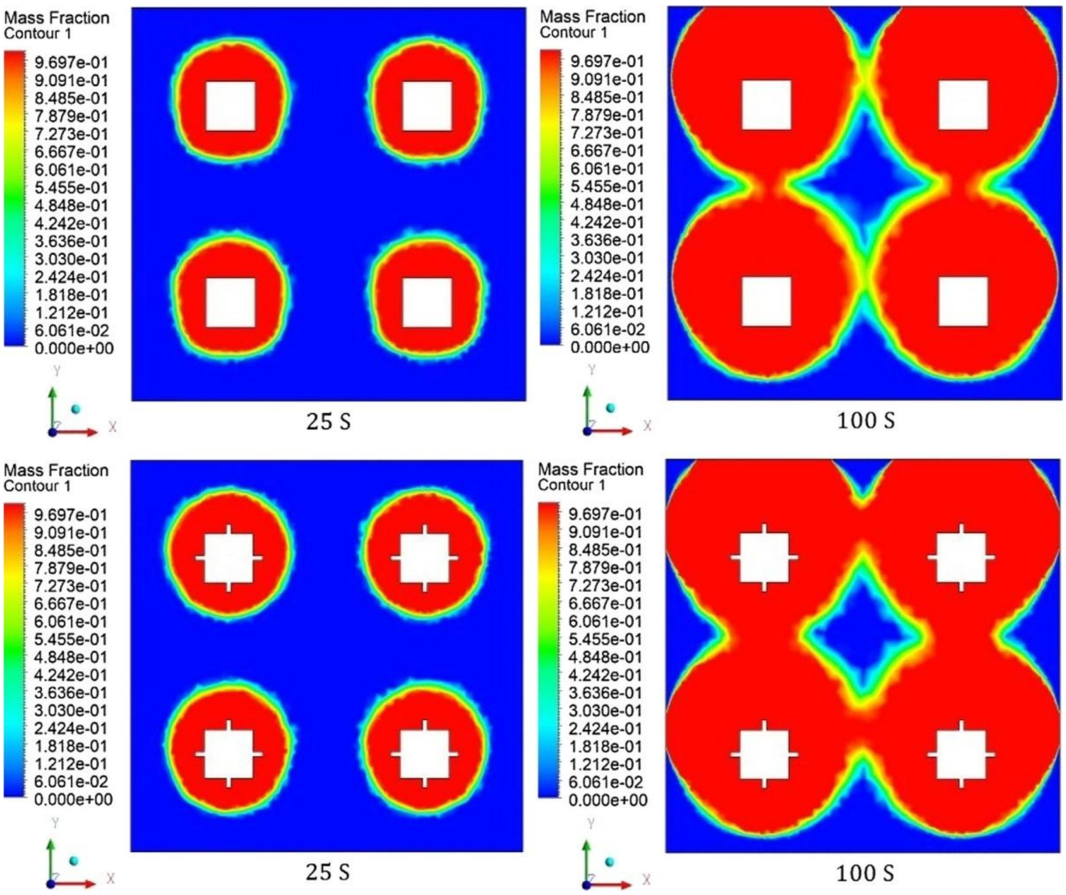
Fig. 4. Contours of Liquid Fraction Evolution for Configuration without Fins

II. Results and discussion

Numerical simulations are performed to investigate the melting phenomenon of gallium like PCM to see the effect of wing integration on the rectangular tubes in STHE. The effect of inserting four wings on tubes is investigated in terms of melting time, liquid content of gallium and temperature profile. 5S, 50S, 120S and. Liquid fraction for configuration without fans

225 s is shown in Figs. 3 and 4. These contour plots exhibit geometric shape without wings applying a constant temperature of 80 C on the outer surface of the rectangular tubes. Most of the heat transfer in PCM is at the beginning of melting due to conductivity, the melting areas are in the shape of rectangular tubes due to the symmetry of the geometry about the axis. After 80 seconds, it can be seen from the plot that heat transfer takes place inside the gallium due to natural convection and much melting occurs around the rectangular tubes moving upwards due to the effects of gravity and boussinoc approximation. Initially each melt zone around the four tubes is not affected by the presence of other melt zones until the four melt zones around the tubes merge. Temperature profiles for the gallium melting process at different times for wingless geometry are shown in Figure 3 and the melting process of gallium at different times for wingless geometry is shown in fig. 4. The time it takes for the gallium to completely dissolve for this configuration is 5 minutes 10 seconds. For geometry with four wings the shape of the liquid fraction of gallium is comparable to that of wingless geometry after 25 s and 100 s and the temperature is 50 DegreeC

150s and depicted in Figs. 5 and 6. These design plots compare the evolution of the gallium melting process in liquid form.



25 S

100 S

25 S

100 S

Fig. 5. Comparison of Contours of Liquid Fraction for both configurations after 25 s and 100

fraction for geometry with four fins where a constant temperature of 80 C is imposed on the outer surface of tubes. In addition these plots compare the effect of rectangular tubes geometry on melting time of Gallium. It can be seen from the plots that when the melt- ing of PCM starts, conduction is dominant and melt zone around the tubes are identical. But the heat transfer in PCM due to convec- tion starts after 80 s in configuration without fins and 60 s in con- figuration with 4 fins. The amount of PCM converted into liquid after 25 s is 31.4% in configuration without fins and 43.6% in con- figuration with 4 fins. Whereas liquid fraction of PCM after 100 s is 61.1% in configuration without fins and 72.5% in configuration with 4 fins. The temperature of PCM after 50 s is 39.8 C in config- uration without fins and 45.7 C in configuration with 4 fins. Whereas temperature of PCM after 150 s is 54.8 C in configuration without fins and 61.2 C in configuration with 4 fins.The time taken to completely melt the Gallium for configuration without fins is 310 s and for configuration with four fins is 290 s and time taken by the PCM to attain the temperature of 80 C for configuration without fins is 460 s and for configuration with four fins is 425 s as presented in Fig. 7. The fraction of Gallium con- verted into liquid with respect to time for both the configurations is presented in Fig. 8. It was observed from the plot that minimum melting time of Gallium is obtained with integrating fins on the circumference of the rectangular tubes in STHE which enhances the heat transfer in the Gallium. The temperature evolution of PCM inside the heat exchanger is illustrated in fig 9

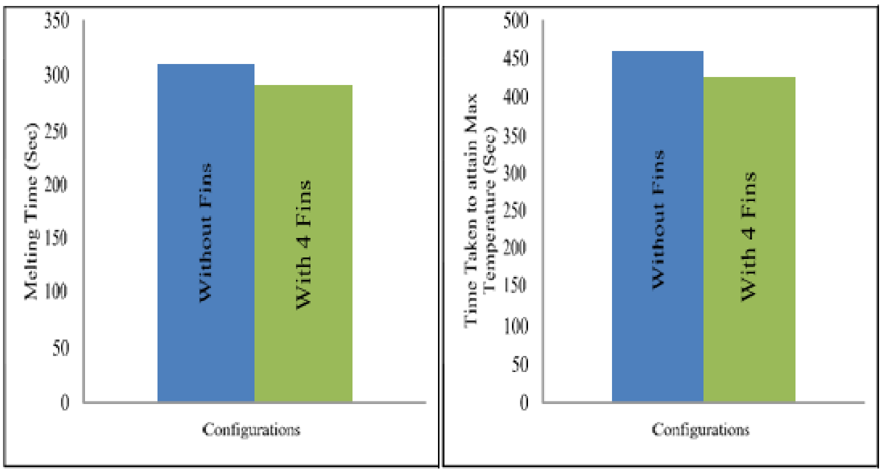


Fig. 7. Comparison of Melting Time of PCM and Time Taken to attain Maximum Temperature for both configurations

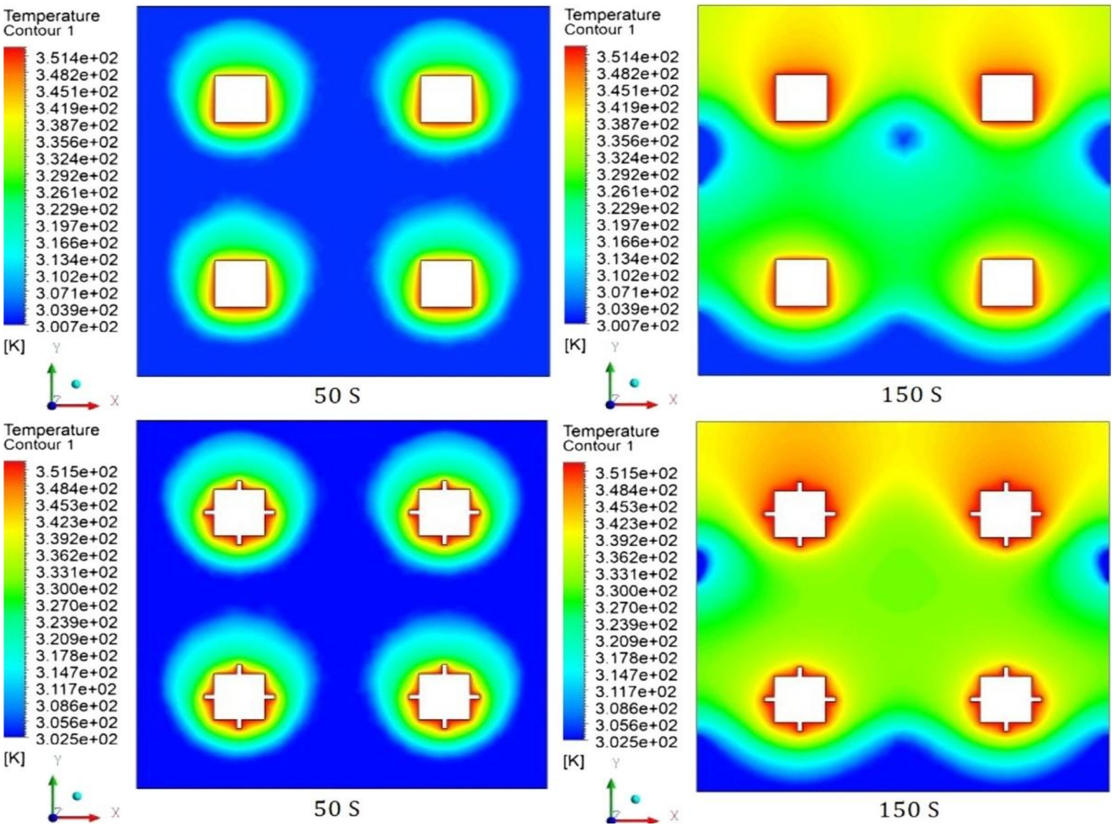


Fig. 6. Comparison of Contours of Temperature for both configurations after 50 s and 150

Studies have shown that inserting wings into each tube reduces the melting time of gallium from 301 seconds to 290 seconds, resulting in increased heat transfer from the tubes to the PCM. The time it takes the PCM to reach the temperature of the water (800C) flowing into the tubes is also reduced by inserting the wings into the tubes from 460 s to 425 s.

Credit Author Contribution Statement

Sachin Rana: Writing - Basic Drafting, Concept, Software, Visualization, Testing. Mohammad Junaid: Methodology, Observation. Rajesh Kumar: Data curation, monitoring

Fig. 8. Evolution of Liquid Fraction with Time at 80 C

References

[1]. F. Mohammadnejad, S. Hossainpour, A CFD modeling and investigation of a packed bed of high temperature phase change materials (PCMs) with different layer configurations, J. Storage Mater. 28 (2020) 101209.

[2]. Y. Wu, X. Zhang, X. Xu, X. Lin, L. Liu, A review on the effect of external fields on solidification, melting and heat transfer enhancement of phase change materials, J. Storage Mater. 31 (2020) 101567.

[3]. A. Sharma, V.V. Tyagi, C.R. Chen, D. Buddhi, Review on thermal energy storage with phase change materials and applications, Renewable Sustain. Energy Rev.13 (2009) 318–345.

[4]. T. Yan, J. Gao, X. Xu, T. Xu, Z. Ling, J. Yu, Dynamic simplified PCM models for the pipe-encapsulated PCM wall system for self-activated heat removal, Int. J. Therm. Sci. 144 (2019) 27–41.

[5]. G. Diarce, A.C. Celador, K. Martin, A. Urresti, A.G. Romero, J.M. Sala, A comparative study of the CFD modeling of a ventilated active facade including phase change materials, Appl. Energy 126 (2014) 307–317.

[6]. K. Kumarasamy, J. An, J. Yang, E. Yang, Novel CFD-based numerical schemes for

[7]. conduction dominant encapsulated phase change materials (EPCM) with temperature hysteresis for thermal energy storage applications, Energy 132 (2017) 31–40.

[8]. M. Iten, S. Liu, A. Shukla, Experimental validation of an air-PCM storage unit comparing the effective heat capacity and enthalpy methods through CFD simulations, Energy 155 (2018) 495–503.

[9]. W. Youssef, Y.T. Ge, S.A. Tassou, CFD modeling development and experimental validation of a phase change material (PCM) heat exchanger with spiral-wired tubes, Energy Convers. Manage. 157 (2018) 498–510.

[10]. P. Ping, R. Peng, D. Kong, G. Chen, J. Wen, Investigation on thermal management performance of PCM-fin structure for Li-ion battery module in high-temperature environment, Energy Convers. Manage. 176 (2018) 131–146.

[11]. S.A. Atouei, A.A. Ranjbar, A. Rezania, Experimental investigation of two-stage thermoelectric generator system integrated with Phase Change materials, Appl. Energy 208 (2017) 332–343.

[12]. T. Bouhal, S. Fertahi, T. Kousksou, A. Jamil, CFD thermal energy storage enhancement of PCM filling a cylindrical cavity equipped with submerged heating source, J. Storage Mater. 18 (2018) 360–370.