NUMERICAL MODELING OF PHASE CHANGE MATERIAL TO ENHANCE HEAT TRANSFER USING EXTENDED SURFACES

Biswajit Borah[1], Dr. Sudip Kumar Deb

[1]Student, Mechanical Engineering Dept, Assam Engineering college, Assam -781013
[2]Professor, Mechanical Engineering Dept, Assam Engineering college, Assam -781013

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Abstract - *Pollution and depletion of fossil fuels have forced us to use more and more renewable energy. Solar energy is the best form of renewable energy but the problem associated with this is the intermittent nature. The solar energy can also be stored by using latent heat thermal storage (LHTS) that uses a phase change material (PCM). But the main disadvantages of PCMs are its low conductivity, which may be increased by incorporating fins. In this paper proper fin length and proper fin positions are determined inside a horizontal tube filled with PCM to enhance heat transfer.*

Keywords: *LHTS; PCM; Fins*

I. INTRODUCTION

In the recent years, due to increasing concern over renewable energy, the study of thermal energy storage has gained serious momentum. Thermal Energy Storage can be classified as sensible heat thermal storage (STHS), latent heat thermal storage (LHTS) and thermo-chemical storage (TCS). Latent heat thermal storage is used mainly because of certain advantages over the other two such as high heat storage capacity, small unit size and isothermal behaviour during charging and discharging. LHTS system uses a phase change material (PCM), which changes its phase from solid to liquid or liquid to gas and thereby stores energy called as charging process. PCM that changes its state from solid to liquid is used widely because it consumes less space as compared to the one that changes from liquid to gas. PCM later releases energy by changing it state from liquid to solid called as discharging process. Investigations of latent heat thermal storage system have been subject of extensive research, due to more and more use of solar energy. A large number of researches have been carried out in charging and discharging process of PCM experimentally or numerically. A number of researches have been carried out to enhance heat transfer in PCM. The motivation of the present study is to facilitate a comparative study in heat transfer enhancement technique in PCM by using different shape and location of fin. Bellah has done thermal conductivity enhancement in a latent heat storage system. They have carried out experiments to investigate a method of enhancing the thermal conductivity of paraffin wax by embedding aluminium powder in it where charging time is reduced by 60%. The useful heat gain is also increased. Bellan has done a numerical investigation of PCM-based thermal energy storage system. They have found that, heat transfer rate is increased and charging/discharging time is decreased when the capsule size is decreased and the HTF flow rate is decreased. Reddy has studied, thermal modelling of PCM-based solar integrated collector storage water heating system. He has done experiments with 4, 9, and 19 fins inside the wax having a pitch of 20 cm, 10 cm, and 5 cm, respectively. The configuration with 9 fins gives the optimum design and reaches the maximum water temperature. The temperature drop at night time is approximately 1.5-2 ^{0}C. It eliminates the use of a separate storage tank.

II. METHODOLOGY

ANSYS FLUENT 14.5 has been used to model the PCM inside a horizontal tube with and without fin, with more fins at bottom side and with more fins at upper side. The inner diameter of the tube is 38 mm and the outer diameter is 40 mm, the length of the fin used is 14 mm. The material of both tube and fins are copper. The PCM used is paraffin. The computational domain is shown in Fig. 1 and dimensions are shown in Fig. 2. The tube is exposed to a heat flux of 600 W/m^2, initially heat is only conducted through the tube and the solid PCM, so energy equation plays role. Then once the PCM melts convection dominates and continuity and momentum equations play role to get velocity field.

Continuity Equation: $$\nabla \cdot \vec{v} = 0 \quad (1)$$

Momentum Equation:

$$\rho \frac{\partial \vec{v}}{\partial t} + \rho\left(\vec{v} \cdot \nabla\right)\vec{v} = -\nabla P + \mu \nabla^2 \vec{v} + \rho \vec{g} \beta \left(T - T_0\right) \quad (2)$$

Energy Equation: $\rho c_p\left(\frac{\partial T}{\partial t}+\vec{v}\cdot\nabla T\right)=\nabla\left(k\nabla T\right)$ (3)

(a) (b) (c)

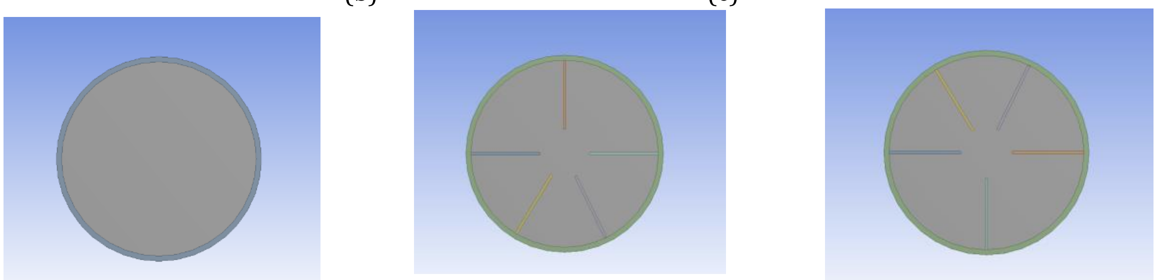

Fig.1 Computational domain of (a) without fin, (b) with more fins at bottom, (c) with more fins at top

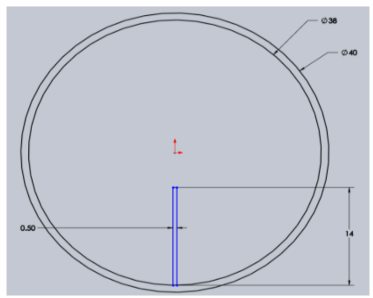

Fig.2 Schematic diagram of a PCM filled tube with a typical rectangular fin. (All dimensions are in mm)

III. RESULTS AND DISCUSSION

Simulations have been performed in ANSYS for PCM with and without fin. Various contours of melting fraction temperature have been shown in Fig. 3 and Fig. 4. It is evident from figures that melting rate is more uniform and higher if the numbers of fins are increased.

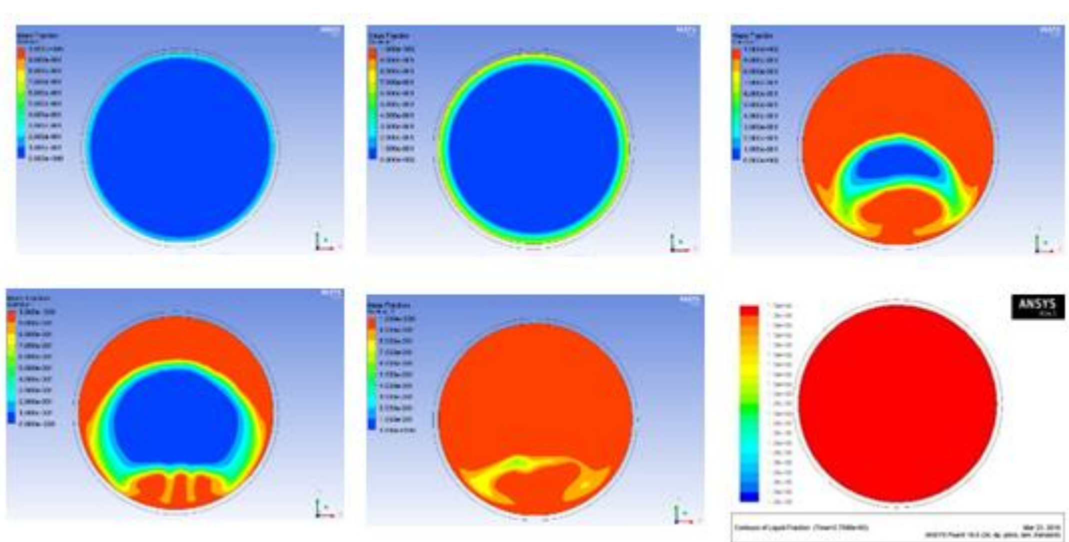

Fig. 3 Melting fraction contours of PCM without fin configuration at various intermediate stages till the end of melting.

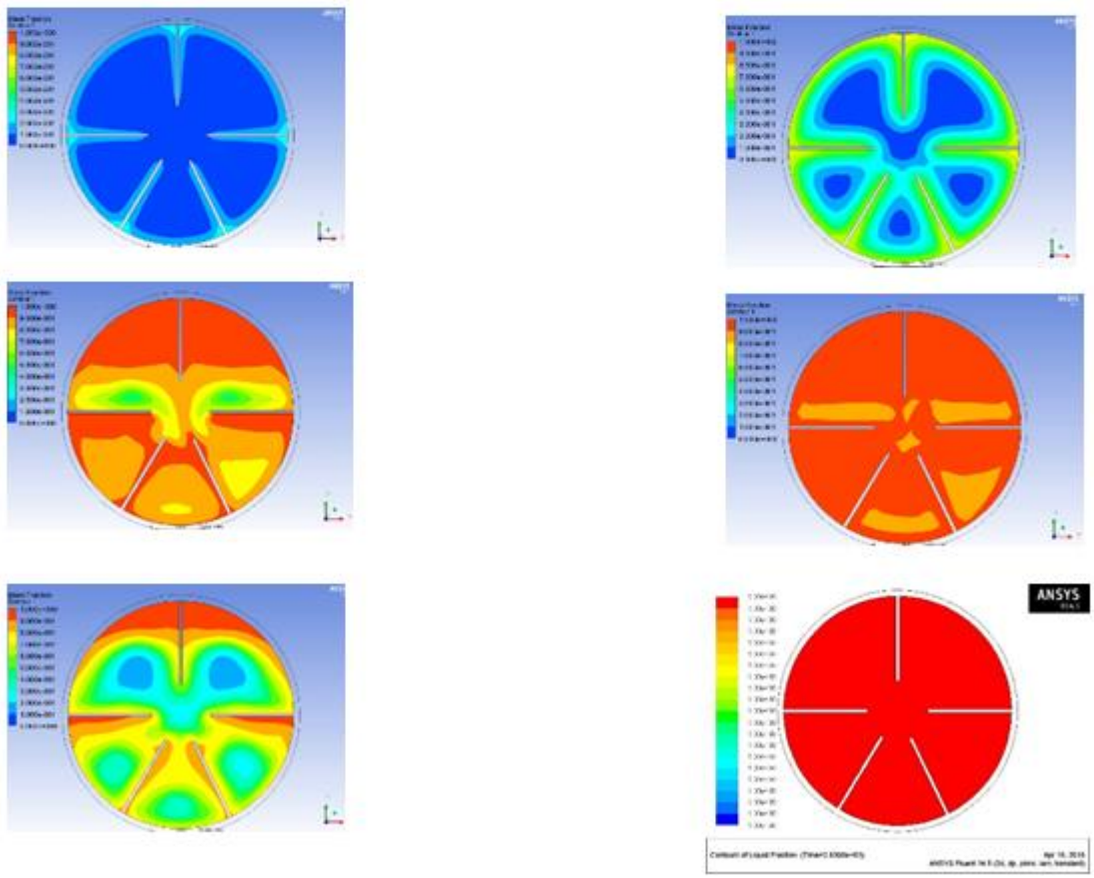

Fig. 4 Melting fraction contours of PCM with fins configuration at various intermediate stages till the end of melting.

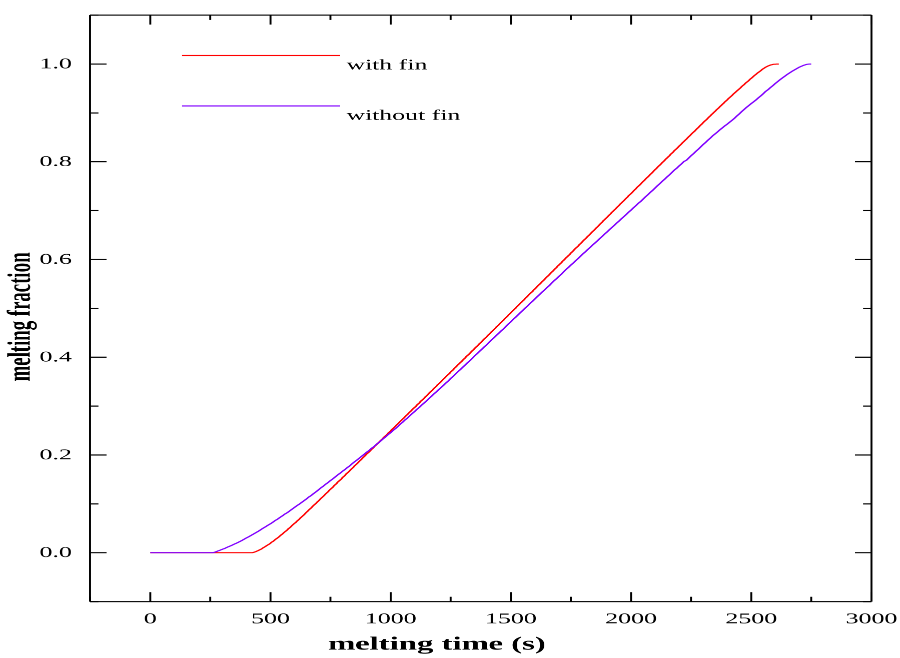

Fig. 5 Graph of melting time v/s melting fraction with and without fin.

Fig. 5 shows the graph of melting fraction v/s melting time It is clearly visible from the graph that, melting starts more quickly for the PCM without fin but it takes more time to melt completely than the PCM with fin. At near 1000 second the melting fraction for both the cases are equal, after that melting fraction of PCM with fin is more at every point and complete melting is achieved at 2615 seconds. However, for PCM without fin the complete melting is achieved at 2750 seconds.

Various contours of melting fraction temperature and velocity vector of PCM have been shown in Fig. 6 with more fins at upper side of tube. Fig. 7 shows the graph of melting fraction v/s melting time.

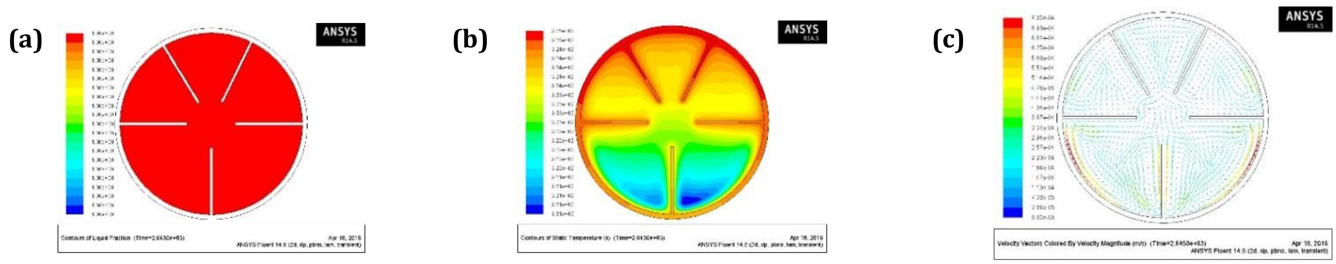

Fig. 6 Contours at the end of the melting of more fins at upper side (a) melting fraction, (b) static temperature, (c) velocity vector

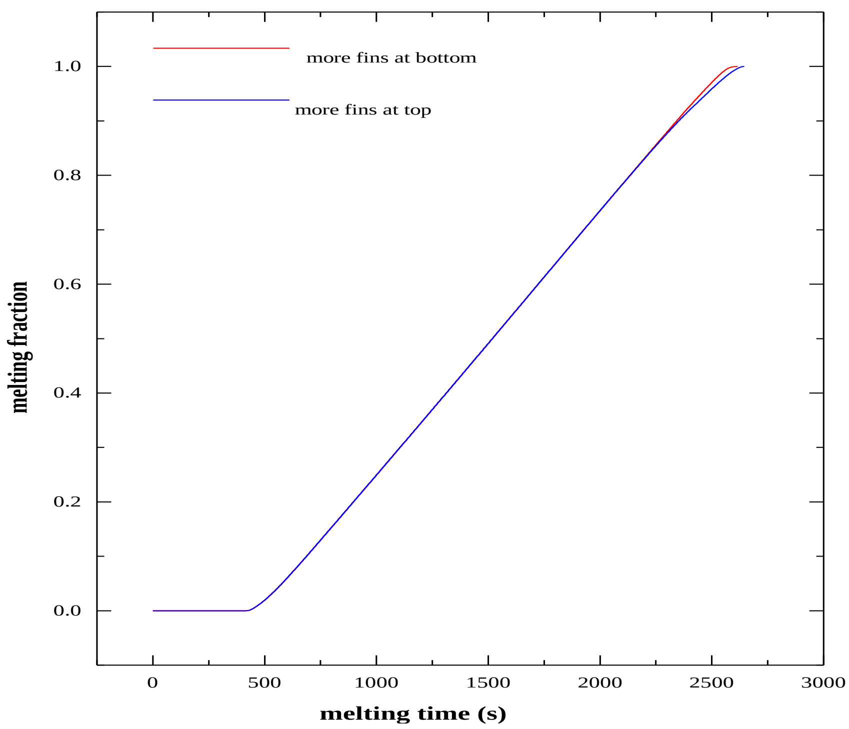

Fig. 7 Graph of melting time v/s melting fraction for fins more at bottom side and more at top side.

It is evident from the graph Fig. 7, that complete melting is achieved for fins more at bottom side at 2615 whereas for fins more at upper side complete melting is achieved at 2645 seconds. This is mainly because due to convective current heat transfer rate will be more at upper side because of lower density hot and molten PCM will try to occupy the upper part of the filled tube. So, by implementing more fins at bottom side heat transfer rate at bottom side is also increases. Hence, complete melting is achieved more quickly.

IV. CONCLUSION

Heat transfer enhancement in melting of PCM has been analyzed by incorporating fins. It has been observed that, with fins melting is achieved at 2615 seconds whereas without fins melting is achieved 2750 seconds. The melting time is reduced by 135 seconds. Fins at different locations have been placed and analyzed. During this analysis volume of fin material has been kept same. It has been observed that, if more fins are placed at bottom side melting is achieved more quickly.

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