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DESIGN AND FABRICATION OF HOT WATER TANK USING PHASE CHANGE MATERIAL WITH ANSYS MODEL

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ABSTRACT

The use of a latent heat storage system using phase change materials (PCMs) is an effective way of storing thermal energy. In this paper a latent heat storage box is designed and developed. The study focus on design and fabrication of hot water tank, the results are obtained by experimentally carrying out the charging and discharging process at different mass flow rates. Coconut oil has been used as the phase change material because of its availability in the market and low cost. This type of thermal energy storage system has a good potential of storing latent heat and can be used in solar water heating application. Performance analyses have done with ANSYS software.

Key words: Phase change materials, Storage tank, Heat transfer fluids.

INTRODUCTION

The continuous increase in the level of green house gas emissions and the increase in fuel prices are the main driving forces behind efforts to more effectively utilize various sources of renewable energy. In many parts of the world, direct solar radiation is considered to be one of the most prospective sources of energy. The scientists all over the world are in search of new and renewable energy sources. A variety of thermal energy storage techniques have been developed over past 4 to 5 decades. For the country like India where 70% of its population lives in rural areas and the average electricity supply is approx 3 to 4 hours, so there is need to develop the alternative method to store the energy. By considering these, we are going to design and fabricate the thermal storage tank using PCM material .the present work is to design and fabricate the hot water tank using PCM. Coconut oil is used as a PCM. PCM materials and their performance of charging and discharging of storage tank were tested experimentally.

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EXPERIMENTAL

Literature review

Thermal energy storage system allows excess thermal energy to be collected for later use, hours days at various place depending on the specific technology. Various methods have been proposed to enhance the efficiency of system. Jesumathy s.pet (2012)[1], designed an energy storage system to study the heat transfer characteristics of paraffin wax during melting and solidification processes in a vertical energy storage system. In the experimental study some of the issues are focused. The first issue is temperature distribution in PCM during charging and discharging processes and other issue is thermal characteristics of paraffin wax. Efterkhar et al.[2] have experimentally studied a different heat transfer enhancement method for melting of paraffin by constructing a model that consists of vertically arranged fins between two isothermal planes which not only provides additional conduction paths but also promotes natural convection with the molten PCM. Chen and Yue[3] developed an ID porous medium model to determine the thermal characteristics of ice-water cool storage in packed capsules for air conditioning. Comparisons of this theory with experimental data of temperature profiles of PCM (water) and coolant (alcohol) for various porosities flow rates and different inlet coolant temperatures showed good agreements. Lacroix has presented a theoretical model for predicting the transient behavior of a shell and tube storage test in which annular fins externally fixed in the inner tube with the PCM on the shell side and the HTF flowing inside the tube. The numerical results have also been validated with experimental data for various parameters like shell radius, mass flow rate inlet temperature of the HTF. R. Meenakshi Reddy, N. Nallusamy (2012)[4]. In the present experiment, investigations are carried out in the TES system for different phase change materials by varying flow rates and varying the diameter of PCM capsule. The results show that the 38mm diameter spherical capsule shows better performance compared to spherical capsules of other size. Oluwaseun S. Alajo, Victor C. Ibekwe, Emmanuel C. Nsofor (2013)[5], Solar energy storage system based on a vegetable, non-toxic, non-flammable, renewable and biodegradable phase change material (PCM) was developed. Various data were collected on heat absorbing capacity in various seasons. The objective of present work is to enhance the performance of heat storage tank. Spiral Copper tube is used, Copper tube is filled with water and it is surrounded by PCM .Reflector is used to heat the water initially with the help of sun light. Kanimozhi B. et al. (2012)[8] from experimental setup it has found out that the Mass flow rate has a significant effect of temperature difference between them. The experimental results that the enhancement technique were implemented through the numbers of copper tube in the fabricated storage tank, the smaller diameter of copper tubes could effectively enhance the heat transfer rate It is also reported that the rate of heat recovery is large at the beginning of the discharging process.

Hot water tank and copper tube specifications

Hot water tank consists of copper tube and PCM. Tank is divided into two parts. First part contains cold water and attached with inlet and second part contain spiral copper tube surrounded by PCMm .copper tube is filled with water. Capacity of tank is 10 liter. Total length of copper tube is1.2 meter with 10 mm inner and 13.6 mm outer diameter as shown in Fig. 1.

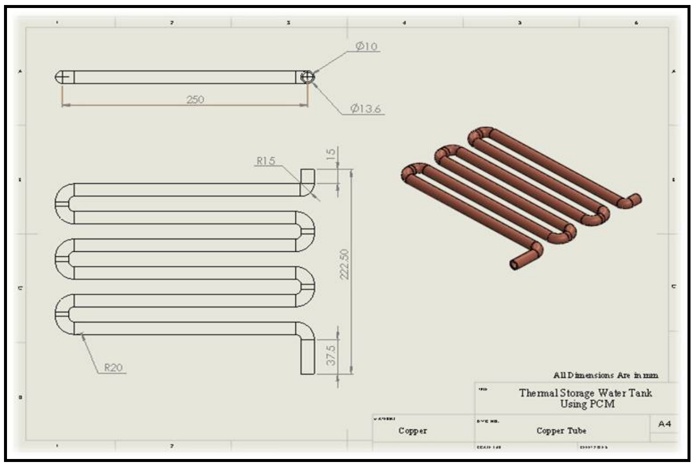

Fig. 1: Copper tube specification

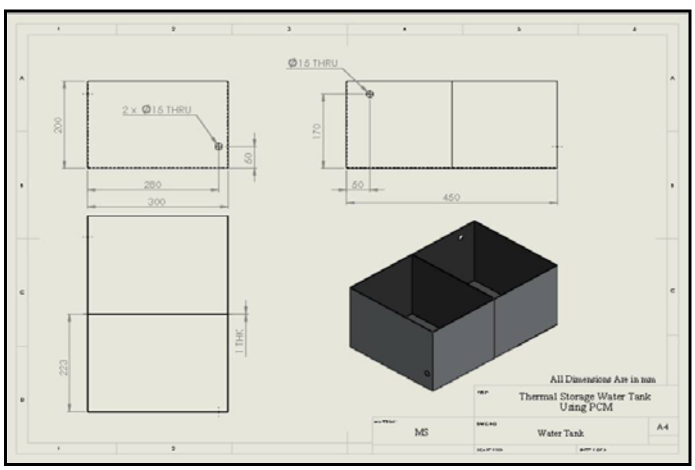

Fig. 2: Storage tank specification

Fig. 3: Outer casing of water tank

Water tank is designed as the insulated tank is fabricated .it consists of outer and inner casing as shown in Fig. 2 and Fig. 3. Insulation is done with the help of thermocol. The storage tank accurately considered as adiabatic no heat transfer.

Phase changing materials

Coconut oil is used as PCM material. Coconut oil or Copra oil is edible oil extracted from the kernel or meat of matured coconuts harvested from the coconut palm (*Cocoas nucifera*). It has various applications in food, medicine, and industry. Because of its high saturated fat content it is slow to oxidize and, thus, resistant to acidification, lasting up to two years without spoiling. Coconut oil is colorless at or above 30°C. It is white when in its solid form. Density of coconut oil is 924.27 Kg/m^3.Melting point of coconut oil is 26°C.

Experimental procedure

The experimental set-up consists of single insulated storage tank which is divided into two chamber; the first one is a cold water tank with a capacity of 8 liters. The second one is PCM storage tank with a capacity of 6.2liters, and it also consist of spiral copper tube which is surrounded by PCM, the tank was instrumented to measure the inlet and outlet water temperatures with a thermocouple arrangement.

Flow meters were fit at outlet of storage tank through pipe line to vary the flow rates. Here, water is used as the Heat transfer fluid and coconut oil are used as phase change material. The temperature variation of the HTF in storage tank is measured using thermocouple. First, cold water is passed through inlet valve to the first chamber. Initially water will get heated by solar energy with the help of reflector. Outlet valve will remain close till water gets heated up to required temperature as shown in Fig.4 Now hot water is passed though copper tube in second chamber. During charging process, PCM will absorb heat from hot water present in copper tube. In the absence of sun light, when cold water is passe**d** though Cu tube then PCM will release heat to cold water. So, we can get hot water through out. Temperature of HTF and PCM is noted at every 20 minutes at different flow rate. The same procedure is repeated for different mass flow rates.

Fig. 4: Experimental setup

RESULTS AND DISCUSSION

The temperature distribution of PCM during charging and discharging was taken at different mass flow rate. For each mass flow rate, curve was plotted for variation of temperature at each point**.**

Case 1: PCM Temperature Vs time (Charging process)

In this case, the mass flow rate of heat transfer fluid was taken as 2 kg/min. Fig. 5 shows the temperature variation of PCM during charging process. Initially, temperature of PCM is 20 to 22^{o}C. As the temperature reaches at 25^{o}C, then PCM will melt. With the help of reflector, temperature of PCM will increase.

Case 2: Heat transfer fluid (water temperature) Vs time (Discharging process)

In this case, temperature variation of discharging process has shown in Fig. 6. During the night time, when cold water is passed through the copper tube then PCM will release heat to the cold water. The heat has been retrieved from the PCM with respect time and temperature variation.

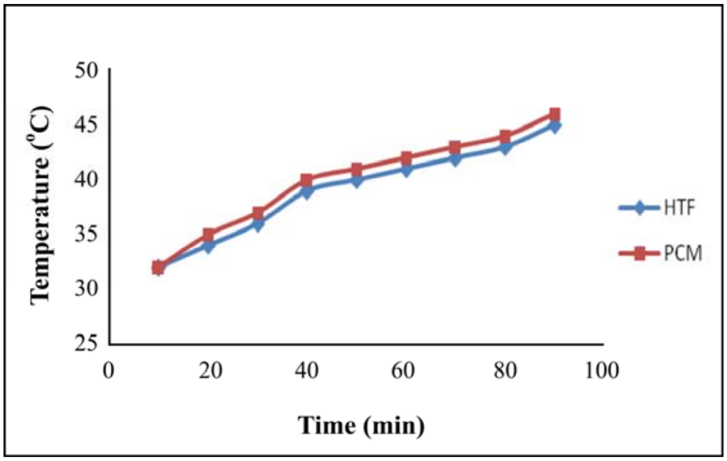

Fig. 5: Charging process

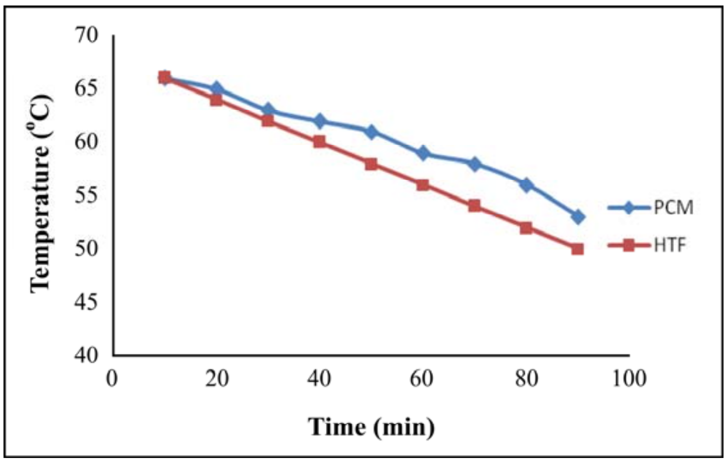

Fig. 6: Discharging process

Case 3: Heat absorbed by PCM

Heat absorbed by PCM (coconut oil) is calculated using the formula. Heat absorbed by PCM = sensible heat of PCM (solid medium)+latent heat of PCM (liquid medium)+ sensible heat of PCM (liquid medium)

It is absorbed from Fig. 7 that heat absorbed by the coconut oil is combination of sensible heat and latent heat. First PCM melts at 26^{o}C (melting temperature). It changes phase from solid to liquid medium. It starts to store the heat in liquid medium. Initially, it store the sensible heat in solid medium and after melting it store in liquid medium.

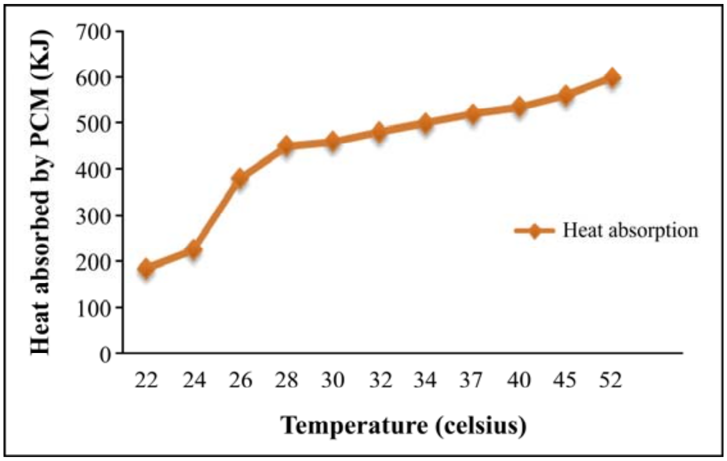

Fig. 7: Heat absorption

Thermal analysis using ANSYS

Meshing of storage box

Mesh generation is one of the most critical aspects of engineering simulation. ANSYS meshing technology provides a means to balance the requirement and obtain the right mesh for each simulation in the most automated way possible. Fig. 8 shows the meshing of storage tank. Meshing ensure that best design is made. It checks the defect of the model. It also checks whether there is any miss alignment in the design. By integrating best in class meshing technology into a simulation driven workflow, ANSYS meshing provides a next generation meshing solution through a wide variety of methods

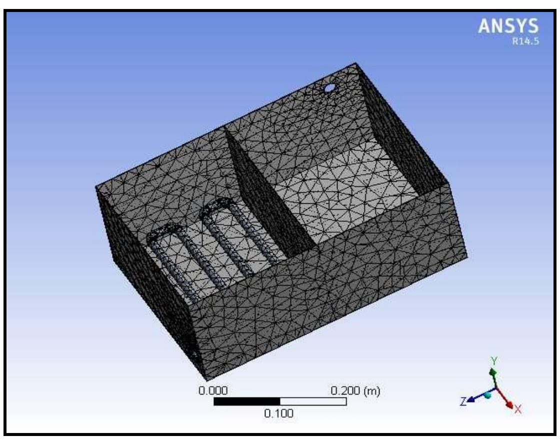

Fig. 8: Meshing of storage tank

Steady state thermal analysis

A steady-state thermal analysis calculates the effects of Steady thermal loads on a system or component. Steady-state thermal analysis to determine temperatures, thermal gradients, heat flow rates, and heat fluxes in an object that are caused by thermal loads that do not vary over time, Red color of tube shows the maximum temperature of water inside the copper tube as shown in Fig. 9.

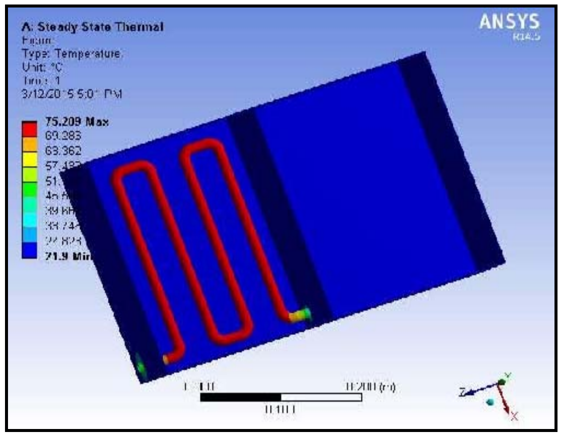

Fig. 9: Model of storage tank with copper tube

CONCLUSION

A thermal energy storage system has been developed for the use of hot water at an average temperature of 60ºC, for domestic applications using combined sensible and latent heat storage concept. Mass flow rate has a significant effect of temperature difference between them. Design analysis gave good results in the ANSYS modeling. Also it represents 16% reduction in heating time. The investigation has revealed that hot water can be increased by using PCM arrangement with the help of copper tube in the tank. Storing of hot water system plays an important role in sustainable energy management in Indian households as well as worldwide.

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