

Investigation of Sensible and Latent Heat Storage System using various HTF

N Beemkumar^{*}, A Karthikeyan, A Manoj, J S Keerthan, Joseph Paul Stallan, Amithkishore P

School of Mechanical Engineering, Sathyabama University, Chennai, India

E-mail: beem4u@gmail.com

Abstract. The objective of the work is investigating the latent heat storage system by varying heat transfer fluid (HTF). In this experiment, the effect of using different heat transfer fluids on the combined system is studied while using a low melting phase change material (PCM) i.e., paraffin wax. The heat transfer fluids chosen are water (low boiling fluid) and Therminol-66 (High boiling fluid). A comparison is made between the heat transfers by employing both the Heat transfer fluids. In the beginning, water is made to flow as the HTF and the charging process is undertaken followed by the discharging process by utilizing the different encapsulation materials namely, copper, aluminium and brass. These processes are then repeated for therminol-66 as HTF. At the end of the experiment it was concluded that even though therminol-66 enhances the latent heat storage capacity, water offers a higher sensible heat storage capacity, making it a better HTF for low melting PCM. Similar to above said process the experiments can be conducted for high and medium range melting point PCM with variation of HTF.

1. Introduction

Energy is widely available in various forms. It is also used for various activities throughout the world. It can be converted from one form of energy to another, but it cannot be created nor destroyed according to the first law of thermodynamics. However, this energy may also get converted into some waste energy, mostly in the form of heat. This leads to some energy losses and reduction in the efficiency of energy systems. Harnessing energy when supply is limited has led to researchers conducting detailed studies with this regard. One method to overcome this problem is to store the energy when there is excess supply and use it when supply is restricted. In this paper, two heat storage units are used [1]. The first one is the heat transfer fluid that stores energy as sensible heat. The second unit is the paraffin wax which is used as PCM. It stores the energy as sensible and latent heat. The advantages of using paraffin as PCM are its high storage density, low weight, a low melting point as compared to other PCM. The PCM along with a HTF can be used as a combined sensible and latent heat system. A combined sensible and latent heat storage system overcomes the drawbacks of using either one of them separately [2]. These drawbacks include low heat transfer and low efficiency of these storage systems. Different materials have different thermal conductivities and so appropriate materials should be chosen depending on the various applications [3]. Certain methods and techniques that can also be used to increase the amount of heat stored and recovered, thus increasing the overall efficiency of the heat storage systems [4]. The study into the usage of molten salts started in the early 1980's [5]. Scientists then attributed the energy storage to applications in heating and cooling



spaces [6]. Low melting molten salts were of particular interest as a large number of fluids can be used for the heat transfer [7]. Techniques to improve the rate of heat transfer between storage systems were also studied [8]. The storage unit uses encapsulations of various materials like copper, aluminium and brass etc. This is done to increase the heat transfer between the HTF and PCM, thus increasing heat energy stored. A comparative study is carried out between water and therminol-66 as HTF. Their effect on the amount of heat stored and recovered while using a low temperature PCM is analyzed. A final comparative study of the performance of heat transfer is done for all three encapsulating material copper, brass and aluminium and the most effective encapsulation is identified.

The main purpose of encapsulation is containing the PCM, when it changes from solid state to liquid state and vice- versa. Also, it is used to increase the rate of heat storage and recovery by the use of metals of high conductivity (aluminium, brass, copper). However, one drawback of using PCM is its low sensible heat capacity which is relatively low. This disadvantage is overcome by its excellent latent heat storage capacity, which is relatively larger.

2. Experimental Setup and Methodology

The set up consists of two thermal storage tanks, a heater and a circulating pump showed in figure 1. The storage tank consists of both, the PCM and the Heat Transfer fluid. Each cylindrical tank has a Diameter of 256 mm and 300 mm length. The storage tank is well insulated using glass wool of 0.10 m thickness and pipe lines are also insulated with same material. A total quantity of 55 L of water or therminol-66 is charged in the storage tank and the piping circuit, and it is ensured that there is no leak in the oil flow path. An additional tank is also fabricated to house the heaters which will be used to provide the required heat energy. Valves are present at regular intervals to control the amount of HTF flow. This is used to reduce build up of high pressure in the circuit, which could be dangerous.

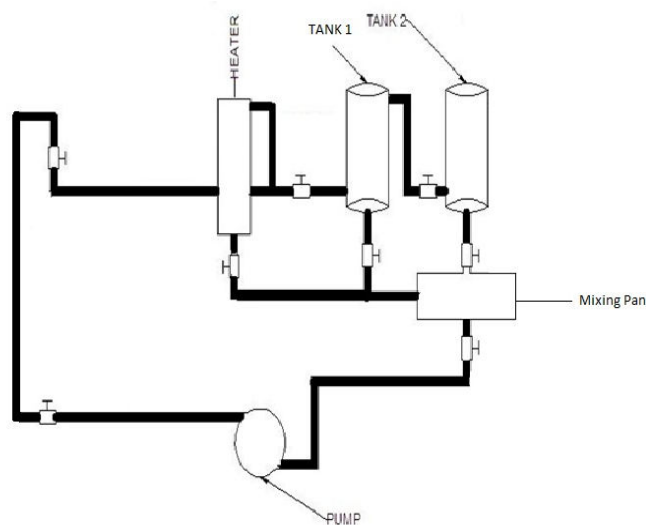


Figure 1. Experimental layout.

The selection of PCM depends on the required temperature range. The PCM chosen here is paraffin wax, due to its stability and low melting point ($50 - 60^{\circ}\text{C}$) that enables to use either water or therminol-66 as HTF. A gear pump maintains the HTF flow in the circuit, through the heater and storage tanks during charging process in which the heated oil transfers heat to the PCM. The PCM is encapsulated in spherical balls of copper, aluminium and brass. The copper, aluminium and brass encapsulating materials are used in this study and the experimentation was done by changing different encapsulating material. The heater is switched on along with the pump. The temperature of HTF in all the tanks and the PCM are noted after regular intervals of 10 minutes. This is the charging process. After attaining a temperature of about 85°C , the heater is switched off. Keeping the flow rate on, the above process is repeated. This is the discharging process. Hence heat is subsequently stored and

recovered in these processes. The above processes are conducted for all the three type of encapsulations using water as HTF initially and then using therminol-66. The observations are noted down.

3. Results and Discussion

The results obtained from the heat transfer characteristics of the combined heat storage system using paraffin as PCM, water and therminol-66 as HTF during charging and discharging process with different encapsulation materials (i.e., copper, brass and aluminium) are discussed in detail.

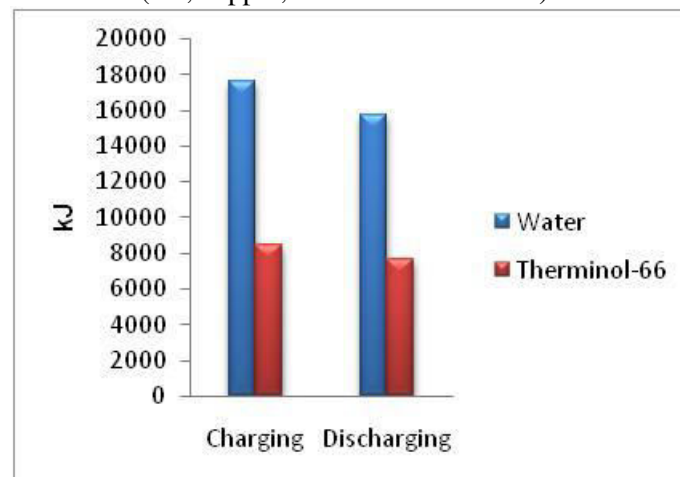


Figure 2. Charging and discharging for copper encapsulation.

Figure 2 represents the charging and discharging rates of the combined storage system while using both water and therminol-66 for copper encapsulation. A comparison is made between a high temperature heat transfer fluid (therminol-66) and a low temperature heat transfer fluid (water). It can be interpreted that the total heat stored while using water is around 18000 kJ which is almost double to that while using therminol-66 (8200 kJ). The total energy is inclusive of the sensible and latent heat energy. While discharging, the heat energy recovered is higher, while using water (17500kJ) as compared to therminol-66 (7050 kJ). Heat losses of about 50-1000 kJ are observed.

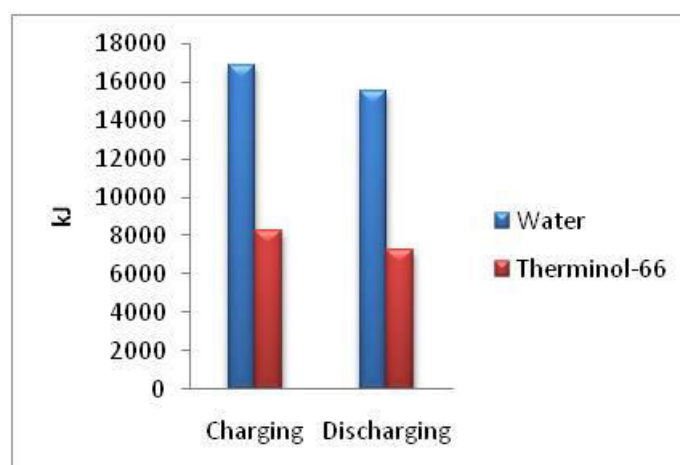


Figure 3. Charging and discharging for Aluminium encapsulation.

Figure 3 depicts the charging and discharging rates of the combined storage system while using both water and therminol-66 for aluminium encapsulation. Similar to the case for copper encapsulation, the

heat stored for aluminium encapsulation is more while using water i.e., around 17000 kJ, in contrast to the heat stored using therminol-66, which is about 8050 kJ. During discharging also, water helps recover more heat (15500 kJ) as compared to therminol-66 (6100 kJ). This is due to the higher specific heat capacity of water.

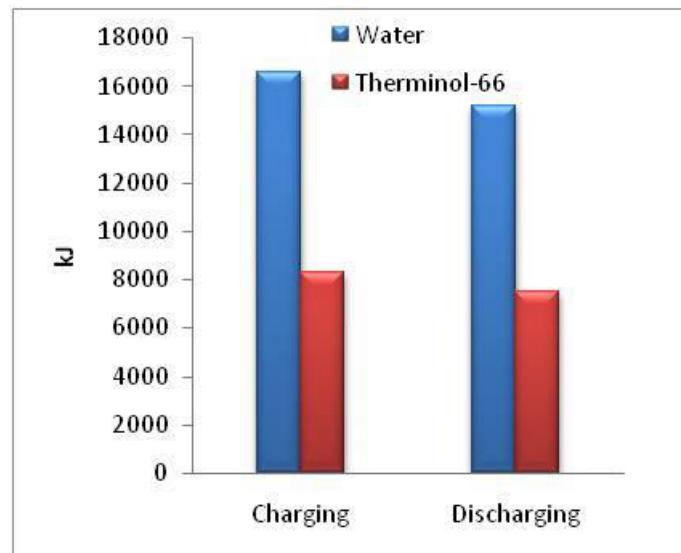


Figure 4. Charging and discharging for brass encapsulation.

For brass encapsulation from figure 4, the heat energy stored is 16565 kJ while using water while with therminol-66, it is around 8000 kJ. A similar trend is observed during discharging. The heat recovered from water (15000 kJ) is almost double of that recovered from therminol-66 (7800 kJ). This is also due to the high specific heat capacity of water and a relatively low heat capacity for therminol-66.

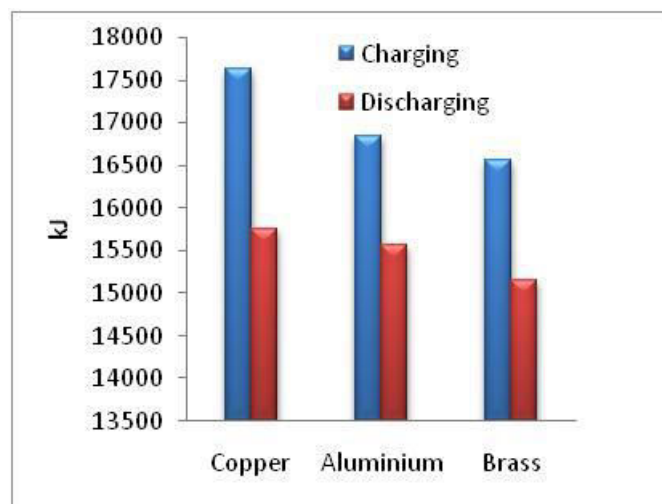


Figure 5. Comparison between different encapsulations while using water as HTF.

A comparison of the heat stored and recovered in Copper, Aluminium and Brass encapsulations while using water as HTF is shown in figure 5. From the figure, it can be easily interpreted that copper stores the most heat energy while brass stores the least. The same is observed during heat recovery. But at the same time, the heat loss (difference between heat stored and recovered) is the highest in copper encapsulation, then in aluminium encapsulation and it is the least in brass encapsulation. This can be

attributed to the high thermal conductivity of copper and a relatively low thermal conductivity for brass.

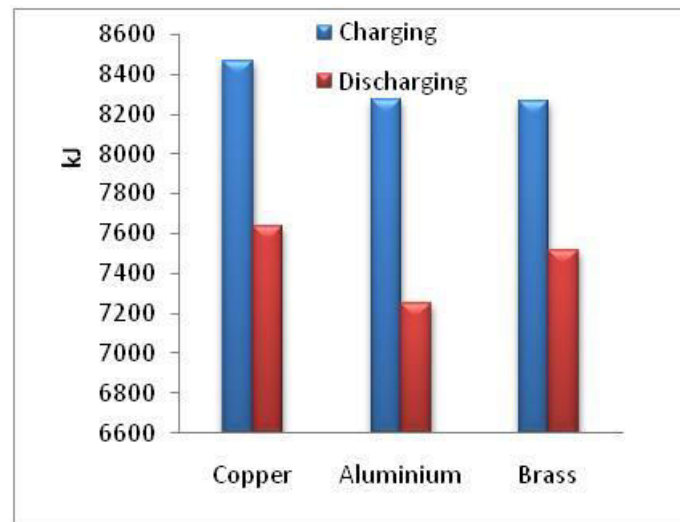


Figure 6. Comparison between different encapsulations while using therminol-66 as HTF.

Figure 6 shows a comparison between copper, brass and aluminium encapsulations while using therminol-66 as HTF. The heat stored and recovered are much lower than that while employing water. From the comparison it can be understood again that copper is the most effective. But its high thermal conductivity leads to an increase in heat losses. The cost effectiveness is also to be considered.

4. Conclusion

The heat transfer in the combined solar thermal energy storage system was studied and analyzed. A comparative study was made between a high temperature HTF and a low temperature HTF. Their effect on a low melting PCM like paraffin was analyzed. It can thus be concluded that water, when used as the HTF stores more energy (total energy) as compared to the case where therminol-66 is used. This is due to the high specific heat capacity of water. However, the application of water as HTF is limited due to its low melting point. While heating to very high temperatures, therminol-66 can store more energy due to its high melting point (around 350 – 400°C). A comparison was also made between the different encapsulations and it was found that copper encapsulation was the most efficient, storing and recovering more energy. However, its high thermal conductivity promotes larger heat losses. Its cost is also on the higher side. Thus, water is a better heat transfer fluid when used for low melting PCM and copper is a better material for encapsulation as it improves the heat transfer rate.

References

- [1] Ponshanmugakumar A, Sivashanmugam M and Stephen Jayakumar S 2014 Solar driven air conditioning system integrated with latent heat thermal energy storage *Indian Journal of Science and Technology* **7**(11) pp 1798–1804.
- [2] Nallusamy N, Sampath S and Velraj R 2007 Experimental investigation on a combined sensible and latent heat storage system integrated with constant/varying (solar) heat sources *Renewable Energy* **32** pp 1206–1277.
- [3] Vahid Agyenim Francis, Neil Hewitt, Philip Eames and Mervyn Smyth 2010 A review of materials, heat transfer and phase change problem formulation for latent heat thermal energy storage systems (LHTESS) *Renewable and Sustainable Energy Reviews* **14**(2) pp 615–628.

- [4] Auriemma M and Iazzetta A 2016 Numerical analysis of melting of paraffin wax with Al_2O_3 , ZnO and CuO nanoparticles in rectangular enclosure *Indian Journal of Science and Technology* **9**(3) DOI: 10.17485/ijst/2016/v9i4/72601.
- [5] Telkes M 1980 Thermal energy storage in salt hydrates *Solar Energy Materials* **2**(4) pp 381–93.
- [6] Sciacovelli A, Gagliardi F and Verda V 2015 Maximization of performance of a PCM latent heat storage system with innovative fins *Applied Energy* **137** pp 707–715.
- [7] Durgun E and Jeffrey C Grossman 2013 Photoswitchable molecular rings for solar-thermal energy storage *The Journal of Physical Chemistry Letters* **4** (6) pp 854-860.
- [8] Zalba B, Mann J M, Cabeza L F and Mehling H 2003 Review on thermal energy storage with phase change: materials, heat transfer analysis and applications *Applied Thermal Engineering* **23** pp 251-283.