Experimental Study of Thermal Energy Conservation by using PCM and its Composites

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Abstract— The system works on the basic concept of conservation of energy within the system. The heat energy taken for changes its (PCM) phase from solid to liquid from the hot water source. After long time this latent heat is utilized to maintain the temperature of the water for long time. Thermal energy storage performance of the composite PCM was tested in a latent thermal energy system. The thermal energy storage charging duration for the composite PCM was reduced obviously compared to paraffin. Here We need to find method to improve PCM of thermal properties by using graphite particles as heat transfer rate enhancers by store the heat energy while the hot fluid are flow. Depends on our results, it may be fulfilled that the equipped PCMs can be regarded of use heat storage materials for some purpose in energy storage system. It can be resulted that by adding graphite particles to improve thermal properties are improved in comparison with pure PCM.

Keywords: PCM, Thermal Energy Conservation, HTF, LTES

I. Introduction

The main aim of this project is to utilize the heat energy from the heat water carries from solar collector tube. There we introduce the high specific heat capacity with low thermal conductivity material like paraffin wax and the mixture of paraffin wax and graphite. Here we are going to study the behaviour of the pure paraffin and with graphite. Latent thermal energy storage (LTES) based on phase change material (PCM) as a storage medium is one of the most effective ways of energy storage, which can provide high energy storage densities and nearly isothermal operating characteristics. LTES has wide applications in many field, such as solar energy utilization, industrial waste heat recovering, and active and passive cooling of electronic devices. A significant amount of heat is wasted in manufacturing process, electricity generation, chemical and industrial process. Recovery and reuse of this energy through storage can be useful in conservation of energy. In the present study, a double pipe type heat exchanger has been designed and fabricated for low temperature industrial waste heat recovery using phase change material (PCM) paraffin wax (PW). Experiments were performed for two different mass flow rates and inlet temperature of heat transfer fluid (HTF) is maintained at constant in charging process. In order to recovery of heat during discharging process temperature of HTF is maintained at atmospheric temperature. The effect of mass flow rate on the performance of the system was studied. Calculations for amount of heat stored and released during charging (melting of PCM) and discharging (solidification of PCM) and heat discharging efficiency were also made. The experimental results show the feasibility of using PCM as storage media in heat recovery systems.

II. Literature review

1) Gagan Sharma, Mani Kanwar Singh, Satbir S. Sehgal , Harkirat Sandhu [1]Observed that Al_2O_3, CuO are taken as nano particles, are added to improve melting points, pour points are improved in comparison with pure PCM. Heat capacity of Nano-composite is decreases with increase in Nano particle concentration.
2) Chenzhen Liu,Xuan Zhang,Peizhao Lv,Yimin Li &Zhonghao Rao[2]Observed that to improve the thermal energy storage efficiency of PCM the following composites are added to the PCM in different mass fraction. The composites are expanded graphite (EG), multi-layer graphene Nano platelet (MGN), graphite powder (GP) and multi-walled carbon nanotube (MWCNT).
3) P K Mahto1, R Chaudhary, S Chowdhury, Md. Alham and S R Dutta[3]Observed that the latent heat storage system is suitable for solar based systems. Our system also solar energy based. Here the heat water (source) are taken from the solar collector.

III. Working principle

Our experiment works based on the principle of regenerative heat exchanger the only change in its medium of heat sink. There we use the insulation layer as the heat sink. Due to its high specific heat capacity the material can able to store the energy in the form of heat (latent heat of fusion) by changing its phase. The thermal energy storage characteristics of paraffin and paraffin/graphite composite PCM in a system were investigated, respectively. The setup mainly consisted of a vertical tube in shell heat exchanger system, a constant temperature water bath, a circulation pump and a data acquisition unit. Water as heat transfer fluid flowed in the tube (copper, outer diameter of 2 inch and wall thickness of 2mm). The tested PCMs were kept in the annular space between an inner tube and a concentrically placed outer shell The outer surface of the shell was thermally insulated to reduce heat loss. A detailed view of the test section with the location of the thermocouples (K-type) indicated. Thermocouples were used to measure the inlet/outlet water temperature inside tube and the temperature field in the PCM. All the thermocouples were calibrated before use, the accuracy was ±0.2 C. The thermal energy storage process was started by flowing the hot water through the tube, when all the temperature recordings in the PCM region present higher values than the melting temperature of the PCM. The inlet water temperature during thermal energy storage was controlled at 70°C. The flow rate of the water was kept constant.

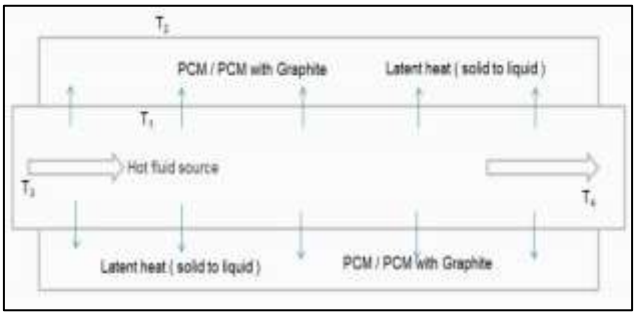

Fig. 1: Heat from water to PCM

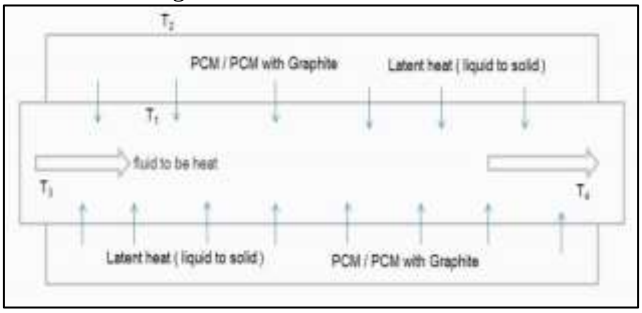

Fig. 2: Heat from PCM to water

Here, T_1 = the wall temperature of inner Cu tube
T_2 = the wall temperature of outer Cu tube
T_3 = the inlet temperature of water
T_4 = the outlet temperature of water

IV. Formulae for Calculation

$$Q_1 = m\,C_P\,\Delta t$$

Where, m = Mass flow rate
C_P = Specific heat capacity of water
= 4.186 joule/gram °C
Δt = Temperature difference
Q_1 = Heat energy by water

$$Q_2 = m\,L$$

Where, Q_2 = Heat energy while phase change
L = Latent heat capacity of Paraffin (PCM)
= 176 kJ/kg

$$Q_3 = \Delta t / R$$

Where, Q_3 = Heat energy transfer between wall
R = Resistance of the material
h = Heat transfer coefficient
A = surface area
k = Thermal conductivity
L = length of the pipe / cylinder
R, r = outer and inner radius of the cylinder

$$R_{cond} = \frac{\ln\frac{R}{r}}{2\pi Lk} \qquad R > r$$

$$R_{conv} = \frac{1}{hA}$$

V. Result

PHASE CHANGE : SOLID TO LIQUID	
MATERIAL : PCM	
	TEMPERATURE °C
T_1	85
T_2	35
T_3	90
T_4	82

Table 1: Condition: Passing Hot Fluid

PHASE CHANGE : SOLID TO LIQUID	
MATERIAL : PCM WITH GRAPHITE	
	TEMPERATURE °C
T_1	85
T_2	34
T_3	90
T_4	79

Table 2: Condition: Passing Hot Fluid

PHASE CHANGE : LIQUID TO SOLID	
MATERIAL : PCM	
	TEMPERATURE °C
T_1	30
T_2	32
T_3	31
T_4	40

Table 3: Condition: Passing Cold Fluid

PHASE CHANGE : LIQUID TO SOLID	
MATERIAL : PCM WITH GRAPHITE	
	TEMPERATURE °C
T_1	31
T_2	32
T_3	31
T_4	45

Table 4: Condition: Passing Cold Fluid

VI. Conclusion

By this experiment we can able to conclude that PCM with graphite have more heat storage capacity then pure PCM material. Their heat interactions are calculated.
For pure PCM we have
Q’ = 4.3005 x 4.18 x (31-40)
= 161.7857 kW
PCM with graphite we have
Q” =4.3005 x 4.18 x (31-45)
= 251.667 kW
As a conclusion we get a solution as Q” > Q’

Acknowledgment

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