ENHANCEMENT OF SOLAR THERMAL STORAGE SYSTEM USING PCM

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Abstract

This paper summaries the investigation and analysis of thermal energy storage extracted from solar heater and use for domestic purpose. Choosing a suitable phase change materials paraffin wax and sodium acetate try hydrate are used for storing thermal energy in two different insulation tanks. Each tank carries minimum of 15 liters capacity of water. These two different phase change materials are encapsulated in balls and planted in two tanks. Inside the tank phase change materials are receiving hot water from solar panel. This solar energy is stored in encapsulated balls as latent heat energy. Latent heat is absorbed and stored in encapsulated PCM balls. Large quantity of solar energy can be stored in a day time and same heat can be retrieved for later use. PCM are kept in encapsulated balls and planted in the insulation container. Temperature of the water is measured in a definite interval of time. The heat storage system is to be applied to store solar energy and the stored heat is used to domestic hot water supply system and comparison study also taken place between two different encapsulated balls.

Key words: Solar panel, thermal storage system, PCM encapsulated balls.

I. INTRODUCTION

Energy can be stored and retrieved as a change in internal energy of a material as sensible heat, latent heat and also in thermo - chemical reactions or combination of these. In case of sensible heat storage (SHS) Thermal energy is stored by raising the temperature of a solid or liquid. SHS system utilizes the heat capacity and the change in temperature of the material during the process of charging and discharging. The amount of stored thermal energy depends on the specific heat of the medium, the temperature change and the amount of storage material. Latent Heat Storage (LHS) is based on the heat absorption or release when a storage material undergoes a phase change from solid to liquid or liquid to gas or vice - versa. Also through certain chemical reactions some energy can be saved.

II. PHASE CHANGE MATERIALS (PCM) ENCAPSULATIONS

Phase Change Material is the latent heat storage material as the source temperature rises, the chemical bonds within the PCM break up and the material changes its phase from solid to liquid. During the charging process, the material begins to melt when the phase change temperature is reached. The temperature then stavs constant until the melting process is finished. The heat stored during the phase change process (melting process) of the material is called Latent Heat. It takes isothermal behaviors during charging and discharge process. Here PCM materials is used as paraffin (Wax), latent heat storage can be achieved through solid-solid, solid-liquid, solid-gas and liquid-gas phase change. However, the only phase change used for PCMs is the solid-liquid change. Liquid-gas phase changes are not practical for use as thermal storage due to the large volumes or high pressures required to store the materials when in their gas phase. Liquid-gas transitions do have a higher heat of transformation than solid-liquid transitions. Solid-solid phase changes are typically very slow and have a rather low heat of transformation. Initially, the solid-liquid PCMs behave like sensible heat storage (SHS) materials; their temperature rises as they absorb heat. Unlike conventional SHS, however, when PCMs reach the temperature at which they change phase (their melting temperature) they absorb large amounts of heat at an

Kanimozhi et al: Enhancement of Solar Thermal ...

almost constant temperature. The PCM continues to absorb heat without a significant raise in temperature until all the material is transformed to the liquid phase. When the ambient temperature around a liquid material falls, the PCM solidifies, releasing its stored latent heat. A large number of PCMs are available in any required temperature range from -5° C up to 190°C. Within the human comfort range of 20° to 30°C, some PCMs are very effective. They store 5 to 14 times more heat per unit volume than conventional storage materials such as water, masonry, or rock.

III. DEVELOPMENT OF ENCAPSULATED PCM

There are two phase change materials paraffin and sodium acetate tri hydrate perform best in small containers they are in the shape of spherical. Such kind of shape is convenient for volumetric expansion while melting of PCM. The packaging material should conduct heat well; and it should be durable enough to withstand frequent changes in the storage material's volume as phase changes occur. It should also restrict the passage of water through the walls, so the materials will not dry out (or water-out, if the material is hygroscopic). Packaging must also resist leakage and corrosion. Common packaging materials showing chemical compatibility with room temperature PCMs include stainless steel, polypropylene and polyolefin. The following Fig - 1 shows description of polypropylene cum storage tank.

3.1 Description of Polypropylene

- The outer diameter of spherical capsule is 60 mm and it is made of high-density polyethylene (HDPE) with a wall thickness of 0.8 mm.
- (ii) The total number of capsules in each thermal energy storage tank is 20.
- (iii) The spherical capsules are uniformly packed in two layers and each layer is supported by wire mesh.
- (iv) The melting point of HDPE is 266°F or 130°C or in a range of 108 – 134°C.
- (v) Thermal conductivity of HDPE capsules = 0.46 0.52 w/m.k.
- (vi) Heat transfer coefficient of HDPE capsules $= 0.5 \text{ w/m}^{\circ}\text{C}.$
 - Fig 1 Encapsulated Spherical balls with PCM

3.2 Specification of Different PCM

The following table shows the Thermo physical



Properties of different PCM materials

Table 1 Thermo physical Properties paraffin and sodium acetate tri hydrate

Properties	paraffin	Sodium acetate tri hydrate
Chemical formula	C_nH_{2n+2}	CH ₃ COONa●3H ₂ O
Melting point	55°C – 62°C	58°C
Melting enthalpy	210 kJ/kg	180 - 200 kJ/kg
Density	1,4 kg/L	1, 35-1, 4 kg/L
Heat capacity	3,5 kJ/kg.K	2,5 kJ/kg.K
Thermal conductivity	3-5 W/m.K.	2-5 W/m.K.

Table 2 Thermo physical Properties of other PCM

PCM	Lauric Acid	Capric Acid
Chemical Formula	C ₁₂ H ₂₄ O ₂	C ₁₀ H ₂₀ O ₂
Molecular Weight (g/mol)	200	172
Melting Point (°C)	43-45	29-32
Latent Heat (kJ/kg)	178	153
ThermalConductivity (W/m∙K)	0.147 (50° <i>C</i>)	0.153 (38°C)

IV. EXPERIMENTAL SETUP

The experimental set-up of these two tank having dimensions of 15 litres capacity with height of 30 cm and 25 cm diameter tanks connected to solar collectors. Two kinds of PCM balls were introduced in

the two tanks and the performance of the system was tested. The tank was instrumented to measure inlet and outlet water temperature. The differences of temperature with respect to time have been noted then calculating heat transfer rate and system effectiveness with required formula. for later use hot water is drained and cold water is supplied to PCM tank these cold water absorb heat from the PCM and releasing hot water continuously. The experimental work consisted on introducing the module containing melted PCM at 60°C into the cold water tank to evaluate the heat transfer phenomenon. The experiment was stopped when PCM and water temperatures were the same.



Fig 3 Schematic diagram of experimental set-up

- 4.1 Description of solar panel
- (i) Length of the solar plate = 1.5 m (150 cm)
- (ii) Breadth of the solar plate = 1 m (100 cm)
- (iii) Height of the solar plate = 8 cm
- (iv) Gap between the tubes = 17 cm if 5 tubes are used.
- (v) Gap between the tubes = 14.5 cm if 6 tubes are used.
- (vi) Diameter of Aluminum pipes = 3 cm.
- 4.2 Formulas and Calculations

Diameter of the capsule = 60 mm

Now, Volume = $4/3 \pi r^3$

$$= 4/3 \times \pi \times (0.03)^3 = 1.1304 \times 10^{-4} \text{ m}^3$$

We are filling 80%, so 80% volume = $1.1304 \times 10^{-4} \times 0.80 \ m^3 = 9.0432 \ tiems 10^{-5} \ m^3$

Now, mass of paraffin wax in 1 capsule = volume

 \times density (density of paraffin = 900 kg/m³)

 $= 9.0432 \times 10^{-5} \times 900 \text{ kg} = 0.0814 \text{ kg}$

So the mass of paraffin wax in 20 capsules $= (20 \times 0.0814) \text{ kg} = 1.63 \text{ kg}$

Mass of sodium acetate trihydrate = volume \times density (density of paraffin = 1450 kg/m³)

= 0.13113 kg

So the mass of sodium acetate tri hydrate 20 capsules = 2.63 kg

Heat transfer rate

$$Q = m \times C_p \left(T_2 - T_1 \right)$$

Cp - specific heat of water at constant pressure = 4.184Kj/kg.k

$$Q = 15 \times 4.184 \times 32 = 2008.32$$
 Kj

HeattransferCo-efficient

$$U = Q/A \times (T_2 - T_1) \text{ W/m}^{2\circ}\text{C}$$

 $U = Q[(\pi \times D \times L) (T_2 - T_1)]$

D - Diameter of container

L = Length of the pipe

Effectiveness of system = It is ratio of actual heat transfer to maximum possible heat transfer

E = Actual heat transfer/ maximum possible heat transfer







Graph - 2 Effectiveness Curve

V. DISCUSSIONS

Once the experimental work was done, heat transfer and effectiveness by natural convection for this specific geometry could be calculated. in which the graph shows both paraffin and sodium acetate hydrate are having equal values very minute variation no great difference between the materials the experimental results showed for both materials like paraffin and sodium acetate tri hydrate an increase in the heat transfer rate when using PCM modules with cool down the PCM from 60°C to 45°C when pouring the cold water after drained the hot water (which assures a complete solidification of the PCM). Hence Efficient and reliable thermal storage systems are an important requirement for many applications due to non-coinciding heat demand and supply or availability. One of the typical examples of such mismatch is solar energy. Among the thermal energy storage concepts, latent heat thermal storage is regarded as a promising technology.

A Phase Change Material (PCM) is any material used for latent heat thermal storage. Their use in Domestic Hot Water tanks would keep hot water for a longer time. In such a system, a lot of energy can be stored as latent heat, but it should be able to be transferred from the PCM to the water when needed, therefore heat transfer within the PCM and to the water is of high interest .The increase of the heat transfer rate obtained by using encapsulation PCM balls storing the hot water PCM balls inside water tanks. These PCM modules are used to store energy in a reduced volume.

VI. CONCLUSION

The insulated thermal storage tank contains number of encapsulated PCM balls which absorbs available heat during peak hour's periods of day time and heat is stored in encapsulated PCM balls in the tank. The same can be ret rived from the tank during off peak hours here we are getting hot water even in absence of sun rays. It is possible to increase the heat carrying capacity in future with the help of little design modifications and changing the PCM with higher Latent Heat capacities.. The use of PCM in a water tank working with a solar system allows a lot of energy to be stored, but it is necessary to transfer this energy to the water during demand. Heat transfer has been optimized in PCM composites and modules but not in the case of natural convection to the water. An experimental work was designed and carried out to determine natural convection heat transfer coefficients for PCM cylindrical modules with two different PCM materials. Results were presented as a temperature variation over time of the PCM and the surrounding water, and the heat transfer and effectiveness. The results proved the technical potential of PCM increases heat storage systems using PCM.

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