

Solar Water Heater Using Multiple PCM and Porous Medium

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ABSTRACT: The solar energy option has been identified as one of the promising alternative energy sources for the future. The solar energy supply is variable in daytime and zero at night, considerable amount of solar energy should be stored during the day time to meet the demands at night. Solar water heater using multiple PCM and porous medium provides reservoir of energy to adjust this mismatch and to meet the energy needs at night. The present work focuses on the process of energy conversion from the collector to the working fluid and improvement of thermal storage system. The system consists of two simultaneously functioning heat absorbing units. One is solar water collector with PCM and other is a heat storage unit consisting of PCM (paraffin wax). Here the system follows thermosyphon system that means, circulation of water will be natural. During the discharging process heat transfer fluid gain large amount of heat from the PCM and it withstood this heat for night hours. For improve the thermal performance of flat plate solar collector using a cheap cost energy absorbing materials, and also increase the efficiency and heat storage capacity. This is experimentally accomplished by using packing of collector's surface with porous medium such as pebble stone. Experiment results shown using PCM and porous medium reduce the cooling rate of water and also increase the efficiency and heat storage capacity.

KEYWORDS: SWH-solar water heater, FPC-flat plate collector, LHS-latent heat storage, PCM-phase changing material, Porous medium.

I. INTRODUCTION

Solar energy could supply all the present and future needs of the world on a continuing basis. This makes it one of the best source among the non-conventional sources. The peak solar energy supply occurs at noon but zero at night. Considerable amount of solar energy should be stored during the day time to meet the demands at night. Thermal energy storage can be stored as a change in internal energy of a material as sensible heat, latent heat and combination of both. Sensible heat storage (SHS) means thermal energy stored by raising the temperature of a solid or liquid. SHS system utilizes that heat capacity and the change in temperature of the material during the process of charging and discharging. 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. Review on thermal energy storage with phase change materials and applications [1] PCMS have been widely used in latent heat thermal storage systems for heat pumps, solar engineering and spacecraft thermal control applications. The uses of PCMs for heating and cooling applications for buildings have been investigated within the past decade. In improving of solar water heater using phase change materials [3] the water heater functions normally and supplies hot water during the day. The storage unit stores the heat in PCMs during the day supplies hot water during the night time.

Solar water heating system can be classified into two categories. First one is natural circulation (thermosyphon) system and the second one is forced circulation system. In thermosyphon system they have mainly two components. These two

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components are collector and a storage unit. The flat plate collector is the most important type solar collector because it is simple in design. It has no moving parts and requires little maintenance. The storage unit is required because of the non-constant nature of solar energy; at certain times only a very small amount of radiation or no radiation will be received.

The thermal energy storage with PCM is used widely because of its large storage capacity and isothermal nature during the charging and discharging process. Certain material will have the capacity to melt and solidify at certain temperature and because of this they are capable of storing or releasing large quantity of energy, such materials with inherent capacity to store or release energy at constant temperature by undergoing a phase change and these materials are called PCM. As compared to sensible heat storage materials, PCM have considerably higher heat storage capacity. Paraffin wax is suitable for solar water heater due to its availability, non-corrosiveness, high thermal efficiency and low cost. Improve the thermal performance of flat plate solar collector using energy absorbing materials. Packing of collector surface with porous medium is for larger heat retention and enhanced heat capture respectively.

II. MATERIALS AND METHODS

The setup mainly consists of a solar flat plate collector and storage water tank. Fig.1 contains Flat plate collector (FPC) which absorbs the solar energy and transfer the heat to liquid. It does not require sun tracking and requires less maintenance. PCM filled PCM tank was installed to the collector tank. FPC having length 1m and width 0.5m. The absorber tubes are made of copper of diameter 10.75 mm. Six copper tubes inside the FPC are use in the setup. The water tank has a capacity of about 30 litres. The water tank consists number of aluminium square pipe filled with PCM and are well insulated. The storage tank is located above the level of the collector. As water in the collector is heated by solar energy, it flows automatically to the top of the water tank and it replaced by cold water from bottom of the tank. Hot water for use is withdrawn from the top of the tank. Whenever this is done, cold water automatically enters at the bottom. RTD are provided at inlet and outlet.



Fig 1: solar water heater without pebble stone

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A. EXPERIMENT SETUP

The entire setup consists of two stages, charging and discharging. The readings were taken for 3 days and average readings were obtained. The setup consist three phases; without using multiple PCM and pebble stone, using multiple PCM, and using multiple PCM and pebble stone. Fig.2 shows the experimental setup of the SWH using multiple PCM and pebble stone. In the first charging process, the water is circulated through the tank and solar collector unit continuously. The water absorbs solar energy sensibly and transfers or exchange this heat with the PCM (PCM tank). The PCM gets slowly heated sensibly at first until it reaches its melting point temperature. As the charging proceeds energy storage as latent heat is achieved as the paraffin wax melts at constant temperature (60°C). After complete melting is achieved, further heat addition from the water causes the PCM to superheat. The temperature of the water at the outlet recorded at intervals of 1hour.

The discharging process used is termed as batch wise process. In this method a certain quantity of hot water (2 litres) is withdrawn from water tank and is substitute by cold water, which gains energy from the multiple PCM. The energy is released by the PCM on charging its phase from liquid to solid. This is then repeated for intervals of 2hours



Fig.2: solar water heater using pebble stone

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Vol. 6, Issue 5, May 2017

III. MATHEMATICAL CALCULATION

The standard formula for efficiency calculation

$$\text{Efficiency} = \frac{\text{heat energy output}}{\text{heat energy input}}$$

$$\eta = \frac{Q_{out}}{Q_{in}}$$

Calculate efficiency of solar water heater without PCM and pebble stone

Q_{out} = heat absorbed by water

$$Q = m C_{pw}(T_f - T_i)$$

$$Q = \rho \times V \times C_{pw} \times (T_f - T_i)$$

ρ = density of water (Kg/m³) V = volume of water (m³)

T_f = final temperature (°C) T_i = Initial temperature (°C)

C_{pw} = specific heat of water (KJ/KgK)

Lets calculate heat supplied by solar radiation

Average heat radiation in a day = $P_{in} = 1164 \text{ w/m}^2$

$$Q_{in} = P_{in} \times \text{area of panel} \times \Delta t$$

Δt = time elapsed (Hrs)

$Q_{in \text{ effective}} = .96 Q_{in}$

$$\eta = Q_{out} / Q_{in \text{ effective}}$$

Efficiency of solar water heater with multiple PCM

Q_{out} = energy gained by water + energy gained by PCM

$$\text{Energy gained by PCM} = \int_{T_i}^{T_m} m C_p dt + m \Delta h_m + \int_{T_m}^{T_f} m C_p dt$$

$$Q = m (C_{sp} (T_m - T_i) + \Delta h_m + C_{lp} (T_f - T_m))$$

Specification of PCM

Melting temperature = 60°C

Specific heat of solid PCM = 2.5 KJ/kg k

Heat of fusion = 215 KJ/kg

Specific heat of molten PCM = 2.13 KJ/kg k

Mass of PCM = 11 kg

$$\eta = Q_{out} / Q_{in \text{ effective}}$$

Efficiency of solar water heater with multiple PCM and pebble stone

Q_{out} = energy gained by water + energy gained by PCM + energy gained by pebble stone

$$\text{Energy gained by pebble stone} = Q = m C_p \Delta t$$

Mass of pebble stone = $m = 10 \text{ kg}$

Specific heat of pebble stone = .879 KJ/kg

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IV. RESULT AND DISCUSSION

The temperature distributions of water in the storage tank for different time periods are recorded during charging and discharging process.

A. CHARGING PROCESS

The charging process of solar water heater without PCM and pebble stone , with PCM , with PCM and pebble stone is shown in Fig.3. While charging the solar water heater in the case of without PCM the water ran up to 73⁰C in 8 hrs time elapsed. With PCM and pebble stone reach 70⁰C at that time. And with multiple PCM without pebble stone is reaches only 67⁰C.

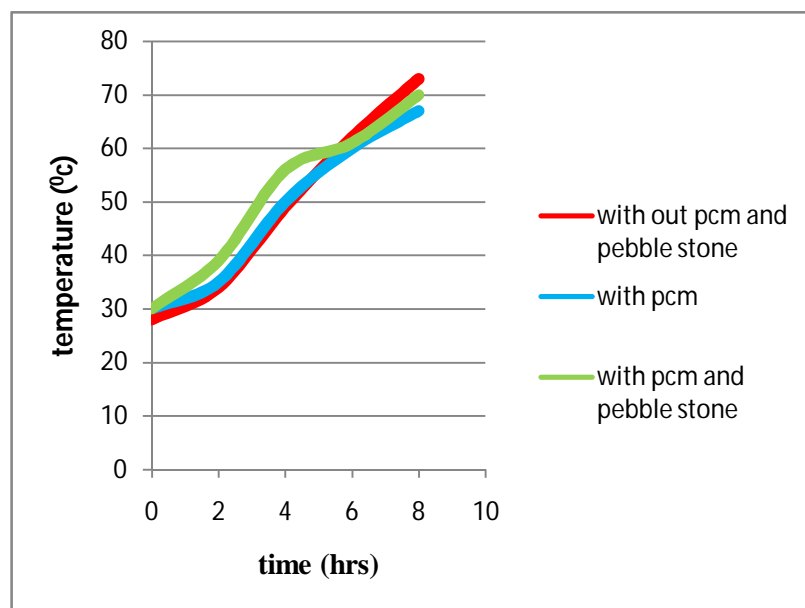


Fig.3: Charging process in SWH

B. HEAT STORED

Fig.4 represents the heat stored during the charging process. Heat storing capacity increases with the use of PCM and pebble stone. The total heat accumulated in the solar water heating system having the heat storage tank combined with PCM and pebble stone is approximately 1.5 times of that in the conventional solar water heating system.

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Vol. 6, Issue 5, May 2017

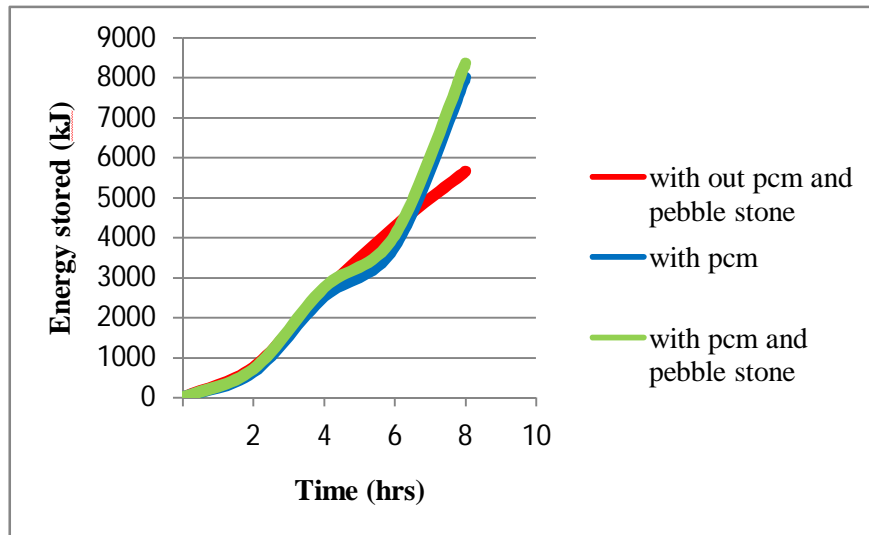


Fig 4 : heat stored in SWH tank

C. SYSTEM EFFICIENCY

Fig.5 shows system efficiency of the solar water heater with, without PCM and with pebble stone. The system efficiency is defined as ratio of the amount of energy stored by water tank to the heat energy available from solar radiation. It is seen that the system efficiency increases with time during the sensible heating of solid PCM, remains nearly constant during phase change period and then further increase during sensible heating of liquid PCM. The solar water heater with multiple PCM and pebble stone have higher efficiency compared to others.

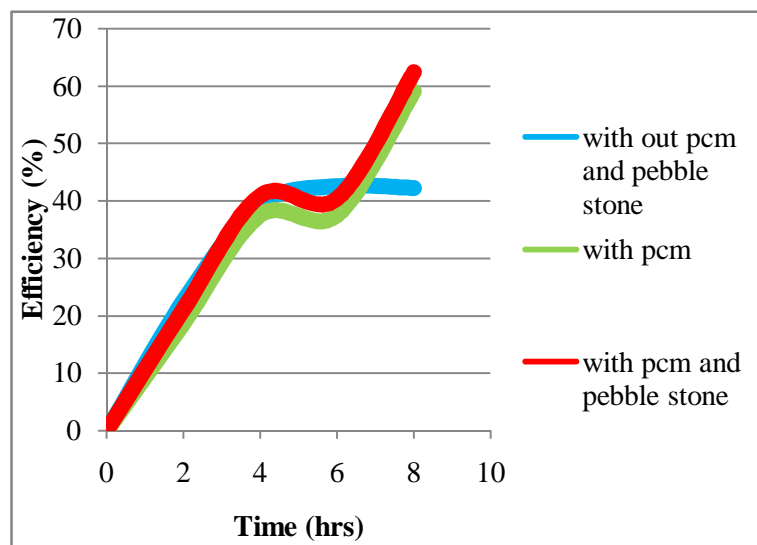


Fig 5 : Efficiency of SWH

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D. DISCHARGING PROCESS

Fig.6 shows the variation of cooling rates without PCM, with PCM, with PCM and pebble stone during discharging process. From graph its clear that cooling rate is higher with PCM and pebble stone comparing to others. Higher cooling rate allows larger heat storage capacity for longer periods of time even without exterior energy supply.

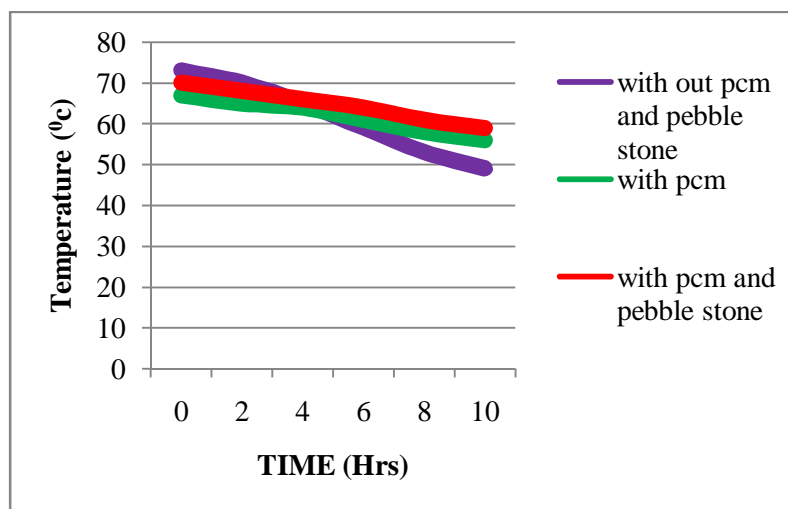


Fig 6 : discharging process in SWH

V. CONCLUSION

The use of PCM and porous medium in solar water helps to reduce cooling rate of water. Thus it enhance the maximum utilization of solar energy and hence improves the efficiency of the system. During the discharging period the heat transfer the fluid gained enormous amount of heat from the PCM. In this research with the use of PCM and porous medium, efficiency of solar water heater increase from 42.2% to 62.4% and also heat storage capacity increases from 5670 to 8367KJ.Hence solar heater with multiple PCM and porous medium store maximum solar energy. It reduces the size of tank and reduce the cost of solar water heater.

REFERENCES

- [1] Atul Sharma, V. V. Tyagi, C. R. Chen, D. Buddhi, "Review on thermal energy storage with phase change materials and applications", *Renewable and Sustainable Energy Review* 13 318-345 , 2009
- [2] Atul Sharma, C. R. Chen, "Solar Water Heating System with Phase Change Materials", *International Review of Chemical Engineering (I.RE.CHE.)*, Vol. 1, N. 4, July 2009
- [3] M.V.Kulkarny, Dr. D.S Deshmukh, "Improving Efficiency of Solar Water Heater Using Phase Change Materials", *IJSSBT* , vol .3.no.1 .Dec 2014
- [4] H.C.Hottl, B.B.Woertz, "The performance of flat plate solar heat collectors," *Transactions of the America Society of Mechanical Engineers*,64, pp.91-104, 1942.
- [5] Mr.Govind Sing Chouhan, Mr. Ram Kumar agarwal " Experimental Analysis Of Batch Type Solar heater With Integrated collector Tank" , *International Journal Of Emerging Technology And Advanced Engineering* ,vol.3 issue 5, may 2013