Performance Analysis of Solar Water Heating System using PCM

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***Abstract*:- In the contemporary era, phase change material (PCM) is used in the solar water heaters to store the extra amount of heat energy available during the full sunshine hours. The primary purpose of this study is to examine the performance of PCM incorporated solar water heating system using the flat plate collector as a heat source. In this study, a cylindrical aluminium PCM tank acts as the thermal energy storage unit. Paraffin wax is used as the PCM. Water is used as heat transfer fluid (HTF) to transfer heat from the flat plate collector to the storage tank. The charging has been carried out on clear days without and with PCM under actual operating conditions. It shows that from the experiments, the PCM improves the performance on the system by bettering the charging energy efficiency and thermal efficiency of the Storage tank.**

Keywords: Component, Sensible Heat, Latent Heat, PCM

1. INTRODUCTION

1.1. SENSIBLETHERMAL ENERGY STORAGE

That is, the internal energy of the storages material is influencing by the energy going stored, which would raise the temperature of the materials [1].

Expressed equation

$$Q= mC_p (T1-T2)$$

Where Q is heat transfer

Cp is specific heat of water

1.2 LATENT THERMAL ENERGY STORAGE

In latent TES, the heat storages material undergoes a phase transformation process for storing or discharging the heat energy [2]. The phase change material either from solid to liquid or near isothermal condition.

Latent heat energy Q = $m C_p \Delta T + m\Delta H$

$$\mathbf{Q=} mC_p (T_1 - T_2) + m\Delta H$$

2. PHASE CHANGING MATERIALS

Thermal energy storage through PCM is capable of storing and releasing large amount of energy. The system depends on the shift in phase of the material for holding and releasing the energy [6].

2.1 PARAFFIN WAX

Paraffin wax refers to a mixed of alkanes that fall with $20\leq n \geq 40$ range. They are found in the solid state at room temperature and begin to either liquid phase approximately 37°C.

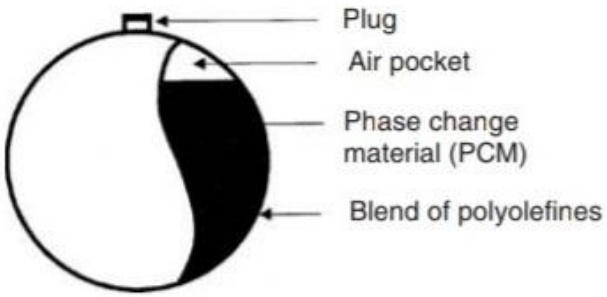

Fig.1 Thermal energy storage using PCM

3. EXPERIENTAL SETUP

COMPONENTS

a. Thermal storage tank
b. RTD
c. Temperature indicator
d. Insulation material
e. Phase change material
f. Flow meter
g. Pressure gauge

a. THERMAL STORAGE TANK

Fig.2 Thermal storage tank

Thermal storage tank is heat water storage in occupies space. Tank has manufacturing stainless steel. The tank is two position one outer tank and other inner tank. There are two physical systems namely LHS system and SHS system considered in the present analysis [3]. The LHS system considered for the analysis is a cylindrical storage system

of height 1100 mm and diameter 500 mm. It consists of three zones.

b. RTD

RTD is a temperature sensor which measure temperature using the principles that the resistance of the metal charge with temperature.

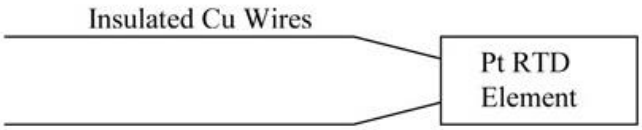

Fig.3 PT100 RTD Sensor of Platinum Resistance Eelement

- Outer diameter: 6 mm
- Length of platinum element: 4 inch or 101.6 mm
- Cable length or lead wire: 4 meter
- Cable insulation: pt fe insulation
- Configuration: 3 wire configuration
- Temperature range: 20°C TO 540°C

Table: 1 Variation Values of PCM

S.NO	DESCRIPTION	VALUE
1	Melting temperature	65°C
2	Thermal conductivity (solid)	0.1383 W/m°C
3	Thermal conductivity (liquid)	0.1383 W/m°C
4	Specific heat (solid)	2890 J/kg.K
5	Specific heat (liquid)	2890 J/kg.K
6	Density (solid)	947 kg/m3
7	Density (liquid)	750 kg/m3
8	Latent heat	190 J/kg

Fig.4 Thermal Insulation

c. INSULATION MATERIAL

Thermal insulation is blocking or reducing heat transfer between two objects (heat transfer is energy moving from one thing to another because of a difference in temperature) [4]. Thermal conductivity is 0.028 W/m.k

d. PUMPS

C.R.I. Self priming mono block pump sets is power-driven by a totally enclosed fan cooled AC induction two pole motor, suitable for continuous duty.

e. PRESSURE GAUGE

Pressure gauge, instrument for measuring the condition of a fluid (liquid or gas) that is specified by the force that the fluid would exert, when at rest, on a unit area, such as pounds per square inch or new tons per square centimeter. Pressure gauge ranges from 0 to 5bar.

f. MASS FLOW METER

A mass flow meter, also known as an inertial flow meter is a device that measures mass flow rate of a fluid traveling through a tube. The mass flow rate is the mass of the fluid traveling past a fixed point per unit time.

g. TEMPERATURE INDICATOR:

Temperature indicators used to indicate or measuring the temperature at corresponding area. Using thermal indicators are 12 cable connections with two segments (red and white). Temperature range measure 20°C to 550°C. Digital temperature is measured.

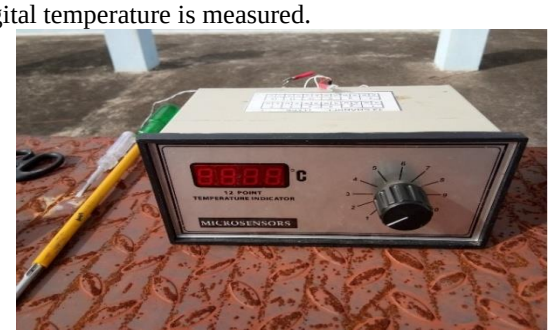

Fig.5 Temperature Indicator

4. EXPERIMENTAL ANALYSIS

Table: 2 Analysis of Sensible Heat

	Time	Mass flow meter reading	Ta	Ti	To	T1	T2	T3
Sensible Heat energy	10 AM	12 LPM	40ºC	42ºC	40ºC	40ºC	40ºC	40ºC
	11 AM	12 LPM	48ºC	49ºC	48ºC	48ºC	48ºC	48ºC
	12 NOON	12 LPM	58ºC	60ºC	59ºC	58ºC	58ºC	58ºC
	1 PM	12 LPM	70ºC	71ºC	70ºC	70ºC	70ºC	70ºC
	2 PM	12 LPM	74ºC	75ºC	74ºC	74ºC	73ºC	74ºC
	3 PM	12 LPM	76ºC	77ºC	76ºC	76ºC	75ºC	76ºC
	4 PM	12 LPM	76ºC	77ºC	76ºC	76ºC	75ºC	76ºC

6.1 EFFICIENCY PARAMETER WITHOUT PCM

Table: 3 Variations of Values without PCM

PARAMETER	SYMBOL	VALUE
VOLUME	V	215 litres
INITIAL TEMPERATURE	Ti	28°C
HEAT RADIATION	Rin	945.28 W/m²
TIME ELAPSED	Δt	1 hr
FINAL TEMPERATURE	To	76°C

6.2 LATENT HEAT ENERGY

Table: 4 Analysis of Latent Heat Energy

PARAMETER	SYMBOL	VALUE
VOLUME	V	215-8.835 = 206.165
INITIAL TEMPERATURE	Ti	28
HEAT RADIATION	Rin	910.58 W/m²
TIME ELAPSED	Δt	1 hr
FINAL TEMPERATURE	To	78

7. CALCULATION

VOLUME OF THE TANK:

VOLUME= AREA* LENGTH

Area (A) = ¶/4 *D2

V tank= 0.200 m³ (or) 200 litres

VOLUME OF PCM:

= (4/3) ¶(D/2)3$\left(\frac{4}{3}\right)\pi(\frac{D}{2})^3$

= (4/3) ¶(0.075/2)3

= 0.22 m per single PCM ball

TOTAL VOLUME OF THE PCM = 40 *0.22

PCM = 8.83 mm or 8.83 litre

SENSIBLE HEAT ENERGY

ENERGY ABSORBED PER ONE HOUR

Q = m Cp (Tf-Tw)

m = 215 litre or 0.215m

Cp = 4.18 KJ/kg

Final temp Tf = 40.4°C

Initial temp Ti =34°C

Q= 0.200 4.18 (40.4 -34)

= 5.7516 KJ

HEAT STORAGE PER HOUR IS **5.57516 KJ**

In time interval of 12 noon to 1 pm is

= 0.200 4.18 (70.2-58.6)

= 8.424 KJ

LATENT HEAT ENERGY:

Q= mcp(T1-T2)+m(^H)+Mpcm cp(Tf-Tw)

Volume of with PCM =volume of water tank - volume of PCM

= 200-8.83 = 191.17 litre

Amount of energy storage /hour

= 191.17 4.18 (68.4 - 59) + (5.2*190)

Q = 8100.84 J + 988 J

Q = 9.088KJ

In time interval of 11 am to 12 noon is

= 191.17 4.19 (68.4 -59) + 5.2(190) + 5.2(2.89)(59-68.9)

= 9.540 KJ

8. RESULT AND DISCUSSION

COMPARE SHE AND LHE

COMPARE THE AMOUNT ENERGY

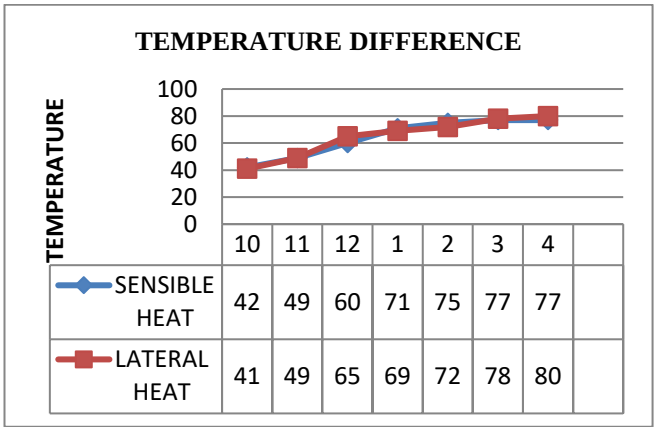

Fig.5 Comparative Analysis of SHE & LHS

9. CONCLUSION

Paraffin wax is a good PCM for energy storages in latent heat storages system. It has a suitable storages system. It has a suitable transition temperature range of 28 °C to 78 °C and relatively high latent heat of 190 KJ/kg. So that sensible heat is 35.11KJ is compare to latent heat energy is 44.724 KJ it is greater than of sensible heat. Comparing with SHE and LTES is 9.614 KJ of energy is excess energy storage.

10. REFERENCE

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