Efficiency Improvement of Thermal Energy Storage using PCM

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Abstract:- Thermal energy storages tank are effective storages and retrieval of heat energy for solar thermal application. Thermal energy storage is normally Sensible Heat Storage (SHS). One another kind of combined thermal energy is Latent Heat Storage (LHS). Phase Change Material (PCM) is used in latent heat storage. Reduce the time required while storing and releasing heat in latent heat storage system for solar thermal application. During these processes phase change material is melted and solidified. The performance of combined sensible thermal energy and latent thermal energy is greater than sensible heat energy.

Keywords: component; sensible heat, latern heat, PCM

1. INTRODUCTION

1.1 SENSIBLE THERMAL ENERGY STORAGES

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

Expressed equation

Q = mcp (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 [1]. The phase change material either from solid to liquid or near isothermal condition.

Sensible heat energy $Q = mCp(Tf - Ti)$

Latent heat energy Q = m (^H)

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

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 [2].

2.1 PARAFFIN WAX

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

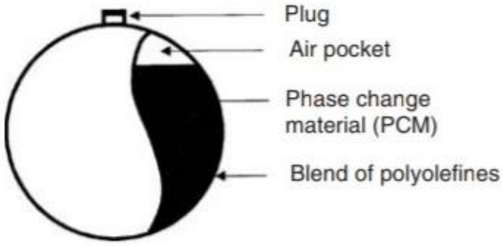


Fig.1 Thermal energy storage using PCM

3. EXPERIENTAL SETUP COMPONENT

i. Thermal storage tank
ii. RTD
iii. Temperature indicator
iv. Insulation material
v. Phase change material
vi. Flow meter
vii. Pressure gauge

i. 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.

Fig.2 Thermal storage 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.

ii. RTD

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

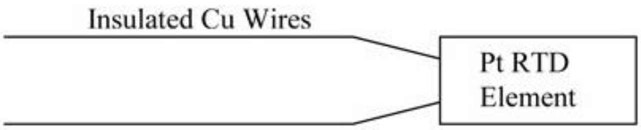


Fig.3 PT100 RTD sensor (platinum resistance element)

- 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

iii. 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.4 Temperature Indicator

iv. 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

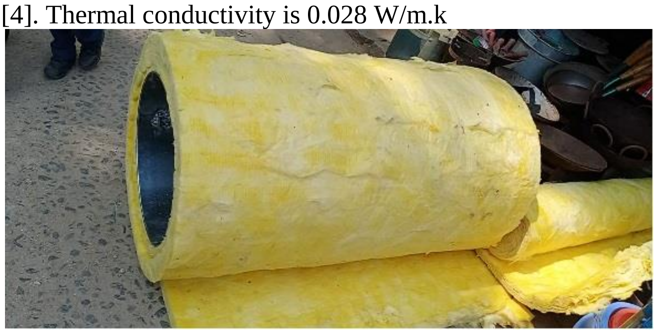


Fig.5 Thermal Insulation

v. PHASE CHANGE MATERIAL

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

vi. 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 [5]. The mass flow rate is the mass of the fluid traveling past a fixed point per unit time.

vii. 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 [6]. Pressure gauge ranges from 0 to 5-bar.

4. EXPERIMENTAL ANALYSIS

Table: 2 Analysis of Sensible Heat

Time	Solar radiation	Ta	Ti	To	T1	T2	T3
10 AM	818.7 W/M²	28 °C	40°C	42°C	40°C	40°C	40°C
11 AM	880.6	31.3°C	48°C	49°C	48°C	48°C	48°C
12 AM	997.8	36.2°C	58°C	60°C	59°C	58°C	58°C
1 PM	990	37.2°C	70°C	71°C	70°C	70°C	70°C
2 PM	870.3	35.7°C	74°C	75°C	74°C	74°C	73°C
3 PM	986.4	33.1°C	76°C	77°C	76°C	76°C	75°C
4 PM	1073.2	32.3°C	76°C	77°C	76°C	76°C	75°C

4.1 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**

4.2 LATENT HEAT ENERGY

Table: 4 Analysis of Latent Heat Energy

Time	Solar radiation	Ta	Ti	To	T1	T2	T3
10 AM	**928.6 W/m²**	**28.1**	**39**	**41**	**41**	**40**	**40**
11 AM	**1097.4**	**31.4**	**47**	**49**	**48**	**47**	**47**
12 NOON	**991.2**	**41**	**57**	**60**	**60**	**59**	**59**
1 PM	**808.3**	**38.1**	**68**	**69**	**69**	**68**	**68**
2 PM	**885.0**	**43.1**	**73**	**74**	**74**	**73**	**72**
3 PM	**861.7**	**41.7**	**75**	**76**	**75**	**74**	**73**
4 PM	**801.9**	**37.4**	**77**	**78**	**78**	**77**	**76**

4.3 EFFICIENCY PARAMETER WITH PCM

Table: 5 Analysis of Efficiency Parameter with PCM

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**

5. 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 $\left(\frac{4}{3}\right)\pi\left(\frac{D}{2}\right)^3$

= (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

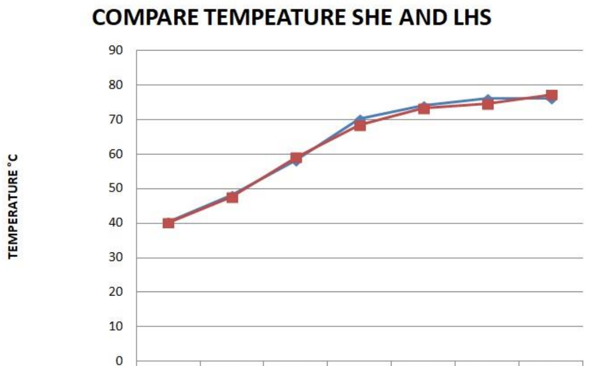
= 200-8.83 = 191.17 litre

Amount of energy storage /hour= 191.17
4.18 (68.4 - 59) + (5.2*190)

Q = 8100.84 J + 988 J
Q = 9.088KJ

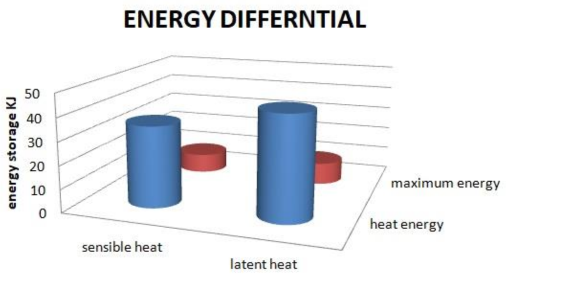
In time interval of 11 am to 12 noon is
= 191.17 4.19 (68.4 -59) + 5.2(190) + 5.2(2.89)(59-68.9)
= 9.540 KJ

6. RESULT AND DISCUSSION



	10:00 AM	11:00 AM	12:00 AM	01:00 PM	02:00 AM	03:00 AM	04:00 PM
SENSIBLE HEAT	40.4	48.2	58.2	70.2	74	76	76
LATENT HEAT	40.2	47.6	59	68.4	73.2	74.6	77.2

Fig.6 Comparative Analysis of SHE & LHS



	sensible heat	latent heat
heat energy	35.11	44.724
maximum energy	8.424	9.54

Fig.7 Comparative Analysis of Energy

7. 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.

8. REFERENCE

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