Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 7, No. 2, July : 2023

PHASE CHANGE MATERIALS

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Abstract
Phase change materials (PCMs) have emerged as a captivating class of materials with unique properties that enable efficient energy storage and effective thermal management across a wide range of applications. This abstract explores the significant potential and recent advancements in the field of PCMs, highlighting their role in addressing the pressing challenges of energy storage, renewable energy integration, and thermal regulation.
PCMs possess the remarkable ability to store and release large amounts of energy during the process of phase transition, making them ideal candidates for energy storage applications. By harnessing the latent heat associated with phase changes, PCMs enable compact and efficient thermal energy storage systems that can enhance the performance and reliability of renewable energy sources, such as solar and wind. Moreover, the integration of PCMs into buildings and vehicles can enable intelligent energy management, load shifting, and waste heat recovery, thereby reducing overall energy consumption and carbon emissions.Beyond energy storage, PCMs find extensive applications in thermal management, where they act as effective heat sinks or sources. By leveraging their ability to absorb and release thermal energy at precise temperatures, PCMs enable passive temperature regulation in electronic devices, automobiles, and various industrial processes.
Recent advancements in PCM research focus on enhancing their thermophysical properties, expanding their operational temperature ranges, and developing novel PCM composites to address specific application requirements. The incorporation of nanoparticles, encapsulation techniques, and the use of hybrid materials have shown promise in improving the overall performance and reliability of PCMs. Furthermore, advancements in characterization techniques and modelling approaches have facilitated a deeper understanding of PCM behaviour and enabled tailored design and optimization.
In summary, these abstract highlights the significant potential of phase change materials as game-changing solutions for energy storage and thermal management. With their ability to store and release large amounts of energy, PCMs offer a pathway towards a sustainable and efficient energy future. Continued research and development efforts in this field hold promise for unlocking even greater capabilities, paving the way for innovative applications in diverse sectors and contributing to the global pursuit of clean and renewable energy solutions.

I. Introduction

Most of the available renewable energy is intermittent and seasonal by its nature and is dependent on the meteorological conditions of the location. On sunny days, solar energy systems generally collect significantly more energy than is needed for direct use. To meet heat demand when using an intermittent natural heat supply requires thermal energy storage. Effective heat transfer during both charge and discharge of the store using solar energy and the ability to retain the heat are essential to achieve a significant solar saving fraction. Effective and economic thermal energy storage is essential on at least a daily basis for the effective use of solar energy for heating purposes. Ideally, the thermal store should store all available energy for a long duration and be able to release any stored energy efficiently, independent of the amount of energy actually available in the storage unit.

Among the thermal energy storage concepts, latent heat thermal storage using PCM's is regarded as a promising technology. Latent heat storage in phase change materials (PCM) is used for short term storage. The main advantages of PCMs are high storage density and isothermal operation. PCMs can be incorporated in solar domestic hot water (SDHW) tanks to enhance stratification. Thermally stratified water tanks are widely used for short term thermal energy storage. This method is usually used in solar energy and waste heat recovery systems. Heat demand can be supplied from the upper part at the highest available temperature. A low temperature at the bottom connected to the solar collector inlet will yield better collector efficiency. When a PCM module is added to the high temperature upper part of the tank, energy storage density will be increased. Therefore, more energy will be available to meet the heat demand from the upper part of the tank. Heat transfer in the vertical axis between stratification layers with different temperature and density is very low. This causes a delay in reaching thermal equilibrium between the high temperature upper layer and low temperature at the bottom layer. Consequently, heat can be stored for a longer time at the upper part. When PCM modules are added to the high temperature upper part, even longer storage duration can be attained by keeping the temperature above the melting point of PCM. Moreover, when water is extracted from the upper part to meet heat demand, cold water entering the system will cause the PCM to freeze and release its latent heat.

Hot water will be available for even longer durations. Residential, commercial and industrial buildings often have hot water requirements at around $60°C$ and bathing, laundry and cleaning operations in the domestic sector generally need it at about $50°C$. PCMs with melting ranges within $50–60°C$ can be used in the SDHW system to meethot water requirements in buildings.

The use of PCM in domestic hot water (DHW) 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. There are several methods to enhance the heat transfer in a latent heat thermal store. The use of fins inside the PCM has been extendedly studied. These fins can be axial or radial and are usually attached to the tubes. By using fins the heat transfer area is extended and the coefficient of heat transfer by natural convection changes, improving heat transfer from the container to the water. Fins geometry is an important parameter when considering the addition of fins in a PCM module.

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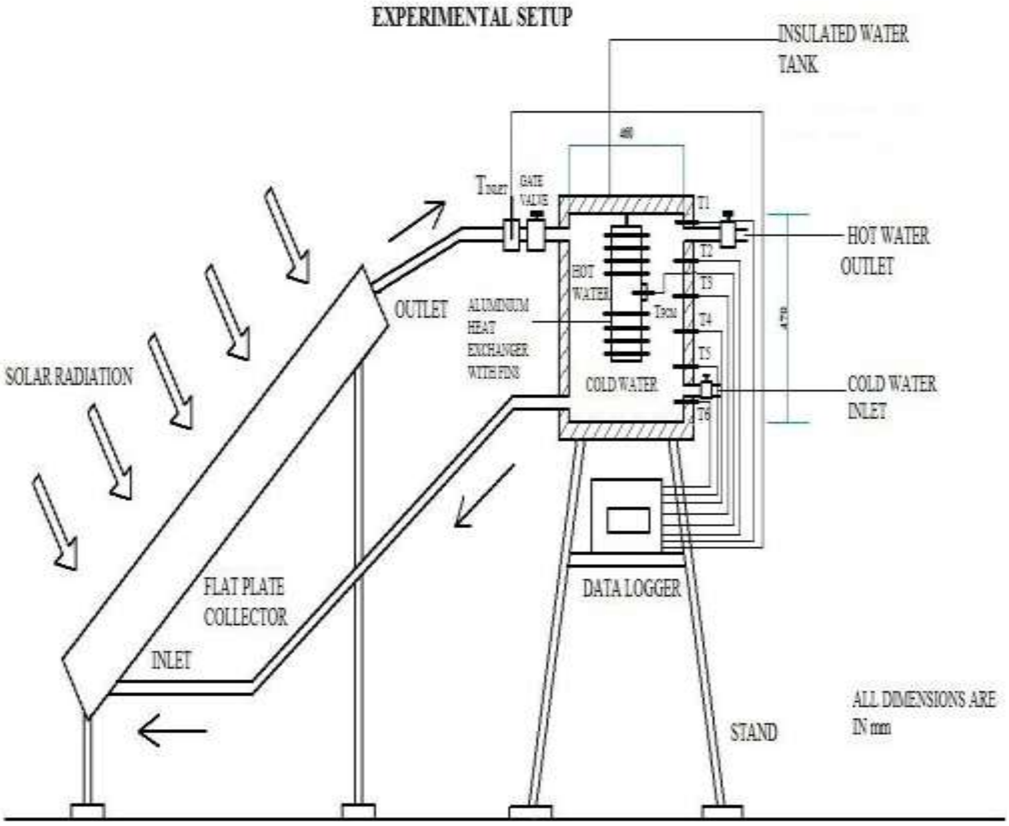
II. Methodology or Materials and methods



III. CALCULATION OF VOLUME OF MAIN TANK:

The length of the main tank L = 470 *mm*
The diameter of the main tank D= 460 *mm*
The volume of the tank $V = \frac{\pi}{4} d^2 L$
= 78109418.15 mm^3

The volume of the tank $V = 0.07810\ m^3$

we know that 1000 litres = 1 m^3

The volume of the main tank =78 *litres*

DESIGN CALCULATION FOR CYLINDRICAL PCM TANK WITHOUT FINSTO FIND VOLUME OF CYLINDER

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

The density of paraffin wax is = 714 kg/m^3
Mass of paraffin wax is fixed as 2.5 *kg*
The volume of cylinder is = $0.00349 m^3$

TO FIND INNER DIAMETER OF CYLINDER

Volume of cylindrical PCM module = $\frac{\pi}{4} d^2 l$The length of cylinder is fixed as 0.3*m*
The inner diameter of PCM tank is = 0.120*m*Inner diameter of PCM tank is taken as 0.121*m*

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TO FIND SURFACE AREA OF CYLINDER

Surface area of cylinder $A_{PCM}= \pi dl$ Surface area of cylinder $= 0.114m^2$

DESIGN CALCULATION FOR CYLINDRICAL PCM TANK WITH FINSTO FIND DIAMETER OF CYLINDER

Volume of cylindrical PCM module $= \frac{\pi}{4} d^2 l$

The volume of cylindrical PCM tank with fins is taken as same as that of cylindricalPCM tank without fins.

The length of cylinder is fixed as 0.3m

The inner diameter of PCM tank is = 0.120mInner diameter of PCM tank is taken as 0.121m

And outer diameter of cylinder is taken as 0.127m

TO FIND SURFACE AREA OF CYLINDRICAL PCM TANK WITH FINS

Surface area of cylindrical PCM tank with fins = surface area of PCM tank + Surfacearea of 8 fins

Surface area of PCM tankSurface area of PCM tank $A_{PCM}= \pi dl$ $= 0.114m^2$

TO FIND SURFACE AREA OF FINS

Surface area of fins $A= \pi R^2-\pi r^2$

Outer radius of fin $R = 0.180m$

Inner radius of fin $r = 0.127m$

Surface area of one fin $= 0.0128m^2$

Surface area of 8 fins

$= 0.102m^2$

Surface area of cylindrical PCM tank with fins = $0.216m^2$

6.4 CHARGING ENERGY EFFICIENCY

The charging energy efficiency is defined as the ratio of amount of heat absorbed bywater to the amount of heat supplied to water.

$\eta_{ch} = \frac{T_{avg} - T_{initial}}{T_{inlet} - T_{initial}}$ Where,

T_{avg}= Average charging temperature (°C)$T_{initial}$ = Average initial temperature (°C) T_{inlet} = Inlet temperature of water (°C)

STRATIFICATION NUMBER

The stratification number evaluates the thermal stratification of the water inside the tank. It is defined as the ratio of the mean of temperature gradients at each time interval to that of the beginning (t=0).

Stratification number $= \frac{\left(\partial T/\partial z\right)_{t=j}}{\left(\partial T/\partial z\right)_{t=0}} \frac{\partial T}{\partial z} = \frac{1}{j-1}\left[\sum_{j=1}^{j-1}\left(\frac{T_j - T_{j+1}}{\Delta z}\right)\right]$

Where,

ΔZ = Distance between two thermocouplesj = number of thermocouples

IV. Results and Discussions

The effect of using cylindrical PCM tank with and without circular fins, in a stratified solar domestic water heater tank was investigated. Charging and discharging experiments were performed without cylindrical PCM heat exchanger, with cylindrical PCM heat exchanger with and without circular fins using solar flat plate collector, in clear days. During charging experiment without PCM heat exchanger took 6.30 *hours*, charging with PCM heat exchanger without fins took 6.30 *hours*, and charging with PCM heat exchanger with fins took 6.30 *hours* to heat the water in the tank approximately up to 65^oC. During discharging experiment without PCM heat exchanger took 18.30 *hours*, for with PCM heat exchanger without fins discharging process took
25.30 *hours*, and for with PCM heat exchanger with fins discharging process took 21.30
hours to release the heat from hot water from 65^oC to 45^oC.

CHARGING WITH CYLINDRICAL PCM MODULE WITHOUT FINS

Date: 27.02.2013 Latitude: Hosur 12°N, 70°E
Collector angle: 32° Day: Clear day

Time	Time (*min*)	Temperature (°*C*)							
		T_1	T_2	T_3	T_4	T_5	T_6	T_{PCM}	T_{INLET}
09:00 AM	0	22	19	19	19	19	18	20	24
09.30 AM	30	23	20	19	19	19	18	20	32
10:00 AM	60	26	19	19	18	18	18	19	35
10.30 AM	90	34	20	18	18	17	18	20	46
11:00 AM	120	51	27	21	18	17	18	27	64
11.30 AM	150	72	34	23	18	17	18	34	89
12:00 PM	180	79	53	31	21	18	18	43	94
12.30 PM	210	83	64	41	25	19	18	50	93
01:00 PM	240	85	71	51	32	22	18	56	93
01.30 PM	270	86	77	60	42	28	19	56	94
02:00 PM	300	86	79	66	50	36	21	56	94
02.30 PM	330	81	76	67	54	46	33	62	93
03:00 PM	360	76	73	70	69	61	36	69	82
03.30 PM	390	74	69	69	68	68	43	69	75

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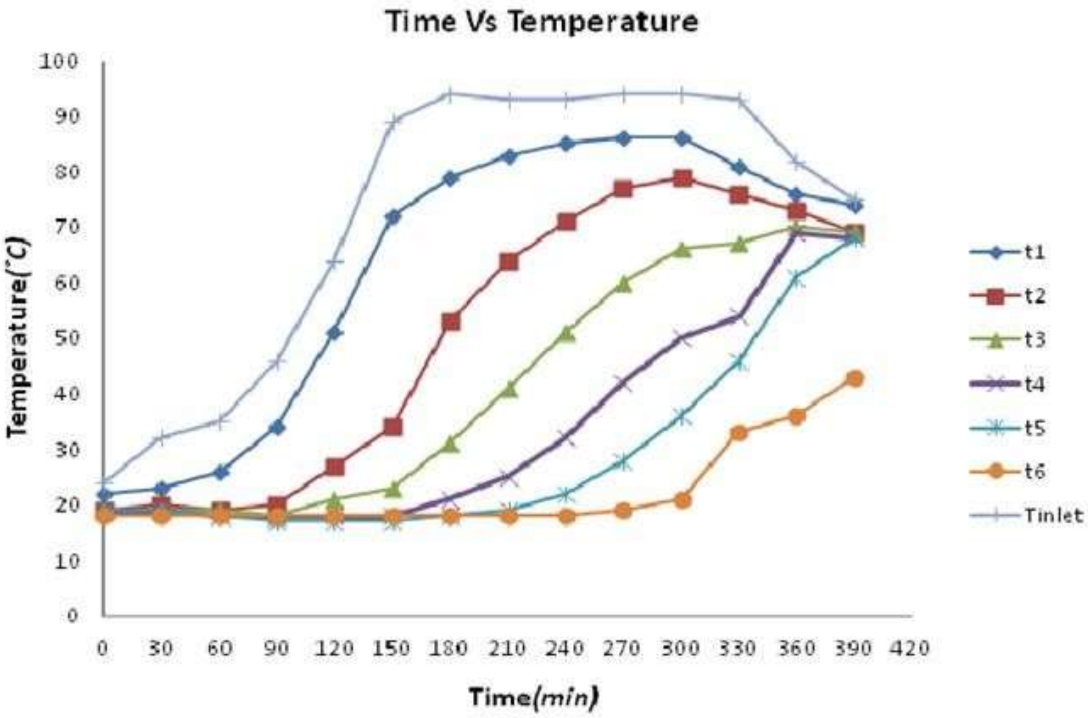


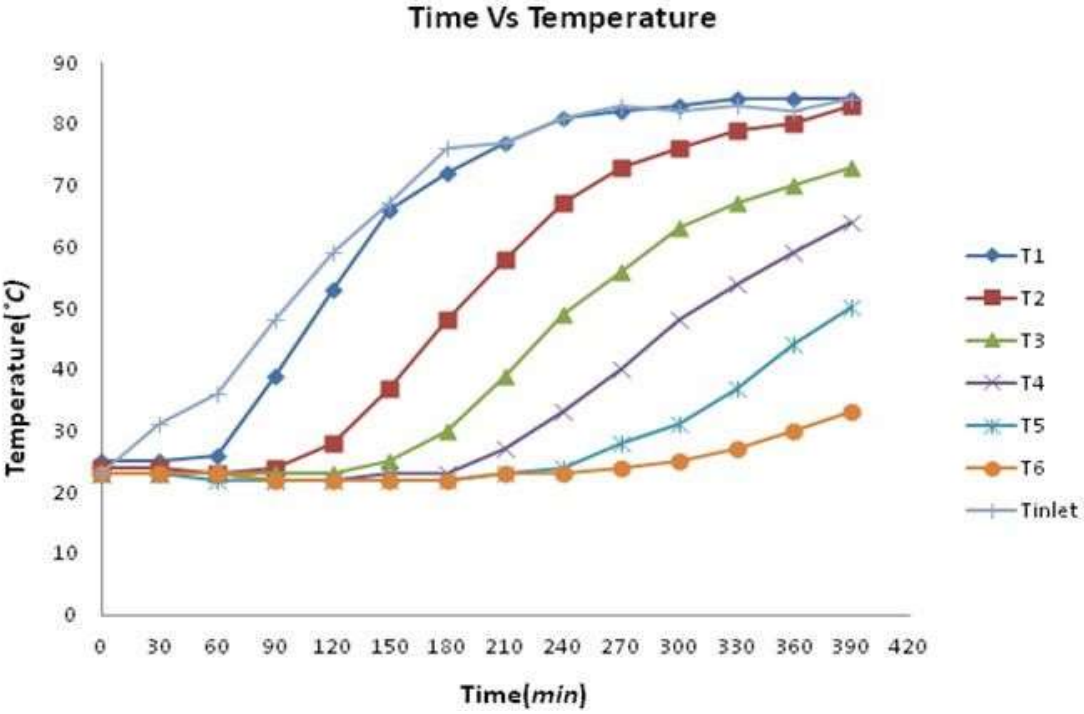
Charging with cylindrical PCM module without fins

CHARGING WITH CYLINDRICAL PCM MODULE WITH FINS

Date: 03.03.2013 Latitude: Hosur 12°N, 70°E
Collector angle: 32° Day: Clear day

TIME	TIME (*min*)	Temperature (°*C*)							
		T_1	T_2	T_3	T_4	T_5	T_6	T_{PCM}	T_{INLET}
09.00 AM	0	25	24	23	23	23	23	22	23
09.30 AM	30	25	24	23	23	23	23	23	31
10.00 AM	60	26	23	23	23	22	23	24	36
10.30 AM	90	39	24	23	22	22	22	24	48
11.00 AM	120	53	28	23	22	22	22	32	59
11.30 AM	150	66	37	25	23	22	22	36	67
12.00 PM	180	72	48	30	23	22	22	40	76
12.30 PM	210	77	58	39	27	23	23	46	77
01.00 PM	240	81	67	49	33	24	23	56	81
01.30 PM	270	82	73	56	40	28	24	56	83
02.00 PM	300	83	76	63	48	31	25	63	82
02.30 PM	330	84	79	67	54	37	27	68	83

03.00 PM	360	84	80	70	59	44	30	75	82
03.30 PM	390	84	83	73	64	50	33	78	84



Charging with cylindrical PCM module with fins

V. <u>Conclusions</u>

In this project the stratification study on thermal energy storage tank without PCM, with cylindrical PCM tank, cylindrical PCM tank with circular fins was conducted and also hourly based charging efficiency was calculated for the three cases and compared. It was found from the stratification study that the thermal energy storage tank with cylindrical PCM tank gave better performance compared to the thermal energy storage tank without PCM and cylindrical PCM tank with circular fins. But in the charging energy efficiency comparison thermal energy storage tank with cylindrical PCM tank with circular fins gave better results than the thermal energy storage tank with cylindrical PCM tank and without PCM. So this study shows that PCM improves the performance of thermosyphon solar water heating system. Also when circular fins were used to the heat transfer rate increased, which improves the charging energy efficiency.

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