

An Overview of Solar Water Heating System Using Phase Change Material

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ABSTRACT: Due to periodic and irregular nature of solar energy, it has limitation for its usage. Even in location with pleasurable solar radiation gives only few hours of high radiant incident per day. As human being developed equipment that can capture the solar radiation. But due to lack of storage equipment most of the captured solar energy get lost. To reduce the gap between solar energy captured and energy stored, it is necessary to search for better thermal storage system. This is possible only by using phase change material along with storage system. Thermal energy storage system using phase change material is effective way to solve the above problem. This paper present an introduction to previous work on solar energy storage system and it also focuses on the types of phase change material.

KEYWORDS: PCM, Sensible heat storage, Latent heat storage.

I. INTRODUCTION

From last two decades the increasing level of greenhouse gas emissions along with the overall increase in fuel prices are the main reasons behind efforts devoted towards improvement in the use of various sources of energy. Engineers, scientists throughout the world are in search of: 1) way to reduce the demand; 2) techniques to increase the efficiency of power systems; and 3) new and renewable sources of energy to minimize the use limited and harmful fossil fuels.

As the population of the world increases the demand of the energy also increases. So find out the way to reduce the demand of energy is not possible. So only option is to increase in the energy efficiency of the power systems. The above mentioned problem can be solve by searching new and renewable sources of energy to reduce the demand of conventional energy sources.

Solar energy is the one of the best option over all the energy crises problems. Solar energy is environmentally clean, free source of energy and therefore recognized as one of most outstanding alternating source of energy [1]. Solar energy is being stored and used as heat energy for various devices such as solar water heater, solar cooker, solar dryer and much more. One of the direct and attractive assets of solar energy is the solar water heating system. In recent year there is variety of developments to improve the efficiency of solar water heating system [2]. But due to unpredictable and intermittent nature of solar energy, its use is limited. Solar energy is available only few hours of the day. So it becomes necessary to find out the storage system that can stored the more solar energy. Many scientist, engineers are in search of the most effective storage system to make the efficient use of solar energy.

One of the prospective techniques for storing thermal energy is the use of phase change material along with storage system. Phase change material takes the heat energy during charging time and release the heat during discharging by changing the phase.

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II. CHARGING

The charging process start with circulation of the heat transfer fluid heated in the collecting system at a temperature higher than the melting temperature of phase change material. The charging process occurs during day time when solar energy incident on collecting system takes and terminates after the completion of the melting of the PCM, charging of the store does not terminate after melting of the PCM if the inlet fluid temperature is above the melt temperature, charging of sensible heat continues. Increase in the temperature of fluid during charging is more when storage system is without PCM. When PCM is used along with storage system, the temperature attained by fluid is low, as system has to increase the temperature of both fluid and phase change material.

III. DISCHARGING

The discharging process is starts with circulation of the cold heat transfer fluid in collecting system having inlet temperature lower than the phase change material melting temperature. The discharging process occurs during night time when solar energy does not present and terminates after the completion of the solidification of the PCM. The heat transfer fluid exit temperature is depends upon time because the rate of solidification of the PCM varies with time. This process terminates after complete solidification of the PCM[3]. Discharging rate of the storage system is low with PCM.

IV. SENSIBLE HEAT STORAGE MATERIALS

In sensible heat storage systems, the thermal heat energy is stored by increasing the temperature of a liquid or solid used as an assembler to be charged or discharged according to the optimization of the energy requirement/availability and energy cost. Such systems are depends on the ability of a material to store energy without changing phase (their heat capacity) which in turn based upon their specific heat (the amount of energy stored by unit mass per degree). Another important parameter is the density of the materials as the volume of the systems may be an issue (physical, technical, economical). A third important parameter of study is the stability of the material. Fourth parameter is the change in the temperature that has to be adjusted to the process, and finally, their relative abundance at low cost [4].

Table I shows a list of selected solid and liquid materials used for sensible heat storage ([5]).

Medium	Temperature Range [K]	Density [Kg/m ³]	Specific heat [Kg/Kg K]
Water	280-370	1000	4190
Rock (avg)	280-300	2500	880
Brick (avg)	290-310	1600	840
Concrete (avg)	280-300	2100	880
Sand (dry, avg)	280-300	1550	800
Soil (dry, avg)	280-300	2040	1840
Caloria HT43	285-553	867	2200
Engine oil	Up to 430	888	1800
Ethanol	Up to 350	790	2400
Propanol	Up to 390	800	2500
Other organic liquids (avg)	Up to 420	800	2300

Of the above sensible heat storage material water is consider as the most suitable material due to its availability at free of cost. But its use is limited due to its operating temperature limit (limited to 100°C) at atmospheric pressure. Sand, rock, soil and other heat storage materials are also used in some of the application such as geexchange application.

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However, in many application above listed materials becomes unsuitable for storage application due to temperature range and availability of the space to install the system.

V. LATENT HEAT STORAGE MATERIALS

Latent heat storage materials are also termed as phase change material as it changes the phase by absorbing heat energy at constant temperature. Latent heat storage material change their phase from solid to liquid, liquid to gas and vice versa and there by absorbing or releasing heat energy. Latent heat storage materials are most delightful due to its high heat storage capacity at constant temperature.

Table II provides information of different thermal storage material.

Medium	Density [Kg/m ³]	Specific Heat [KJ/KgK]	Latent Heat [KJ/Kg]	Relative Storage mas
Rock bed	2240	1.0	-	15
Water	1000	4.2	-	4
Organic PCM	800	2.0	190	1.25
Inorganic PCM	1600	2.0	230	1.0

Latent heat storage materials should have following thermophysical, kinetics and chemical properties [4], [6], [7] and [8].

1. PCM should have high latent heat of fusion.
2. PCM should have high thermal conductivity.
3. PCM should have low viscosity of the fluid phase.
4. PCM should have favorable phase equilibrium.
5. PCM should have low thermal expansion.
6. PCM should have high density.
7. PCM should have low vapor pressure.
8. There should not be ideally supercooling.
9. There should be high crystallization rate.
10. No toxicity
11. No fire hazard.

Apart from above properties other parameters are also important which are availability in abundance with minimum cost of transportation, installation and maintenance.

VI. CLASSIFICATION OF PCMs

A plenty of phase change materials (organic, inorganic and eutectic) are available. Phase change materials are available at any required range of temperature. PCMs are classified as organic, inorganic and eutectic PCMs. There are a large number of organic chemical and inorganic chemical materials, which can be used as PCM from the point of view latent heat of fusion and melting temperature. As no single material can have all the properties required for an ideal thermal-storage media, one has to use the optimum materials to match system designs.

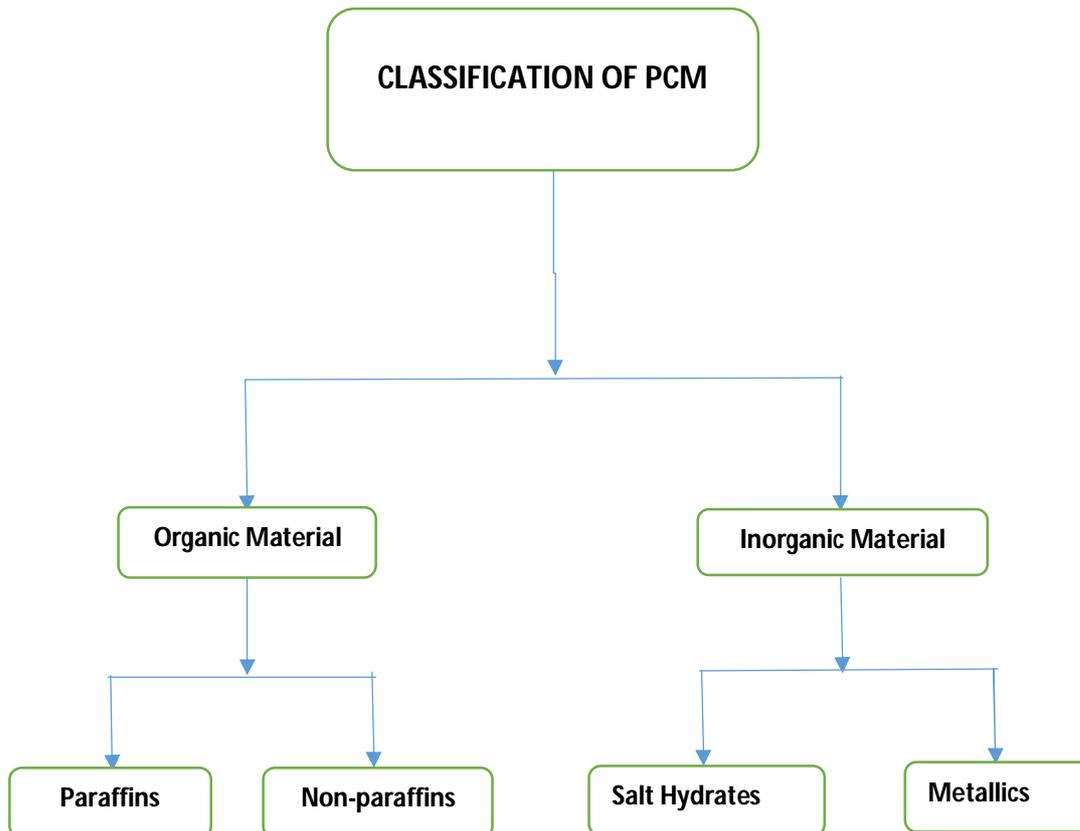


Fig 1. Classification of PCM

VII. ORGANIC PHASE CHANGE MATERIALS

Organic materials are further classified as paraffin and nonparaffins. The main important features of the organic materials is that they consist of long term cyclic chemical and thermal stability without phase separation and consequent degradation of the system performance in which they are insert. Their important feature is non corrosive in nature.

VIII. PARAFFIN

Paraffin wax consists of a mixture of n alkanes $\text{CH}_3\text{-(CH}_2\text{)-CH}_3$. The crystallization of the $\text{(CH}_2\text{)-}$ chain is responsible for absorption or release a large amount of latent heat. Melting point and latent heat of fusion increase with the length of CH_2 chain. Paraffin consider as heat storage materials due to its availability in a large temperature range. Due to its cost, only technical grade paraffin may be used as PCMs in latent heat storage systems
Paraffin material is safe, reliable, foreseeable, less expensive and non-corrosive. They are chemically inert, show little changes in volume on melting and have low vapor pressure in the liquid form. For these properties of the paraffin, system-using paraffin usually have very long freeze–melt cycle [9].

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IX. NON-PARAFFIN

The non-paraffin organic are the most common of the phase change materials and involved different properties. Each of these materials have different properties unlike the paraffin. Non paraffin have high heat of fusion. These have low inflammability, thermal conductivity, instability and toxicity at high temperature.

X. INORGANIC PHASE CHANGE MATERIALS

Inorganic materials are again classified as salt hydrate and metallics. These phase change materials does not supercool and there is not degradation of heat of fusion with cycling.

XI. SALT HYDRATES

Salt hydrates are the one of the most important group of PCMs, which have been broadly studied for their use as latent heat storage material for thermal energy storage systems. The most delightful properties of salt hydrates are: (i) high heat of transformation per unit volume, (ii) relatively high thermal conductivity (almost double of the paraffin's), and (iii) small volume changes after melting. They are not very corrosive, suited with plastics and only slightly toxic. Many salt hydrates are economical for the use in storage.

Salt hydrates are the alloys of inorganic salts and water forming a crystalline solid of general formula $AB.nH_2O$. The solid to liquid transformation of salt hydrates is dehydration or hydration of the salt, although this process resembles melting or freezing thermodynamically.

Following are the some problems associated with the use of salt hydrate as phase change material.

1. Incongruent melting
2. Problem of supercooling
3. Spontaneous of salt hydrates with lower number of water moles during discharging process.

XII. CONCLUSION

This paper aimed to study and presents overall information about phase change materials. Charging and discharging process are also studied and presented. Various sensible heat storage material (SHSM) and latent heat storage materials (LHSM) are also studied. After studying, it is found that latent heat storage materials show more attractive features than sensible heat storage materials due to their temperature range and high heat storage capacity.

Various types of PCM are also studied and presented along with their properties. It is conclude that paraffin wax is more suitable PCM than any other PCM.

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