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Study of PCMs Used for Energy Storage in TES System

Manthan Deshmukh[1], Meghana Pagare[2], Rupali Sewane[3]

Department of Mechanical Engineering, Savitribai Phule Pune University

Abstract

TES (Thermal Energy Storage) system is how the efficiency of any thermal systems can be improved and hence research in this area is drastically increasing. In this paper, the review of the different types of PCM materials used for latent heat storage is discussed along with its application. This paper is useful for understanding about TES for learners who are new to this topic.
***Keyword** — PCM, Thermal Energy Storage, LHTES, Hot Energy Storage, Cold Energy Storage*

I. INTRODUCTION

Nowadays, the demand for energy is increasing tremendously and to fulfil this demand, the required resources are decreasing. On the other hand, it is very important to improve the efficiency of the thermal system to tackle rising pollution problems. Thermal Energy Storage is the system that primarily stores the excess energy, which is most likely to be get wasted, and when required this stored energy can be used. Also, the refrigeration system is considered to have high efficiency at night time because of lower atmospheric temperature, for this scenario, the TES system can be used to store energy at night and then use it for daytime when the efficiency of a system is lower.

There are three main categories of the TES heat storage system, first is sensible heat storage, second is latent heat storage and third is thermochemical heat storage. In sensible heat storage, the heat is stored by shifting the temperature of the storage medium without phase change and release energy by reducing the temperature. For a latent heat storage system, a different type of phase-changing material is used which stores energy at constant temperature and provides heat recovery with a small temperature drop. Whereas in the case of thermochemical heat storage, Thermochemical energy storage is produced when a chemical reaction with high energy involved in the reaction is used to store energy. The products of the reaction should be able to be stored and the heat stored separately during the reaction should be able to be retrieved when the reverse reaction takes place, but this process is hard to control. Hence, the latent heat storage system, competitively, has more applications [1].

II. PHASE CHANGING MATERIAL

A phase change material (PCM) is a substance that releases/absorbs sufficient energy at phase transition to provide useful heat or cooling. Generally, the transition is from among the primary two basic states of matter i.e. solid and liquid. In the case of refrigeration, the storage medium changes phase from liquid to solid and for solar thermal storage medium changes phase from solid to liquid. It has an important advantage of hight storage density i.e. system construction becomes simple and less bulky.

In the last decade, PCMs are widely studied for TES due to the need for processes and applications of increased energy efficiency. 2018. Figure 2 shows the yearly distribution since the energy crisis of the early 70s indicating the recent blooming scientific interest [2].

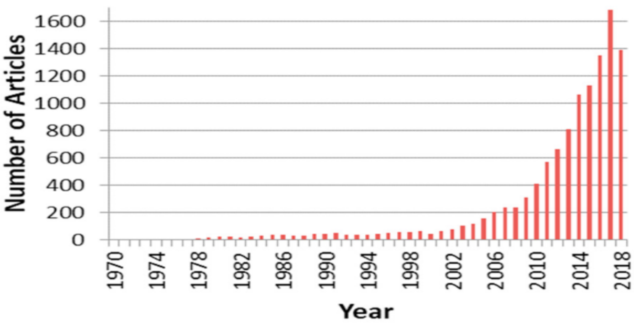

Fig. 2 Number of articles dedicated to PCM and TES [2]

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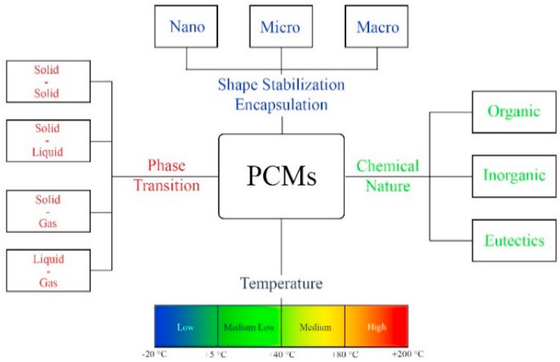

Fig. 3 Classification of PCM [2]

PCM can be classified under, basically, four types namely phase transition, Chemical Nature, shape stabilization encapsulation and temperature. According to a phase transition, PCM is categorized into four types solid-solid, solid-liquid, solid-gas, liquid-gas the phase changing depends upon the quantity of heat to be stored and temperature range. Based on chemical nature 1. organic PCM is one which consists of Hydrocarbons, primarily paraffin and lipids but also one sugar alcohol. 2. Inorganic involving salt hydrates and/or alloys and metals 3. Eutectic is a mixture of any of the organics and/or inorganic materials. In the encapsulated systems PCM is mainly encased in containers where the heat transfer fluid flows around them. Such containers can be in micro, nanoscale as well as in the macroscale for building envelope materials and shape stable PCMs [3].

Required properties of PCM materials are given below,

TABLE I
REQUIRED PCM PROPERTY [4]

Thermal Properties	**Physical Properties**	**Chemical Properties**	**Economic Properties**
1. Suitable phase changing temperature 2. High change in enthalpy during phase change 3. High thermal conductivity 4. Volume change should be minimum	1. Low-density variation. 2. High density 3. No subcooling	1. Stability 2. No phase separation 3. Compatible with various materials used in the system 4. Non-toxic, non-flammable, non-polluting	1. Cheap and abundant

III. PCM FOR HOT THERMAL STORAGE

Several studies have been reported using different types of PCMs for LHTES (Latent Heat Thermal Energy Storage). Those PCMs generally known for thermal storage applications include organic compounds, inorganic salts and eutectics. Those PCMs from organic compounds generally have low melting points and can only be used for room-heating thermal storage. For high-temperature thermal storage, molten salts have been widely considered by researchers [6]. Nevertheless, molten metals and alloys are considered as HTFs (Heat Transfer Fluid) in nuclear power plants.

From the working temperature point of view, Hoshi et al. [6] categorized those materials with melting points below 220° C as 'low' temperature materials, melting temperatures up to 420°C as 'medium' temperature materials, and melting point greater than 420°C as 'high' temperature materials suitable to CSP (Concentrated Solar Power) thermal storage. They collected the latent-heat energy storage capacity of PCMs for various materials with melting points in the range from 300 K to 1200 K as given in Fig. 4. Specifically, for inorganic materials such as fluoride salts, chloride salts, carbonate salts, sulfate salts, bromide salts, nitrate salts, and three eutectic salts. Fig. 5 showed the latent-heat energy storage capacity with melting point ranging from 500 K to 1300 K. It is seen that the melting point of single material tends to increase in the order of nitrates, chlorides, carbonates, and fluorides.

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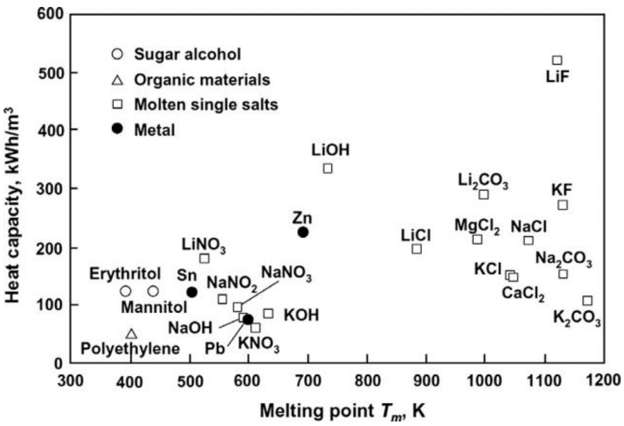

Fig. 4 Latent heat storage capacity of different PCM [6]

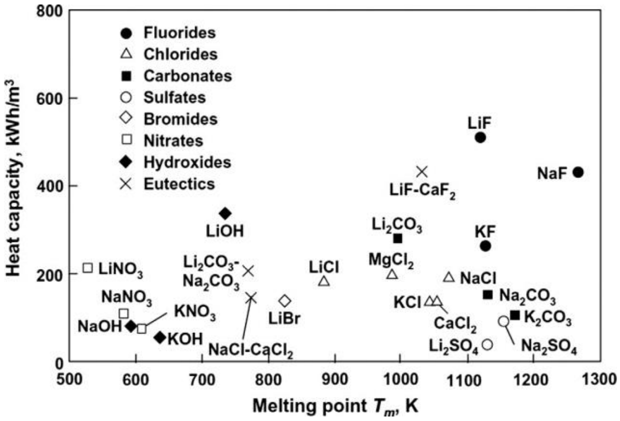

Fig. 5 Heat capacity of molten salts [6]

IV. PCM For Cold Thermal Energy Storage

Inorganic materials are classified as compounds and eutectics. A eutectic material is a composition of two or more components, which melts and freezes congruently forming a mixture of the component crystals during crystallization. Eutectic nearly always melts and freezes without segregation, leaving little opportunity for the individual components to separate. The eutectic mixture melts almost at a constant temperature. Main inorganic materials are salts, salt hydrates, aqueous solutions and water.

Fig. 2 shows a binary phase diagram compound for sodium chloride (NaCl) and water (H2O), where E is the eutectic point of this solution. Furthermore, if the melting temperature of the PCM is critical then using these eutectic systems is beneficial, a small change in the proportion of components changes the property of solution drastically hence it has a wide range of application [8]. Yatseko and Chudotvortsev [7] developed correlations between the physicochemical properties of salts and their aqueous solutions. Most water-salt systems have eutectic phase diagrams, having hypo-eutectic, eutectic, and hyper-eutectic compositions. With the known approaches of mapping and analysing such phase diagrams, detailed information can only be obtained for hyper eutectic regions, where salt crystals or crystal hydrates are formed on cooling. It was noted that for hypo-eutectic compositions the salt concentration in the liquid is first higher than that in the initial solution, and in the course of melting, the salt concentration decreases approaching zero. For hyper-eutectic compositions, the opposite behaviour was observed. During the melting of the eutectic composition, the salt concentration in the liquid remains virtually constant, this can be used to locate the eutectic point. It was concluded that there are strong correlations between the physicochemical properties of salts, the phase diagrams of the corresponding water-salt systems, and the crystallization and melting behaviours of ice in such systems.

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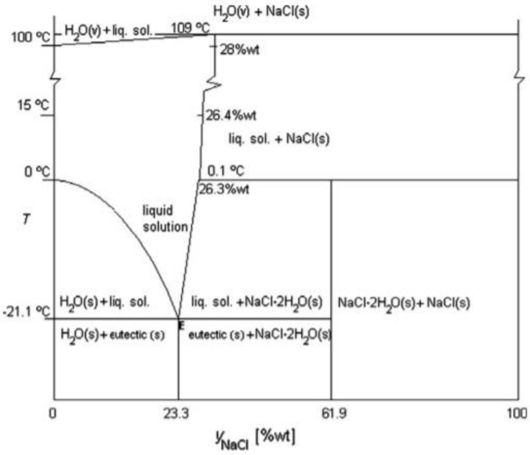

Fig. 2. Binary phase diagram for NaCl–H_2O at 100 kPa [8]

V. Conclusion

The emerging issue of energy efficiency is boosting the research effort in the field of PCMs over the past years. A large number of papers has been published dealing with various aspects of PCMs in thermal energy storage technologies. For understanding, different material properties are observer through the graph of heat capacity against temperature. Also, the behaviour of the NaCl-H_2O compound is observed, since it offers a wide range of properties, for cold storage.

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