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Thermal Energy Storage Using Phase Change Materials (PCMs): A Literature Review

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Abstract

Increasing energy consumption in today's world and the resulting major environmental problems have made researchers develop renewable energy and reduce energy consumption. These measures serve as an effort to deal with environmental issues, especially global warming, which is a major concern in modern world research. It is predicted that by 2050, energy consumption and environmental damage will increase by 1.8% annually. In addition, with the sharp increase in cooling and heating needs in various industries, and especially the need for thermal energy around the world, it is vital to come with appropriate technologies that improve thermal performance in various systems. These restrictions have resulted in a move toward renewable energy and a reduction in fossil fuel consumption. Besides, new technologies such as batteries and drugs highly depend on temperature changes. In this respect, phase change materials (PCMs) to store thermal energy can be used in various industries to solve energy shortage problems. This article provides an overview of energy management practices using PCMs. The background of PCMs in different industries is also examined. In the next step, applications of PCMs in construction, batteries, home water heating systems, and other applications are investigated. Finally, a summary of the PCMs used is provided.

Keywords: PCM; Phase change material; Latent heat energy; Passive cooling; Energy storage system

1. INTRODUCTION

The growth of the world's population and economy has increased the world's energy consumption, leading to the destruction of the environment. Emissions of greenhouse gases (GHG), especially CO_2, are the main cause of this problem [1]. These problems increase the energy demand. In today's modern world, several efforts have been made to generate energy from renewable sources [2]. Although renewable energy technologies produce 24.5% of global electricity generation, this amount of production is not enough yet [3]. It has been found that about 60% of energy consumption in buildings is used to operate Heating, Ventilating, and Air Conditioning (HVAC) devices [4]. Thermal energy storage (TES) technologies have reduced the energy consumption of various devices. TES is done in three ways: energy storage as sensible heat, energy storage as latent heat, and thermal energy storage through chemical reactions. The division of these methods is schematically shown in Figure 1.

The potential for latent energy storage is between 5 and 14 times greater than other storage methods. Table 1 provides a comparison between sensible heat storage using rock, water reservoir, and latent heat storage using inorganic compounds [5].

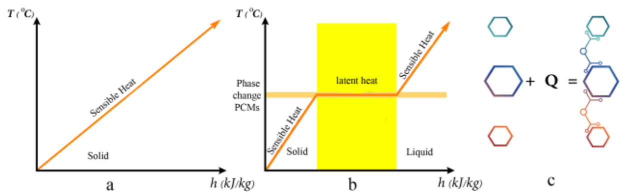

Figure 1. Schematic of three states, a) sensible heat storage; b) latent heat storage; and c) storage of thermal energy by chemical reaction [4]

Table 1. A comparison between TES systems in sensible and latent thermal energy storage to increase the temperature by 15 K and energy by 300 kWh [5]

Characteristic	Rock	Water	Inorganic matter
Density (kg / m^3)	2240	1000	1600
Specific heat (kJ / kg)	1	4.2	2
Latent heat (kJ / kg)	-	-	230
Storage mass for 10^6 J (kg)	67000	16000	4350
Relative storage mass	15	4	1

In recent years, using phase change materials (PCM) as one of the energy storage technologies has received much attention regarding their high energy storage capability and ability to store energy during a phase change process at almost constant temperature (energy storage as latent heat). Estimates have shown that PCMs can be used to manage energy consumption. Depending on their composition, PCMs can cover heat management from -20 to 200℃ [6].

2. PHASE CHANGE MATERIAL (PCM)

PCMs can be divided into liquid-solid, liquid-gas, and solid-solid. Lid-liquid phase change materials are the most widely used among the three available forms. They are divided into three categories of organic matter (paraffin and fatty acids), minerals (hydrates and metals), and eutectic [7]. Organic PCMs are a group of natural substances found in nature. Inorganic PCMs usually have a higher heat storage capacity of equal mass, less flammability, and a better price than organic PCMs. In addition, eutectic PCMs can have fundamental properties by combining two or more materials and forming the final material. A suitable PCM for the application is selected by examining its thermal, physical, kinetic, chemical, and thermodynamic properties and its economics [8].

3. APPLICATIONS OF PCMS

The application of thermal energy storage with PCMs is not limited to heating and cooling solar energy or special devices. In the following, it is tried to examine the major classification and applications of those materials.

- Construction applications

Studies have shown that using PCM in buildings can reduce the temperature during the day to about 4℃. Certainly, this temperature fall depends on the ambient temperature [9].

- Battery

Battery usage is on the rise today. Given the efficiency of renewable energy production systems and the fact that they do not have a uniform and permanent production during the day, it is necessary to store this energy [10]. Batteries are among the highly sensitive devices to temperature, and temperature changes affect their performance.

- Home water heating systems

One of the energy consumption sectors in today's world is heating domestic water, especially in the cold months of the year. In this regard, cold seasons can consume up to 70% of the home energy consumption to heat the space and water. PCMs, regarding their ability to store thermal energy, can significantly improve heating water during the day and especially at night [11].

The applications of PCMs are so much as they are found almost in every industry. For example, in the medical and health industries, PCMs can be used to maintain the temperature of drugs and vaccines constant during transmission.

4. CONCLUSIONS

This paper examines the features of PCMs as part of thermal energy management systems and temperature control systems. The results obtained from the article are as follows:

PCMs can be used to control the temperature of buildings. Research has shown that PCMs can lower peak heat and cold temperatures. In addition, PCMs can reduce power consumption in most systems and reduce power consumption. Overall, PCMs can be selected in various temperatures depending on the work requirements and the system. Finally, PCMs can keep the battery temperature constant.

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