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Review

Review of free cooling system using phase change material for building

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ABSTRACT

Buildings are responsible for 40% of our nation's total annual energy consumption and for one-third of our greenhouse gas emissions. These greenhouse gases are the cause of global warming. Lighting, heating, cooling, and air conditioning are all heavy energy consumers. Interestingly, advances in the understanding of the environmental effects of greenhouse gas emissions have led to a rise in the use of environmentally friendly cooling and heating systems in buildings. Free cooling systems rely on phase change materials that absorb heat from indoors during the day and then release it outdoors during the night.

The investigations undertake by different researchers will be explained in this article. Phase change materials, climate applicability, feasibility analysis, and factors affecting the charging and discharging are discussed briefly. The reduction in CO_2 emissions resulting from the application of free cooling systems to buildings is also discussed.

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Contents

1. Introduction

Fossil fuels are currently the world's main energy source. They will continue to generate 80% of the world's energy until 2030 [1]. However, global ecological concerns about the usage of fossil fuels have led to attempts to decrease the rate of fossil fuel consumption. Residential and commercial buildings consume 40% of the world's primary energy and generate one-third of the greenhouse gas emissions around the world [2]. Heating and cooling systems use a major portion of the energy consumed by buildings, and HVAC equipment alone uses around 15% [3]. To mitigate the environmental effect of fossil fuel usage for HVAC system, passive techniques for heating and cooling buildings have been pursued [4]. Such passive cooling/heating systems can cool/heat buildings with a minimum of electricity usage.

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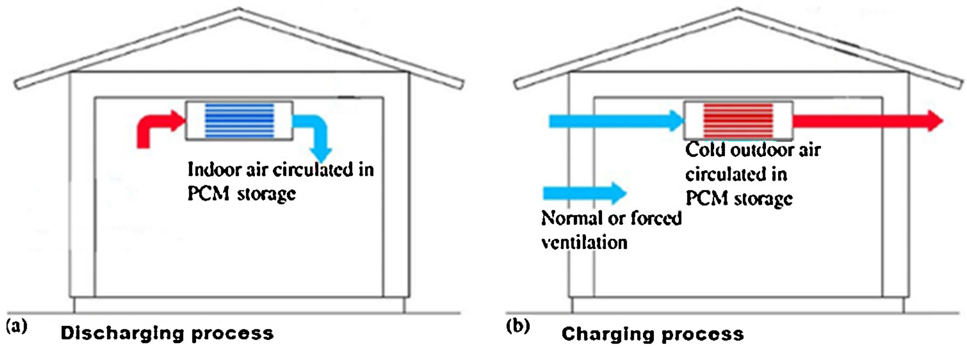

Fig. 1. Principle of free cooling system operation.

Storage materials are cooled when the outside temperature is less than room temperature, and then cold air is obtained from the storage material using an electric fan when the room temperature goes up [5,6].

Many studies have been performed on phase change materials (PCMs) for energy storage and their usage in buildings on free cooling systems.

2. Free cooling system utilising phase change materials

The crucial component of any free cooling system is thermal energy storage. The storage material allows the ambient cold at night-time to be used during the daytime. In particular, thermal energy is stored by changing the internal energy, phase, or both of the storage materials [7,8]. PCMs are used instead of other latent heat thermal energy storage (LHTES) technologies because of their high energy storage density and isothermal storage process. PCMs have a high fusion heat and solidify and melt at a specific temperature. Thus, they are capable of releasing and storing a huge volume of thermal energy at the phase change temperature. Changing the phase of the material from a solid to liquid absorbs thermal energy, and revere process releases thermal energy. The working principles of a free cooling system with a PCM are shown in Fig. 1, which is explained below:

2.1. Discharging process (heat absorption)

Cold stored in the PCM is released when the room temperature increases beyond comfortable levels (Fig. 2a). The solid PCM absorbs heat from the hot indoor air. The temperature of the indoor air is reduced as a result of flowing through the PCM unit. This cooled air is circulated into the interior of the building. The PCM starts to melt as it absorbs heat from the air while remaining at a constant temperature [9].

2.2. Charging process (heat release)

This occurs during the night when the outdoor air temperature is lower than room temperature (Fig. 1b). Cool outdoor air flows through the PCM and absorbs heat from the liquid PCM. The PCM then begins to solidify at a specific temperature [9]. This process stops when the ambient temperature is almost equal to that of the solid PCM.

3. Previous research on PCM-based free cooling systems

Fig. 2 shows an experimental laboratory-scale PCM application [10]. Flat plates encapsulate RT25, a commercially available PCM. The methacryl encapsulation plates allow us to observe the phase change. The system thermal function was assessed using the following energy balance equation.

$$Q = Q_{env} + [mC_p(T_{inlet} - T_{outlet})]_{air} - \frac{dU_{ins}}{dt} \qquad (1)$$

On the right-hand side of Eq. (1), the heat released into the environment is given by the first term, the change in the air enthalpy as it passes through the PCM is considered in the second term, and the heat loss from the unit insulation is explained by the third term.

The PCM solidification process is triggered by a temperature difference (between the melting point and inlet air), encapsulation and the airflow rate.

The aluminum fins that are attached to the rectangular PCM container increase the PCM cold storage thermal capacity. The aluminum fins, filled with 3.6 kg of RT 20, maintain the hot ambient air at 24 °C for around 2 h with a 7.8- l/s airflow rate. For small spaces, the cooling load will be low so the airflow rate can also be low. In large spaces, on the other hand, the cooling load is high so the airflow rate will be high. Thus, parallel-connected cold storage can satisfy the required load [11–13].

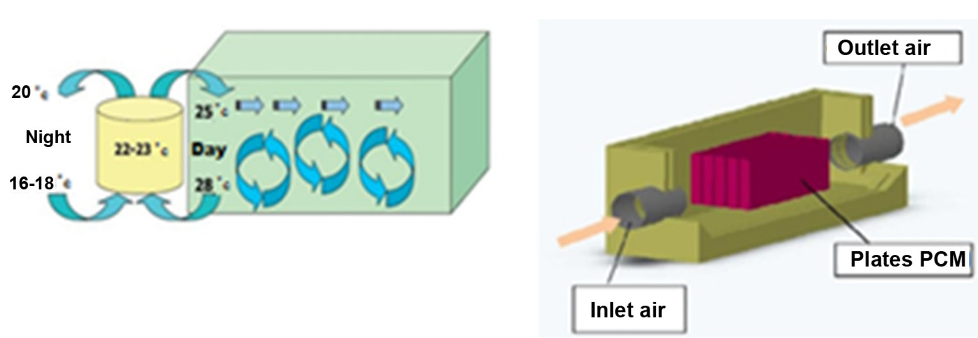

Fig. 2. Free cooling concept [10].

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