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Review

Review on phase change material based free cooling of buildings—The way toward sustainability

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ABSTRACT

The present world energy scenario signifies the importance of renewable energy utilization and paves the pathway towards green and net zero energy building concepts for a sustainable future. In the recent years, substantial energy is spent in building space heating/cooling applications to meet the human comfort requirements. In order to reduce the unnecessary losses associated with the buildings, several advancements toward energy efficient concepts are also being proposed and implemented in many buildings. Free cooling is one such novel concept through which building cooling demands can be met without compromising the indoor air quality. Free cooling concept stores the abundant atmospheric night cool energy in phase change materials (PCM) and uses the stored energy during the day hours to achieve the desired room comfort conditions. This review article aims to update and consolidate the substantial work carried out in the recent years by various researchers on free cooling technology using PCMs in latent heat thermal energy storage (LHTES) systems. In addition, future potential of free cooling technologies, scope for further improvement, policies that needs be promoted by the government toward its sustainability to ensure market penetration of free cooling technologies are also discussed in detail.

Contents

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1. Introduction

Residential and commercial buildings are among the few sectors that possess large energy saving potential by means of renewable energy utilization, green building concepts and building energy management. Ancient buildings were constructed with heavy mass that reduced fluctuations in indoor air temperature during the day and night. In recent years these concepts are not being followed much by the architects/construction engineers and in addition the buildings are constructed with low thermal mass to reduce the cost of construction. Hence modern buildings consume lots of energy to meet the requirements of human comfort. Mechanical type air conditioners/electric heaters are being used for space cooling/heating applications which are not only energy intensive but also responsible for indirect damage to the environment. The increasing demand for energy along with worldwide environmental threat has drawn the attention of researchers to devise the necessary steps for energy efficiency and sustainability in buildings. In order to reduce the energy consumption and to address the global environmental issues in buildings, more importance is given toward the implementation of energy efficient passive cooling technologies. Passive cooling technology adopts the principle of supplying cool air to the buildings with minimal electricity consumption by avoiding the energy intensive mechanical type air conditioning systems.

The use of PCM as storage medium for both cooling and heating applications appreciably reduces the energy demands of building sectors during the peak hours. The concept of using PCMs for building application has gained momentum only in the recent years. Though free cooling potential shows promising characters toward space cooling applications, it is not yet been commercialized and implemented in residential sectors. In order to create awareness and to make it sustainable some initiatives need to be taken by building technocrats, engineers and policy makers. Reviews on phase change material based thermal storage for energy efficiency in buildings have been carried out by various groups of researchers in recent years [1–12]. Fig. 1 represents the number of worldwide publications on PCM based energy storage from the year 1995 to 2014, which indicates the increase in development of PCM based storage in several applications. Fig. 2 shows the number of publications on free cooling technology by various authors with a minimum of three publications to their credit.

2. Concept of free cooling

The main principle of free cooling is to either receive or release an adequate amount of cool energy during phase transition at constant temperature with low amplitude of temperature [13]. Free cooling technology requires a storage unit which stores the thermal energy either by varying the internal energy of the storage medium (sensible heat storage) or by varying the phase of storage material (latent heat storage) or by both these processes. When the PCM loses its cool energy, it gets discharged and to charge it again, cool ambient air is allowed to pass through it during the night or early morning hours. Fig. 3(a) and (b) shows the operation of free cooling system during the day time and night time. The system consists of a shell and tube structured PCM regenerative heat exchanger in which the PCM is placed in the shell side and air is circulated through the tube passages. The cool energy available in the atmospheric air during the early morning hours is made to pass through the regenerative heat exchanger. When the cool air passes through the regenerative heat exchanger, PCM in the modules gets charged and stores the cool energy. Air circulation is made by using a fan during the night/early morning hours and dampers are used to control the air flow rate. Hot air from the room is made to pass through the PCM module through a small capacity fan and thus PCM releases the stored cool energy to the room.

3. Phase change materials for free cooling

PCMs are commonly classified into three main categories based on organic, inorganic and eutectic compounds. Based on the operating temperatures, PCMs are also classified as low temperature PCM, medium temperature PCM and high temperature PCM. The advantages and disadvantages of various types of PCM are briefed in Table 1. Various researchers have summarized the list of suitable PCMs for building applications [11,14–17]. Detailed reviews of phase change materials for free cooling of buildings have been done by various researchers [11,18,19]. Suitable phase change materials used by researchers in recent years for free cooling applications are given in Table 2 and the commercial PCMs available are given separately in Table 3.

4. Selection criteria of PCM for free cooling applications

Selection of suitable PCM is very essential for the successful implementation of free cooling concept. Performance of the free

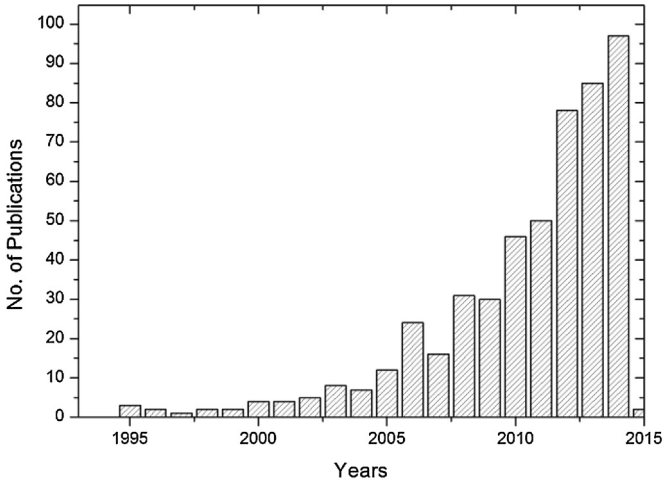

Fig. 1. No. of publications on PCM based energy storage.

Source: www.scopus.com, as on March 2015.