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RESEARCH ARTICLE-MECHANICAL ENGINEERING

Design and Optimization of Air to PCM Heat Exchanger Using CFD

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Abstract

Energy storage may shift and reduce peak power demand throughout the year. The ventilation system can be improved by incorporating phase change materials in heat exchangers as thermal energy storage. Optimizing and developing the air to a PCM heat exchanger is crucial. Using ANSYS (FLUENT 19.2), the numerical 2D model is used to optimize the heat transfer performance between airflow and PCM slabs. As latent heat thermal energy storage, nine rectangular slabs filled with PCM-RT25 were proposed. The PCM panels are 10 mm thick, and there is a 20-mm air channel between them. The PCM is encapsulated in 3-mm steel, and the shell is insulated with 10-mm wood. The length of the heat exchanger is 1 m, and its width is 0.6 m. The CFD model has been used to investigate the liquid fraction in PCM panels, as well as outlet air temperature and pressure drop through air channels. The findings revealed that air channel height, PCM panel height, melting temperature of PCM, and the heat exchanger's length-to-width ratio significantly impact melting and solidification rate through charging and discharging PCM. The proposed APHX takes 4 and 3.25 h to melt and solidify, respectively. The result of using RT25 + RT21 in succession is the same as using RT21 for melting, with a 1-h reduction in solidification time.

Keywords Air to PCM heat exchanger · CFD · Energy storage · Optimization · PCM—RT25

1 Introduction

Renewable energy only accounted for 11% of total energy production in 2021 due to various obstacles [1]. Thermal energy storage (TES) can help to stabilize renewable energy sources since it is intermittent [2]. The total energy stored by latent heat thermal energy storage (LHTES) is greater than that of sensible heat storage [3]. Materials that can switch between solid, liquid, and gas phases are known as phase change materials (PCMs) [4]. PCMs are widely incorporated with LHTES [5–7]. PCM's poor heat conductivity is the main downside [8, 9]. The free cold or heat energy is stored in LHTES for later use in free cooling system (FCS). PCMs may be solidified (charged) by cold air at night and melted (discharged) by hot air during the day [10]. Due to the high ventilation load on the heating, ventilation, and air conditioning (HVAC) system, the use of free cooling in the ventilation system is crucial [11]. The TES stores the cool night-time air as an FCS and releases it during the day. Outdoor air comes in contact with the PCM storage, which charges (solidifies) PCM at night and discharges (melts) PCM during the day. Investigating FCS and APHX reveals that proper system design is more critical for improving system performance than improving the thermal conductivity of the PCM [12]. The TES provides free heating by combining an APHX and a solar collector [13]. The conjunction of PCM storage with the refrigeration cycle during the day is being investigated experimentally. The PCM reduced the chiller's operating hours by up to 67% during peak load [14]. The case paraffin melted in a horizontal shell, and tube heat exchanger was investigated experimentally. The fins are attached to the bottom of the inner tubes to improve melting rates. Fins of various heights have been tested. According to the findings, the melting rate increased by 72.8% for fins 40 mm in height [15]. Fins have been investigated concerning the discharging and charging rate of LHTES in a building. Natural convection improves the heat transfer rate during melting, whereas conduction dominates during solidification. Implying fins have a more significant impact on the solidification rate [16]. CFD analysis was used to examine the impact of fins on the tube heat exchanger. The findings demonstrated that using fins improves heat transfer and shortens PCM melting and solidification times [17]. The flat plate APHX is most widely

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