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Experimental and numerical analysis of double-pass solar air heater utilizing multiple capsules PCM

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A B S T R A C T

This paper aims to investigate and analyze the thermal performance of a double-pass solar air heater using multiple rectangular capsules filled with paraffin wax-based on a phase change material PCM. An indoor projector simulator was used to test a new system during the charge/discharge process. In order to verify the accuracy of these readings, a mathematical model based on finite-volume scheme SIMPLE algorithm was applied to solve the three-dimensional forced convection turbulent flow in the double-pass solar heater. The computational results were in reasonable agreement with the experimental readings. The investigations were carried out at various airflow speed of (0.6, 0.9, 1.2, 1.5, and 1.8) kg/min and three solar irradiance intensities of 625, 725, and 825 W/m^2. The results showed that the increased airflow rate leads to delay in the melting period and decrease melting temperature of the paraffin during the melting period. Furthermore, it can be detected that the optimal discharging period and the air temperature rise of the heater were reached of: 3hr with (17.95–3) °C, 2 h with (14–3) °C, and 1.25 h with (11–2.5) °C, for various solar intensity of 825, 725, and 625 W/m^2 at the same airflow speed of 0.6 kg/min, respectively.

1. Introduction

Sunlight energy is the most abundant natural resource for humankind and a promising source of unpolluted energy. Accordingly, it can be guided economically and practically in thermal engineering applications through solar air heaters SAHs which are widely applying in many usages such as; heating of homes and glasshouse, and drying of agricultural products. These applications cannot effectively operate without some form of thermal energy storage, as reviewed comprehensively by authors [1–3]. Despite its safety and efficacy, the conventional SAH application suffers from two major drawbacks: firstly, the SAH has low convective-coefficient between airflow and absorbent surface as well as lost energy to the atmosphere. Numerous researchers have improved the thermal efficiency of the SAH through increasing the convective area using various techniques as artificial roughness, V- grooves, obstacles or fins to the absorbent surface [4–9]. Moreover, a new technology employing many transparent covers [10], or airflow mechanisms such as parallel flow or counterflow of the DP-SAH [11,12], that contributed for improving heat exchange and reducing lost energy.

Secondly, the intensity of solar energy in nature is intermittent at night, and its intensity is low when the clouds existed. However, thermal energy storage technology integrated with the solar collector can play an essential role in addressing this problem. Therefore, recent studies focused on thermal energy storage technologies-based on latent heat storage in the SAH systems, which utilize a phase change material (PCM) like paraffin wax which has the highest possible heat capacity. Phase change materials are capable of absorbing and releasing a large quantity of energy at a nearly constant temperature during charge/discharge processes. To achieve optimum performance of thermal energy and provide demand energy during cloudy periods and at night for different engineering fields: e.g., thermal storage with air conditioning or solar drying of paddy [13,14].

In particular, the latent heat storage system is a very desirable technique due to the use of paraffin wax-PCM which has a high capacity for thermal energy storage. Although the paraffin wax is easily available and safe form, at the same time it has a low

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