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A Study of the Melting Performance of CuO-coconut oil / Aluminum Foam Composite in a Thermal Energy Storage System: Rectangular Cavity

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ABSTRACT

In this study, the melting performance of a Cuo-coconut oil integrated in aluminum foam was investigated through numerical analysis, considering various porosities. The Cuo-coconut oil / aluminum foam composite subjected to different inclination angles. Utilizing a finite-volume-based transient solver in the ANSYS FLUENT software, a transient mathematical model was employed for simulations. It was observed that a reduction in porosity was effective in decreasing the total melting time. Moreover, modifying the inclination angle resulted in a 3.7% decrease in melting time. The study concluded that adopting higher inclination angles and employing aluminum foams with lower porosity could further enhance the melting rate of the Cuo-coconut oil / aluminum foam system.

Keywords: Natural convection, Cuo-coconut oil, Aluminum foam, Inclination angle, Melting performance.

1. Introduction

Phase change materials (PCMs) are considered as prospective thermal energy storage materials due to their capacity to release and store a high amount of thermal energy over a small temperature range. This property enables PCMs to be used in various thermal energy storage systems as well as thermal management systems. However, the primary disadvantage of PCMs is their poor thermal conductivity, which results in lower solidification and melting rates, and therefore lower heat transfer performance is achieved[1, 2]. Numerous strategies for increasing the thermal conductivity of PCMs have been proposed, including the encapsulation of PCMs, addition solid nanoparticles with high thermal conductivity, encapsulating PCMs, employing metal foams (i.e., porous media),and using fins [3].In the present study. The impacts of inclination angle and porosity have been considered to analyze the melting behavior of Cuo-coconut oil /aluminum foam composite in a rectangular cavity.

2. Physical model

The composite is filled with NePCM (CuO nanoparticles dispersed in coconut oil), embedded with aluminum foam. The left wall of the cavity is subjected toa constant heat flux and the others walls are adiabatic. The pore density of the aluminum foam is constant at 20 PPI.

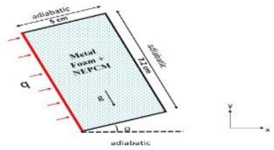

Figure 1. Schematic of the physical system.

A numerical model with consideration of natural convection is adopted to describe the melting process in PCM-filled metal foam. The momentum equation can be expressed using the Brinkman–Forchheimer-extended Darcy model. The current numerical code is validated against the experimental data from Gau

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and Viskanta [4] and numerical results reported by Brent at al [5].

3. Results and Discussion

The present computational study is conducted for metal foam porosity ranging between 0.88 and 0.96, inclination angle between 0° and 90°and pore density fixed at 20 PPI. The effect of these parameters on the melting front, isotherms, and melting rate is analyzed. The obtained results are presented and discussed below. Figure. 2 shows the impact of inclination angle on the melting process at t = 25 min and t = 32 min for a porosity of 0.88. As seen, the inclination angle of 30^o, 45^o, and 60^o has a little influence on the melting process of the NEPCM-filled metal foam. However, this effect becomes apparent at 30^o because the convection flow is intensified inside the cavity.

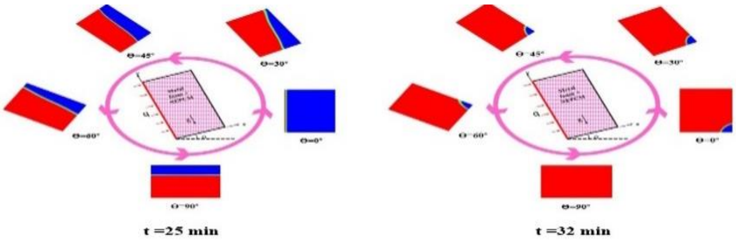

Figure .2 Evolution of the melting front for different inclination angles at ε=0.88

Figure 3 illustrates the melting time of the NEPCM-filled metal foam at various porosities and inclination angles. As seen, the tendency of melting time is the same for all cases. for the range of inclination from 0^o, and 60^o, the melting time slightly decreases with the increase of the inclination angle. However, this decrease becomes more significant as the inclination increases beyond 60^o, particularly, at higher porosity values. With the increase of inclination from 0^o to 90^o, the melting is reduced by 3.7%, 4.6%, and 5.7%, at time at ε=0.88, ε=0.92, and at ε=0.96, respectively.

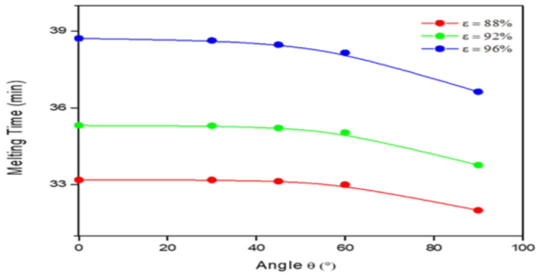

Figure 3. The melting time of NEPCM for different porosities and inclination angles.

4. Conclusions

In the current study, the effect of the inclination angle and porosity on the melting performance of a NEPPCM-filled metal foam in a rectangular cavity is investigated numerically. Two-dimensional models adopting theenthalpy-porosity method and thermal equilibrium equation wereestablished to describe the melting process of the NEPCM. The main conclusions are as follows:

(1) Thermal equilibrium model has proven accuracy in predicting the melting process within a wavy cavity. A maximum deviation of 4 % is observed between the predictive and experimental data.
(2) The melting time is decreased with the decreasing porosity. When the porosity is reduced from 0.96 to 0.88, the melting time is reduced by 15.3 %.
(3) Inclination of the storage unithas a positive impact on the melting performance, particularly at 90^o and ε=0.96, where the melting time is reduced by almost 6%.

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