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Heat Transfer Behaviors of Parallel Plate Systems in Sensible Thermal Energy Storage

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Abstract

In the present investigation a simplified analysis is accomplished to handle a parallel plate system with parallel channels as a porous media and to evaluate the permeability, inertia coefficient, the interfacial heat transfer coefficient between solid matrix and fluid and the specific area for the equivalent porous medium. In the local heat transfer coefficient is also considered the radiative heat transfer which will be temperature dependent. The evaluation of these two terms will be carried out numerically by the Ansys-Fluent code to compare the simplified and numerical model results. The analysis should allow the estimation of an optimized configuration, in terms of number of pore per inch (PPI) or channels per unit of length (CPL), as a balance between pressure drop and heat transfer rate inside the parallel plates configuration. Results show the effects of storage medium, different porosity values, porosity effect and mass flow rate on stored thermal energy and storage time. Results in terms of stored thermal energy as function of time are presented. Moreover, the behavior related to fluid pressure losses and internal heat transfer is analyzed.

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Keywords: Honeycomb, parallel plate system, parallel channels, porous media

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1. Introduction

In many industrial and commercial applications the management of thermal system represents one of the major problems, because the energy demands could be varied on daily, weekly and seasonal bases. Therefore, much attentions have been given on Thermal energy Storage (TES) [1], in order to build a thermal buffer that could limit the discrepancy between the energy demand and the supply energy. The employment of a TES system is particularly notable especially for energy solar applications, because it improves the efficiency of the whole solar power plant [2]. In a TES system, different solid matrices can be employed as storage medium, such as packed beds [3], foams [4] and parallel plate channels (honeycomb) [5]. Among these, the parallel plate systems seem more flexible in terms of porosity compared to the other matrices [5], because it is easy to design the modular geometric units and the symmetric structure allows a uniformly flowing of the heat transfer fluid in each channel. A transient analysis of an high temperature thermal storage honeycomb system with parallel squared channels is numerically studied by Andreozzi et al.[6]. The honeycomb system is then compared with an anisotropic porous medium model. By the results, it can be seen that the honeycomb system can be manage as a porous model for higher channel number. Luo et al. [7] numerically and experimentally investigated of a ceramic honeycomb. They have built a one-dimensional numerical model and then it was compared with the experimental data. The results have showed that larger channels and thinner walls bring about a faster increase of the exit temperature in charging phase and an higher drop in discharging phase.

In this paper an analytical and numerical analysis is accomplished for a parallel plate honeycomb system with parallel channels. The permeability, the specific area and the interfacial heat transfer coefficient between solid matrix and fluid have evaluated. A comparison is then carried out with an equivalent porous medium. Radiative effects are considered in the local heat transfer coefficient which will be dependent by the temperature. The analysis should allow the estimation of an optimized configuration, in terms of number of pore per inch (PPI) or channels per unit of length (CPL). Results in terms of stored thermal energy as function of time are presented. Moreover, the behavior related to fluid pressure losses and internal heat transfer is analyzed.

Nomenclature

A	area, m^{-2}
c, c_p	specific heat, J $kg^{-1}K^{-1}$
D	cylinder diameter, m
H	height of a single elementary channel, m
h	surface heat transfer coefficient, $Wm^{-2}K^{-1}$
h_{sf}	interfacial heat transfer coefficient between solid matrix and fluid, $Wm^{-2}K^{-1}$
k	thermal conductivity, J/kg K
K	permeability, m^2
L	length of parallel plates, m
n	air Channel per unit of length (CPL)
p	static pressure, Pa
Pe	Peclet Number
s	thickness of a single elementary channel, m
t	time, s
T	temperature, K
u	velocity x-component, ms^{-1}
U	unit of length,m
V	velocity y-component, ms^{-1}
V	volume, m^3
x, y, z	rectangular Cartesian coordinates, m