TRANSIENT FORCED CONVECTION FLOW THROUGH A PACKED BED FOR HEAT STORAGE

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Two-dimensional steady forced convection in a vertical rectangular cavity bounded by adiabatic walls has been studied numerically by adopting a two-temperature model of heat transfer. Such a model, which allows the fluid and solid phases not to be in local thermal equilibrium, is found to modify the flow behaviour and heat transfer rates. Knowledge of this behaviour is very important for the design of thermal storage systems and other practical applications in porous media.

INTRODUCTION

Forced and free convection in porous media occur in many systems and in nature including geophysical, environmental and technological problems. Such problems are of great interest, for example, in the utilisation of geothermal energy, high-performance building insulation, heat storage, Inert gas plant system is used on board the tanker ships, post-accident heat removal from pebble-bed nuclear reactors, multi-shield structures used in the insulation of nuclear reactors, pollutant dispersion in aquifers, solar power collector, etc.

The problem of free convection flow in differentially heated cavities, with top and bottom walls insulated, and filled with Darcian or non-Darcian fluid-saturated porous media, is of fundamental interest to many technological applications in the modern industry. Some of these investigations[1-4] have contributed with theoretical results to this topic.

However, it was assumed in these studies that the convecting fluid and the porous medium are everywhere in local thermodynamic equilibrium. The inclusion of more physical realism in the Darcian fluid model is, however, important for the accurate modelling of any practical problem. Although the problems of convective heat transfer in porous cavities when the fluid and the porous medium are in the local thermodynamic equilibrium have received great attention in the literature, the analyses devoted to convective flows using a thermal non-equilibrium model are to our knowledge scarce. A literature search indicates that this model of porous medium convection has been considered for enclosure problem[5-6] .A recent restatement of the full equations has been presented by Nield and Bejan[7], where the equations governing the evolution of temperature in the solid and fluid phases are coupled by means of terms allowing the local transfer of heat to be proportional to the local temperature difference between the phases. In this study, the non-thermal equilibrium unsteady forced convection flow through a heat storage porous bed is presented and comprehensive numerical investigations of the phenomenon are carried out.

The aim of the present investigation is to study the unsteady state forced convection in an open ended rectangular porous cavity using a non-equilibrium model of heat transfer between the fluid and the solid phase of the porous medium. This is accomplished by focusing on the thermalization time, the time required for both the fluid and solid to attain approximately the same temperature.

The study considers the transient thermal behaviour of forced convection flow in porous channel that is shown in the following figure. The channel boundaries are assumed to be insulated and the unsteadiness in the channel thermal behaviour is a result of sudden change in the fluid inlet temperature. In this problem, it is found that four dimensionless parameters control the local thermal non- equilibrium assumption. These parameters are the porosity, the volumetric Biot number, the dimensionless channel length, and the solid to fluid total thermal capacity ratio.

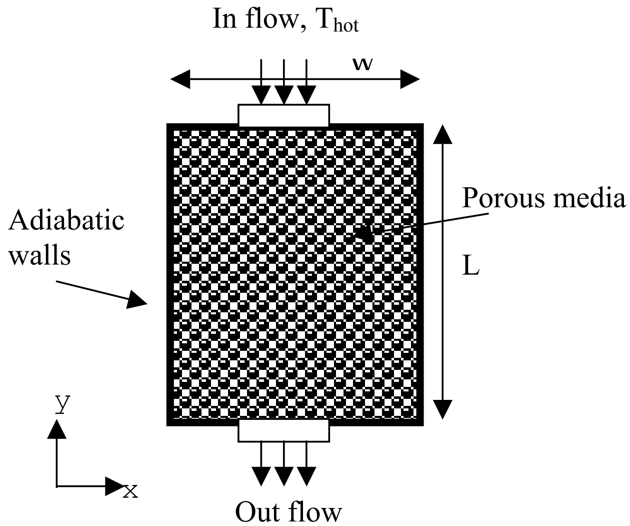

Figure: Schematic diagram of physical model

The results reported in this study have been numerically obtained by solving the evolutionary model using a cell-centered finite volume scheme and the Alternating Direction Implicit (ADI) method for a range values of parameters like the solid/fluid-scaled heat transfer coefficient and the porosity-scaled conductivity ratio for different values of the Reynold numbers. The thermal response of the packed bed during a given operating condition is shown graphically. In addition, the temporal impact of the Darcy and Reynold number on energy storage is explored over a broad range of pertient non-dimensional parameters by means of error maps. Results are also presented in terms of isotherms, streamlines and average Nusselt numbers for the fluid and solid phases.

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