5

Variable Viscosity Forced Convection in Porous Medium Channels

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CONTENTS

Summary

A review of recent studies on the hydrodynamics and heat-transfer effects of variable viscosity flows in saturated porous media is presented in the restricted context of a liquid, whose viscosity variation is strongly dependent on the temperature variation, flowing through porous media bounded by solid wall(s) on one (flat plate) or two sides (parallel-plates channel). Section 5.2 on Hydrodynamics unravels the effects of temperature-dependent viscosity on the Hazen–Dupuit–Darcy (HDD) model, and on the departure from Darcy flow. This section also presents the need for fundamental modifications necessary to correct both the viscous- and form-drag effects, leading to the introduction of the Modified-HDD (M-HDD) model. Also, the inlet temperature effects on the variable viscosity-affected transition parameter are explained in detail. Influence of variable viscosity on the Nusselt number, defined suitably for the chosen porous medium configuration, the power gain in the pump used to maintain flow in a heated porous configuration, and other aspects related to heat-transfer enhancements, are reviewed in Section 5.3. Substantial effects on the local velocity variation but surprisingly small effects on the heat transfer (Nusselt numbers) are the noteworthy outcomes of previous studies. Section 5.4 reviews the analytical efforts to address the problem of both hydrodynamics and heat transfer in porous medium channels with temperature-dependent viscosity flows. Before concluding, a brief section is devoted on the experimental validation of the proposed models.

5.1 Introduction

What are the hydrodynamics and heat-transfer effects of variable viscosity flows in saturated porous media? In this chapter, this question is answered in the restricted context of a liquid, whose viscosity variation is strongly dependent on the temperature variation, flowing through porous media bounded by solid wall(s) on one (flat plate, Figure 5.1[a]) or two sides (parallel-plates channel, Figure 5.1[b]). The pressure-dependency of a liquid's viscosity is usually negligible and is not considered here.

The chapter is divided into three major sections. Section 5.2 enunciates recent studies on the effects of temperature-dependent viscosity on the Hazen–Dupuit–Darcy (HDD) model (also referred to as the Darcy–Forchheimer model), and on the departure from Darcy flow. Here the review of porous medium channel flows with temperature-dependent viscosity is done in line with the historical development of the present-day HDD model, from Darcy's experiments (1856) to the ad hoc generalization to three dimensions by Stanek and Szekely (1973) — which were all done essentially, with porous channels. Section 5.3, titled Heat Transfer reports on the effects of

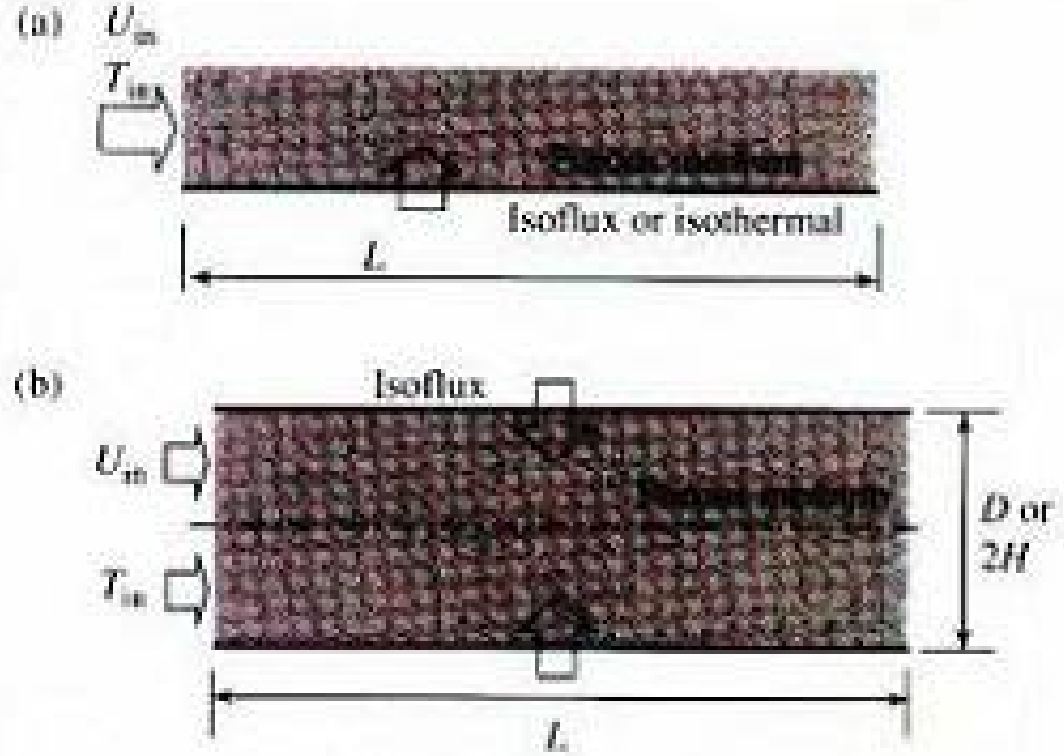

FIGURE 5.1
Schematic of (a) flat-plate bounded porous medium flow; (b) parallel-plates channel sandwiching porous medium flows.