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Analytical Studies of Forced Convection in Partly Porous Configurations

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I. INTRODUCTION

Forced convection in a composite region, part of which is occupied by a clear fluid and part by a fluid-saturated porous medium, has recently attracted considerable attention and become a subject for numerous investigations (Alkam and Al-Nimr, 1998; Al-Nimr and Alkam, 1997, 1998; Chikh et al., 1995a,b; Rudraiah, 1985). This interest is due to many important thermal engineering applications relevant to this problem. Solid matrix heat exchangers, the use of porous materials for heat transfer enhancement, fault zones in geothermal systems, and solidification of binary alloys are a few of these problems.

Momentum transport in the fluid/porous interface region was first investigated by Beavers and Joseph (1967). Proceeding from the results of their experimental investigation, Beavers and Joseph suggested the slip-flow boundary condition at the fluid/porous interface. According to this boundary condition, the velocity gradient on the fluid side of the interface is proportional to the slip velocity at the interface. The investigation by Beavers and Joseph was continued in works by Taylor (1971) and Richardson (1971). In all the papers mentioned above, fluid flow in the porous region was modeled by the Darcy equation. Considerable progress on this problem was made by Vafai and Kim (1990a), who modeled the flow in the porous region utilizing the so-called Brinkman–Forchheimer–

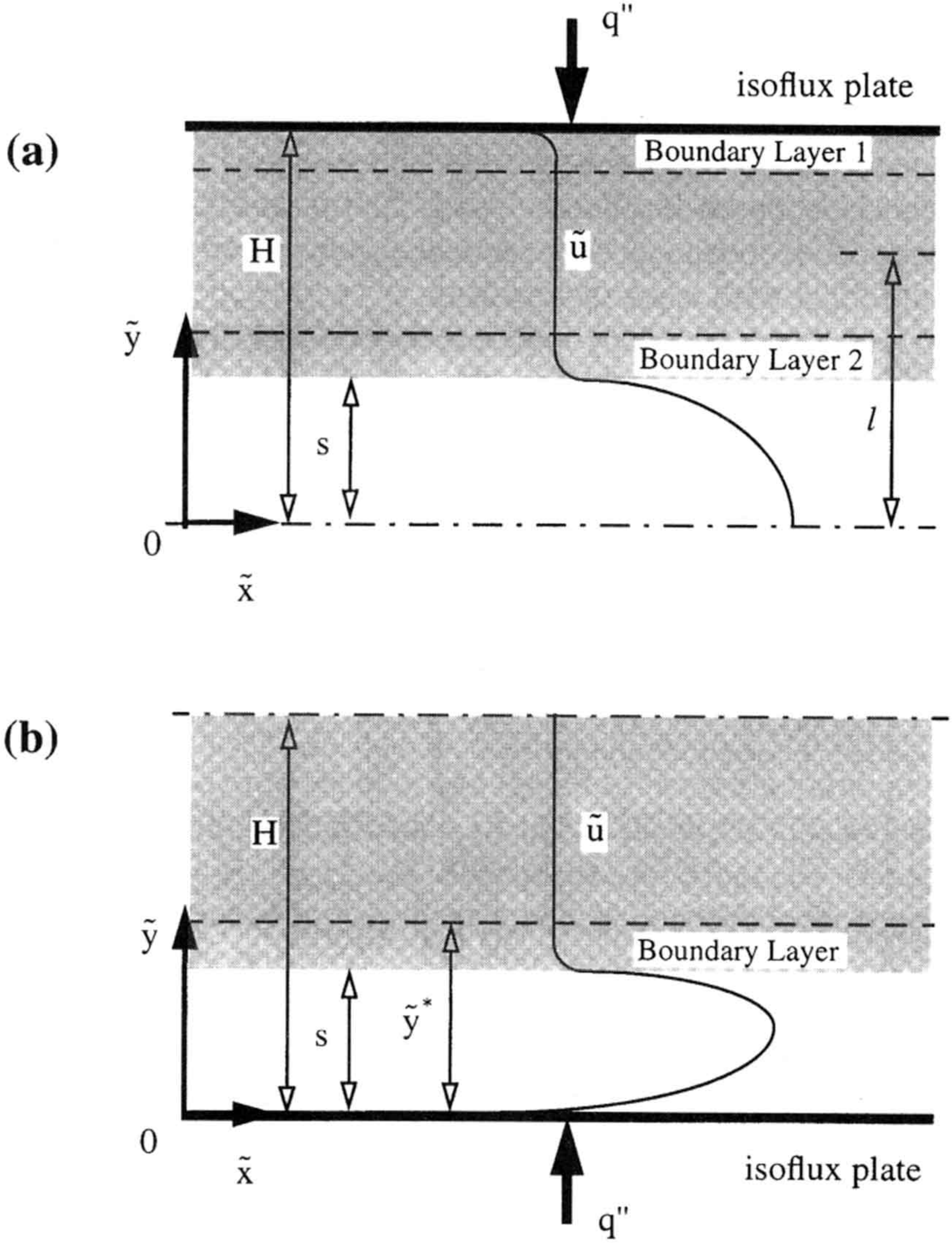

Figure 1. Different geometrical configurations of a parallel-plate channel partly filled with a porous medium: (a) parallel-plate channel with a porous layer at the walls; (b) parallel-plate channel with a porous core; (c) parallel-plate channel with a porous layer at one wall and a clear fluid layer at the other—heating from the fluid side; (d) parallel-plate channel with a porous layer at one wall and a clear fluid layer at the other—heating from the porous side.