Abstract

This thesis mainly focuses on the development and implementation of a non-primitive boundary element method for Stokes and Brinkman flows through channels. However, the geometries considered in this thesis deal with some specific applications. **Chapters 1** and **2** of the thesis are introductory.

In **Chapter 3** we investigate steady, pressure-driven, two dimensional (2D) flow of Newtonian fluid through a slip-patterned microchannel in the low Reynolds' number limit. The slip flow regime is modeled using Navier's slip boundary condition. Depending on the relative location of slip regime on the top and bottom walls of the channel, in-phase and out-phase configuration of patterned slip are defined. Moreover, based on the periodicity of patterning, we have considered two subcases of the patterned slip, namely large and fine patterning. Boundary element method (BEM) is used to numerically solve Stokes equation and obtain the streamline profiles. Streamlines, velocity profiles, pressure gradients, and shear stresses are analyzed to gain a proper understanding of the flow mechanics.

Chapter 4 focuses on the investigation of two-dimensional (2D) steady Stokes flow inside a topographically patterned microchannel. Boundary element method (BEM) is used to solve the Stokes equation and obtain the streamline profiles. We restrict ourselves to rectangular stepped geometries and study the effect of variation of step width, step height and step frequency. Interestingly, 'crown-shaped' patterns in the horizontal velocity profiles are formed when a sudden contraction is met in the flow region. Pressure gradients, together with the velocity and streamline profiles are analyzed to gain a wholesome understanding of the flow physics.

In **Chapter 5** we develop a non-primitive boundary integral equation (BIE) method for steady two-dimensional (2D) flows of an incompressible Newtonian fluids through porous medium. We assume that the porous medium is isotropic and homogeneous in nature, and utilize Brinkman equation to model the fluid flow. First, we present boundary integral equation (BIE) method for two-dimensional Brinkman equation in terms of the non-primitive variables namely, stream-function and vorticity. Subsequently, we discuss an application of our proposed method to flows through porous wavy channel, which is a problem of significant interest in the micro-fluidics, biological domains and groundwater flows.

In **Chapter 6** we develop a non-primitive boundary integral formulation (BIF) for modeling steady two-dimensional (2D) flow through a composite porous channel. We consider a planar channel having two packings that are filled with fully saturated porous media. We assume that the two porous media are isotropic and homogeneous in nature, but with different permeabilities. Brinkman equation is used to model fluid flow through porous media. Stress-jump condition is utilized at the porous-porous interface to account the flow exchange due to two layers porous media. We present BIF for steady two-dimensional Brinkman-Brinkman system in terms of non-primitive variables namely, stream-function and vorticity. We derive the Brinkman layer thickness for Brinkman-Brinkman system as a function of various flow parameters.

Keywords : Boundary element method; Stokes's equation; Navier's slip; Patterned slip; Patterned topography; Brinkman's equation; Wavy channel; Darcy number; Permeable interface; Stress-jump condition; Brinkman layer.