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Theoretical investigation of steady isothermal slip flow in a curved microchannel with a rectangular cross-section and constant radii of wall curvature

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Abstract

The paper presents results of an investigation of the slip flow in a curved microchannel with a rectangular cross-section. Solutions of the problem were obtained analytically using the Fourier method and the method of the eigenfunction decomposition demonstrating thus the applicability of two different analytical approaches to the solution of the fluid flow problems in microchannels. In addition, a numerical approach based on the Lattice Boltzmann method (LBM) was employed. The velocity profiles in the microchannel were obtained with the help of the infinite series solutions validated against the numerical simulations. The solution yields the relations, which enable estimating the hydraulic resistance coefficient and the initial length of the developing flow in the microchannel as the functions of the Knudsen number and the flow curvature parameter.

1. Introduction

The microchannel flows, which take place in various micro-fluidic devices such as micro-electro-mechanical systems, bioengineering and micro-energy systems, have been in the focus of the persisting scientific and practical interest during the last few decades. The micro-fluidic devices are extremely small and operate in the range of the micro-scales whose characteristic length is of the micrometer order of magnitude. This engenders the situation, where the scaling laws used for the common engineering applications do not hold for the microscale geometries influenced predominantly by the decrease in the length scales in the flow pattern and to a smaller extent by the rarefaction effects due to the reduced density [1].