Microchannels and Nanochannels Gas Flow for the Entire Knudsen Number Domain

Microchannels and nanochannels gas flows are often present in Micro-Electro-Mechanical-Systems (MEMS) and Nano-Electro-Mechanical-Systems (NEMS). Hence, the research of the gas flow in small scales enable deeper understanding and development of more precise and more efficient micro and nano-devices like micro/nano sensors, actuators, motors, pumps, valves etc.

This paper presents an analytical solution for steady rarefied compressible viscous gas flow in the microchannels and nanochannels with constant or slowly varying cross section. It covers both all gas rarefaction regimes (from continuum to free molecular gas flow) and all Mach number regimes (from subsonic to supersonic). The solutions for the velocity and pressure distribution in the channels is obtained by the macroscopic approach, using the one-dimensional model of continuum equations. A specially modeled friction factor is attained by an approach that includes both the general velocity slip boundary condition, and the dynamic viscosity generalized by the rarefaction correction parameter. This method spreads the application of the solution to the entire range of Knudsen numbers. Moreover, inclusion of the inertia effect into the governing equations allows the application of the solution to both subsonic and supersonic gas flows. The presented solution confirms the existence of the Knudsen minimum in the diverging, converging and microchannels and nanochannels with constant cross section.

The proposed analytical solution was verified by its comparison with the results available in the literature. As it is simple and reliable, it can serve as an accuracy verification of experiments and numerical calculations for a variety of gas flow conditions. Moreover, the presented method is not only suitable for solving pressure-driven gas flows in micro/nanochannels, but also for various shear-driven gas flows (lubrication) in micro/nano scales.