A Marie-Curie-ITN
within H2020

Proceedings of the 2nd MIGRATE Workshop
June 29-30, 2017 – Sofia, Bulgaria

MIGRATE2017:154767

RAREFIED GAS FLOW BETWEEN TWO PARALLEL PLATES WITH BOTTOM INJECTION AND TOP SUCTION

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KEY WORDS

Kinetic theory, Rarefied gas dynamics, Knudsen number

ABSTRACT

Rarefied gas flow in the presence of porous walls, eventhough it could be of high importance for various industrial application, is a topic that has not attracted significant attention. In the present work, the typical Poiseuille flow subjected to boundary conditions that can be considered as porous media is studied as a benchmark problem.

Consider the rarefied fully developed gas flow between two parallel porous plates, located at $x = \pm 1/2$, subject to a pressure gradient in the main flow direction y. Let the porous plates be such that a uniform vertical crossflow U is generated in the x direction from the bottom towards the top plate (vertically to the main flow). The flow configuration is shown in Fig. 1.

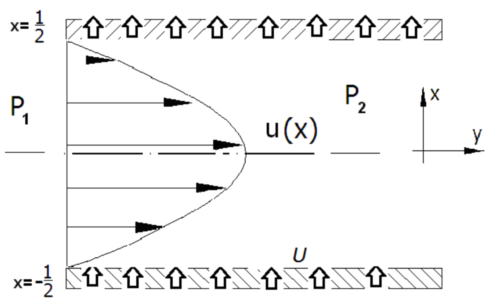

Figure 1. Flow configuration between two parallel plates with suction and injection.

In the hydrodynamic regime the solution is trivially obtained [1]. In the transition and free molecular regimes however, a kinetic approach is required. Since this is a pressure driven flow and the flow is fully developed the linearized BGK kinetic model is implemented. Linearization is based on a global Maxwellian with velocity U in the x direction. The non-dimensional governing equation becomes

$$c_x \frac{dg}{dx} + \delta g = \delta u_y\left(x\right) - \frac{1}{2} \tag{1}$$

$$u_y\left(x\right) = \frac{1}{\sqrt{\pi}} \int_{-\infty}^{+\infty} g\left(x, c_x\right) \exp\left[-(c_x - U)^2\right] \mathrm{d}c_x \tag{2}$$

with boundary conditions $g\left(-1/2, c_x\right) = 0$ when $c_x > 0$ and $g\left(1/2, c_x\right) = 0$ when $c_x < 0$. In equations (1) and (2), $g\left(x, c_x\right)$ is the unknown distribution $c_x \in \left(-\infty, \infty\right)$ is the x-component of the molecular velocity, $u_y\left(x\right)$ is the macroscopic velocity and $\delta \in \left[0, \infty\right)$ is the gas rarefaction parameter which is proportional to the inversed Knudsen number.

Some indicative results are presented in Fig. 2, where the macroscopic velocity is shown for $\delta = 10, 200$ and various values of the uniform vertical velocity U.

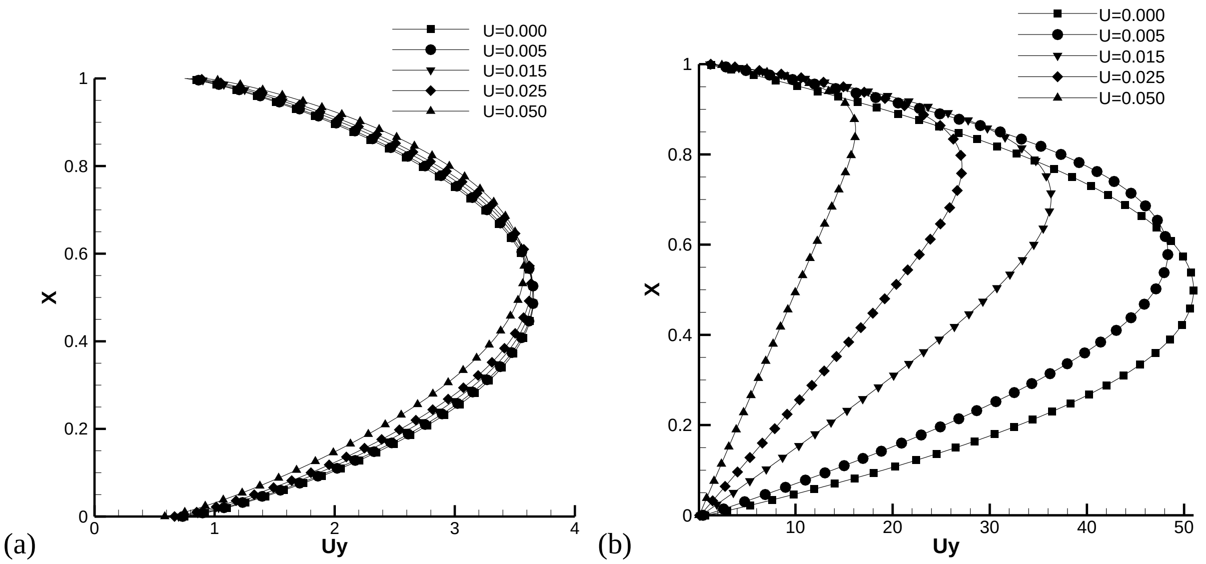

Figure 2. Dimensionless velocity distributions for flow between two parallel plates with uniform suction and injection with (a) $\delta = 10$, (b) $\delta = 200$ and various vertical velocities U

As it is shown in Fig. 2a for $\delta = 10$ the effect of the vertical velocity is small. On the contrary for $\delta = 200$ (Fig. 2b) the effect of the vertical velocity is significant. It is noted that the velocity distributions in Fig. 2b obtained by kinetic modeling are in excellent agreement with the corresponding continuum solution [1].

Acknowledgements

This publication is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 643095.

References and Citations

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