Proceedings of CHT-15
ICHMT International Symposium on Advances in Computational Heat Transfer

May 25-29, 2015, Rutgers University, Piscataway, USA

CHT-15-xxx

CONJUGATE HEAT TRANSFER IN MICROCHANNEL INCLUDING RAREFACTION AND VISCOUS DISSIPATION

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In this paper, the simultaneously developing laminar slip-flow in parallel plates microchannel with constant temperature is numerically study. The effects of combined axial fluid/wall conduction and viscous dissipation are considered. The fluid is assumed to be incompressible and with constant properties. The finite volume method is used to solve the two-dimensional Navier–Stokes and energy equations with slip velocity and temperature jump at the fluid/solid interface. The results are obtained from different Brinkman numbers, Knudsen numbers, and thickness of wall. The influence of viscous dissipation on the heat transfer rate is demonstrated for all values of Kn.

KEYWORDS

Conjugate heat transfer, Brinkman number, Knudsen number, Axial conduction, Viscous dissipation, Microchannel, Simultaneously developing.

ANALYSIS

For modelling the slip flow we use the conventional continuum momentum and energy equations with modified boundary conditions for slip velocity and jump temperature at the walls. The first slip and jump conditions derived by Maxwell in 1879 and by Smoluchowski in 1898 for velocity and temperature are respectively as follows:

$$u_{slip} - u_w = \frac{2-\sigma_v}{\sigma_v}\lambda \left.\frac{\partial u}{\partial n}\right|_w \tag{1}$$

$$T_{slip} - T_w = \frac{2-\sigma_T}{\sigma_T}\frac{2\gamma}{(\gamma+1)}\frac{k}{C_p\mu}\lambda\frac{\partial T}{\partial y} \tag{2}$$

The geometry of the problem is shown in figure 1

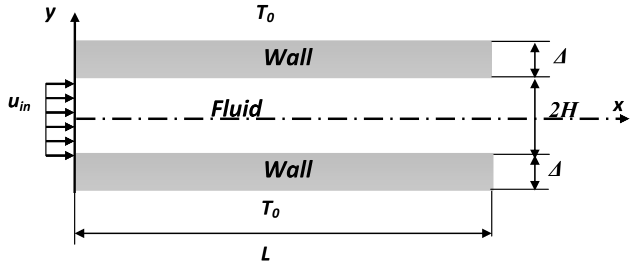

Figure 1 Geometry of problem.

NUMERICAL MODEL

The conservation equations of mass, momentum, and energy for a two dimensional laminar convection and incompressible flow, with the associated boundary conditions of slip velocity and jump temperature at the interface, are solved using a finite volume technique. The implementation of slip velocity and jump temperature at the interface is detailed in the work research of Madhawa et al [2008] and Kabar et al [2013].

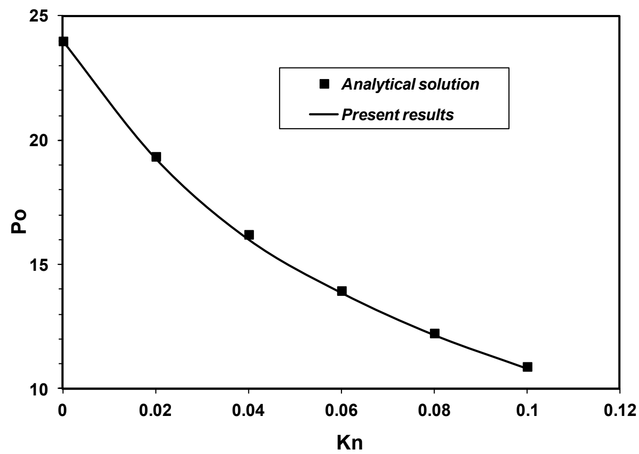

Figure 2. Comparison of Poiseuille number obtained in the present study with the analytical solution.

The numerical code developed for this study, has already been validated with the analytical solution of Poiseuille number in fully developed region of parallel plates microchannel given by Kandiklar et al. [2006] Figure 2 shows a very good agreement between the present work and the analytical solution given by Kandiklar et al. [2006] concerning Poiseuille numbers in fully developed region.

RESULTS AND DISCUSSION

In this stady, we consider a long microchannel $X^* = x/_{PeD_h} = 2$. The gas is air (Pr = 0.7;γ = 1.4 and β = 1.67). Three non dimensional thicknesses of the wall are studied $E = \frac{\Delta}{2H} =$ 0, 0.1 and 2. Reynolds number is Re = 100; K = 100, this value covers some materials used in the manufacture of micro-heat exchangers or used in the electronics industry such as Ceramics, and Semiconductors. The more Kn increases the more the jump temperature increases and the thermal resistance at wall–fluid interface resulting in a decrease in the heat transfer (see figure 4). The influence of the wall thickness E is more pronounced, especially at the entry of the microchannel. A small variation of fully Nusselt number is obtained when E increases for all values of Kn and Br. The effect of viscous dissipation is clearly highlighted far from the entry. The establishment length of thermal boundary layer increases when Kn and E increase, especially when the viscous dissipation is taken into account.

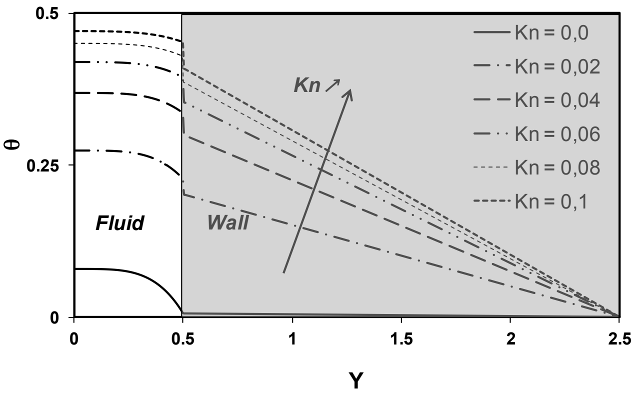

Figure 3. Temperature profiles at exit for differents Kn, Br = 0.1.

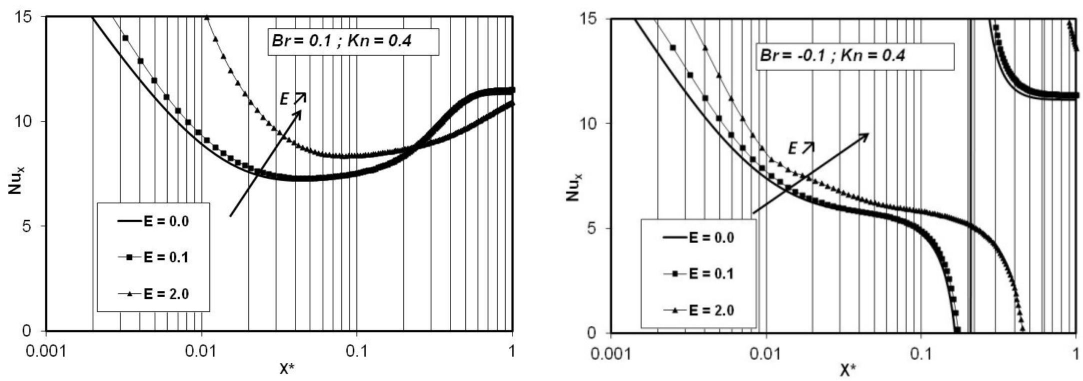

Figure 4. Evolution of local Nusselt number along the microchannel for differents wall thickness; Br =0.1; -0.1

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