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Conjugate heat transfer with rarefaction in parallel plates microchannel

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ABSTRACT

In this paper, we study numerically the effects of axial wall conduction and rarefaction in parallel plates microchannel. The simultaneously developing laminar flow with a constant heat flux (H2) boundary condition will also be considered. The finite volume method is used to solve the two-dimensional Navier–Stokes and energy equations, with slip velocity and temperature jump boundary implemented at the fluid/solid interface. The results obtained by our computer code are compared to the analytical results found in the literature. For different Knudsen number Kn, thermal conductivity ratio K and dimensionless thickness E, the influence of axial conduction is demonstrated for Kn = 0, especially for large values of K and E. Concerning slip-flow, the effect of axial conduction proved to be negligible for all values of K and E.

1. Introduction

The use of micro-channels for removal heat is undertaking a great interest in various industrial fields, such as electronics, micro heat exchangers and bio-engineering. This type of cooling offers high performances in heat transfer. However, to conceive and manufacture such channels, it is necessary to understand and characterize flows as well as heat transfer in micro-scale heat transfer problems. It is also important to examine the interaction of convective heat transfer in the fluid with conduction in

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Nomenclature

a	coefficient in the discretization equation
b	source term in the discretization equation
Cp	specific heat (J/kg K)
D_h	hydraulic diameter (m)
E	dimensionless thickness of the plate
H	height of microchannel (m)
h	heat transfer coefficient (W/m^2 K)
K	thermal conductivity ratio $K = k_s/k_f$
k	thermal conductivity (W/m K)
Kn	Knudsen number $\mathrm{Kn} = \lambda/D_h$
L	length (m)
Nu	Nusselt number
Nu_x	local Nusselt number
P	dimensionless pressure
p	pressure (N m^{-1})
Pe	Péclet number $\mathrm{Pe} = \mathrm{Pr}\cdot\mathrm{Re}$
Po	Poiseuille number $\mathrm{Po} = f\,\mathrm{Re}$
Pr	Prandtl number
q_0	heat flux (W/m^2)
q	dimensionless heat flux at the interface
q^*	normalized heat flux $q^* = q/q_m$ at the interface
Re	Reynolds number $\mathrm{Re} = \rho u_m D_h/\mu$
T	temperature (K)
U, V	dimensionless velocity
u, v	velocity components in Cartesian coordinates (m s^{-1})
X^*	dimensionless axial coordinate $X^* = x/\mathrm{Pe}D_h$
X^+	dimensionless axial coordinate $X^+ = x/\mathrm{Re}D_h$
x, y	Cartesian coordinates (m)
Y	dimensionless coordinate
β	ratio of accommodation coefficient
γ	heat capacity ratio
Δ	thickness of the plate (m)
θ	dimensionless temperature
λ	molecular mean-free-path (m)
μ	viscosity dynamic (kg/m s)
ρ	density (kg/m^3)
τ	shear stress (N/m^2)
σ_T	thermal accommodation coefficient ($\sigma_T = 1$)
σ_v	momentum accommodation coefficient ($\sigma_v = 1$)
ϕ	independent variable

Subscripts

b	Bulk
f	Fluid
N, S, E, W	neighboring grid points
in	inlet
int	interface
m	mean
s	solid
slip	slip
w	wall