Numerical investigation of counter flow microchannel heat exchanger with slip flow heat transfer

Ahmed M. Shakir a, Ahmed K. Mohammed a, Mushtaq I. Hasan b,*

a Mechanical Engineering Department, College of Engineering, Basrah University, Iraq
b Mechanical Engineering Department, College of Engineering, Thi-Qar University, Thi-Qar, Iraq

1. Introduction

In recent years, progress in micro fabrication and assembling various small systems has lead to the development of extremely small scale machines commonly referred to as MEMS (Micro Electro-Mechanical Systems). These systems are generally defined as electro mechanical devices having a characteristic length scale between 1 μm and 1 mm such as microchannel heat exchangers, micro reactors, micro sensors, …etc. Microchannel heat exchanger has found applications in highly specialized areas such as microelectronics cooling, biomedical processes, metrology and robotics [1]. Miniaturization has provided many benefits including faster response time, high levels of system integration, high heat transfer rates and reduced cost [2]. Knudsen number is a measure of the degree of the rarefaction which is defined as the ratio of mean free path to the characteristic length scale of the system. For small Knudsen numbers, Kn ≤ 0.001, the fluid is considered to be a continuum, while for large values, Kn ≥ 10, free molecular flow is assumed. The slip-flow region studied in this paper has Knudsen number in the range of 0.001 ≤ Kn ≤ 0.1 rarefaction effects start to influence the flow and the flow can be described by the Navier–Stokes equations with slip flow wall boundary conditions. To understand the flow through microchannels, many researchers have studied experimental, analytical and numerical investigations in last two decades. For example, Yu and Ameel [3] (2001) analytically studied laminar slip-flow forced convection in rectangular microchannels with constant wall temperature by applying a modified generalized integral transform technique to solve the energy equation. Assuming hydro dynamically fully developed and thermally developed flow. They concluded that the normalized fully developed Nusselt number decrease with increasing aspect ratios. The effect of Knudsen number on heat transfer is a result of the reduction of the wall normal velocity and temperature gradients with the increasing velocity and temperature jump that accompany the departure from the continuum regime.

Khan and Yovanovich [4] (2007) analytically investigated the laminar forced convection in 2-D rectangular micro and nanochannel heat sinks under hydro dynamically and thermally fully developed conditions with velocity-slip and temperature jump boundary conditions at the channel walls. They used the air as the coolant fluid. Iso flux thermal boundary condition is applied on heat sink base. They neglected the axial conduction and assumed that the pressure gradient varied linearly in the axial direction. They illustrated that pressure drop decrease with decreasing of Knudsen number and increasing of the channel aspect ratio. Also,