Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 55(5) (2023) 123-126
DOI: 10.22060/mej.2023.17993.7562

Heat Transfer of Nanofluids in Converging and Diverging Microchannels by Mixture Model

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ABSTRACT: Today, the use of nanofluids in microchannels is widely used for cooling microelectronic components. In this study, the flow and heat transfer of nanofluid in a converging and diverging microchannel has been investigated. The governing equations are solved by the finite element method and two-phase mixture model in COMSOL Multiphysics software. The results of this simulation were obtained for Reynolds numbers (100-700) and different concentrations of nanoparticles (0-0.02) for diverging and converging microchannels with different slopes (0-0.05). Also, the effect of two different nanofluids water-copper and ethylene-glycol-copper has been considered. The nanoparticles diameter is 50 nm. The results show that for water-copper nanofluid with a volume fraction of 1% in a converging microchannel with a slope of 3% and Reynolds 100, it increases by about 1.6 times for a converging microchannel and 1.1 times for a diverging microchannel compared to a flat microchannel. In this case, the performance coefficient for convergent and divergent microchannel is 1.37 and 1.74, respectively. In the same conditions, for ethylene glycol-copper nanofluid, the Nusselt number for converging microchannel becomes 1.22 times compared to flat microchannel and 1.13 times for divergent microchannel.

Review History:

Received: Jan. 02, 1402
Revised: Mar. 07, 2023
Accepted: Jun. 18, 2023
Available Online: Jul. 02, 2023

Keywords:

nanofluids
converging and diverging micro-channel
two-phase mixture model

1- Introduction

Compared to base fluid like water, nanofluids have different thermophysical properties. Microchannels have wide applications in various industries. Eastman et al. [1] by measuring the thermal conductivity, by adding 5% volume fraction of nanoparticles, reported, 60%, improvement in the thermal conductivity. high produced heat increases the temperature of the component during operation and thus reduces the performance of microchannels [2]. In this research, the effect of diverging and converging microchannel geometry for different nanofluids with different wall slopes in different Reynolds numbers for two nanofluids has been investigated. The two-phase mixture method has been used to simulate the problem. Due to the difference in the density of nanoparticles and the base fluid, the distribution of particles during movement will not remain homogeneous [3]. Then in the two-phase mixture method, homogeneous distribution of particles is not assumed and an equation is solved for volume fraction.

2- Governing Equations and Boundary Conditions

The studied geometry has been shown in Fig. 1.

The governing equation in the mixture method is as follows [4, 5],

2-1- Continuity

$$\nabla.(\rho_m V_m) = 0 \tag{1}$$

2-2- Momentum

$$\nabla.(\rho_m V_m V_m) = -\nabla p_m + \frac{1}{\rho_m}\sum_{k=1}^{n}\phi_k \tau_k - \sum_{k=1}^{n}\phi_k \rho_k V_{mk} V_{mk} \tag{2}$$

2-3-Volume fraction

$$\nabla.(\phi_k V_m) = -\nabla.(\phi_k V_{mk})\ v \tag{3}$$

2-4- Energy

$$\nabla.[\phi V_p(\rho_p Cp_p) + (1-\phi)V_f(\rho_f Cp_f)]T = \nabla.(k_{nf}\nabla T) \tag{4}$$

The boundary conditions of inlet and outlet are fully developed conditions and for the wall is zero velocity and constant temperature, and the upper boundary is the symmetry boundary. The governing equations have been solved using COMSOL Multiphysics software.

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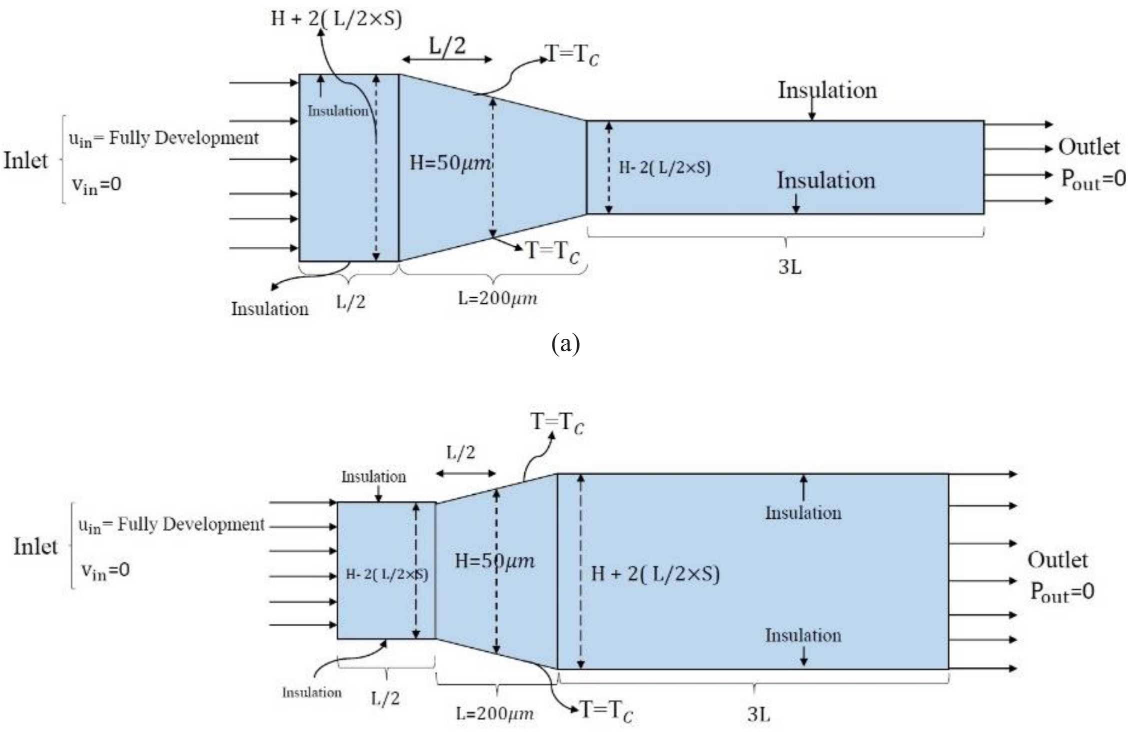


Fig. 1. Schematic of the a) convergent microchannel b) divergent microchannel

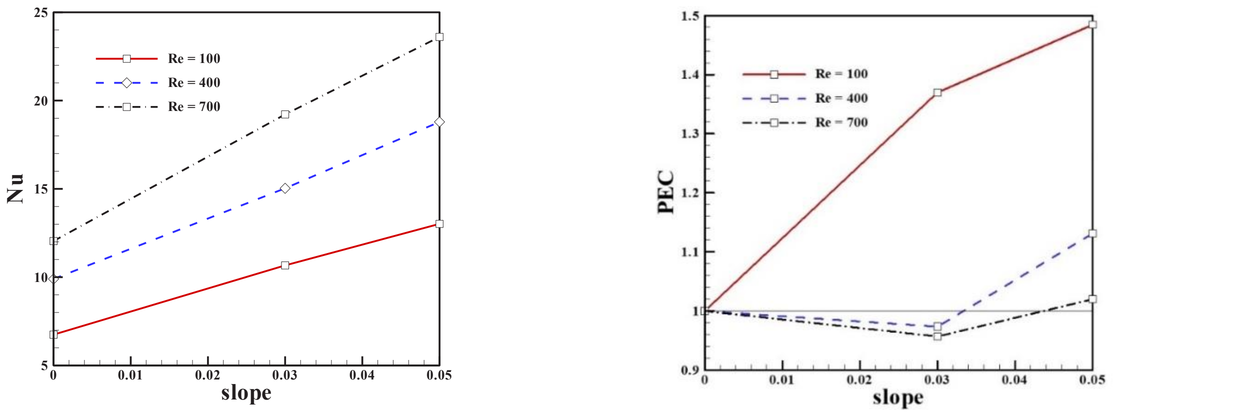
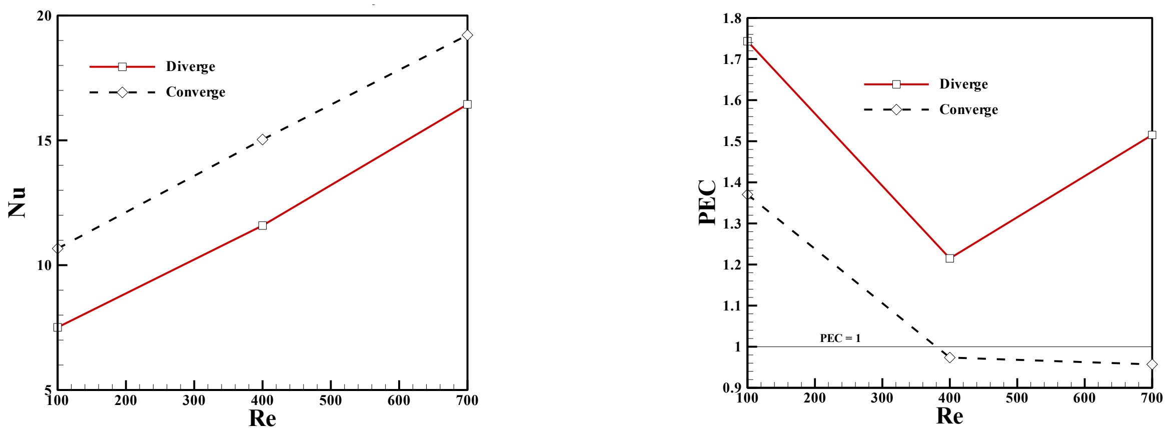


Fig. 2. a) mean Nusselt number, b) performance coefficient in converge microchannel versus slope in different Reynolds number and 1% volume fraction

3- Results and Discussions

In Fig. 2, the average Nusselt number and performance coefficient (PEC) can be seen. Results show that in each Reynolds number Nusselt number increases with increasing slope. It can be seen that in all cases, the Nusselt number is higher than the Nusselt number for the flat microchannel, and it increases with the increase in the slope of the channel. Fig. 3, shows for both microchannels, the slope is 0.03 with a volume concentration of 1% for the water-copper nanofluid. It is observed that the Nusselt number for both slopes increases with the Reynolds number. Also, for the convergent channel, the Nusselt number is higher than the divergent channel. Fig. 3-b, shows the PEC for different Reynolds numbers in converging and diverging microchannels. It can be seen that the PEC is higher in Reynolds 100. This coefficient first decreases and then increases with the increase of the Reynolds number. The PEC for the divergent channel is higher than the convergent channel.



(a) (b)

Fig. 3. a) mean Nusselt number, b) performance coefficient in converge and diverge microchannel with 3% slope and 1% volume fraction of Water-Cu nanofluid versus Reynolds number

4- Conclusion

In this article, nanofluid flow and heat transfer in converging and diverging microchannels have been studied by mixed two-phase numerical methods. For water-copper with a volume fraction of 1% in a converging microchannel with a slope of 3% and Reynolds 100, it increases by about 1.6 times for a converging microchannel and 1.1 times for a diverging microchannel compared to a flat microchannel, and the PEC are 1.37 and 1.74, respectively. For ethylene glycol-copper nanofluid, the Nusselt number becomes 1.22 and 1.13 times for converging and divergent microchannels, respectively. Also, the PEC are 1.17 and 1.4, respectively.

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HOW TO CITE THIS ARTICLE
F. Rezvannezhad, J. Rostami, Heat Transfer of Nanofluids in Converging and Diverging Microchannels by Mixture Model, Amirkabir J. Mech Eng., 55(5) (2023) 123-126.

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