Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 53(Special Issue 1) (2021) 129-132
DOI: 10.22060/mej.2019.16269.6316

Numerical Simulation of Magnetic Field Effect on Thermal and Thermo-Hydraulic Performance and Entropy Generation of a Silicon Microchannel Heat Sink Under Uniform Heat Flux

M. Sepehrnia[1*], H. Khorasanizadeh[1], M. B. Shafii[2]

[1]Faculty of Mechanical Engineering and the Energy Research Institute, University of Kashan, Kashan, Iran
[2]Department of Mechanical Engineering, Sharif University of Technology, Tehran, Iran

ABSTRACT: In this three-dimensional numerical study, the effects of uniform magnetic field on the thermal and thermo-hydraulic performance and entropy generation of water flow through a trapezoidal heat sink, with four different inlet/outlet configurations, have been investigated. An electronic chip embedded on the base plate of the heat sink generates uniform heat flux of 50 kW/m2. Simulations have been performed for mass flow rates of 0.02, 0.03, 0.04 and 0.05 g/sec and Hartmann numbers of 0, 2, 4, 8 and 16. The results show that in overall the best configuration is the A-type arrangement, in which the flow enters the center of the distributing chamber and exits from the center of the collecting chamber. For this arrangement and a constant mass flow rate, with increasing Hartmann number from 0 to 16, thermal resistance reduces between 4.39% and 9.15%, theta between 1.81% and 7.91% and performance evaluation criterion between 81.61% and 87.15%, but total entropy generation increases between 10.13% and 77.07%. For the best arrangement, the best thermal performance occurs for the mass flow rate of 0.05g/sec and Hartmann number of 16 and the best thermo-hydraulic and entropy generation performances occur for the mass flow rate of 0.02 g/sec and Hartmann number of zero.

Review History:

Received: 2019-05-07
Revised: 2019-10-03
Accepted: 2019-11-05
Available Online: 2019-11-14

Keywords:

Thermo-hydraulic performance
Magnetic entropy
Frictional entropy
Thermal entropy
Silicon heat sink

1. INTRODUCTION

Microfluidic is an interdisciplinary science including different fields such as physics, chemistry, electronics, polymers, mechanic, nano and biomedical [1, 2]. Soltanipour et al. [3] numerically studied the effect of the location of applying a magnetic field on the entropy generation and heat transfer of Al_2O_3-water nanofluid flow inside a 2-D microchannel. The results illustrated that nanofluid flow is affected by the magnetic field, hence, vortexes are generated in the vicinity of applying magnetic field location and the number and intensity of vortexes are dependent on Hartmann number. A numerical study of CuO-water nanofluid flow in a 2-D microchannel with parallel plates was carried out by Abbaszadeh et al. [4]. The impact of the magnetic field by considering slip velocity boundary conditions and temperature jump on the walls was investigated. Their results represented that by enhancing the volume fraction of nanoparticles and Hartmann number, Nusselt number and total entropy generation augmented. Hosseini et al. [5] studied the flow field and heat transfer of Al_2O_3-water and CuO-water nanofluids in a porous 2-D Microchannel Heat Sink (MCHS) under the influence of magnetic field. The results showed that by applying magnetic field, average Nusselt number enhances. Review of the literature showed that there has been no research on the effects of magnetic field on thermal and thermo-hydraulic performances and entropy generation of flow in a trapezoidal microchannel heat sink, so far. So in this three dimensional research, water flow through a trapezoidal microchannel heat sink, with five trapezoidal microchannels and four different inlet/outlet configurations has been considered.

*Corresponding author's email: msepehr_91@yahoo.com

2. METHODOLOGY

The location of the flow inlet and outlet for four heat sink configurations are shown in Fig. 1. As shown in Fig. 2, uniform heat flux and magnetic field are applied vertically. The continuity, momentum equations in the x, y and z directions and energy equations in the fluid and solid part are as follows:

$$\frac{\partial}{\partial x}(\rho u)+\frac{\partial}{\partial y}(\rho v)+\frac{\partial}{\partial z}(\rho w)=0 \tag{1}$$

$$\frac{\partial}{\partial x}(\rho uu)+\frac{\partial}{\partial y}(\rho vu)+\frac{\partial}{\partial z}(\rho wu)=-\frac{\partial p}{\partial x}+ \frac{\partial}{\partial x}\left(\mu\frac{\partial u}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu\frac{\partial u}{\partial y}\right)+\frac{\partial}{\partial z}\left(\mu\frac{\partial u}{\partial z}\right)-\sigma B_0^2(u+w) \tag{2}$$

$$\frac{\partial}{\partial x}(\rho uv)+\frac{\partial}{\partial y}(\rho vv)+\frac{\partial}{\partial z}(\rho wv)=-\frac{\partial p}{\partial y}+ \frac{\partial}{\partial x}\left(\mu\frac{\partial v}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu\frac{\partial v}{\partial y}\right)+\frac{\partial}{\partial z}\left(\mu\frac{\partial v}{\partial z}\right) \tag{3}$$

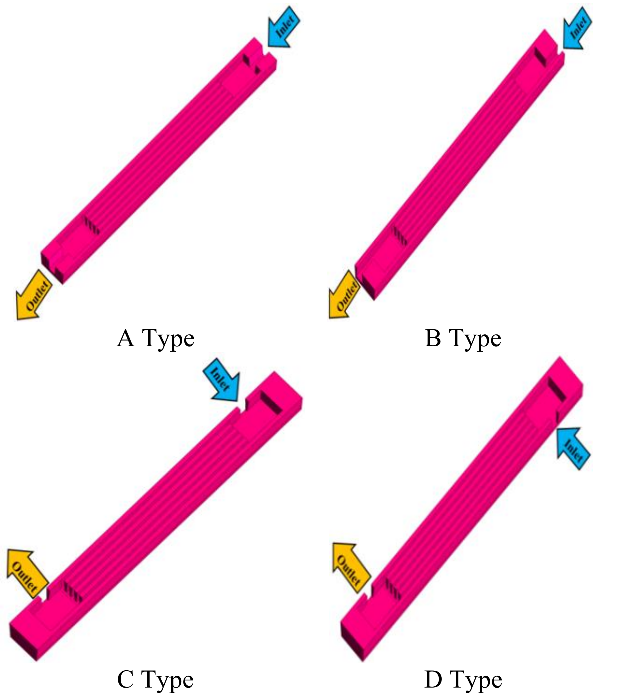

Fig. 1. The geometry of the A- B-, C- and D-type inlet/outlet configurations.

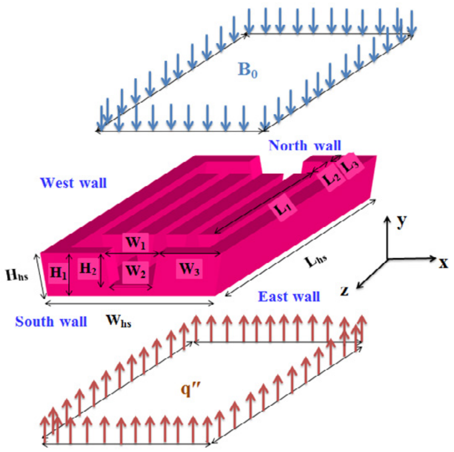

Fig. 2. The applied heat flux and magnetic field

$$\frac{\partial}{\partial x}(\rho uw)+\frac{\partial}{\partial y}(\rho vw)+\frac{\partial}{\partial z}(\rho ww)=-\frac{\partial p}{\partial z}+\frac{\partial}{\partial x}\left(\mu\frac{\partial w}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu\frac{\partial w}{\partial y}\right)+\frac{\partial}{\partial z}\left(\mu\frac{\partial w}{\partial z}\right) \tag{4}$$

$$\frac{\partial}{\partial x}(\rho uT)+\frac{\partial}{\partial y}(\rho vT)+\frac{\partial}{\partial z}(\rho wT)=\frac{\partial}{\partial x}\left(\frac{k}{c_p}\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{k}{c_p}\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(\frac{k}{c_p}\frac{\partial T}{\partial z}\right) \tag{5}$$

$$\frac{\partial}{\partial x}\left(k_s\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(k_s\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(k_s\frac{\partial T}{\partial z}\right)=0 \tag{6}$$

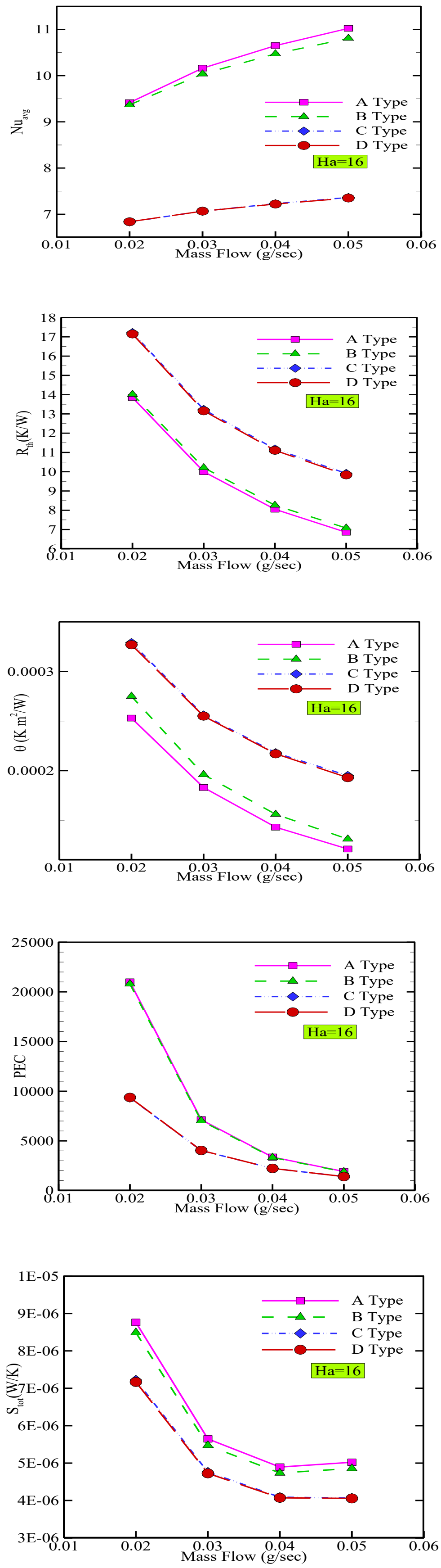

Fig. 3. The variations of performance indicators and total entropy generation versus mass flow rates for four heat sink configurations and Hartmann number of 16

Four performance indicators of average Nusselt number, thermal resistance, theta, and *PEC* are:

$$Nu = \frac{\bar{h} D_h}{k_f} \tag{7}$$

$$R_{\text{th}} = \frac{T_{\text{CPU,max}} - T_{\text{in}}}{q''_{\text{w}} W_{\text{hs}} L_{\text{hs}}} \tag{8}$$

$$\theta = \frac{T_{\text{CPU,max}} - T_{\text{CPU,min}}}{q''_{\text{w}}} \tag{9}$$

$$PEC = \frac{\dot{Q}_{\text{flow}}}{PP} = \frac{\dot{m} c_{\text{p}} (T_{\text{out}} - T_{\text{in}})}{\dot{v}(P_{\text{in}} - P_{\text{out}})} = \rho c_{\text{p}} \frac{\Delta T}{\Delta P} \tag{10}$$

3. RESULTS AND DISCUSSION

Fig. 3 shows the variation of performance indicators and total entropy generation versus mass flow rates for four heat sink configurations and Hartmann number of 16. The results show that from the viewpoint of thermal indicators (average Nusselt number, thermal resistance and ratio of the maximum electronic chip temperature difference to heat flux), the A-type arrangement is superior to other arrangements. From the viewpoint of entropy generation, D-type arrangement performs better, while it performs poorly according to thermal and thermo-hydraulic indicators. Considering all of the performance indicators, the A-type arrangement is the best arrangement, followed by the B-, D- and C-type arrangements.

4. CONCLUSIONS

In this three-dimensional research, the effects of the magnetic field on the performance of water flow through a trapezoidal microchannel heat sink, with four different inlet/outlet configurations, have been investigated. The results show that considering all of the performance indicators, A-type arrangement is the best arrangement, followed by B-, D- and C-type arrangements. For the best arrangement, the best thermal performance occurs in the mass flow rate of 0.05g/sec and Hartmann number of 16.

REFERENCES

[1] B.K. Jha, P.B. Malgwi, B. Aina, Hall effects on MHD natural convection flow in a vertical microchannel, Alexandria Engineering Journal, 57(2) (2018) 983-993.

[2] G. Zhao, Z. Wang, Y. Jian, Heat transfer of the MHD nanofluid in porous microtubes under the electrokinetic effects, International Journal of Heat and Mass Transfer, 130 (2019) 821-830.

[3] H. Soltanipour, S. Khalilarya, S.Y. Motlagh, I. Mirzaee, The effect of position-dependent magnetic field on nanofluid forced convective heat transfer and entropy generation in a microchannel, Journal of the Brazilian Society of Mechanical Sciences and Engineering, 39(1) (2017) 345-355.

[4] M. Abbaszadeh, A. Ababaei, A.A.A. Arani, A.A. Sharifabadi, MHD forced convection and entropy generation of CuO-water nanofluid in a microchannel considering slip velocity and temperature jump, Journal of the Brazilian Society of Mechanical Sciences and Engineering, 39(3) (2017) 775-790.

[5] S. Hosseini, M. Sheikholeslami, M. Ghasemian, D. Ganji, Nanofluid heat transfer analysis in a microchannel heat sink (MCHS) under the effect of magnetic field by means of KKL model, Powder Technology, 324 (2018) 36-47.

HOW TO CITE THIS ARTICLE

M. Sepehrnia, H. Khorasanizadeh, M.B. Shafii, Numerical Simulation of Magnetic Field Effect on Thermal and Thermo-Hydraulic Performance and Entropy Generation of a Silicon Microchannel Heat Sink Under Uniform Heat Flux, Amirkabir J. Mech Eng., 53(Special Issue 1) (2021) 129-132.

DOI: 10.22060/mej.2019.16269.6316