A REVIEW OF NUMERICAL STUDIES OF MICROCHANNEL HEAT SINK USING NANOFLUID

Aashish Sharma[1*]
[1]Department of Mechanical Engineering, Lovely Professional University, (India), 144411

Abstract

There is a requirement of quick heat dissipation, particularly from compact electronic systems. High-performance microchannel heat sinks (MCHS) can tackle this problem smartly. To enhance the performance of microchannel heat sink, nanofluids are introduced as a coolant in recent years. Several numerical studies have been performed in this field so far. This review summarizes the computational studies on the performance of microchannel heat sink using nanofluids in recent years. This paper covers the effect of different nanofluids on different parameters like temperature, heat transfer coefficient, Nusselt number, friction factor, pressure drop. It has been concluded that the performance of microchannel heat sinks is improved by using nanofluids as coolant. Nanofluids can be considered as a future coolant for microchannel heat sinks.

Key Words: *MCHS, Nanofluid.*

I. INTRODUCTION

The size of electronic devices has reduced impressively over some time. Heat dissipation from these devices has become a significant issue nowadays. Proper heat dissipation from these devices is essential for their proper functioning. At this stage, the microchannel heat sink can play an important role. A number of studies have been performed by researchers in recent years. Coolant flowing through microchannel carries heat away from the hot surface. Due to limitations of heat dissipation by conventional coolant, nanofluids are introduced in the microchannel heat sink. Suspension of the metal oxide particles of nanometer size in the base fluid is known as nanofluid.

The concept of cooling of electronic devices by microchannel heat sink was introduced by Tuckerman and Pease [1] in 1981. The channel which they used had a dimension of 60 µm (width) and 287-376 µm (hight). Since then, a significant number of numerical studies have been performed.

II. NANOFLUID

Suspension of nanosized particles of metals, oxides, carbides, or carbon nanotubes in a base fluid is known as nanofluid. Different base fluids are being used like glycerin, water, oil, ethylene glycol. One of the biggest traits of nanofluid is its high thermal conductivity. It is critical for rapid heat dissipation. Due to having high thermal conductivity, nanofluids improved the performance of the microchannel heat sink. Different nanofluids like Al_2O_3-H_2O, CuO-H_2O, SiC-H_2O, TiO_2-H_2O, SiO_2- H_2O, diamond-water, diamond-ethylene glycol, and diamond-glycerin are being analyzed as the coolant in microchannel having different channel geometries. Nanofluids have applications in industries, power generation, engine cooling, the nuclear cooling system also besides information technology. Pressure drop becomes minimum on using nanofluid. Heat transfer rate increases by a nanofluid. Despite these advantages, there are problems associated with nanofluids. These problems include a lack of understanding of nanofluid at an atomic level, cost, toxicity, and erosion. One can calculate properties of nanofluid by putting values of the base fluid in these formulae. There are various formulae for density, thermal conductivity, viscosity, heat capacity.

Table 1 Advantages and disadvantages of nanofluid

Nanofluids	
Advantages	**Disadvantages**
Enhanced heat transfer will lead to a lighter and smaller heat exchanger	Channel clogging, sedimentation of particles, costly, toxicity, erosion

Table 2 Details of previously performed numerical studies on MCHS using nanofluid

Authors	Nanofluid As Coolant	Geometry Of Channel	Type of flow
J.Koo, C.Kleinstreuer	CuO-H_2O and ethylene glycol	Rectangular	Laminar
Manay et al.	Al_2O_3-H_2O and CuO-H_2O	Square	Laminar
Seok Pil Jang, Stephen U.S. Choi	Diamond-Water	Rectangular	Laminar
H.A., Mohammed, et al.	Al_2O_3-H_2O	Rectangular	Laminar
H.A., Mohammed, et al.	Al_2O_3, Ag, CuO, diamond, SiO_2, and TiO_2	Triangular	Laminar
Navin Raja Kuppusamy et al	CuO-H_2O	Trapezoidal grooved	Laminar
Mohammad Kalteh et al.	Al_2O_3-H_2O	Rectangular	Laminar
Saeed Zeinali Heris et al.	Al_2O_3-H_2O	Triangular	Laminar
M. Hatami, D.D. Ganji	Cu-H_2O	Rectangular	Laminar
Yue-Tzu Yang et al.	CuO-H_2O	Trapezoidal	Laminar and turbulent

III. PERFORMANCE OF MCHS

Computational studies performed by different researchers on MCHS performance using nanofluid. After simulating and analyzing nanofluid flow in microchannels for two nanofluids, i.e., CuO nanospheres in H_2O (at low volume concentrations) or ethylene glycol author [2] recommended the use of high-Prandtl number carrier fluids. Manay et al. [3] investigated Al_2O_3 and CuO particles in 0%, 0.5%, 1%, 1.5%, and 2% volume fractions, in the square microchannel heat sink. Nusselt number, the pressure drop was calculated. This study showed that the nanofluids enhance heat transfer with an increase in the Reynolds number and the volume fractions.

Mohammed et al. [4] investigated Al_2O_3-H_2O in a MCHS with a cross-section of rectangular shape. Findings implied that with the rise in the volume fraction of nanoparticles, both the heat transfer coefficient and wall shear stress increases, with the decrease in thermal resistance. In the comparison of water, pressure drop increased slightly. H.A. Mohammed et al. [5] numerically investigated various nanofluids (as in table 2) for the triangular-shaped microchannel heat sink. The heat transfer coefficient was minimum for Al_2O_3-H_2O, but it had the highest temperature. The highest pressure drop and highest wall shear stress occurred in the case of SiO_{2-} H_2O. Glycerine based nanofluid had the highest heat transfer coefficient among other nanofluids. Navin Raja Kuppusamy et al. [6] numerically investigated the trapezoidal grooved microchannel heat sink using CuO-H_2O. The effect of different geometrical parameters was examined in this study.

Mostafa and Maziar [7] investigated laminar flow and heat transfer of water-Al_2O_3 nanofluid under constant heat flux numerically. Heat transfer and friction factors were increased by the use of nanofluid. Mohammad Kalteh et al. [8] performed a numerical study for Al_2O_3-H_2O in rectangular microchannel heat sink having dimensions 94.3 X 28.1 X 580 mm (L X W X H) by a two-phase Eulerian Eulerian method. Through this study, it was concluded that the 2-phase method is suitable over the homogeneous method for simulating the heat transfer using nanofluid. Nusselt number was increasing with an increase in Reynolds number. M. Hatami, D.D. Ganji [9] investigated the fin-shaped microchannel heat sink using Cu-H_2O by porous media approach and least square method. Due to the increase in the Brownian motion of the particles, the temperature difference between coolant and wall became less.

Yue-Tzu Yang et al. [10] performed a numerical study of trapezoidal MCHS using CuO-H_2O as coolant. The volume fraction of particle and volumetric flow rate were studied. It was shown that thermal resistance would decrease with increasing particle volume fraction and volumetric flow rate. Yun Yue et al. [11] investigated manifold MCHS using Al_2O_3-H_2O nanofluid. It was concluded that pumping power and Nusselt number would increase on the increasing volume fraction of nanoparticles. It was also showed that the Nusselt number would increase on increasing Reynolds number. M.A. Ahmed et al. [12] studied the trapezoidal corrugated microchannel heat sink using CuO-H_2O nanofluid. The result showed that the Nusselt number would increase the increasing volume fraction of nanoparticles. Mostafa Keshavarz Moraveji [13] performed CFD modeling for mini channel heat sink using Al_2O_3 nanofluid. The effect of Reynolds number and nanoparticles' concentration was examined. In this study, experimental data was represented by two-phase models more approximately in comparison to the single phase model.

Table 3. Results from previous numerical studies

Nanofluid	Used Method	Parameters					
		Nusselt number	Heat transfer coefficient	Friction factor	Wall shear stress	Pressure drop	Thermal resistance

Al_2O_3-H_2O and CuO-H_2O	Finite volume method	Increased	Best for 2% volume fraction for CuO-H_2O	No significant increase in it	-	-	-
Al_2O_3-H_2O	Finite volume method	-	Increased	Slightly increased	Increased	Increased with increased value of Re	Decreased
Al_2O_3, Ag, CuO, diamond, SiO_2, and TiO_2	Finite volume method	-	Highest for diamond-H_2O and lowest for Al_2O_3-H_2O	-	Highest for SiO_2-H_2O and lowest for Ag-H_2O	Lowest for Ag-H_2O and highest for SiO_2-H_2O	-
Al_2O_3-H_2O, diamond-water, diamond-ethylene glycol, diamond-oil, diamond-glycerin,	Finite volume method	-	Highest for nanofluid having ethylene glycol as base fluid	-	-	-	-
Al_2O_3-H_2O	Finite volume method	Increased	-	-	-	-	-
CuO-H_2O	Finite volume method	-	-	-	-	Increased	Decreased

IV. CONCLUSION

This paper has reviewed numerical studies of nanofluids as a coolant in microchannel heat sink in recent years. It is certain that nanofluid enhances heat transfer from different studies. But the enhancement of heat transfer varies with the type of nanofluid and geometry of channel used in microchannel heat sink mainly. The material of heat sink, the base fluid used in nanofluid, also influences the heat transfer.

- In microchannel heat sinks, the laminar flow of coolant is preferred by different researchers.
- On increasing volume fractions of nanoparticles, wall shear stress, and friction factor both increase.
- Order of thermal efficiency in different microchannel heat sinks is found as:
  Triangular MCHS > Trapezoidal MCHS > Rectangular MCHS
- On increasing volume fraction, the Nusselt number is also increased.
- The friction factor is not affected by different base fluids significantly.
- Order of value of Nusselt number for different nanofluids is found as:

$$Nu_{(SiO_2-EG)} > Nu_{(CuO-EG)} > Nu_{(Al_2O_3-H_2O)}$$

So if problems associated with nanofluids are solved, nanofluids definitely will be used as coolants in the microchannel heat sink.

References

[1] David B. Tuckerman and R.F.Pease, High performance heat sinking for VLSI,IEEE Electronic Devices Letters, (2), 126-129, 1981.

[2] J. Koo, C. Kleinstreuer, Laminar nanofluid flow in microheat-sinks, International Journal of Heat and Mass Transfer, (48), 2652–2661, 2005.

[3] Manay E., Sahin B., Yilmaz M., Gelis K., Thermal Performance Analysis Of Nanofluids In Microchannel Heat Sink, World Academy of Science, Engineering and Technology, (6), 2012.

[4] H.A. Mohammed, P. Gunnasegaran, N.H. Shuaib, Heat transfer in rectangular microchannels heat sink using nanofluids, International Communications in Heat and Mass Transfer 37 , 1496–1503, 2010.

[5] H.A. Mohammed, P. Gunnasegaran, N.H. Shuaib, Influence of various base nanofluids and substrate materials on heat transfer in trapezoidal microchannel heat sinks, International Communications in Heat and Mass Transfer Volume 38, Issue 2, Pages 194–201, February 2011.

[6] Navin Raja Kuppusamy, H.A. Mohammed, C.W. Lim, Numerical investigation of trapezoidal grooved microchannel heat sink using nanofluids, Therochimica Acta 573, 39-58, 2013.

[7] Mostafa Mirzaei, Maziar Dehghan, "Investigation of flow and heat transfer of nanofluid in microchannel with variable property approach", Heat Mass Transfer 49, 1803–1811, 2013.

[8] Mohammad Kalteh , Abbas Abbassi , Majid Saffar-Avval , Arjan Frijns , Anton Darhuber , Jens Harting, Experimental and numerical investigation of nanofluid forced convection inside a wide microchannel heat sink, Applied Thermal Engineering 36, 260-268, 2012.

[9] M. Hatami, D.D. Ganji, Thermal and flow analysis of microchannel heat sink (MCHS) cooled by Cu–water nanofluid using porous media approach and least square method, Energy Conversion and Management 78, 347–358, 2014.

[10] Yue-Tzu Yang, Kuo-Teng Tsai, Yi-HsienWang, Shih-Han Lin, Numerical study of microchannel heat sink performance using nanofluids, International Communications in Heat and Mass Transfer 57, 27–35, 2014.

[11] Yun Yue, Shahabeddin K. Mohammadian, Yuwen Zhang, Analysis of performances of a manifold microchannel heat sink with nanofluids, International Journal of Thermal Sciences 89, 305-313, 2015.

[12] M.A. Ahmed, M.Z. Yusoff, N.H. Shuaib, Effects of geometrical parameters on the flow and heat transfer characteristics in trapezoidal-corrugated channel using nanofluid, International Communications in Heat and Mass Transfer 42, 69–74, 2013.

[13] Mostafa Keshavarz Moraveji, Reza Mohammadi Ardehali, CFD modeling (comparing single and two-phase approaches) on thermal performance of Al_2O_3-H_2O nanofluid in mini-channel heat sink, International Communications in Heat and Mass Transfer 44, 157-164, 2013.