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Numerical study of nanofluids effect on heat transfer and pressure drop of triangular microchannel heat sink

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Abstract : The present work deals with study the heat transfer and pressure drop of the triangular microchannel heat sink(MCHS), along different working fluids. The nanofluids such as CuO and $Al_2O_3$are used as coolants to enhance the performance of triangular microchannel heat sinks.The modeling and analysis were done with the help of Solid works. The heat transfer performance of the triangular fins were studied with the Reynolds number varying from 96 - 460. Thenumerical result shows that the triangular oblique finned microchannel heat sink has large heat transfer rateof 12.9 % for varying Reynolds number when compared to a straight channel. Similarly, the pressure drop also increases with 38.2% for triangular microchannel flowing nanofluid. Consequently triangular microchannel is enhancing the heat removed in electronics chip cooling.
Keywords : Microchannel, Triangular, Nanofluids,Heat transfer, Pressure drop.

1. Introduction

A remarkable global approach en route for miniaturization carried out by the microelectronics industry is attracting ever greater awareness to various cross-sectional areas as the advantage of the cooling process. The discussion has been made on channel configurations, type of fluids, based on flow arrangements as discussed in the following literatures, Yan Fan et al. (2013) introduced the jacket-type cylindrical oblique fin mini-channel heat sink,while comparing cylindrical oblique fin mini-channel with conventional straight in the Nusselt number raise up to 75.6%, and thermal resistance reduce to 59.1% for cylindrical oblique fin and gets heat sink. Xiang-feiYu et al. (2013)had tried a new concept in a fractaltree-like construction of microchannel heat sink. They take on three major parts to fabricate rectangular sized microchannel heat sink. That is silicon wafers, Pyrex glass and polymethylmethacrylate (PMMA) for the base plate. They concluded with both hydraulic and thermal

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characteristics explore the greater impact on aspect ratio. Hamid Reza Seyf et al. (2012)investigated numerically to find the heat transfer behavior on nanofluid over the water as coolant.They reported that the flow is laminar of maximum Reynolds's number ranges up to 75.Finally they resulted in CuO with the addition of water nanofluid of diameter 29mm explore high coolant effect than Al_2O_3/water of diameter 38.4nm. Leela et al.(2014)proposed new type channel in which the flow and heat transfer performance in different MCHS are carried out by numerical analysis method. They compared the results with conventional MCHS. Gongnan Xie et al.(2015)presented on the analysis of heat transfer and pressure loss of double-layered microchannels for cooling of electronic chip.The parallel and counter flow arrangements are made on various inlet and outlet and conditions. They resulted that the performance of the lower channel is better than the upper channel in the sense of heat removing if the flow is uniformly distributed. Hao et al. (2016)stated that, due to the combined effect of Thermoelectric Cooler (TEC) and microchannel heat sink (MCHS), the hotspot couldbe removed in diameter of 0.5mm.They finally concluded with that is, TEC can decrease its temperature to 2.6^{o}C, the temperature difference is about 0.2^{o}C, and also it can work under 3A current where the chip size is 3mm*3mm, and heat flux is 60W/cm^2. The present work is focus to study the heat transfer and pressure drop in the oblique finned triangular microchannel heat sink. The cooling fluid used in this study is water and nanofluids by varying Reynolds number keeping heat flux as constant.

2. Design calculation for triangular MCHS

The main parameters such as mass flow rate, heat transfer rate, heat transfer coefficient, and the Nusselt number. These calculations are used to find the design of the microchannel. Before proceeding to fabricate the microchannel section the exact dimensions for calculating this is important, the dimensions were selected based on our application. The design parameters for oblique finned MCHSare given in table 1.

Table 1 Design parameters for Triangular oblique finned MCHS

Characteristic	Triangular channel
Microchannel Area	75 x 48 mm^2
No. of channels	46
No. of fins per row	143
Total no. of fins	6593
Oblique angle,ϴ (deg)	26^{o}

2.1 Modeling of triangular MCHS

The modeling of the microchannelwas done in the SOLIDWORKS package.. The microchannel and base parts are assembled and fixed with a glass plate over it which is shown in the fig. 1. The figure gives you an idea about the assembled model of the triangular fin and base plate. This assembly was done by the SOLIDWORKS package. The solid part was made by the part file, and then the assembly was done. An insulating layer is made around the triangular channel plate to prevent conduction of heat between the base plate and the microchannel. A fiberglass plate is fitted over the base plate.

Figure 1 The triangular oblique finned MCHS

3. Numerical Study

The numerical analysis was carried out for triangular microchannel and achieves temperature and pressure variation along the microchannel length for flowing water and nanofluids. The analysis is done with SOLIDWORKS – flow simulation software by varying the mass flux, and keeping constant heat flux.

3.1 Boundary Conditions

First, the assembly model is imported, and the flow simulation wizard is stimulated. The material used and the base fluid is selected. Then the number of Mesh count is selected with the purpose of precedes the simulation. The following boundary conditions are applied to the Triangular microchannel.

- Pressure at inlet : 1 bar
- Temperature at inlet : 293.20 K
- Mass flow rate : 0.1,0.2,0.3,0.4 and 0.5 Lpm
- Heat flux : 200W

3.2 Mesh Optimization

The Mesh is the term that significantly influences the accuracy of the numerical analysis. The analysis is carried out using the SolidWorks software which consists of eight meshes. The precision of the results depends upon the number of mesh selected. In this project 6, 7, and 8 meshes were used. On comparing them, it shows that the timing taken for 7mesh and 8mesh is more than the 6 mesh. But the accuracy didn't vary for 6 meshes when compared with 7 and 8mesh. So, that the numerical analysis of triangular oblique finned MCHS is carried with 6mesh and the results were taken.

3.3 Temperature and Pressure variation for triangular oblique finned MCHS using water

The pressure and temperature variation of the water inthe triangular channel is analyzed in the fig. 2 and fig.3, where the fluid exits temperature and pressure of the microchannelare 311.01 K&101.384 kPa. In this case, the inlet pressure and temperature are 101.318kPa and 293.20 K for water. The temperature difference and pressure drop for triangular microchannel are 17.81 K and 68.92 Pa by flowing the water. The temperature difference of microchannel enhances the overall heat transfer coefficient.

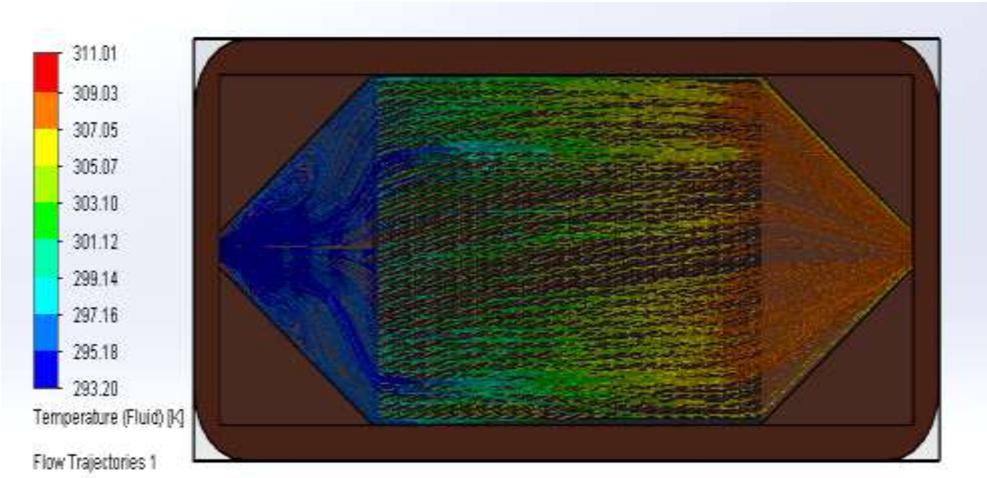

Figure2 Temperature distributions over triangular oblique finned MCHS for0.1 kg/min using water as the base fluid

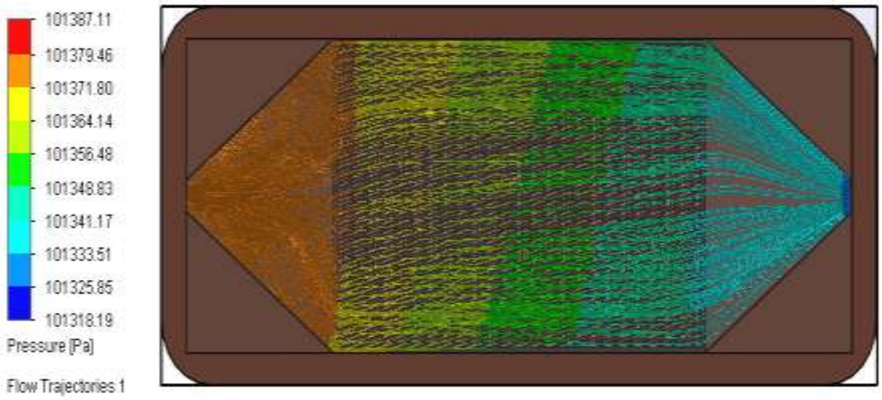

Figure 3Pressure distribution over the microchannel triangular oblique finned MCHS for 0.1 kg/min water as the base fluid

3.4 Temperature and Pressure variation for triangular oblique finned MCHS using Al_2O_3 nanofluid

In this, fig. 4 and fig. 5 shows the temperature and pressure distributions for triangular MCHS by using Al_2O_3 nanofluid. The results show that the pressure varies from 101318 Pa to 101389 Pa and the temperature varies from 293.20 K to 313.59 K. The pressure drop and temperature rise is obtained in triangular microchannel is 71.42 Pa and 20.39 K by varying the mass flow rate. The pressure drop is more due to the presence of Al_2O_3 nanoparticles,and the temperature is also high when compared with water.

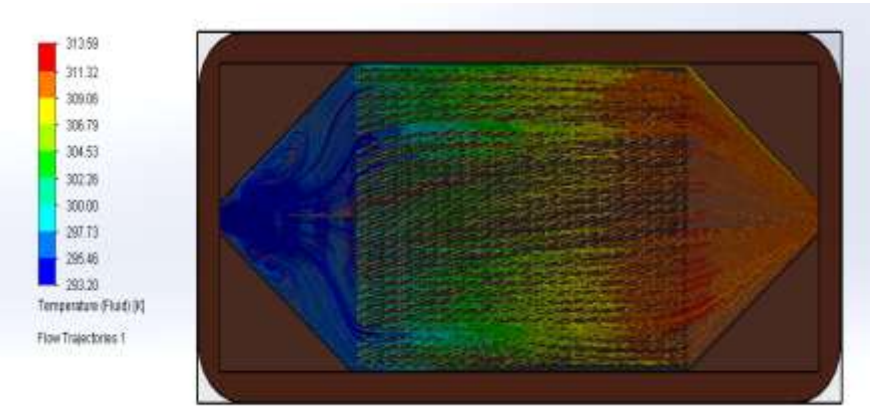

Figure4 Temperature distribution over the Triangular oblique finnedMCHS for 0.1 kg/min Al_2O_3 nanofluid

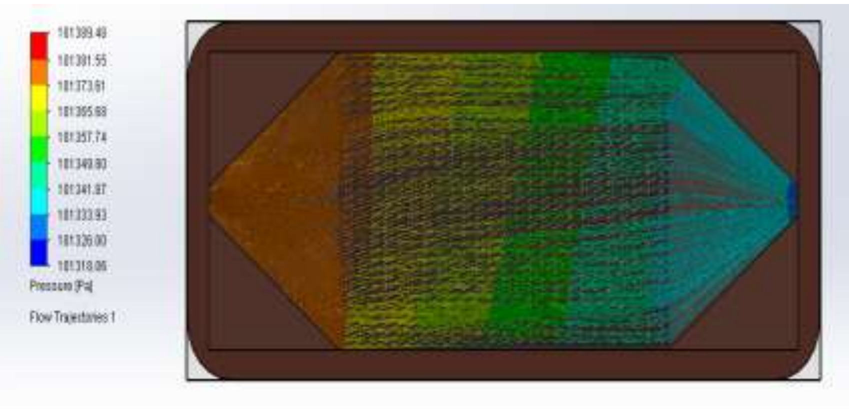

Figure5 Pressure distribution over the triangular oblique finned MCHS 0.1 kg/min using Al_2O_3 nanofluid

3.5 Temperature and Pressure variation for triangular oblique finned MCHS using CuOnanofluid

The fig 6 and fig 7 shows the pressure and temperature distributions by using CuO nanofluid. The numerical results show that the pressure drops from 101318.11 Pa to 101389.15 Pa also the temperature varies from 293.20 K to 313.64K.The pressure drop and temperature variation obtained is 71.04 Pa and 20.44. The numerical result confirm that the pressure drop and temperature rise is more for CuO nanofluid when compared with Al_2O_3 nanofluid and water in triangular oblique finned MCHS.

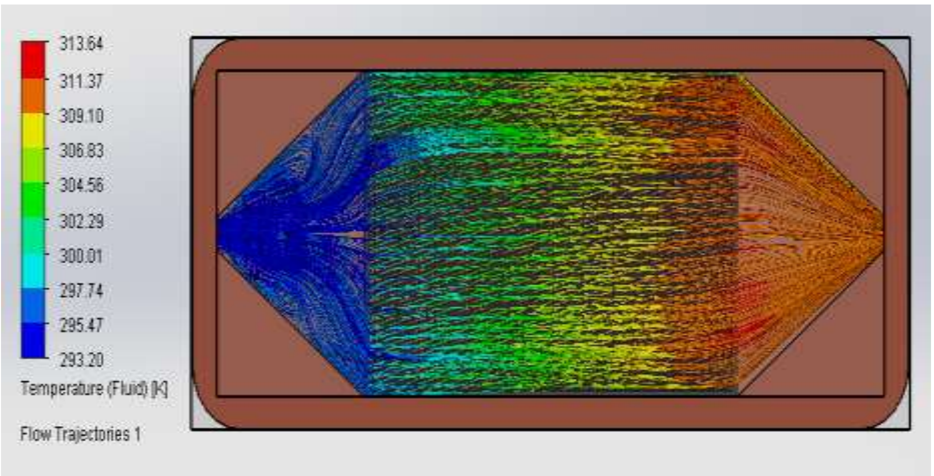

Figure 6Temperature distributions over the triangular oblique finned MCHS for 0.1kg/min using CuO nanofluid

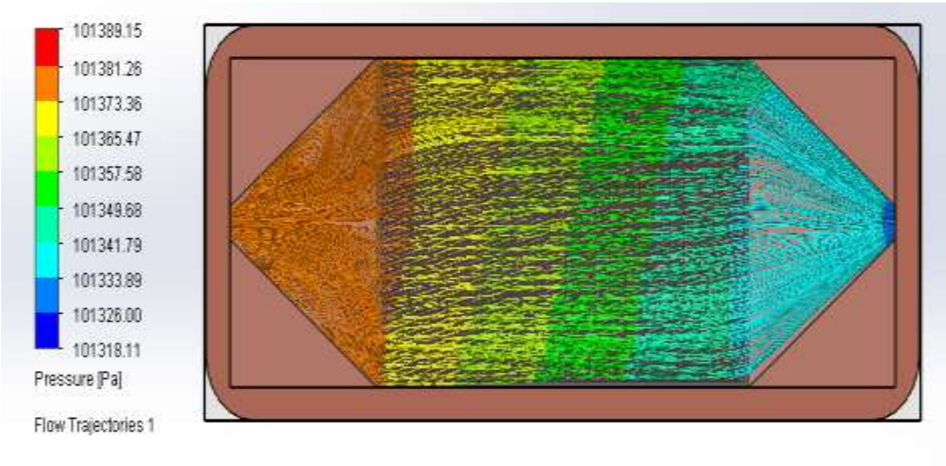

Figure 7 Pressure distributions over the triangular oblique finned MCHS for 0.1 kg/min using CuO nanofluid

3.6 Data reduction

The rate of heat transferred is calculated from the temperature variation between inlet and an outlet of the microchannel. The heat transfer equation is specified by Xiao-Hu Yang et al. (2017)

$Q = mc\,(T_{out}-T_{in})$ (1)

The average Nusselt number is calculated with the subsequent equation given by Gongnan Chieh et al. (2012)

$Nu = \frac{h_{exp} \times D_h}{k}$ (2)

The pressure drop was obtained from the work of Chieh et al. (2012)

$\Delta p = p_{in} - p_{out}$ (3)

Where$p_{in}$is the pressure at the inlet and p_{out} is the pressure at the outlet of the micro-channel.

4.Results and discussions

4.1 Temperature distribution

Temperature is an imperative aspect in evaluating the heat transfer coefficient. Fig. 8 represents the variation of Temperature distribution with Reynolds number both water and nanofluid. The Reynolds number is in the range of 96, 190, 286, 366, and 460. It is clear that the temperature difference reduces with the increase with a rise in Reynolds's number. The numerical results show that temperature difference is higher for triangular microchannel compares to a straight channel in the present study. The highest temperature variation is achieved by the Reynolds number of 96.

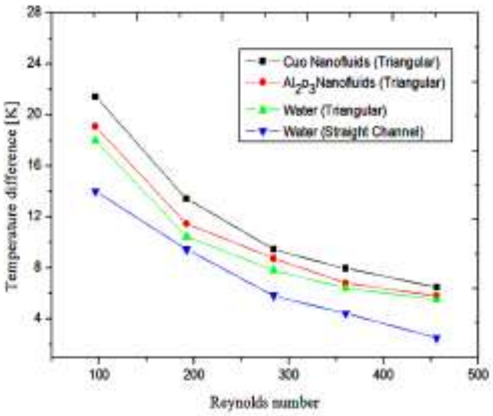

Figure 8 Reynolds number vs Temperature difference

4.2 Nusselt number and Heat transfer characteristics

Nusselt number is the most significant characteristic that influences the heat transfer rate.Fig.9shows that the Nusselt number very with Reynolds's number and for water and nanofluid. It has been knownthat developing the region in the triangular channel is high and hence average Nusselt number. While comparing Nusselt number for water and nanofluid gives 9.48% higher than water. Since nanofluid has high viscosity and density natures.. Also, Nusselt number for triangular microchannel is 24.7 % higher than the straight channel. When the Reynolds number increases, the heat transfer rate also raise shown in fig 10. While flowing nanofluid, the heat transfer is enhanced highly because particles touch each other in individual aggregates which provide a faster heat transfer through the microchannel. Thisstudy gives you an idea about the Heat transfer rate is a little superior to the straight channel with 12.9%.

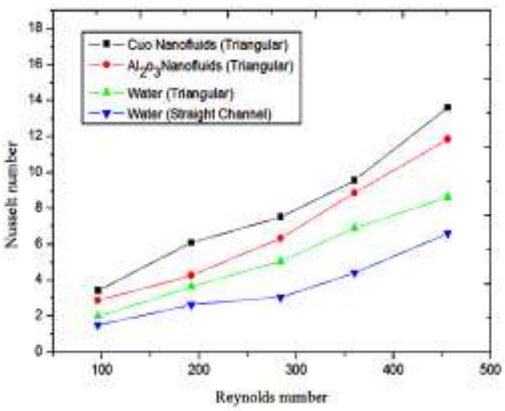

Figure 9 Variation of Nusselt number with Reynolds number

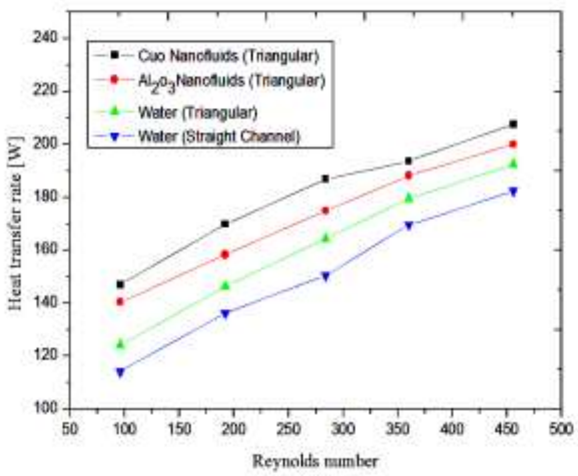

Figure 10Variation of Heat transfer rate with Reynolds number

4.4 Pressure drop characteristics

The pressure drop is the most important factor to raise the heat transfer in the microchannel. The pressure drop versus Reynolds number has been plotted in Figure 4.5. The pressure drop which increases constantly with Reynolds number. The oblique fins create more interconnecting passages of secondary flow that resulted in a 38.2 % increment pressure drop while comparing to the straight channel. The triangular cross-section with nanofluid acquiresa higher pressure drop than any other water.

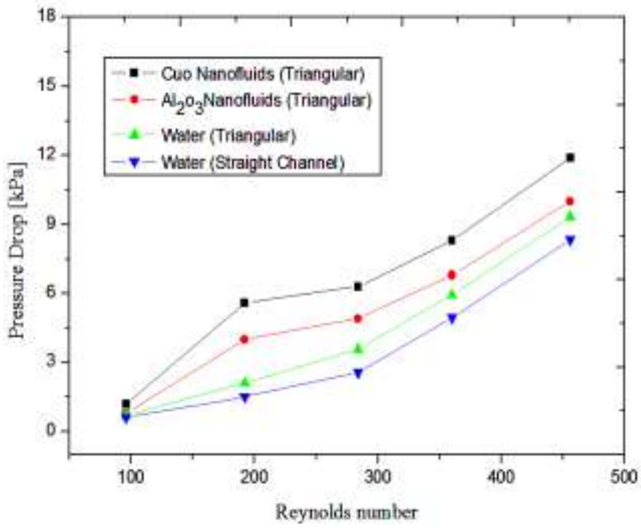

Figure 11 Pressure drop vs Reynolds number

5. Conclusions

The effect of nanofluids in triangular microchannel was analyzed keeping constant heat flux and varying the mass flow rate. The important finding are summarised below,

1. The Nusslet number and a heat transfer rate of the triangular channel are 24.7 % more efficient than the straight channel. Also, while flowing nanofluid, the triangular cross-section gives more efficient results of 36.5 % with n water as a coolant.

2. Pressure drop also increases in the triangular channel which is about 38.2 % when compared to a straight channel. It also procures a higher heat transfer rate of 12.9 % than straight channel.
3. Thus the triangular microchannel cross-section is paramount suitable for the electronics cooling industry.

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