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Study and Analysis on Differernt Flow Arrangements Using Different Fluids in Micro Channel Heat Sink for High Performance

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Abstract - The high performance of the micro channel depends upon the number of parameters like geometrical & flow parameters. In this paper a flow analysis of the different arrangements of the fluid entrance for micro channel based heat sink has been carried out. The fluid can enter in the different ways like upper flow, front flow and side flow. The arrangement is important because the formation of the boundary layers will be affected based on the flow arrangements. The fluid after entering goes into the plenum & based upon these arrangements there is a flow variation. Ultimately the performance of the liquid through the channel varies here we investigate the best flow arrangement for the high performance of micro channel heat sink that is independent of the scaling. Fluid flow and heat transfer are investigated on the basis of the simulation.

Keywords: Simulation of MCHS using flow simulation in solid works.

I.INTRODUCTION

Tuckerman and Pease [1] in 1981, many studies have been conducted on micro-channel heat sinks as summarized by Phillips [2] and more recently, by Morini [3].A number of studies has investigated the thermal design optimization of micro-channel heat sinks to determine the geometric dimensions that give optimum performance. For the heat transfer study purpose, the channel walls were assumed to behave as fins. With the increasing heat production of electronic devices, the air cooling technology reaches its limits, whereas liquid cooling represents a promising opportunity to develop cooling devices with much higher heat transfer coefficient. Today's rapid IT development requires high PC performance capable of processing more data and more speedily. To meet this need, CPUs are assembled with more transistors, which are drawing more power and having much higher clock rates. This leads to an ever-larger heat produced by the CPU in the computer, which will result in a shortened life, malfunction and failure of CPU. The reliability of the electronic system will suffer if high temperatures are permitted to exist. Therefore, removal of heat has become one of the most challenging issues facing computer system designers today. However, conventional thermal management schemes such as air-cooling with fans, liquid cooling [4], thermoelectric cooling [5–9], heat pipes [10], vapour chambers [11], and vapour compression refrigeration [12] have either reached their practical application limit or are soon become impractical for recently emerging electronic components. Therefore, exotic approaches were regarded as an alternative to these conventional methods in sufficient for cooling further high power processors. As the fluid is passing through the different section of the micro channel the distribution of the fluid in the passage is disturb the flow condition of the fluid that affect the velocity and thermal boundary layer of the flow. As flow is reached fully developed there is no change in the velocity of the fluid layer. The thermal and velocity boundary layer are playing a significant role in the fluid flow in micro channel. The different shapes of micro channel are used to dissipate the large amount of heat from the system or electronic circuit.

As a practical cooling fluid, the liquid metal must satisfy the following requests: Non-poisonous, non-caustic material, low viscosity, high thermal conductivity and heat capacity. Most studies in this approach employed the classical fin theory which models the solid walls separating micro channels as thin fins. The heat transfer process is simplified as one- dimensional, constant convection heat transfer coefficient and uniform fluid temperature. However, the nature of the heat transfer process in MCHS is conjugated heat conduction in the solid wall and convection to the cooling fluid. Xuan and Li (2003) and Pak and Cho (1998) experimentally measured the convection heat transfer and pressure drop for nano fluid tube flows. Their results indicated that the heat transfer coefficient was greatly enhanced and depended on the flow Reynolds number, particle Peclet number, particle size and shape, and particle volume fraction. These studies also indicated that the presence of nano particles did not cause an extra pressure drop in the flow. Recently, Yang et al. (2005) carried out an experimental study attempting to construct a heat transfer correlation among the parameters that affected heat transfer. For a laminar flow regime in a circular tube, they indicated that the heat transfer coefficient for the nano fluid flow had a lower increase than predicted by either the conventional heat transfer correlation for the homogeneous or particle-suspended fluid. Ding et al. (2006) reported heat transfer coefficient data for the force convection in circular tubes using carbontube (CNT) nano fluid. In most of the studies mentioned above, the nano fluid heat transfer flow characteristics were carried out in macro-scale dimensions. Only a few studies addressed the nano fluid flow and heat transfer in micro-scale dimensions. CHEIN AND HUNAG (2005) EMPLOYED a macro-scale correlation to predict micro channel heat sink performance. In experimental aspect, Chein and Chuang (2007) studied the general behaviour heat sink performance and particle deposition effect when nano fluid is used as the working fluid. In the study of lee and mudawar (2006), al2o3–h2o nanofluid was used as working fluid. They pointed out that the high thermal conductivity of nano particles can enhance the single-phase heat transfer coefficient, especially for the laminar flow. Due to complicated heat transfer phenomena and large variety in nano fluids , further studies on nano fluid flow and heat transfer characteristics in microscale dimensions are still necessary. In this study, thermal resistance characterizing MCHS performance using nano fluids as coolants are investigated. We particularly focus on the micro channel geometry effect on the MCHS performance when nano fluid is used as the working fluid. Although micro-channel heat sinks are capable of dissipating high heat fluxes, the small flow rate produces a large temperature rise along the flow direction in both the solid and cooling fluid, which can be damaging to the temperature sensitive electronic components. Therefore, more sophisticated predictions of the temperature field are essential for an effective micro-channel heat sink design. A more accurate description of the heat transfer characteristics can only be obtained by direct numerical simulation of three dimensional fluid flow and heat transfer in both the solid and cooling fluid.

II.ANALYSIS PROCEDURE

The micro Channel heat sink modelled in this investigation consists of three arrangement of fluid flow. The fluid is flow through the front, upper and the side of the channel there are two shape of micro channel heat sink are used. One is the rectangular shape and another is the trapezoidal shape are used. The aspect ratio for the rectangle and trapezoidal micro channel heat sink is assumed to be same. The arrangement of fluid flow is from the different sections are the front, upper and the side of the micro channel. The two different fluids are used one is the water and another is nano fluid with thermal conductivity 10 times of water. This investigation has to be carried out for the high performance of the micro channel.

These studies can help to clarify some of the variations in the previously published data and provide a fundamental insight into thermal and fluid transport process occurring in the micro-channel heat sinks designed for electronic cooling and other.

III.ASSUMPTIONS

The analysis is based on the following assumptions:

To simplify the analysis, the following assumptions are made in modelling the heat transfer in micro channels of the present study:

- Steady state flow.
- Incompressible fluid.
- Laminar flow.
- Constant properties of both fluids and solid.
- Effects of viscous dissipation are negligible.

IV.MATHEMATICAL FORMULATION

The convective heat transfer between a surface and an adjacent fluid is prescribed by Newton's law of cooling.

$$Q = h A (t_{s} - t_{f}) \qquad (1)$$

Based on above assumptions, the governing equations for fluid and energy transport are

Fluid Flow

$$\nabla \cdot V = 0 \qquad (2)$$

$$\rho (V \cdot \nabla V) = -\nabla p + \mu \nabla^2 V \qquad (2.1)$$

Energy in fluid flow:

$$\rho\, cp\, (V \cdot \nabla T) = k \nabla^2 T \qquad (3)$$

Energy in heat sink solid part:

$$k_s \nabla Ts = 0 \qquad (4)$$

The boundary conditions for these equations are related to the heat sink operating conditions.

V.COMPUTATIONAL DOMAIN

A schematic of the rectangular micro channel heat sink is illustrated with different flow arrangement.

The flow arrangement from the front, upper, side are shown in the fig

A schematic of the micro channel heat sink is illustrated with different flow arrangement. The flow arrangement from the front, side and upper, are shown in the figure.

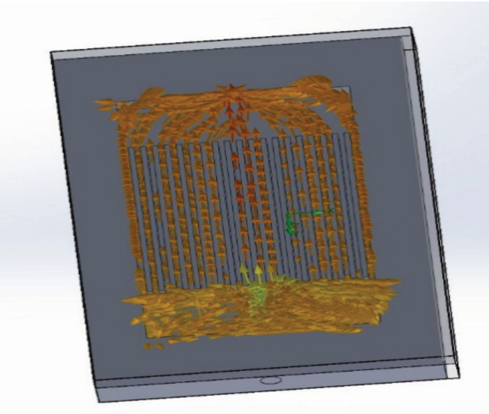

Fig. 1 Front flow arrangement

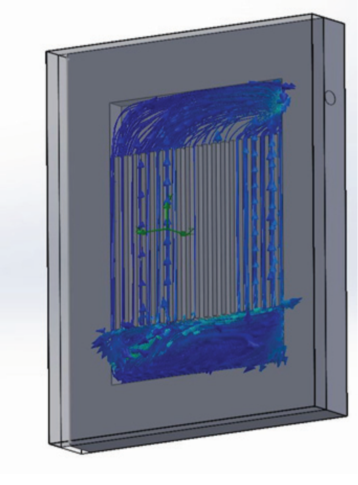

Fig. 2 Side flow arrangement

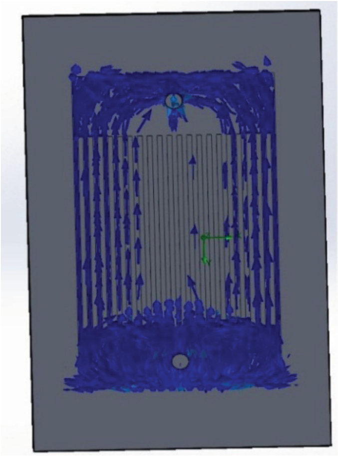

Fig. 3 Upper flow arrangement

VI.MESH MODEL

The mesh model of the flow arrangement is shown in figure. The fluid domain and the solid substrate mesh are shown in figure.

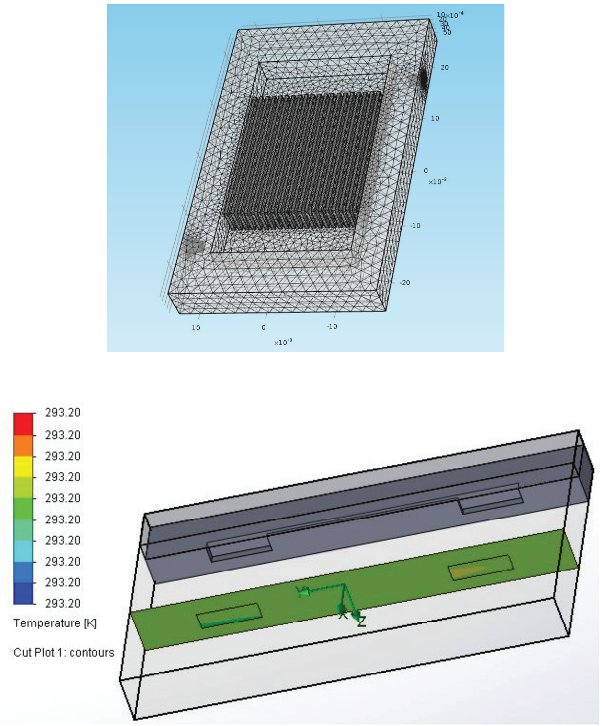

Fig. 4 fluid domain and the solid substrate mesh

A computational domain is chosen and a grid (also called a mesh) is generated; the domain is divided into many small elements called cells. For 2-D domains, the cells are areas, while for 3-D domains the cells volume (figure 4). Boundary conditions are specified on each edge of the computational domain (2-D flows) or on each face of the domain (3-D flows). The type of fluid (water, custom nano fluid etc) is specified along with fluid properties (temperature, density, viscosity, etc) if the flow is laminar the equation the equation 2 and 2.1 are sufficient and CFD solutions can be made as accurate as desired. CFD solution is generation of a grid that defines the cells on which flow variables (velocity, pressure, etc.) are calculated throughout the computational domain. A structured grid consists of planer cells with four edges (2-D) or volumetric cells with six faces (3-D).

VII. EXPERIMENT DESIGN

The study involves the three arrangement of the inlet fluid flow through micro channel heat sink. The fluid is flowing through from the front, upper, and side of the micro channel heat sink. The experiment is set up for the high performance of the micro channel heat sink. The experiment is design on the basis of the different shapes of the micro channel heat sink and the fluid is flowing through the different section from the front, upper and side for the investigation of high performance of micro channel heat sink.
The experimental setup is arranged to be as

TABLE 1 FLUID PROPERTIES

Fluid	Density (kg/m^3)	Dynamic viscosity	Thermal conductivity
water	998.2	0.0083	0.60405
Custom nano fluid	998.2	0.0083	6.0405

Three arrangement of fluid flow at inlet are front, upper, and side .two different shapes of the micro channel heat sink used are rectangle and the trapezoidal .two different liquids are used for analyses the results.

TABLE 2 TYPE OF MICRO CHANNEL HEAT SINK AND THEIR PARAMETERS

Type of MCHS	($D_{h)}$ (m)	L (mm)	w (mm)	h (mm)	No. of MCHS
Rectangle	8.00E-04	22	0.5	2	21
Trapezoidal	8.00E-04	22	0.63	2	21

VIII.SOLUTION METHOD

The fluid flow &thermal analysis of fluids based upon their different arrangements of fluid entrance has-been carried out. To analyse the performance of micro channels using liquid water and the nano fluid with thermal conductivity 10 times of the water as coolant. To analyse the solution using the three arrangement of the inlet flow. The flow from the upper, front and side of the micro channel and two shapes of the micro channel are used with same aspect ratio and the hydraulic diameter. It is known that increasing flow rate affects the performance; hence the flow rate has been kept same in all the cases by adjusting the inflow velocity according to cross-sectional area. The analysis and study the results for the higher value of heat transfer coefficient. Which arrangements give the better results for high dissipation heat from the circuit.

IX.ANALYSIS OF RESULTS

Contour for Rectangle micro channel heat sink:

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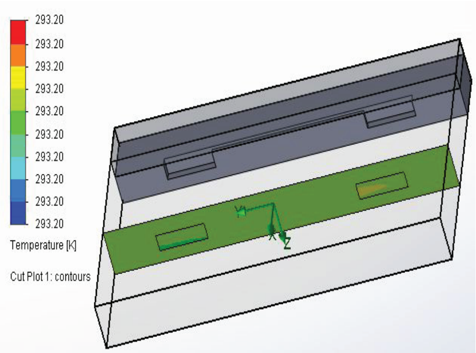

Fig. 5 Temperature contour for upper flow heat sink

Fig 5 shows the temperature contour for the upper flow arrangement for rectangle shape of micro channel in which the coolant is used as normal water in this case as shown from the contour there is not much high temperature difference the temperature at the inlet is approximately is equal to the outlet temperature.

Fig 6 shows the temperature contour for the front flow arrangement for rectangle shape of micro channel in this case as shown from the contour there is not much high temperature difference the temperature at the inlet is approximately is equal to the outlet temperature.

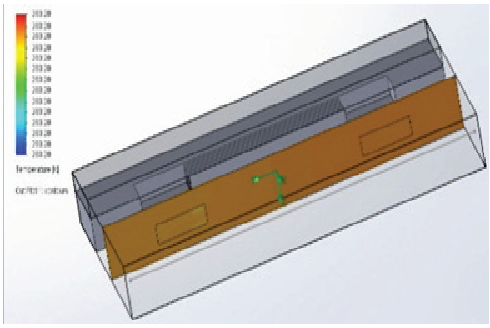

Fig. 6 Temperature contour for front flow

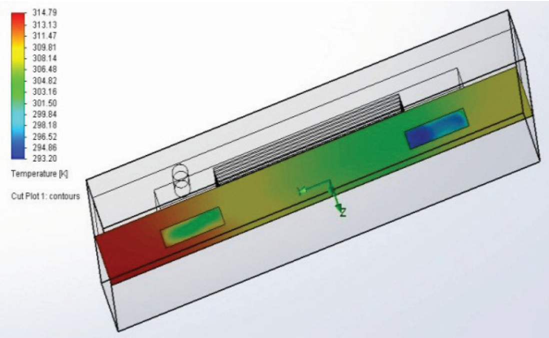

Fig. 7 Temperature contour for side flow

Fig 7 shows the temperature contour for the side flow arrangement for rectangle shape of micro channel in this case as shown from the contour there is not much high temperature difference the temperature at the inlet is approximately is equal to the outlet temperature.

Temprature contour for Trapezoidal micro channel :

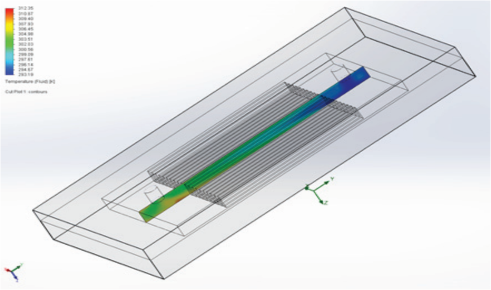

Fig. 8 Temperature contour for upper flow micro channel heat sink

Fig 8 shows the temperature contour for the upper flow arrangement for trapezoidal shape of micro channel in this case as shown from the contour there is not much high temperature difference. There is little variation in temperature between the inlet and outlet.

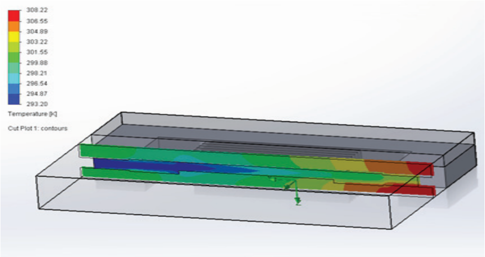

Fig. 9 Temperature contour for front flow microchannel heat sink

Fig 9 shows the temperature contour for the front flow arrangement for trapezoidal shape of micro channel in this case as shown from the contour there is not much high temperature difference. there is little variation in temperature between the inlet and outlet .

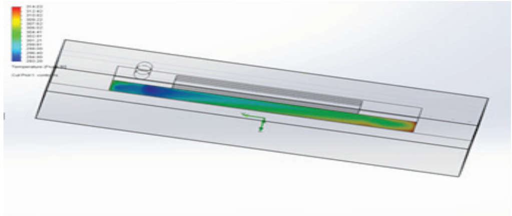

Fig. 10 Temperature contour for front flow micro channel heat sink

Fig 10 shows the temperature contour for the side flow arrangement for trapezoidal shape of micro channel in this case as shown from the contour there is not much high temperature difference. The temperature at the inlet is approximately is equal to the outlet temperature.

Velocity contour for Rectangle micro channel:

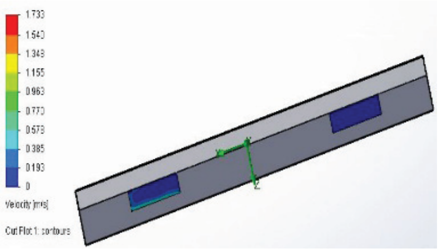

Fig. 11 Velocity contour for upper flow micro channel heat sink

Fig. 11 shows the velocity contour for the upper flow arrangement for the rectangle shape of micro channel.

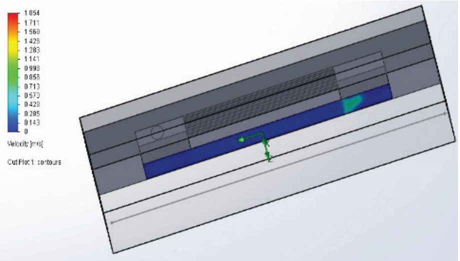

Fig. 12 Velocity contour for front flow micro channel heat sink.

Fig. 12 shows the velocity contour for the front flow arrangement for the rectangle shape of micro channel.the velocity boundary layer as shown in figure.

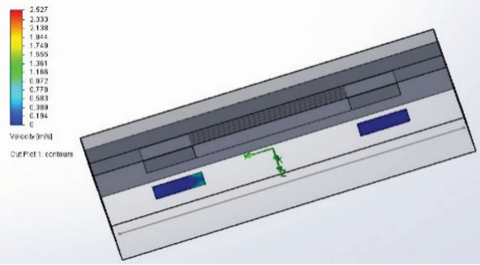

Fig. 13 Velocity contour for side flow micro channel heat sink

Fig. 13 shows the velocity contour for the side flow arrangement for the rectangle shape of micro channel.the velocity boundary layer as shown in figure.

Velocity contour for Trapezoidal micro channel heat sink:

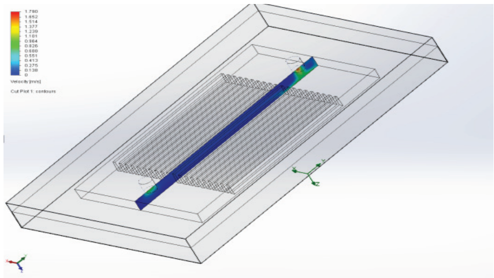

Fig. 14 Velocity contour for upper flow micro channel heat sink:

Fig. 14 shows the velocity contour for the upper flow arrangement for the trapezoidal shape of micro channel.the velocity boundary layer as shown in figure.

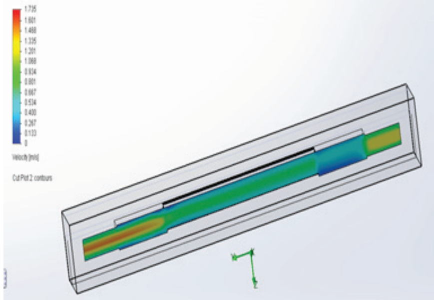

Fig. 15 Velocity contour for front flow micro channel heat sink:

Fig. 15 shows the velocity contour for the front flow arrangement for the trapezoidal shape of micro channel.the velocity boundary layer as shown in figure.

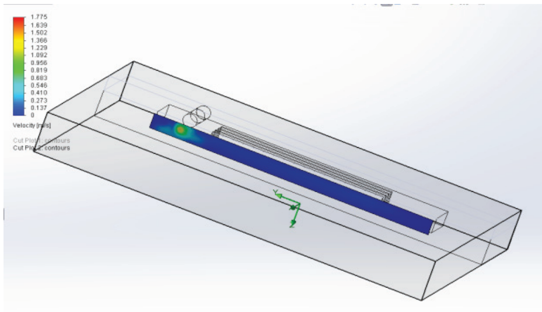

Fig. 16 Velocity contour for side flow micro channel heat sink.

Fig. 16 shows the velocity contour for the side flow arrangement for the trapezoidal shape of micro channel.the velocity boundary layer as shown in figure.The results are obtained from the analysis of the geometry of the micro channel with different shapes and flow arrangement. The analysis is done on the basis of the results obtained from the simulation.

X.RESULTS AND DISCUSSION

The results are discuus with results obtained from the simulation of the micro channel heat sink with different flow arrangement and coolant.

Here a plot between the heat transfer coefficient & Reynolds number using water is shown for rectangular channel in Fig. 17.

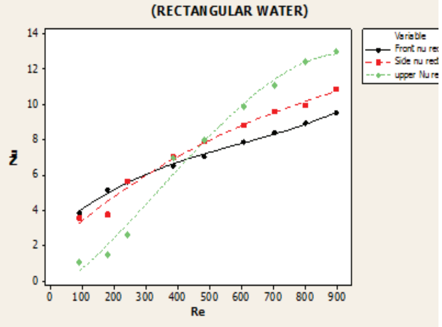

Fig. 17 Plot between the heat transfer coefficient and Reynolds number

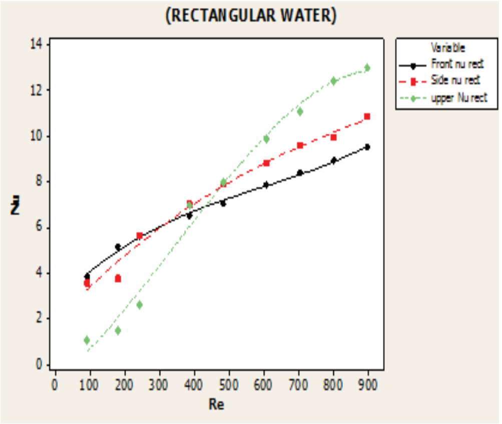

Fig. 18 Plot between the nusselt number and Reynolds number

The heat transfer coefficient is higher for the upper flow arrangement as compared to other arrangements.

It has been noticed in the fluid sub domain that in case of upper flow arrangements the boundary layer starts forming at a certain distance. In side flow & front flow the boundary layer forms early. The flow behaviour is also not uniform in case of upper flow channels & thus because of the variations it has high heat transfer coefficient.

In figure 17 the plot for the Nusselt number is shown. The Nusselt number for upper flow arrangement is higher as compared to other flow arrangements. The maximum value of the Nusselt Number is 13.

In the Figure 19, the plot between heat transfer coefficient & Reynolds number is shown for a trapezoidal geometry. Here the upper flow arrangement has very good performance & even has higher heat transfer coefficient than the rectangular shaped channels. The behaviour through the side flow & front flow is same as in rectangular shaped channels.

In figure 20 a plot between Nusselt number & Reynolds number is shown. The maximum value in case of trapezoidal channel reaches 15 at the maximum Reynolds number.

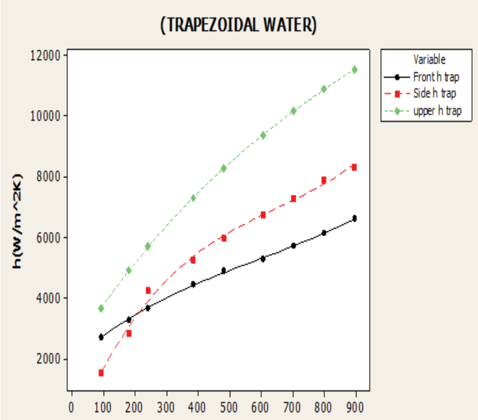

Fig. 19 Plot between the heat transfer coefficient and Reynolds number

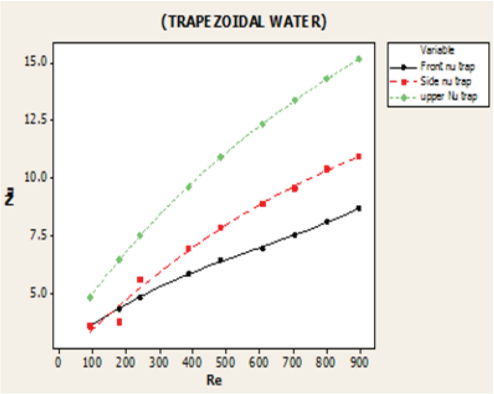

Fig. 20: Plot between the nusselt number and Reynolds number

Plots for custom Nano fluid:

In Figure 21 a plot between heat transfer coefficient & Reynolds number is shown for a rectangular channel using custom nano fluid. The nano fluid has 10 times thermal conductivity as compared to water. Here the maximum value of the heat transfer coefficient reaches to 32000, which is almost 3 times. Thus the nano fluid has very high performance as compared to water.

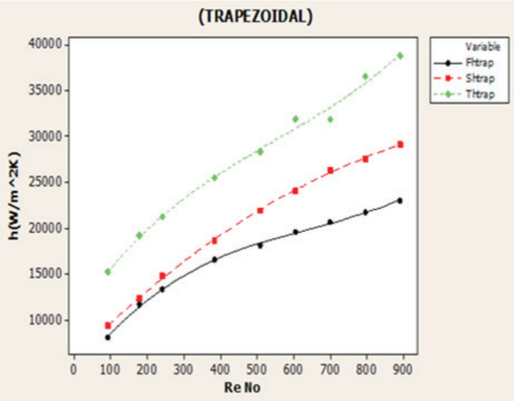

Fig. 21 Plot between the heat transfer coefficient and Reynolds number

The nusselt number using nano fluid reaches to a value of 4.75.In case of nano fluid the front flow arrangement has higher value.

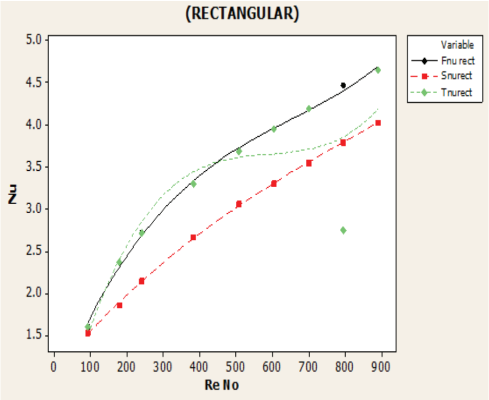

Fig. 22 Plot between the nusselt number and Reynolds number

The upper flow arrangement has lower value. The main reason for this change is due to the viscosity & interaction of nano particles. The particles pose a resistance in case of upper flow arrangement thus has lower performance.

In figure 23, a plot between heat transfer coefficient & Reynolds number is shown for a trapezoidal channel using custom nano fluid. It has been noticed that the value of heat transfer coefficient is higher i.e. 40000 & nusselt number reaches to 5.5 as in figure 24. The main reason for increase in heat transfer coefficient is the increase in thermal conductivity. The upper flow arrangement has higher value as compared to other arrangements. The main reason for this is due to the low resistance posed by the particles as the fluid particles find a space in the upper portion of the channels.

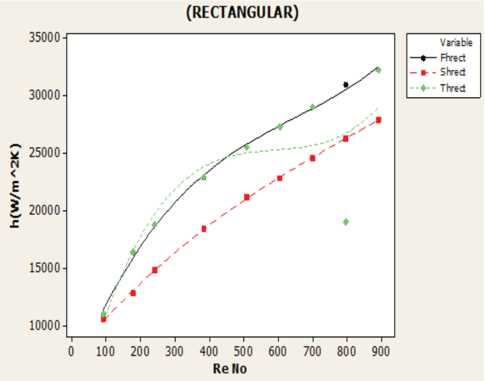

Fig. 23 Plot between the heat transfer coefficient and Reynolds number

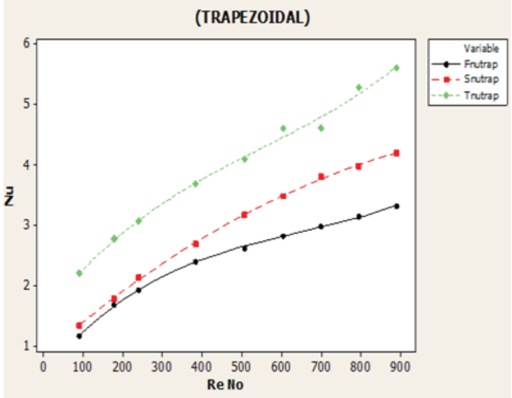

Fig. 24 Plot between the nusselt number and Reynolds number

From the above plots the results are concluded the higher value of heat transfer coefficient is give the better results means higher the heat is dissipated from the circuit. From the above results it has been clear that the better flow arrangement is in the case of trapezoidal shape of micro channel when we are using the upper flow arrangement of the micro channel heat sink and also in the case of the front flow arrangement using rectangle shape of micro channel heat sink gives a high value of heat transfer coefficient using the nano custom fluid in both case.

Overall Performance Plot:

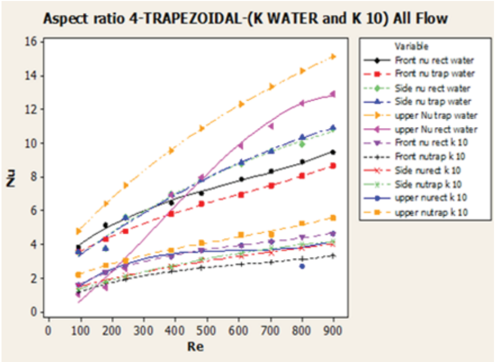

Fig. 25 Plot between the heat transfer coefficient and Reynolds number

Fig. 25 shows the overall performance plot between heat transfer coefficient and Reynolds number for the coolant water and nano fluid and the flow arrangement as shown in figure the highest value of heat transfer coefficient reaches 40000 in the case of upper flow in trapezoidal shape of micro channel. in the case of front flow in rectangle shape of micro channel using coolant nano fluid shows the high performance reaches a value of high heat flux is 32000.

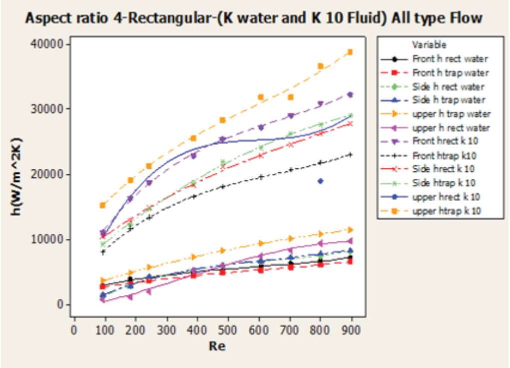

Fig. 26 Plot between the nusselt number and Reynolds number

Fig. 26 shows the overall performance plots between the nusselt number and Reynolds number. The highest value of nusselt number is reaches to 15 in case of front flow when rectangle shape of micro channel and the coolant is used normal water. In the case of upper flow arrangement in rectangle channel gives the high value of nusselt number reaches 12 when the coolant is used as normal water.

XI.CONCLUSION

In this study we are investigating the high performance on micro channel with different flow arrangement. In this study we conclude that flow can enter or exit in the following three ways upper flow, side flow and front flow. There are two different shapes of micro channel and coolants are studied with different flow arrangement.

1. For all the heat sink it is found that highest heat sink temperature in the case of trapezoidal shape of micro channel in the front flow arrangement when coolant is used as normal water.
2. The low-temperature region of heat sink occurs at the entrance zones of the micro channels due to high heat transfer coefficient. Heat sink temperature increases along the flow direction because of constant heat flux applied at the heat sink base plate.
3. From this investigation we conclude that the high heat is dissipation from the circuit in the case of when we using the upper flow arrangement in trapezoidal shape of micro channel and the coolant are used as nano fluid. The value of heat transfer coefficient is reaches 40000.
4. From the above results it has been conclude that the custom nano fluid having thermal conductivity 10 times more as compare to the normal water is more suitable as compare to normal water.

Nomenclature

A	Area exposed to heat transfer
c_p	Specific heat (J kg^{-1} K^{-1})
D_h	Hydraulic diameter (m)
H	Height of micro channel (mm)
h	Coefficient of convective heat transfer (W m^{-2} K^{-1})
k	Thermal conductivity ($wm^{-1}K^{-1)}$)
L	Length of micro channel (mm)
t_s	Surface temperature (K)
t_f	Fluid temperature (K)
V	Fluid velocity (m/s)
w	Width of micro channel
μ	Viscosity ($kgm^{-1}s^{-1)}$
P	Pressure (pa)
ρ	Density (kg/m^3)
nu	Nusselt number
Re	Reynolds no.
f	Front flow
s	Side flow
t	Upper flow
rect	Rectangle
trap	Trapezoidal

ACKNOWLEDGEMENT

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