Analyzing the Effect of Different Shapes of Microchannel on the Performance of Heat Sink through Numerical Analysis

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***Abstract*: Effect of different shapes of microchannel was also analysed and find the optimum design of microchannel. Effect of change in Reynolds number was also performed during the numerical analysis of heat sink. For that 100, 200, 300 and 400 Re number was considered for each design of heat sink. Using ANSYS Fluent different case was examined and measure the value of heat transfer coefficient and maximum temperature on the base of heat sink. Through analysing it is found that microchannel heat sink having trapezoidal fins shows the maximum heat transfer as compared to other. After analysing the different shape of fins in single stage, effect of discontinuous multistage of fins was also analysed. Four different set of stage was considered for the CFD analysis and found that with the increase in stages of fins heat transfer from heat sink decreases.**

***Keywords*: microchannel, heat sink, fins design, heat transfer, stage system.**

1. Introduction

Microchannel are closed channels for fluid flow, with hydraulic diameter ranging from a few tens to hundreds of micrometres. Due to smaller hydraulic diameters of microchannel, higher heat transfer coefficients can be achieved. Microchannel heat sinks offer several advantages in comparison with millimetre sized and conventional channels, like higher heat transfer area per unit volume and lower coolant requirement (11). It is seen that heat sink is employed to transfers heat (thermal) energy from a higher temperature source to a lower temperature fluid medium. Air is frequently the fluid medium, but water, refrigerant, oil and other liquids can also be used. Heat sinks are cast-off in integrated circuits and power handling semiconductors to diminish their temperature by increasing thermal mass and heat dissipations (chiefly by conduction or convection but to a minor range by radiation).

The emergence of Micro-Electro Mechanical Systems (MEMS) requires increased heat flux dissipation in limited space. Thermal management is essential for the electronic devices to maintain their expected performance, to ensure reliability, and to safeguard from failure. Microchannel heat exchangers, with fluid flow passages of hydraulic diameter below 1 mm, have been widely used to cool electronics that dissipate significant amounts of heat. Usage of smaller dimension channels brings about better heat transfer performance amidst the various hurdles of realization and operational difficulties such as pressure drop.

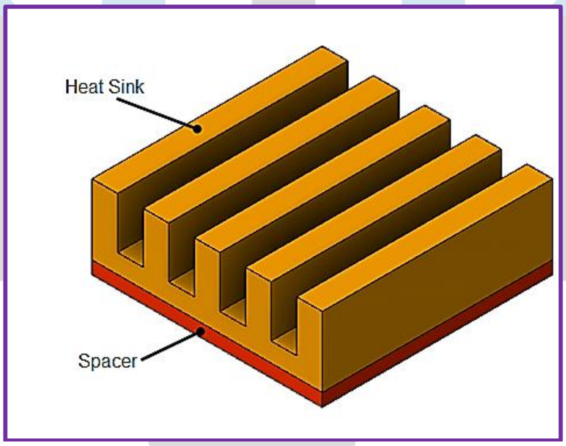

Fig.1 Typical Microchannel Heat Sink

Microchannel heat sink is a very efficient device for heat transfer application, it is basically used where high specific heat transfer is required. It is basically used for small and sophisticated equipment's. So, it is very necessary to used highly efficient heat sink. To increase the heat transfer capacity of the microchannel heat sink and to analysed the effect of different shapes of fins on heat transfer, here in this work four different shapes of fins and microchannels was analysed through CFD analysis using ANSYS Fluent. It also analysed the effect of different Reynold numbers on heat transfer capacity of microchannel heat sink. For each types of fins effect of change in Reynold number is analysed and calculates the maximum temperature and heat transfer coefficient. Rectangular shape microchannel heat sink is analyzed in chapter [3]. Microchannel heat sink with triangular, trapezoidal and cubical shapes fins was analyzed in this chapter. This chapter also includes the temperature and velocity distribution for different microchannel heat sink.

2. Development of numerical model

For performing the CFD analysis of heat sink, first it develops the CFD model. And apply the different boundary conditions as mention in Prajapati et.al [1]. For performing the numerical analysis of heat sink, first it has to develop the solid model of heat sink.

2.1 Development of solid model of heat sink

The solid model of heat sink is developed on the basis of geometric parameters given in the base papers. For validating the numerical model it is necessary to considered same geometric conditions as considered during the analysis performed by Prajapati et.al [1]. The geometric conditions on the basis of which the solid model of heat sink is developed is mention in the below table. Heat Sink width (W)-3.7, Height of heat sink (H) 1.1, Bottom wall thickness (H_b)-0.1, Side wall width (W_W)-0.1, Channel Width (W_c)-0.5, Fin height (H_f)-0.8, Heat sink length (L)-15.

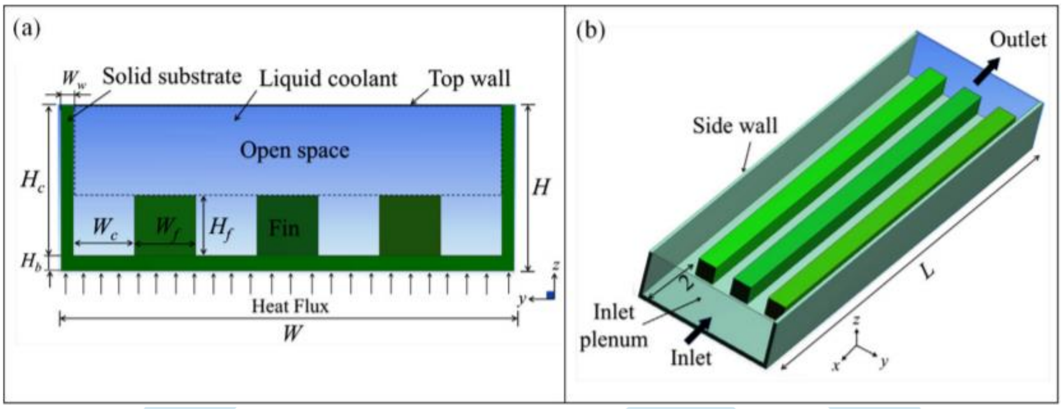

Fig.2 schematic diagram of heat sink considered during the numerical analysis of heat sink [1]

Base on the above geometrical parameters solid model is made, the solid model of heat sink was made with the help of ANSYS design modeler Software. For the validation case rectangular channel heat sink geometry is considered as mention by Prajapati et.al [1]. The solid model of microchannel heat sink is shown in the figure below.

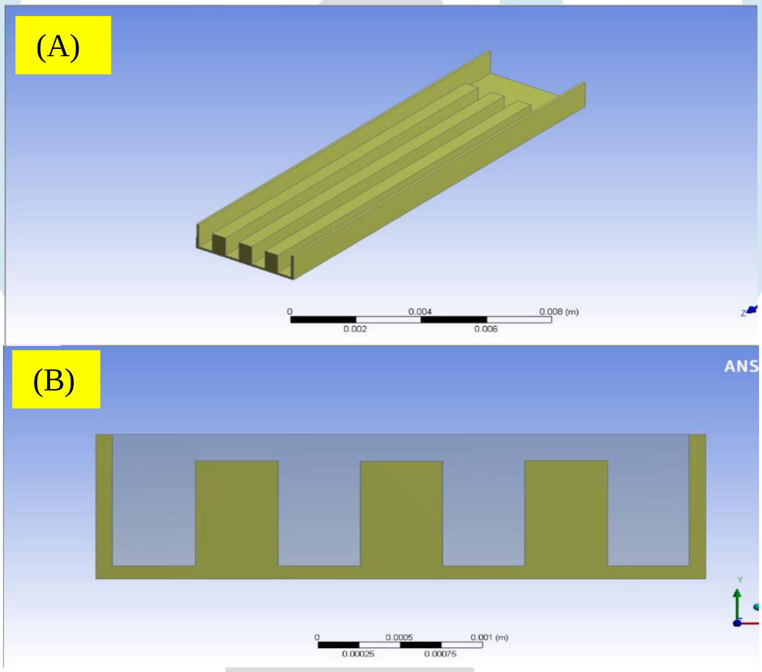

Fig.3 solid model of micro channel heat sink (A) complete view of geometry, (B) side view of the Geometry

From above figure it is clearly shows that there are four microchannels through which coolant fluid is flowing. Through solid model it also shows that microchannels start 2 mm after the inlet position of coolant fluid so that flow can be stabilized after entering in to heat sink channel.

2.2 Meshing:

For performing the numerical analysis of anybody first is get discretized in to number of bodies. While performing the numerical analysis, first it discretized the body in to number of nodes and elements. For optimizing the number of nodes and elements, discretization is performed with different tools to refine the mesh. As the number of nodes and elements increases the accuracy of the analysis also increases but after reaching certain value of Nodes and elements value of parameters will remain constant. Increasing number of nodes and elements also increases the computational time required for the simulation. The heat sink with simple mesh is shown in the figure below.

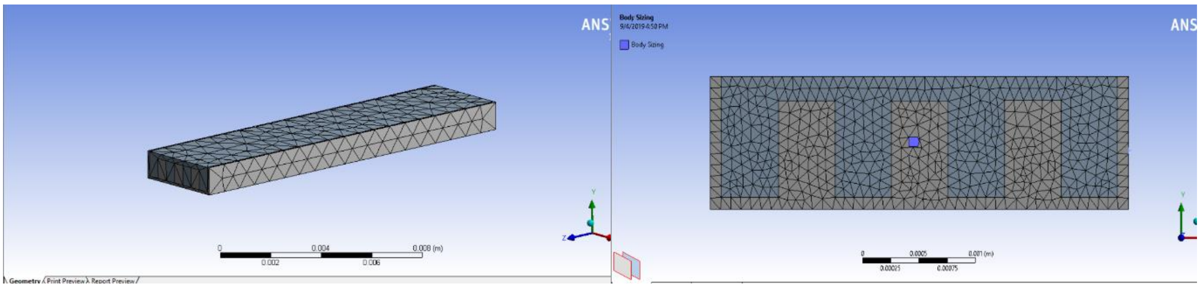

Fig.4 mesh of the microchannel heat sink having 2909 numbers of elements

Above figure shows the mesh of the geometry having very coarser mesh which will not give proper results during the numerical simulation. So, in order to get the accurate result of the heat sink, use of different mesh refinement tools are used. The solid model of microchannel heat sink having very fine mesh is shown in the figure below.

2.3 Boundary condition

Here in this work to analyzed the effect of different Reynold number, it considered four different Re numbers that is 100, 200, 300 and 400 and for each case velocity of air is calculated on the basis of relation mention in below section.

$$\text{Re} = \rho D_h V/\mu$$

Where Re is the Reynolds Number, ρ is the density of water, D_h is the hydraulic mean diameter, V is the velocity of water and μ is the dynamic viscosity of water. For the calculation properties of water as mention in chapter [3] will be considered. For calculation hydraulic diameter is 1.56 mm, after calculating it get 0.057, 0.118, 0.178 and 0.2373 m/s velocity for their respective Reynolds numbers. For numerical analysis 500 kW/m^{2}flux is applied on the bottom surface of heat sink and other wall of heat sink will remain adiabatic. The temperature of water at the inlet of microchannel is 303.15 K and enters at atmospheric pressure.

3. Validation of CFD model of microchannel

For validating the CFD model of microchannel heat sink, here it considered rectangular microchannel heat sink as considered by Prajapati et.al [1]. Here CFD analysis of heat sink is performed with the help of ANSYS Fluent. After applying different boundary conditions simulation was run at different Reynold number, the value of heat transfer coefficient, temperature and velocity distribution throughout the heat sink and maximum temperature of heat sink is calculated. The temperature and velocity distribution for different velocity of water is shown in the below case.

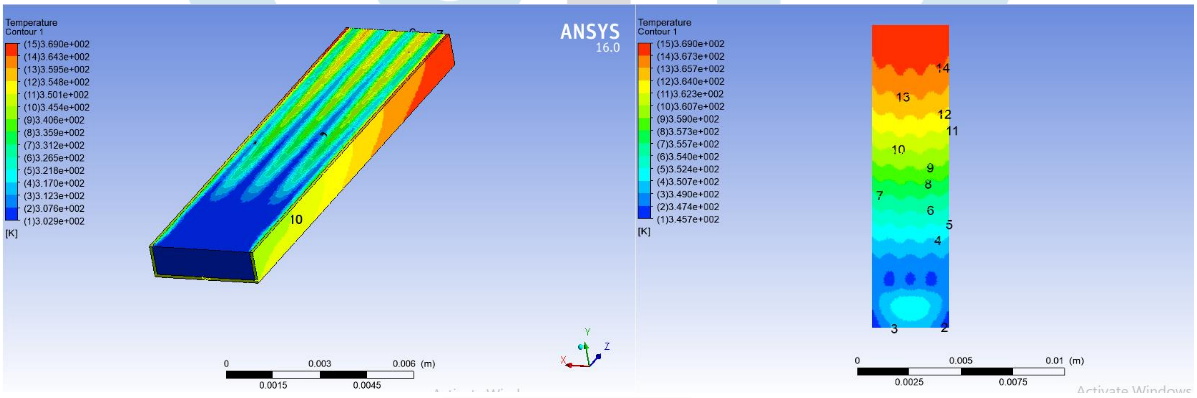

Fig.5 shows the temperature distribution throughout the body of heat sink for Re = 100

Table. Comparison of value of temperature for different Re numbers

S.No.	Re Number	Maximum Temperature from Numerical Analysis	Maximum Temperature from Base paper	Error %
1	100	369	360	2.5
2	200	349	340	2.6
3	300	340	335	1.4
4	400	335	328	2.1

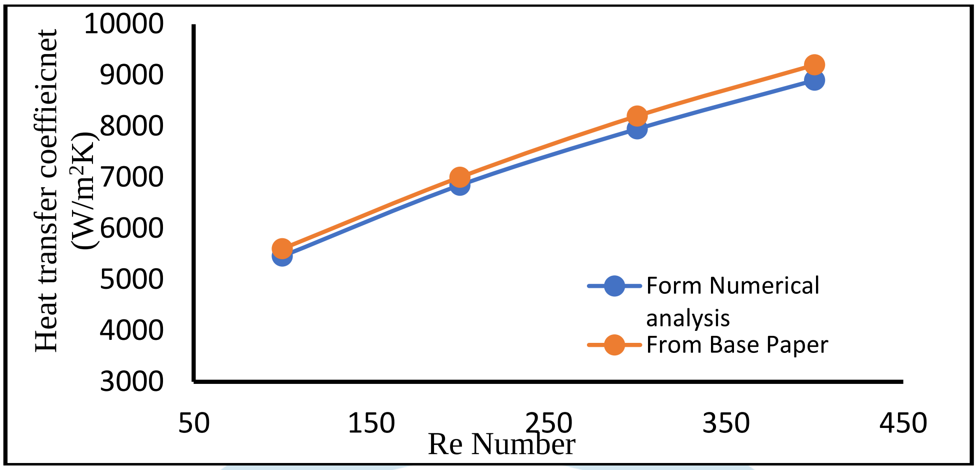

Fig.6 Comparison of value of heat transfer coefficient at different Re numbers

From the above comparison graph it is found that the value of heat transfer coefficient for different Reynold Number calculate through numerical analysis is close to the value given in the base paper at a particular Re number. The error percentage is in under 10 percent for each case. So, it is concluded that the numerical analysis of microchannel heat sink is correct. For more clarity maximum temperature of heat sink at different Re number is also compared.

4. Effect of discontinuous fins on heat sink

After analysing the effect of different shapes of fin, discontinuous fins effect was analysed. For analysing the effect of discontinuous fin trapezoidal shape of fins was considered. Four different discontinuous design was considered during the analysis and measure the value of heat transfer coefficient and maximum temperature at different Reynolds number.

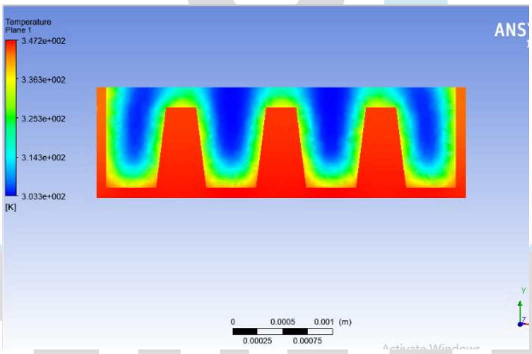

Fig.7 temperature distribution in a vertical plane at 7.5 mm from the inlet section of heat sink

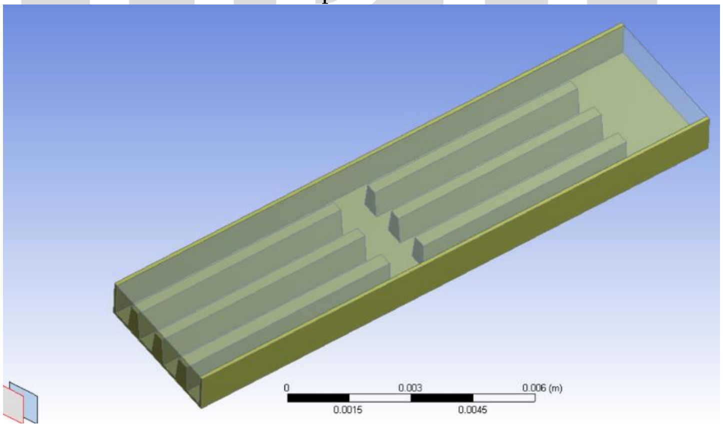

Fig.8 solid model of heat sink having 2 set of fins

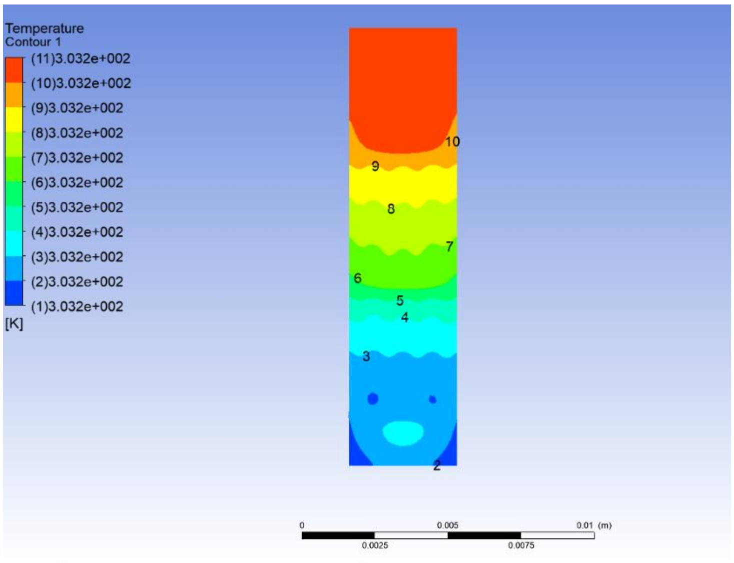

Fig.9 shows the temperature distribution of base of microchannel heat sink for 2 set

5. Comparison of different stages

After analysing the microchannel heat sink with different number of stages of fins separately at different Reynold numbers, comparison was done. The comparison of heat sink was done on the basis of heat transfer coefficient at different Reynolds number, the comparison graph is shown here.

Table. Comparison of value of heat transfer coefficient for different sets of fins

S.No.	Reynolds Number	Heat transfer coefficient (W/m^{2}K) Single stage	Heat transfer coefficient (W/m^{2}K) Double stage	Heat transfer coefficient (W/m^{2}K) Three stage	Heat transfer coefficient (W/m^{2}K) Four stage
1	100	8199.47	8191	8114	8082.13
2	200	9645.32	9637.5	9508	9469.4
3	300	10876.4	10866.4	10737	10703
4	400	11912.4	11903.5	11782.3	11748.5

From above table, it is found that, the value of heat transfer coefficient for single stage fins heat sink is higher than the multistage fins heat sink at each case of Re number. So, it is concluded that heat sink having single stage of fins is better than the multistage fins specially in laminar flow condition. The 3D comparison graph is also mention in the below section

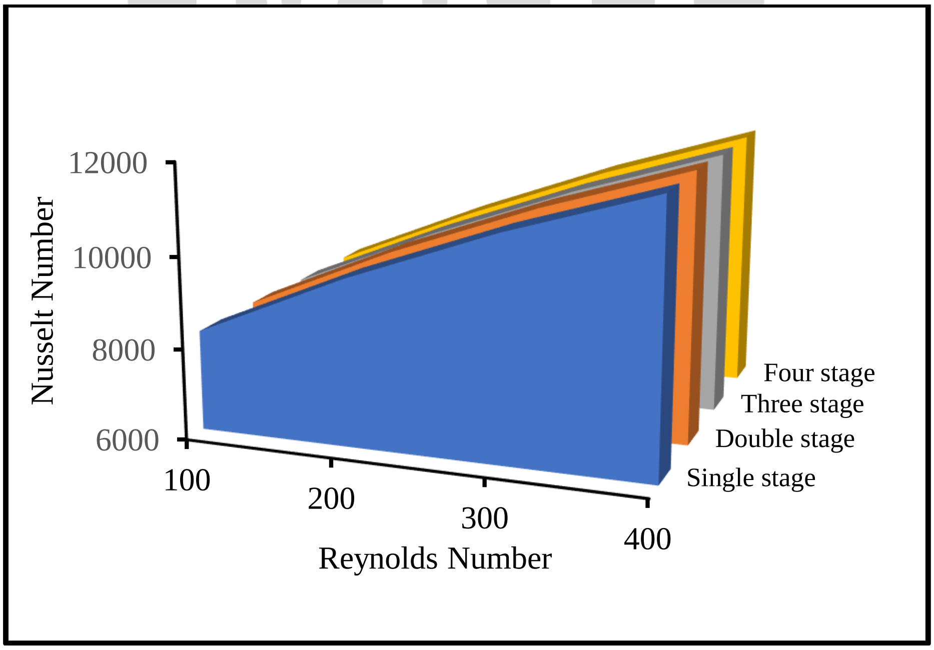

Fig.10 comparison of microchannel heat sink having different stages of fins

Conclusion

- By CFD software ANSYS Fluent version [16.0] microchannel heat sink analysis was done, it was found that temperature and velocity distribution throughout the microchannel plays an important role in heat transfer. Through analysis it was found that as the velocity of water at the inlet of microchannel increases heat transfer also increases which means that heat transfer is directly proportionate with heat transfer for heat sink. Through numerical analysis it was found that when the fins are arranged in different configuration value of heat transfer coefficient decreases, which means that heat transfer from heat sink decreases slightly. For four stage fins, the value of heat transfer coefficient is lowest as compared to three, two and single stage of fins, because the laminar flows in the microchannel heat sink. So it is concluded that microchannel heat sink having single stage trapezoidal shape of fins shows the maximum heat transfer.

6. Future Scope

Further work can be done on different working fluids that can flow inside the microchannel increase the heat transfer capacity of heat sink.

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