EFFECT OF DIFFERENT NANOFLUIDS FLOW IN MICROCHANNEL HEAT SINK

[1]Raghuveer singh Rajput, [2]Prof. Harish Sahu

Department of Mechanical Engineering,
Millennium institute of technology, Bhopal

***Abstract*: For the further enhancement of heat transfer from microchannel heat sink here in this work nano fluid was considered as working fluid inside the microchannel. Four most commonly used nano fluid was considered during the work that is Al_2O_3, Fe_2O_3, TiO_2 and CuO. For each case of nano fluid for different Reynolds number was also considered to analyze the flow behavior with respect to change in velocity of fluid. For analyzing the effect of different working fluid on microchannel heat sink heat transfer coefficient and maximum temperature of base plate was measure in each case of analysis. Through CFD analysis it is found that with TiO_2 nano fluid shows higher heat transfer coefficient as compared to other nanofluid. Through numerical analysis it is also found for all nanofluids at different Reynolds number, the coefficient of heat transfer is more as compared to water as working fluid.**

1. Introduction

A heat sink exchanges thermal energy from a more significant temperature device to actually a lower temperature fluid medium. The fluid medium is often air, however can certainly be water, refrigerants or oil. Whenever the fluid medium is going to be water, the heat sink is typically known as a cold plate. In thermodynamics a heat sink is definitely a heat reservoir which usually absorb an irrelevant amount of heat with no considerably changing temperature. Functional heat sinks for electronic devices need to have a temperature higher than the environment to transfer heat by convection, radiation, and conduction. The power supplies of electronics are generally not 100% efficient, therefore surplus heat is generated that can be averse to the function of device. For increasing the heat transfer rate of microchannel heat sink, researcher have optimized the different parameters of microchannel heat sink. In the same order to increase the heat transfer rate from microchannel heat sink, in this work nanofluid was considered as a working fluid. To analyzed the effect of different nano fluid on microchannel heat sink four most commonly used nano fluid was considered in this work. Fe_3O_4 (Iron oxide), Al_2O_3 (Aluminium oxide), TiO_2 (Titanium oxide) and CuO (copper oxide) were mixed with water in 0.5% volume percentage of water. Nano particle having size less than 100 nm were used to increase the heat transfer capacity of the water. To analyzed the effect of change in velocity for different nano fluids, four different Re number was also considered during the work that is 100, 200, 300 and 400. For all the cases of analysis the flow always remains in the laminar zone. For analyzing the effect of different nanofluid at different Reynolds number, heat transfer coefficient and maximum temperature of base plate was calculated in each case of analysis. Through Ansys fluent CFD analysis was done for different case of analysis. In order to perform the CFD analysis of microchannel heat sink with different nanofluid, single flow model was considered during the work. For considering the single-phase analysis, first properties of nanofluid were calculated through different mathematical relations. For finding the properties of nano fluid at a given proportion of nano powder and water following mathematical relation was considered.

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. 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.

Table.1 Value of geometric parameters considered during analysis of heat sink

Parameters	Value (mm)
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

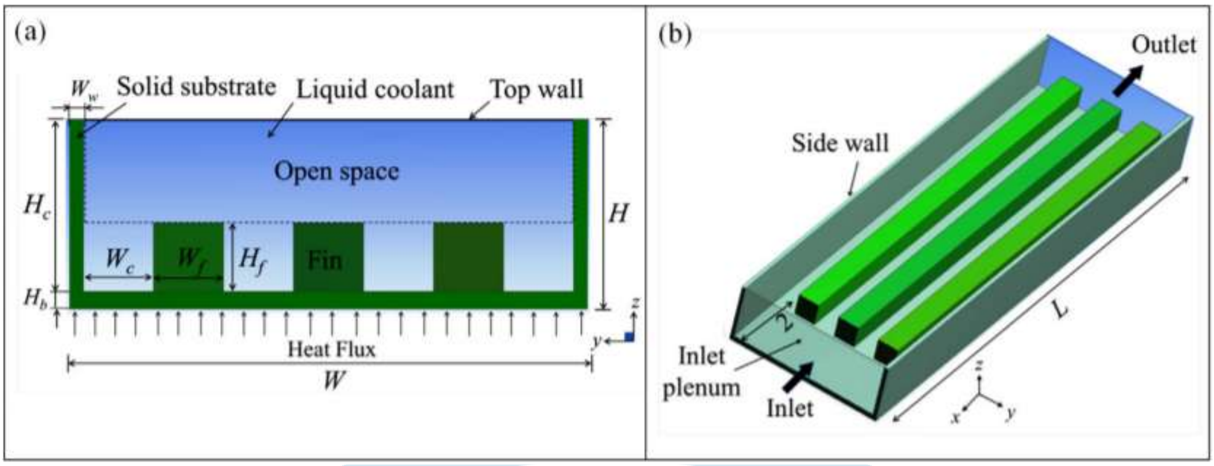

Fig.1 schematic diagram of heat sink considered during the numerical analysis of heat sink [1]

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 micro-channel heat sink is shown in the below fig.

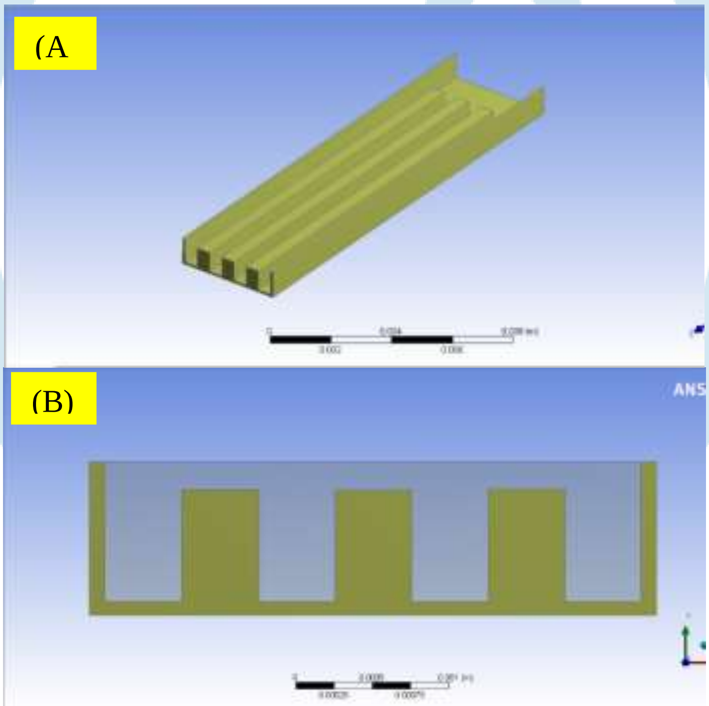

Fig. 2 solid model of micro channel heat sink (A) complete view of geometry, (B) side view of the Geometry

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

3. Meshing

For performing the numerical analysis of anybody first is get discretized in to number of bodies. While performing the numerical analysis, first it discretised 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 below fig.

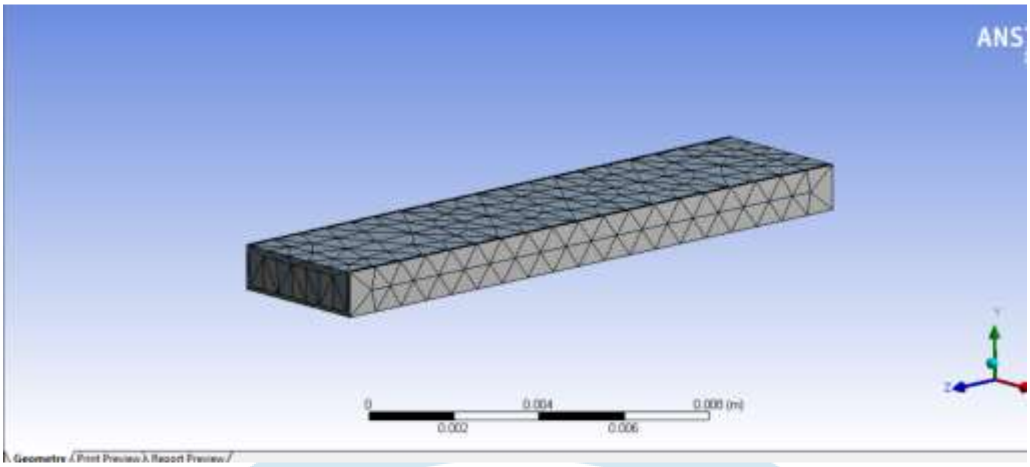

Fig.3 mesh of the micro-channel heat sink having 2909 numbers of elements

Above fig. shows the mesh of the geometry having very coarser mesh which will not give proper results during the numerical simulation. So, in order to gey the accurate result of the heat sink, use of different mesh refinement tools are used. The detail of mesh is shown in the below fig., and it also contains the number of nodes and elements used during the numerical analysis. In this work, 746337 number of Elements and 153453 nodes is use for the numerical analysis.

4. Boundary condition

Here in this work to analysed the effect of different Re 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.

$$Re = \rho D_h V / \mu$$

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 micro-channel is 303.15 K and enters at atmospheric pressure. For analysing the performance of heat sink here it measure the maximum temperature of heat sink and also measure the value of heat transfer coefficient of heat sink base surface at different Re number.

5. Validation of CFD model of micro-channel

For validating the CFD model of micro channel heat sink, here it considered rectangular micro-channel 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 Re 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.

5.1 For Re = 100

In this case water is entering inside the micro-channel with 0.057 m/s velocity and different boundary conditions was applied on different component of heat sink. The temperature and velocity distribution for this case is shown in the below fig. fig. shows the value of heat transfer coefficient value which 5460 W/m^{2}K for rectangular micro-channel at 100 Re number, it also shows the velocity contours of vertical plane made at 7.5 mm from the inlet position of water.

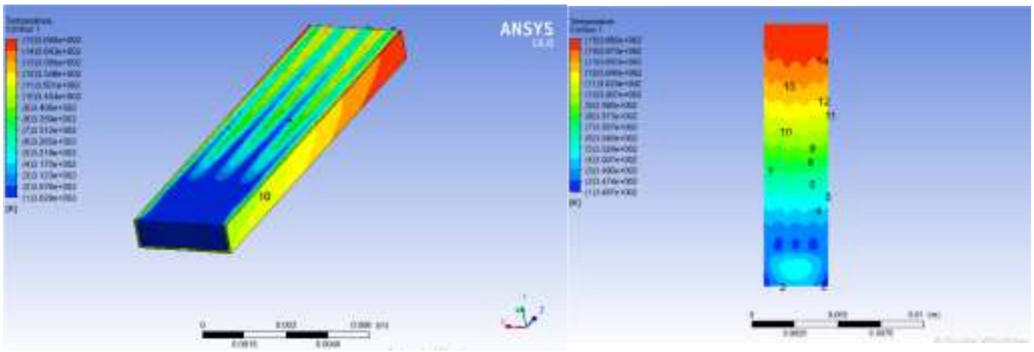

Fig.4 shows the temperature distribution throughout the body of heat sink

6. Comparison

After finding the value of heat transfer coefficient and maximum temperature of heat sink at different Reynolds number it compares the value of both the performance parameters with the base paper value and calculates the error percentage.

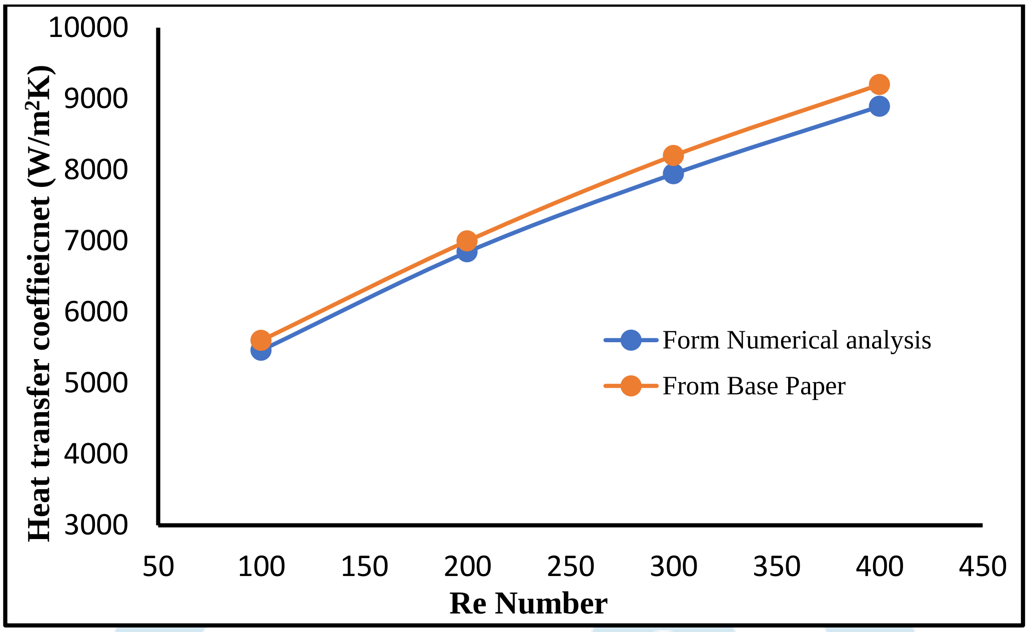

Fig.5 comparison of value of heat transfer coefficient at different Re numbers

From the above comparison graph it is found that the value of heat transfer coefficient for different Re 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 % for each case.

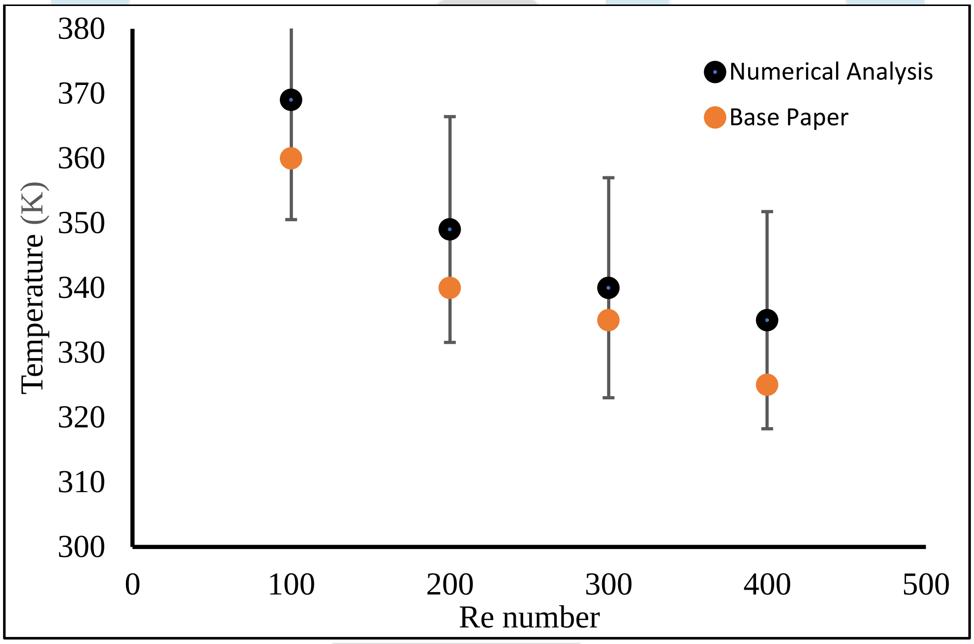

Fig.6 comparison of maximum temperature of heat sink for different Re numbers

So, it is concluded that the numerical analysis of micro-channel heat sink is correct. For more clarity maximum temperature of heat sink at different Re number is also compared. From above graph it is shown that the value of maximum temperature for different Re number calculated through numerical analysis is also in the accepted range as compared to base paper temperature range. Through above graph it is concluded that the numerical analysis of heat sink is correct.

7. For Al_2O_3 (Aluminium oxide)

Aluminium oxide nano particles were used to make Al_2O_3-Water nanofluid at 0.5% of proportion. The properties of nanofluid as calculated in the above section was inserted into the software. Due to this the working fluid inside the microchannel heat sink act as a Al_2O_3-Water nanofluid.

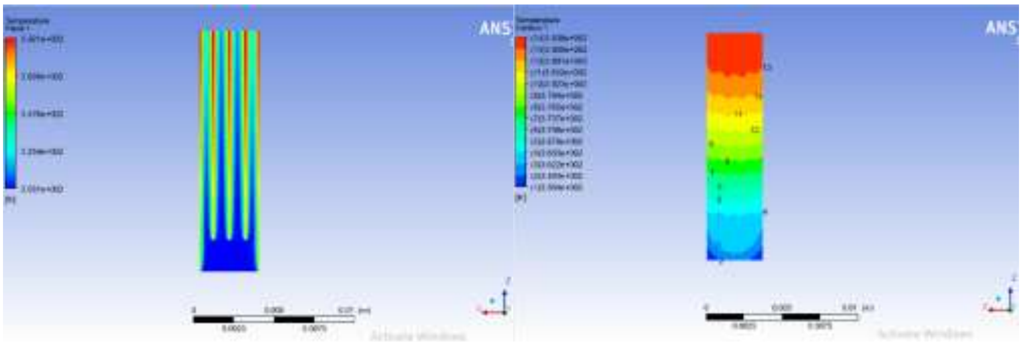

Fig.7 temperature gradient of base plate

Likewise, the above analysis it calculates the value of heat transfer coefficient and maximum temperature of heat sink at 200, 300 and 400 Re number. The value of maximum temperature of base plate and heat transfer coefficient for micro-channel heat sink with Al_2O_3 nano fluid is mention in the below table.

Table.2 Value of heat transfer coefficient and maximum temperature for Al_2O_3 nano fluid

S.No.	Re Number	Heat transfer coefficient (W/m^{2}K)	Maximum temperature
1	100	6781	392
2	200	8476	366
3	300	9732	353
4	400	10121	345

8. Comparison of different Nano fluids

After analyzing the effect of different nanofluids at different Reynolds number comparison was done on the basis of heat transfer coefficient and maximum temperature of the heat sink base plate. The comparative value of heat transfer coefficient for different nano fluids at different proportion is shown in the below table.

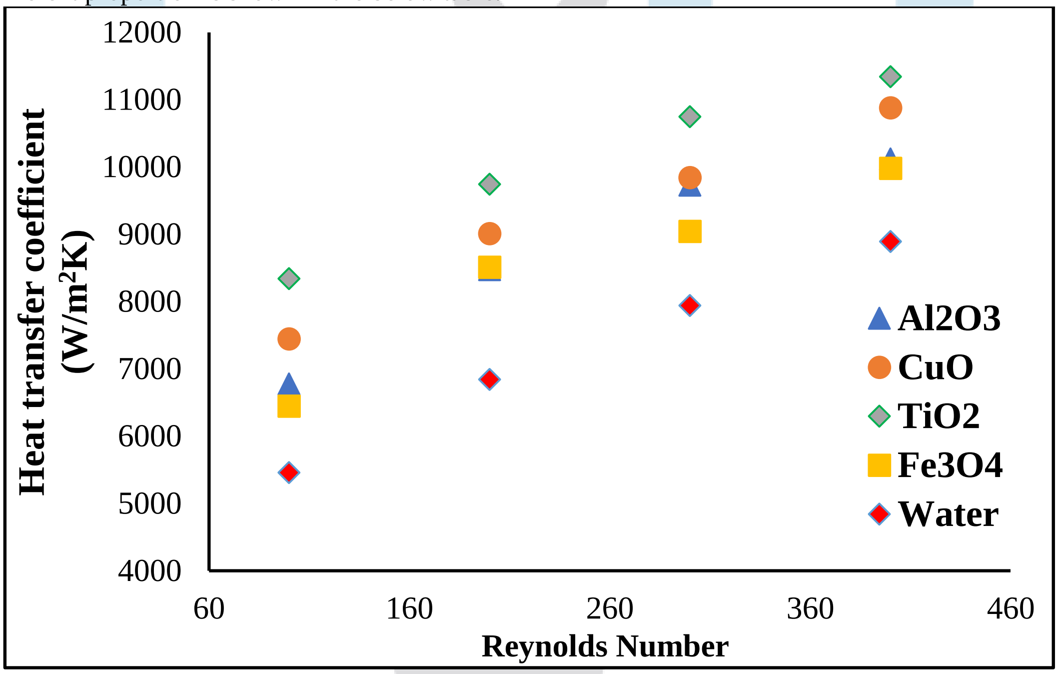

Fig.8 comparison of heat transfer coefficient for different Reynolds number

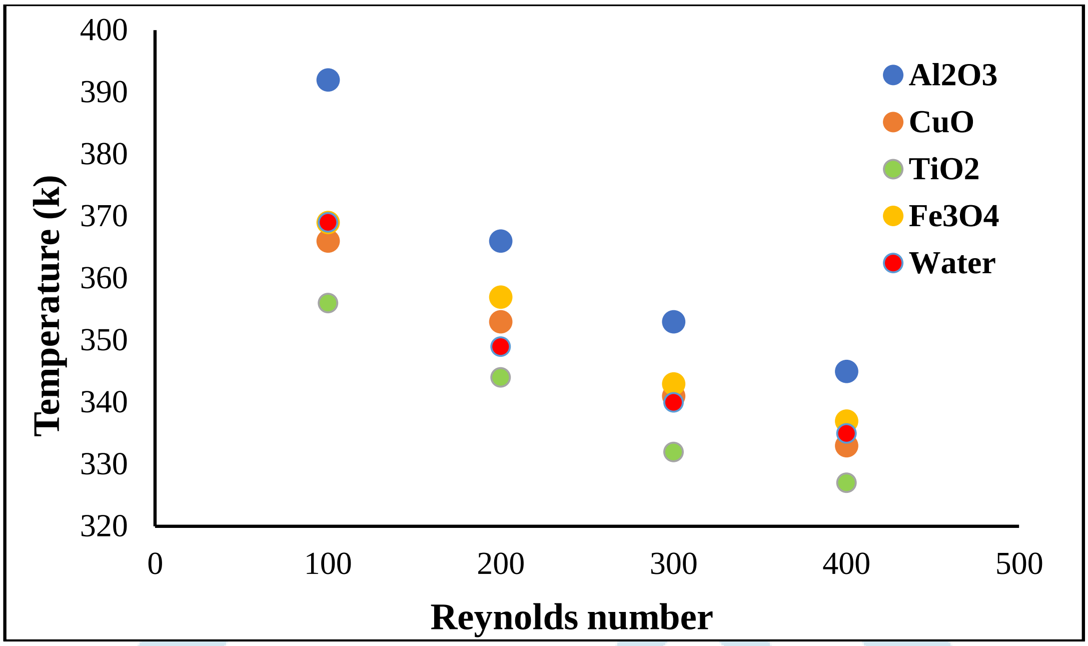

Fig.9 comparison of temperature at the base plate of heat sink

Above graph shows the comparison of different performance parameters of heat sink for different nanofluid at different Reynolds number. From graph it is found that with TiO2-nanofluid, the value of heat transfer coefficient is more as compared to other nanofluids. The base plate temperature of heat sink is also less in case of TiO2-nanofluid, which shows the higher heat transfer rate for this nano fluid as compared to other. After TiO2-nanofluid, CuO nano fluid shows the second highest heat transfer coefficient and also follow the same nature in case base plate temperature. Whereas with respect to water, all nano fluid shows higher heat transfer coefficient which means the heat transfer rate is more with nano fluid as compared to water.

9. Conclusion

Analyzing the effect of different nanofluids on heat transfer from heat sink at different Reynolds number. TiO_2 shows the higher heat transfer coefficient and lowest base plate temperature as compared to other nano fluids. After nano TiO_2, CuO shows the second higher heat transfer coefficient and lowest base plate temperature as compared to other. Through numerical analysis it is found that with increase in Reynolds number the value of heat transfer coefficient get also increases for all nano fluid. As compare to water as a working fluid, nano fluid in each case shows higher heat transfer rate. Overall, it is concluded that nanofluid are the best means for increasing the heat transfer rate from microchannel heat sink.

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