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Cooling of Heat Sink by the Process of Nanofluids

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ABSTRACT

The heat sink is analysed for five different Reynolds number and using Al_2O_3 nanoparticle with Water and Ethylene glycol as base fluid. Ansys fluent is used for numerical computations using single phase model. Results are validated with experimental data for different values of Reynolds number. Other parameters including thermal resistance, Nusselt number, pumping power and coefficient of heat transfer and mini-channel temperature variation are identified and analysed. This paper presents a numerical study of flow and heat transfer characteristics of three- dimensional heat sink with triangular pin fin using water and ethylene glycol (EG) as base fluid. Later the base fluid mixed with diamond powder (DM), aluminium oxide powder (Al2O3) and copper powder (Cu) nanoparticles with 2% and 4% volume concentration is considered. The study is carried out for Reynolds number ranging 100–900 subjected to constant heat flux 10 W/cm^2. A non-dimensional parameter thermal performance index is used to access the heat transfer characteristics of a heat sink. Results indicate heat dissipation rate of the finned heat sink was enhanced employing nanofluids, however, the performance index of nanofluids. the thermal resistance is decreased while at the same time the pumping capacity increases. From simulation study and comparison of all Re and Ø with given three base fluids combination it can be noted that Al_2O_3+EG20 nano-fluid can more efficiently cool electronics device. As with Ø =5% in Al_2O_3+EG20, Nu increases by 47.8% and h increases by 3.05%, also it shows more stability and power required by pump is less.

I. Introduction

The literature is well documented that any progress in the liquid cooling of electronic devices using different fluids can significantly reduce the temperature of ic chips; subsequently improve the performance of electronic devices as well as the lifetime of devices. Although there are many ways through which improvement in electronics device performance can be achieved, the use of nanofluids through mini-channels or micro-channels for cooling electronics device design has attracted particular attention from a large number of scientists over the past decade. The principal parameters affecting the cooling of nanofluids are selection of nanoparticles and base fluid, nanoparticles concentration, stability, power required to operate. Increasing the development of electronic devices to produce high-performance ic chips means that more devices are built per chip, the removal of heat from ic chips is mainly concerned, so researchers are pushing throughout the universe to develop modern approaches to enhance electronic device cooling so that it performs perfectly. In particular, the cooling of mini-channels using nanofluids, due to its higher efficiency and cooling certainty, has been the focus of many scientists and engineers, and can satisfy a wide range of applications at the same. The trend persisted in the 1970s with the new advancement of lsi technologies adding hundreds to thousands of electrical components in one chip, and after that, in the 1980s with the evolution of VLSI technique, thousands to ten thousand of electrical components..

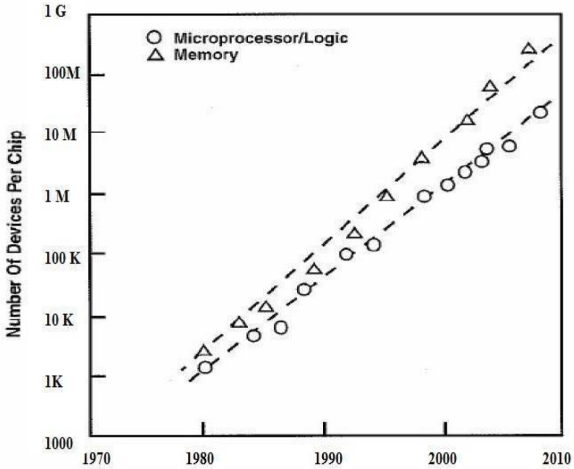

Fig.1.Increasing number of devices per chip.

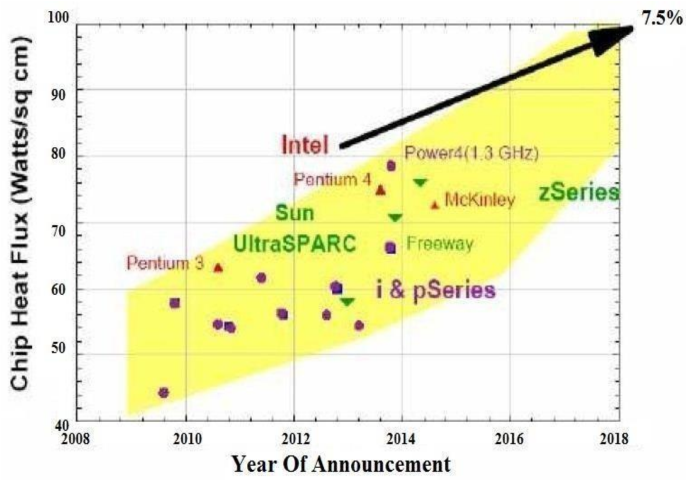

Fig.2. Increasing heat flux progressively as year passes.

The number of devices increases that leads to higher heat flux in a smaller area, if not properly cooled, increase its working temperature that causes decreasing device efficiency or life span. Fig 2 and Fig. 3 Studies have shown that chip heat flux today is increasing at a rate of 7.5 per cent per year.

II. SCOPE OF STUDY

From the literature review it is evident that sufficient research has been carried out on mini- channels or micro-channels heat sinks using different dielectric fluids, deionized water or even using two-three combinations of nanoparticles in water base fluid in nanofluids. Geometry of different dimensions is also studied using different channel numbers and their dimensions. Stability of nanoparticles in concentration in different nanofluids has also been studied for different applications. However, in the case of IC chips which are used nowdays for various applications, little has been reported regarding specific study (abhishek etal.).

The main significance of present study is,

1. To study single mini-channel for five Reynolds number for Al_2O_3 with water and ethyl glycol as base fluids for three different concentrations inmini-channels.
2. Optimizing the base fluid and concentration ofnanoparticle.
3. To forecast temperature variation throughout the channel due tonanoparticles.
4. Tostudylocalheattransfercoefficientsofvariouscombination.Therefore,thisparticular aspect will be thoroughly investigated in the present work in view of the fact that an optimum geometric configuration and concentration of nanofluids should have ahigher
5. Heattransfercoefficientresultinginbettercoolingefficiencyandlesspowerrequirement.

Details of mini-channelconfiguration

In the illustration of heat sink with heat supplied through Integrated circuit (IC) Chip from bottom and it is removed by flowing fluid through mini-channels. Chip is located closed to the inlet of the mini-channels and centered over the width of heat sink as shown in Fig. A constant heat flux q'' is provided through IC device. The inlet temperature of fluid was 313K.

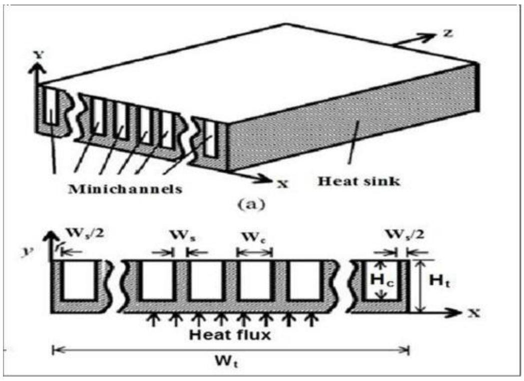

Fig.3 Diagram of mini-channels heat sink

IV. RESULTS ANDDISCUSSIONS

Effects of nanofluids by varying Al2O3 nanoparticles concentration inWater.

To examine the effects of thermal resistance, temperature variation along the fluid flow, local convective heat transfer coefficients, viscosity effects, pressure drop and pumping power, three different base fluid combination and Al2O3 nanoparticle by varying their concentration from as 0%,5% and 8% volume percentages are considered. Simulation results for water, ethylene glycol and water + 20 % Ethylene glycol [EG20] base fluids were discussed. All calculations were done on midsection (z= 25mm.) and local values were considered. Numerical simulation is performed and by calculations with required equation following results were noted. Calculations were performed at midsection and local properties were considered so as to avoid the cumbersome handling of data at various sections with different Reynolds number and concentrations. Values of local heat transfer coefficient h are noted in and graphical representation is shown in Fig.13. It can be noted that for simple cooling with water (i.e Ø= 0%) h shows less responsiveness or less variation with respect to Re. Also for Ø=5% and 8% a variation in values of h w.r.t Re can be seen. Although for 5% maximum increment in h w.r.t Re is noted..

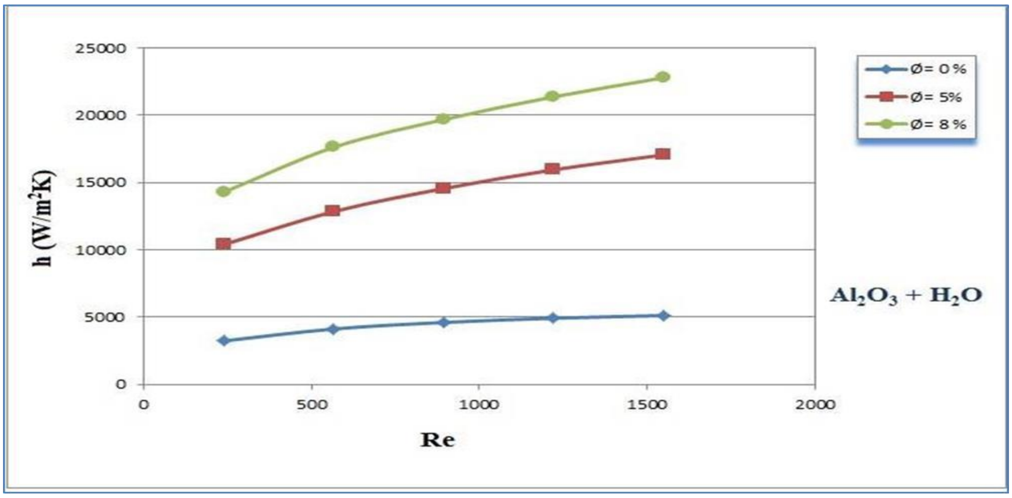

Fig.4 Effects of change in Reynolds number and concentration of Al_2O_3 using base-fluid water: On local heat transfer coefficient.

Values of nusselt number are shown. As value of Re increased Nu increases but increment is more in case of 5% and 8% concentrations as compared to pure water flow. Also value of Nu increases as the concentration of nanoparticle is increased. For 5% and 8% increments in value of Nu were 58% and 84% respctively, with respect to 0%. Numerical simulation is performed and by calculations with required equation following results were noted. Calculations were performed at midsection and local properties.

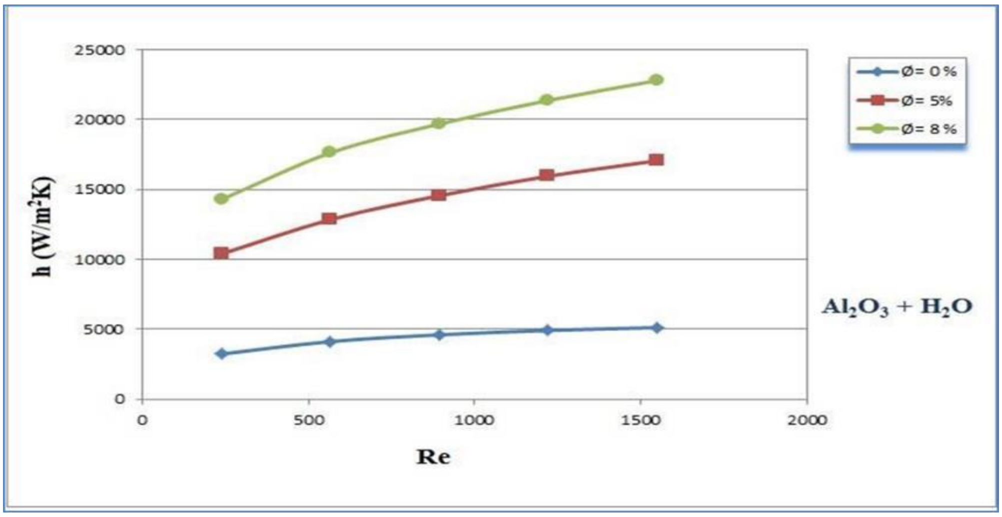

Fig.5 Effects of change in Reynolds number and concentration of Al2O3 using base-fluid water: On Nusselt number.

Effects of nanofluids by varying Al2O3 nanoparticles concentration in Ethylene glycol.

Values for local heat transfer coefficient can be observed. As it can be noted from fig.17 there is very little variation in values for h when pure EG is used. The values were in range of 2300-2600 (W/m2K) thus graph looks nearly straight as compared to other concentrations. In case of Ø=5%, a dramatic change in values can be seen with respect to Re. Firstly value of h increases till a value of Re≈1250 to 1300 then it shows a decrement in value of h. Addition of nanoparticles i.e for Ø=5% results in increment in h by 7.86%. For Ø=8%, h increases till Re≈600 then shown small variation till Re≈1200 and then again increases with Re. Addition of nanoparticles i.e for Ø=8% results in increment in h by 10.91%.

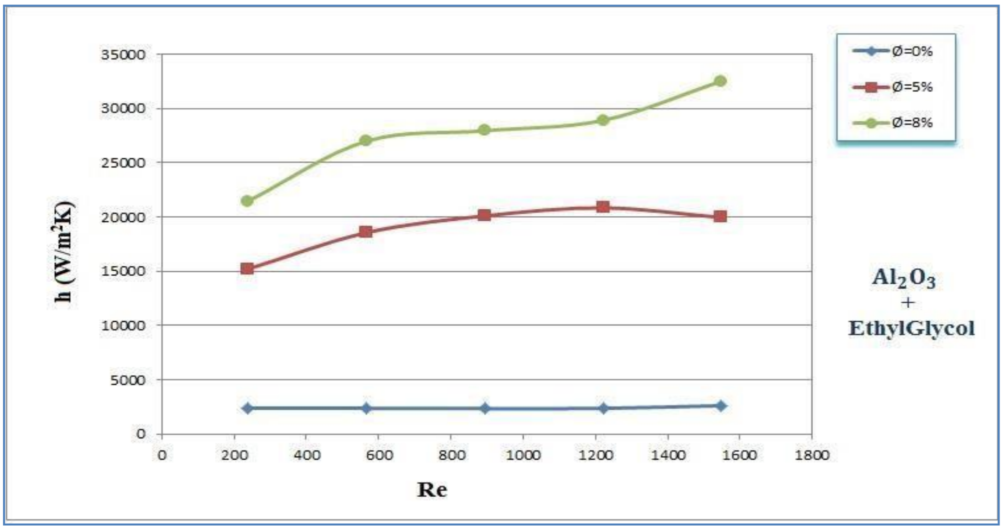

Fig.6 Effects of change in Reynolds number and concentration of Al2O3 using EG base-fluid: On local heat transfer coefficient.

Values of Nu can be noted. Since, Nu depends on h, Dh and keff, it remains nearly constant for pure EG i.e for Ø=0%, similar to h. But as Ø changes thermal conductivity of nanofluid (keff) also changes. For Ø=5% Nu increases till Re≈1250 to 1300, after this it decreases similar to h, but at Re=238 value of Nu for Ø=5% is less than that is for 0%. It can be explained by fact that increment in keff is more than h as Ø changes. Thus it can be noted that for below a particular value of Re, increasing concentration do not results in increment in Nu or heat transfer. Addition of nanoparticles i.e for Ø=5% results in increment in Nu by 28.6%. For Ø=8%, similar to h pattern is observed. Nu increases till Re≈600 then shown small variation till Re≈1200 and then again increases with Re. Addition of nanoparticles i.e for Ø=8% results in increment in Nu by 64.3%.

values of fanning friction factor (f), which follows similar variation for all concentrations with respect to Re. As Re increases f decreases and effect of change in concentration on it decreases. When Ø changes from 0% to 5%, for Re=238 f decreases by 15.4%, and when Re=1549 f decreases by 13.3%. Maximum wall temperature thermal resistance (R) should have a low value for effective cooling of heatsink

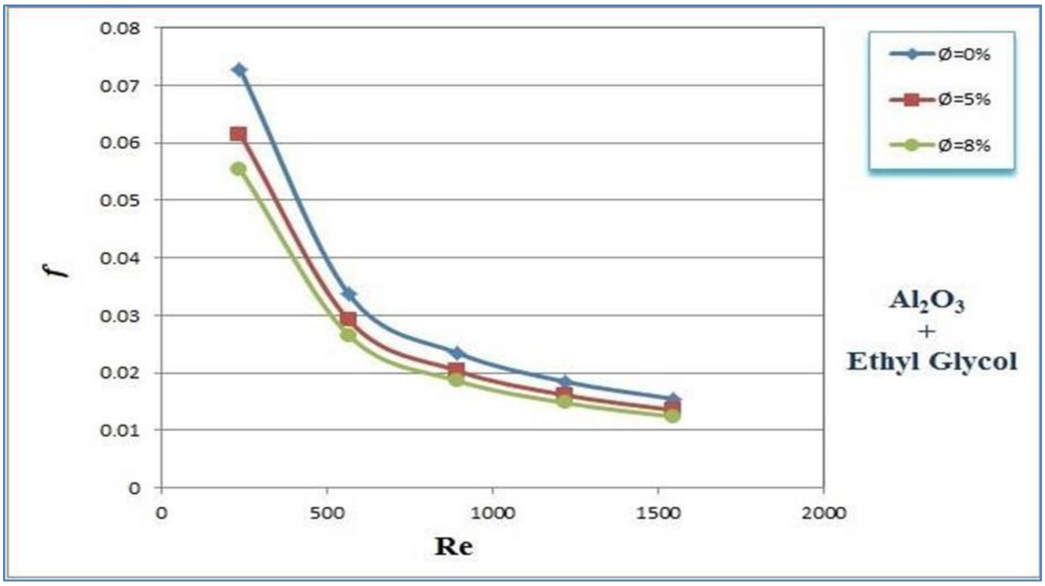

Fig.7 Effects of change in Reynolds number and concentration of Al2O3 using EG base-fluid: On Fanning friction factor.

It can be found that as Re and Ø increases thermal resistance decreases. It is maximum when pure EG is used and thus justifies the use of nanoparticles for effective cooling.

When pure water and EG compared, R is noted less for water, but for Ø= 5%and 8% R is noted less for EG. Therefore, with nanoparticles EG shows less thermal resistance as compared to water.

R decreases by 87.7% and 90.8% when Ø increased to 5% and 8% respectively from 0%.

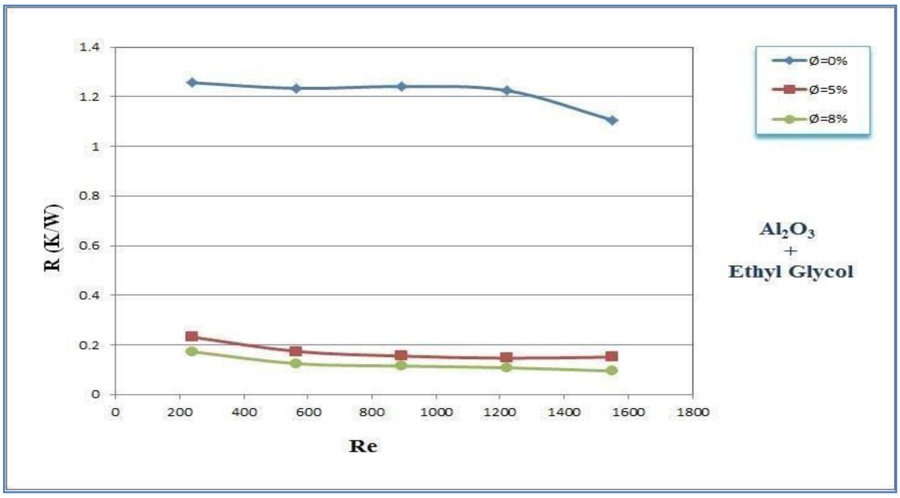

Fig. 8 Effects of change in Reynolds number and concentration of Al2O3 using EG base-fluid: On Maximum wall temperature thermal resistance.

Effects of nanofluids by varying Al2O3 nanoparticles concentration in Water + 20% Ethylene Glycol.

Values of h for Water + 20% Ethylene Glycol (EG20). Here it can be observed that there is less variation in h for change in Re, whereas for change in concentration increment in h, is observed. When Ø changes from 0% to 5% h increases by 3.05%, and for change in Ø from 0% to 8% h increases by 4.75%. Noticing the values, it can be seen that EG20 shows less variation in h with respect to Re but is more effective than EG

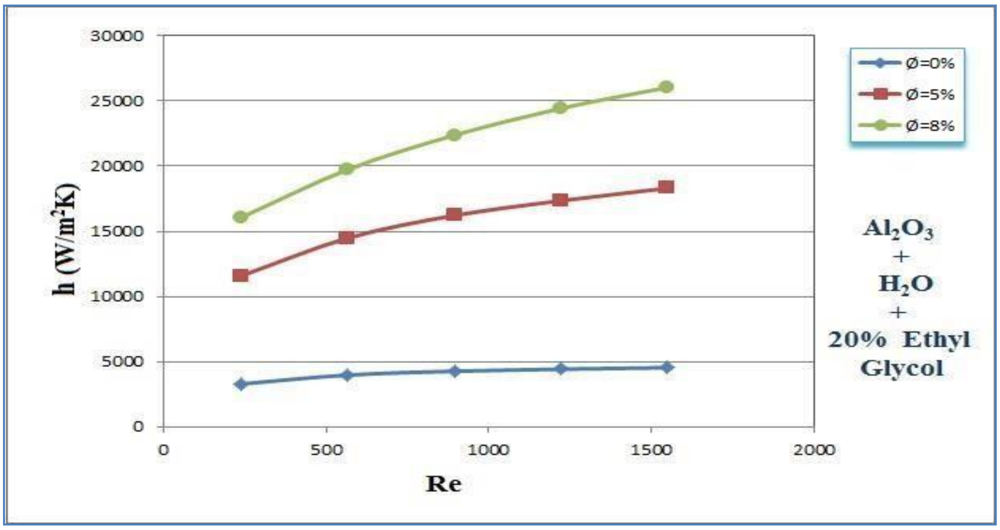

Fig.9 Effects of change in Reynolds number and concentration of Al_2O_3 using Water + 20% EG base-fluid: On Local heat transfer coefficient.

V. CONCLUSIONS

Numerical simulation in ANSYS FLUENT 14.5 is carried out to explore the effects of varying concentration of Al_2O_3 in given base fluids and different Re for mini-channel heat-sink. Following are the observations; even a smaller concentration of nanoparticles in any base fluids decreases its thermal resistance and increases convection heat transfer coefficients and other heat transfer parameters effectively.

- For all three combinations, h increases as concentration of nanoparticle is increased.Exception is in case of Al_2O_3 + EG for Ø=5%, h increases till Re≈1250 to 1300 after that it decreases. Increment in h by adding nanoparticle is maximum in EG and minimum in water.

- For EG at Re=238 value of Nu for Ø=5% is less than that is for 0%. It can be explained by fact that increment in k_{eff} is more than h as Ø changes. Thus it can be noted that for below a particular value of Re, increasing concentration do not results in increment in Nu or heat transfer.
- The value of pumping power for Al_2O_3+EG20 is minimum for all cases. Also for EG power required is most and about 2-3 times more than the other two fluids.
- Among all cases most effective cooling is noted in EG and EG20 fluid and minimum value of T_w was noted for Re=1549, which is Tw=313.7381 K for EG. Overall consistent effective cooling over the range of Re is minimum for EG.
- Also at same time because of increasing concentration pumping power increases. Hence in nanofluids above 5% concentration of nanoparticles is not preferable.
- In spite of higher local convective h beat transfer coefficients in EG compared to water and EG20, still it is less effective for cooling of devices because of higher viscosity for same Reynolds number.
- As concentration of nanoparticles is increases its effects on heat transfer parameters goes on decreasing.
- Fanning friction factor decreases as Re and Ø increases. It is least for 8% also as value of Re increases, effect of Ø on value of f decreases.
- As Re and Ø increases thermal resistance decreases Maximum wall temperature thermal resistance is maximum for EG Ø=0% and minimum for EG Ø=8%.
- From simulation study and comparison of all Re and Ø with given three base fluids combination a concrete observation can be made that Al_2O_3+EG20 nano-fluid can more efficiently cool electronics device. As with Ø =5% in Al_2O_3+EG20, Nu increases by 47.8% and h increases by 3.05%,also it shows more stability and power required by pump is less.

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