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Analysis of heat dissipation in processor chipset with minichannel heat sink using nanofluids as cooling medium – A CFD approach

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ABSTRACT

Due to the reduction in the size of the electronic components, heat dissipation has become a major problem. In many cases, air cooling has failed to provide the required demands. The invention of nanofluid has promised to increase the efficiency of the liquid cooling system. The addition of solid nanoparticles to the liquid actually increases the thermal conductivity of the liquid because of the higher thermal conductivity of the solid particles. In this work, the thermal performance of a minichannel heat sink was analyzed using CFD for cooling of processor chipset using nanofluids instead of pure water. The effect of different mass flow rates and various volume concentrations of nanoparticles on the overall thermal performance are also analyzed. The Alumina and graphene water nanofluids are used as coolants with volume concentrations of 0.1, 0.15 and 0.2%. The cooling fluid is made to flow through an Aluminium mini channel with height 5mm and width 1mm respectively. The maximum allowable temperature that has to be maintained at the chip is below 50oC. By using the liquid cooling system with a heat sink, this temperature is reduced as low as 41.22oC. There is also an enhancement of the convective heat transfer coefficient in using graphene nanofluids when compared to alumina nanofluids. The thermal resistance of the heat sink with nanofluids is lesser than pure water.

Keywords*— Minichannel, Heat sink, Microprocessor cooling, Alumina, Graphene*

1. INTRODUCTION

Due to increase in heat generation of electronic components, several investigations were carried out for over a past decade regarding electronic cooling. One of the most prominent methods is to use liquid cooling systems. A heat sink is a passive type heat exchanger that transfers the heat generated by the electronics to the fluid flowing through its channels. Various fluids had been tried out as a cooling medium but the invention of Nano fluids has provided a new liquid coolant with better thermal characteristics. The nanofluids are nothing but the suspensions of nanoparticles in the base fluid. Due to the addition of nanoparticles to the base fluids increases the thermo physical properties.

C. T. Nguyen et al. experimentally studied the heat transfer increment provided by a particular nanofluid Al_2O_3-water mixture that is used for cooling of processors and heated electronic components. **Bui Hung Thang et al.** used MWCNT-OH-based EG/DW solutions as coolants for the Intel Core i5 processor cooling. Compared to the cooling fan, the processor temperature reduced about 14^{o}C while using liquid cooling system. **M.R. Sohel et al.** experimentally found that nanofluid reduced the temperature of heat sink base (about 2.7^{o}C). The Thermal resistance also decreased 15.72% at 0.25 vol. % when compared to water. **Kays A. Al-Tae'y et al**. used a copper minichannel heat sink with de-ionized water as a coolant liquid for the 2.8 GHz computer processing unit chips in a real personal computer. The water cooling system was very much successful in reducing the CPU temperature from 42˚C to 33˚C at 0.0044 kg/s. **Prasad Mangalkar, Dr.** experimentally investigated the enhancement in heat transfer and behaviour of Aluminium oxide - water mixture for microprocessors or other electronic components in a closed cooling system. **Mehdi Ghobadi et al.** investigated Heat transfer and pressure drop in two types of square minichannel heat sinks for the purpose of cooling. By the literature survey of various papers, there is a clear evident that the liquid cooling system with nanofluids and heat sink can be adopted for electronic cooling techniques. In real case phenomenon, the microprocessor needs various layers of substrates for implanting heat sink over them. This paper presents analysis of the modified model of the heat sink with the electronic chipset layers. At the same time, the use of nanofluids can enhance the heat transfer over and above that which is realise with water. This project envisages on analysing the heat transfer realise in such minichannel heat exchanger using different nanofluids. A CFD analysis would give a better prediction and hence adopted.

2. PROBLEM DOMAIN

Simulation is the imitation of the operation of a real world process or system over time. A computer simulation is an attempt to model a real life or hypothetical simulation on a computer so that it can be studied to see how the system works. By changing the variables in simulation, prediction may be made about the behavior of the system. It is a tool to virtually investigate the behaviour of the system under study. In this work the minichannel heat sink is selected for the simulation.

2.1 Outline model

A simple outline design of the chipset with minichannel heat sink is shown in figure 1. It also shows the problem domain of the project which has different layers of chipset along with the processor and the heat sink. There are two layers of thermal interface materials used for better thermal connection between layers, one between the processor and spreader while the other between the spreader and the heat sink. These layers are made of different materials according to their respective functions. The details and data regarding the layers are provided in the below sections.

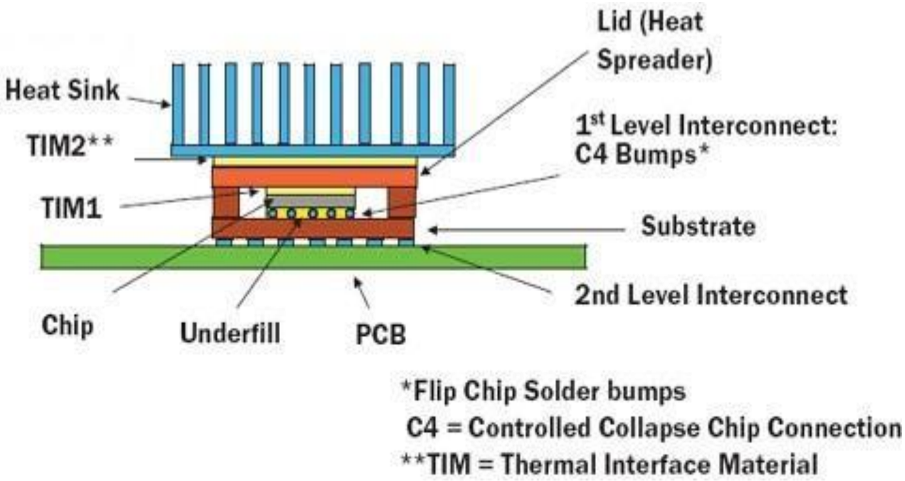


Fig. 1: Sketch for outline of chipset

2.2 Thermo physical properties

Various effective thermophysical properties like the thermal conductivity, the viscosity, the density and the specific heat were measured theoretically using different correlations.

Different models were used to calculate the properties of nanofluids theoretically for various volume concentrations.

1. Pak and Choa density relations,

$$\rho_{nf} = \rho_f (1 - \varphi) + \varphi \rho_p$$

Where,
ρ_{nf}: Density of Nanofluid,
ρ_f: Density of base fluid,
ρ_p: Density of the Nano particle, φ - volume concentration.

2. Hamilton and Crosser model for thermal conductivity,

$$\frac{k_{nf}}{k_f} = \frac{k_p + (SH-1)k_f - (SH-1)\varphi(k_f - k_p)}{k_p + (SH-1)k_f + \varphi(k_f - k_p)}$$

Where,
k_p: thermal conductivity of Nano particle,
k_f - thermal conductivity of base fluid,
k_{nf}: thermal conductivity of Nanofluid.

3. Specific heat model proposed by Xuan and Roetzel,

$$C_{p,nf} = \frac{(1-\varphi)\rho_f C_{p,f} + \varphi \rho_p C_{p,p}}{\rho_{nf}}$$

Where,
Cp_{nf}: specific heat of Nanofluid,
Cp_f: specific heat of base fluid,
Cp_p: specific heat of Nano particles.

4. The viscosity model proposed by Nguyen,

$$\mu_r = \frac{\mu_{nf}}{\mu_f} = (1 + 0.025\,\varphi + 0.015\,\varphi^2)$$

3. METHODOLOGY

3.1 Geometric modelling of the heat sink and chipset

A simple outline design of the chipset with minichannel heat sink is shown in fig2. The chipset has different layers namely PCB board, substrate, thermal interface material (TIM1 and TIM2), heat spreader and heat sink. A minichannel is used as a heat sink with dimension of 50×50 mm length and breadth respectively. Each channel is equally spaced (W_{fin}=W_{ch}=1mm) with height of 5mm. The dimensional features of every layer of chipset are taken from the processor data sheet. Each layer are designed as a separate part and assembled into a whole structure by using SOLIDWORKS 16. After the completion of design, it is successfully imported to ANSYS in .step file format as shown in the figure 2.

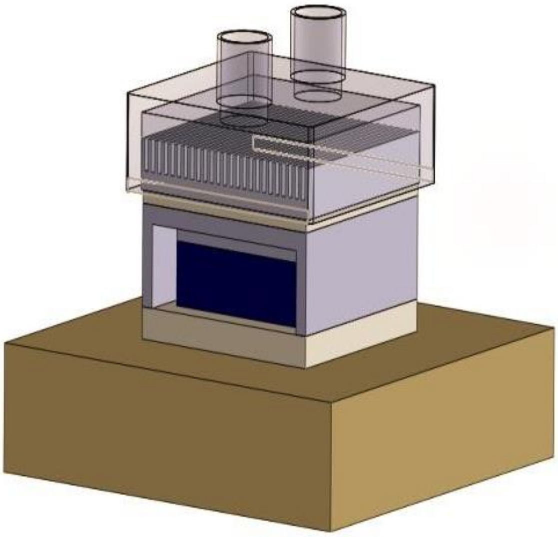


Fig. 2: Solid works design

Table 1: Geometric modeling of minichannel heat sink

Symbol	Description	Units
L	Length of the channel	50mm
H_{ch}	Height of the channel	5mm
W_{ch}	Channel width	1mm
W_w	Thickness of the fins	1mm
H_b	Thickness of heat sink base plate	3mm
D_h	Hydraulic diameter	1.667mm
N	Number of channels	25
N_{fin}	Number of fins	26

3.2 Meshing

Creating the most appropriate mesh is the foundation of engineering simulations. ANSYS meshing is automatically integrated with each solver in ANSYS workbench environment. The channels are selected and meshed in special with rectangular elements for better qualitative results. All the connections are given refinements for better linking between elements.

3.2.1 Grid independency test: Grid Independence is the term used to designate the enhancement of results by using successively smaller cell sizes for the calculations. A calculation should reach the correct result so the mesh becomes smaller; hence the term is known as Grid Independence. The grid independence test has been conducted at a mass flow rate of 0.01kg/s water flowing through the rectangular minichannel with TDP of 95W in ANSYS-FLUENT by decreasing and increasing the size of the elements. The gained results are tabulated in Table 3.4 for base temperature of heat sink.

Table 2: Grid results

No of elements	Nodes	Base Temperature(^{0}C)
83039	34156	44.51
125033	68436	43.91
214684	129440	43.80
377674	238012	43.75
508803	356479	43.72

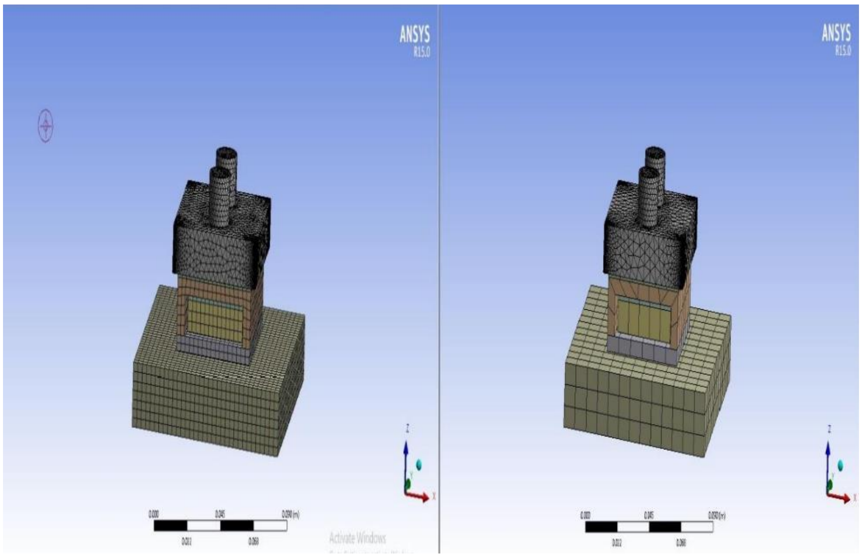


Fig 3: Different meshes based on various face sizes

3.2.2 Mesh adoption

After the generation of geometry, meshing has to be done for the whole domain in order to get accurately converged results. Before meshing, each surfaces and volume should be named. When the mesh generation is complete, you can transfer the mesh to the solution mode using the Mode tool bar or the command switch-to-solution mode. The remaining operations like setting the boundary conditions, defining the fluid properties, executing the solution and post processing the results are performed in solution mode. From the grid independency results, the below mesh model is adopted for simulation.

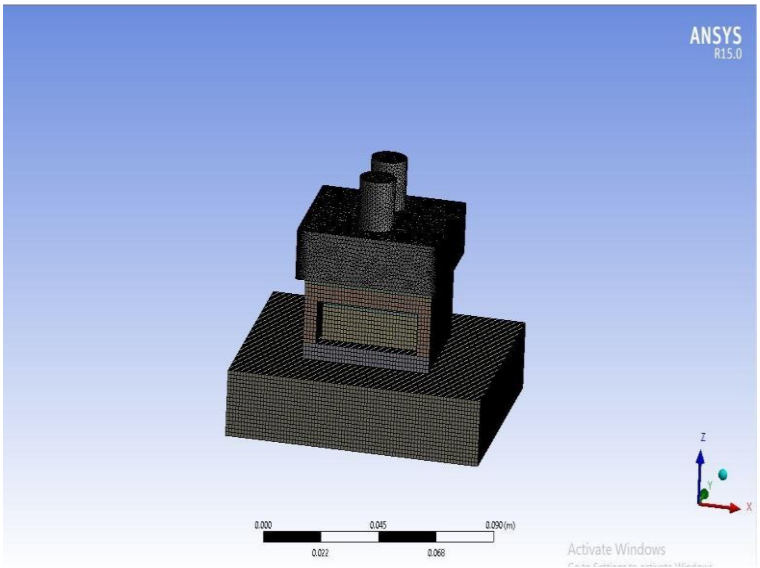


Fig. 4: Selected mesh contour

Nodes=238012	Min size= 0.005m	Face Size= 0.0012m
Elements=377674	Max size= 0.01m	Mesh= smooth

3.3 Solution setup

Every part of the chipset is assigned with its appropriate material from the engineering data sources. All the necessary named selections are provided to get the results at specified points or faces wherever required. The thermo physical properties calculated as given in previous section are added to the fluent database as separate fluidic materials as shown in the fig.5. The Thermal Design power (TDP) of 95W is given as source term to the processor in the cell zone conditions. The mesh interfaces are checked before leading to the simulation.

Table 3: Cell zone conditions

Domain	Assignment	Material
PCB board	Solid	FR4
Processor	Solid	Silicon
TIM1 & TIM2	Solid	HC gap pad 5.0
Spreader	Solid	Copper
Heat sink	Solid	Aluminium
Substrate	Solid	Gallium Arsenide

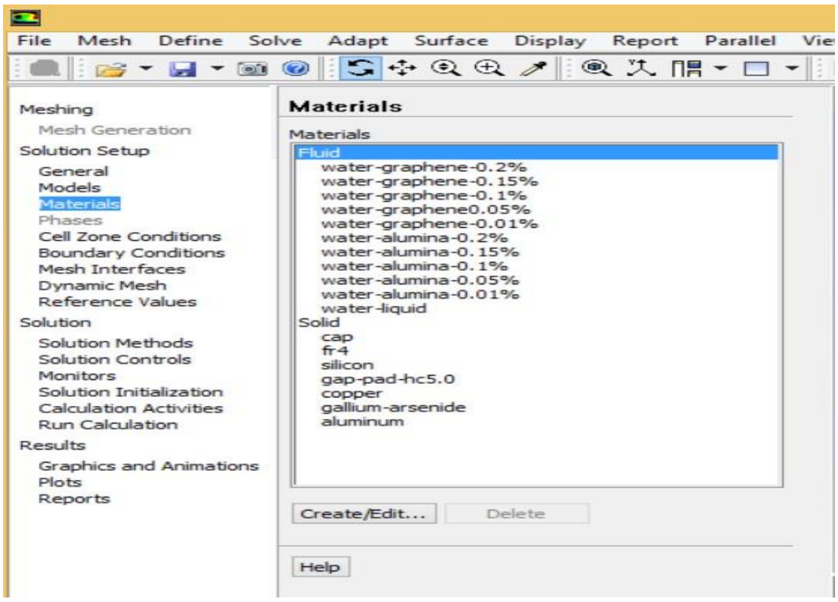


Fig. 5: Material selection and Assignment

3.4 Simulation

The boundary conditions are provided at the inlet for different iterations in the mass flow rate range of 0.01, 0.02, 0.03 and 0.04kg/s. After every iteration, the fluid inlet and outlet, processor and base temperatures are noted down for further analysis.

Table 4: Boundary conditions

Heat source	95W/150W
Mass flow rate at inlet	0.01…in a step of 0.01 upto 0.04kg/s
Initial gauge pressure	0
Fluid inlet temperature	308 K

4. RESULTS AND DICUSSIONS

The simulations were carried for different flow rates of the fluid through the channel. The result parameters namely fluid outlet temperature, processor wall temperature and base temperature are noted down for each case of the flow rates and for different concentrations of Nano particles. These parameters are further used for heat transfer analysis.

4.1 Processor temperature

The primary objective of the cooling system is to reduce the processor temperature to below 50ºC. The effect of graphene and alumina nanofluid is being compared with water in the varying range of Reynolds number as shown in the fig.

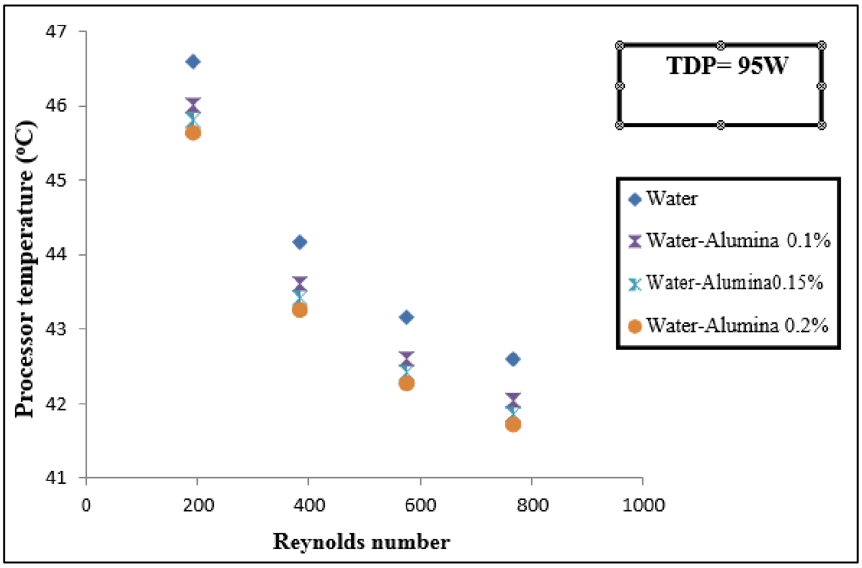


Fig. 6: Reynolds number vs. Processor Temperature Plot

From the figure 6, it is clear that with increase in nanoparticle concentration, the processor temperature reduces further. This is mainly due to the increase in the thermal conductivity of fluid and thermal absorptivity with the varying concentration. The alumina nanofluids provide better performance than the pure water.

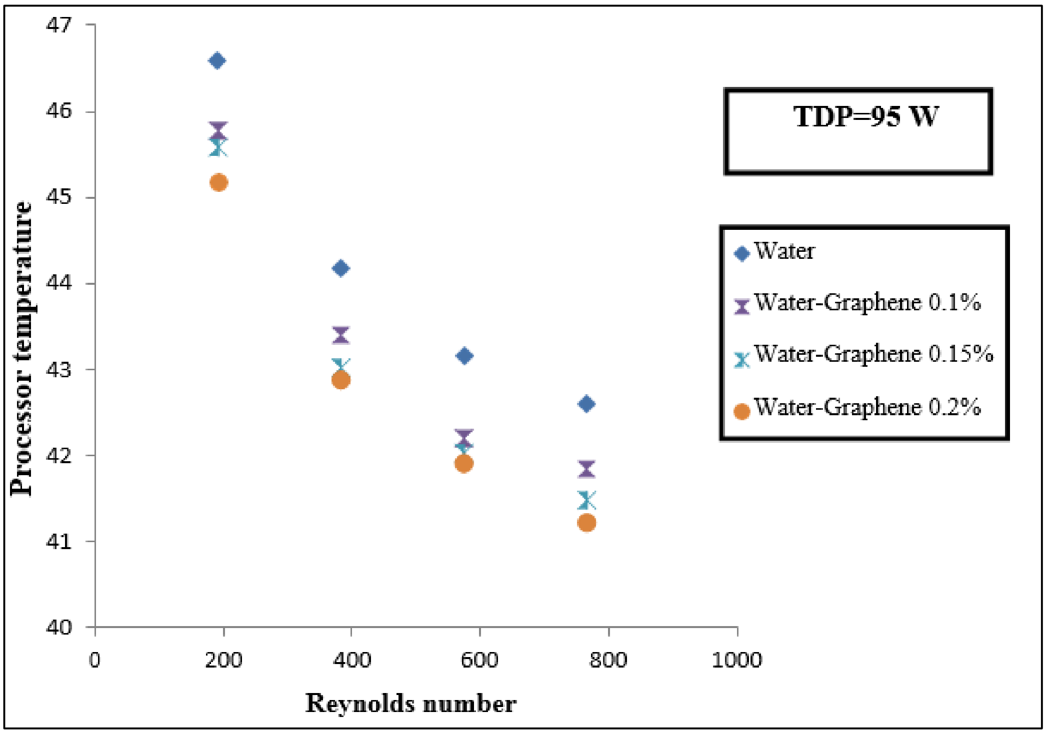


Fig. 7: Reynolds number vs. Processor Temperature Plot3

From the figures, it can be explained that the Graphene nanofluid absorbs more heat compared to the pure distilled water and alumina nanofluids. For TDP of 95W, the decrement in processor temperature while using graphene and alumina nanofluids is 3.22% and 2.04% respectively.

4.2 Heat transfer coefficient

The thermal performance of the fluid is based on its heat transfer coefficient. The h value depends on three temperatures namely average base, fluid inlet and fluid outlet temperatures and the heat carried away by the cooling fluid. Figure 8 reveals that alumina nanofluids have higher heat transfer coefficient than pure water. Also the increase in particle concentration gave higher coefficient values which indicate better performances.

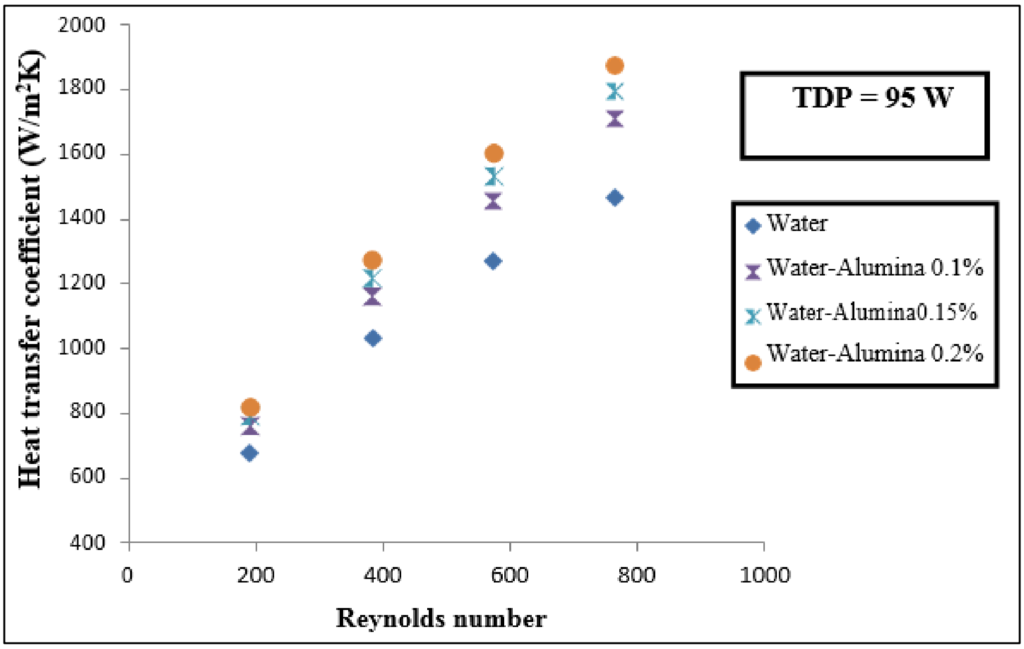


Fig. 8: Reynolds number Vs. Heat Transfer Coefficient Plot

Figure 8 emphasizes that there is an effective enhancement of the heat transfer coefficient in the increasing range of Reynolds number and also with increasing of the volume fraction of 0.1 and 0.2%. The higher thermo physical property of the nanofluid over the deionized water is the main reason for enhancing the convective performance of the nanofluid.

For 95W, at the highest volume fraction alumina nanofluid gave around 27.70% higher value of convective heat transfer coefficient with comparison to the deionized water. The graphene nanofluid gave around 36.08% higher value of convective heat transfer coefficient with comparison to the deionized water.

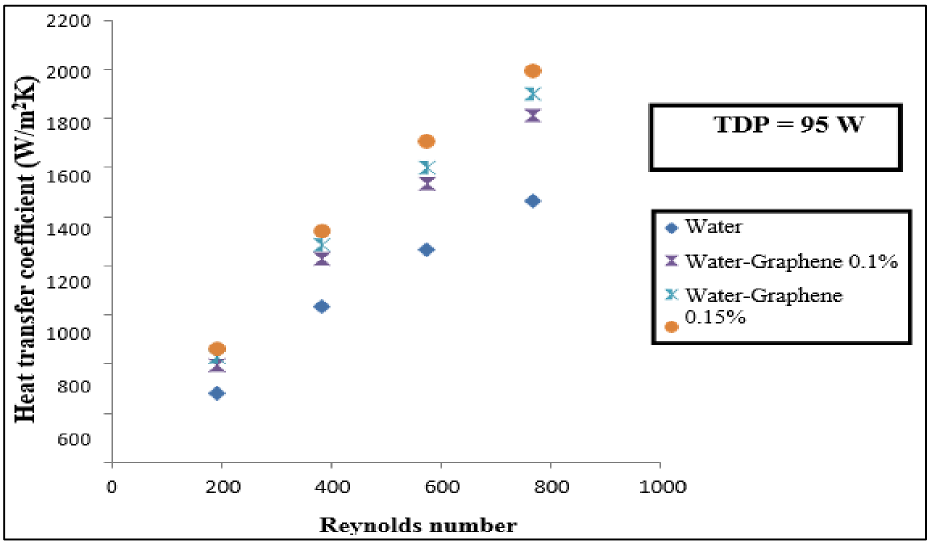


Fig. 9: Reynolds number Vs. Heat Transfer Coefficient Plot

4.3 Thermal resistance

Figure 10 shows that with increase in the flow rate, the thermal resistance decreases. Also it is evident that by using nanofluids instead of water, the system has lower thermal resistance. The increase in enhancement of heat transfer coefficient is the main reason for lowering the thermal resistance. The increase in volume concentration also shows a diminishing trend in the thermal resistance.

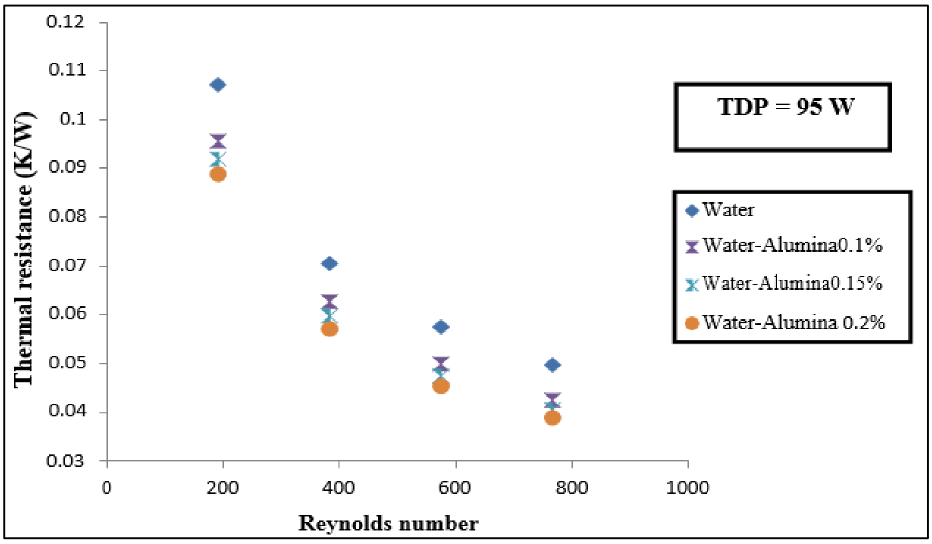


Fig.10: Reynolds number Vs. Thermal resistance Plot

For 95W, at the highest volume fraction of alumina nanofluid gave a decrement of 21.69 % in convective thermal resistance with the comparison to the deionized water. The graphene nanofluid gave around a decrement of 26.52%.

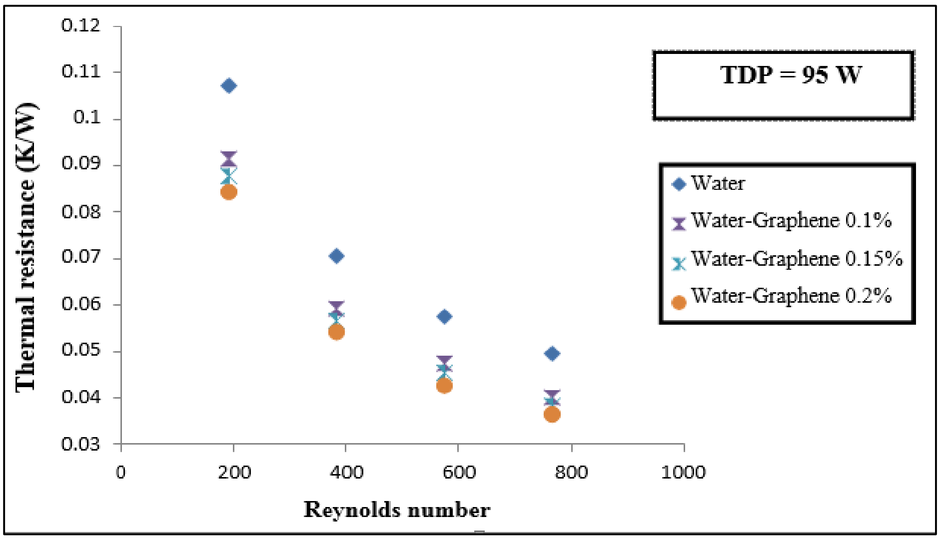
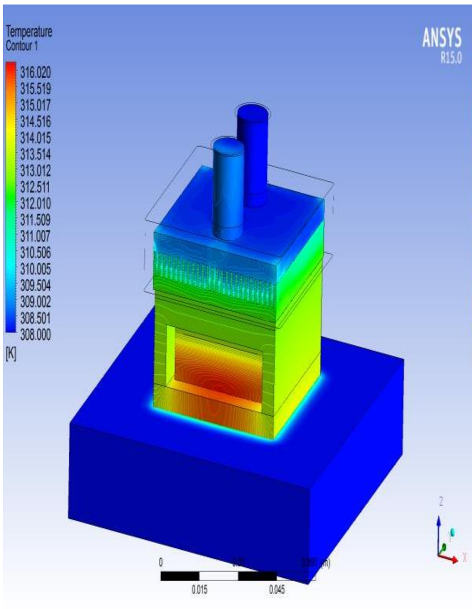
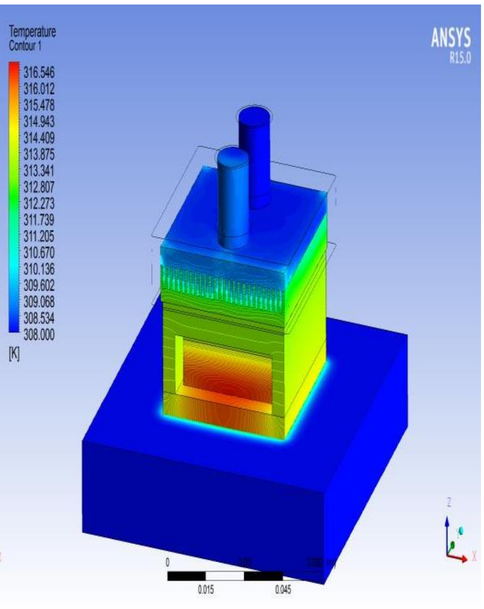
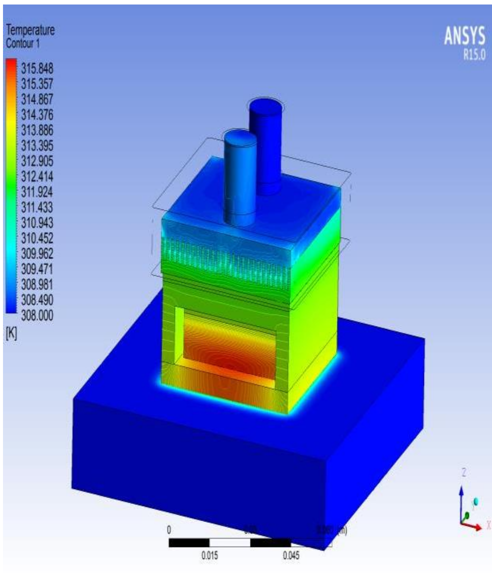


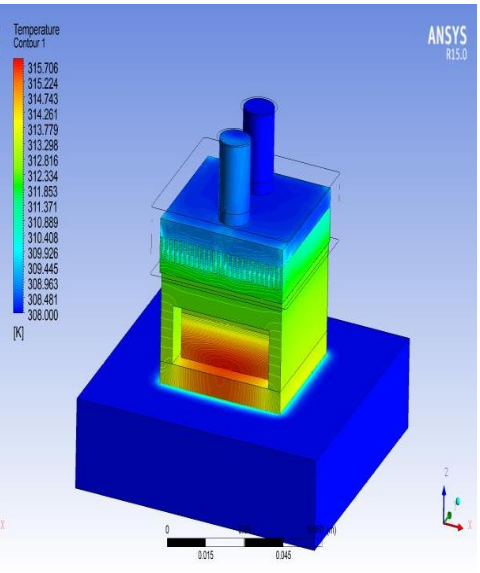
Fig. 11: Reynolds number Vs. Thermal resistance Plot





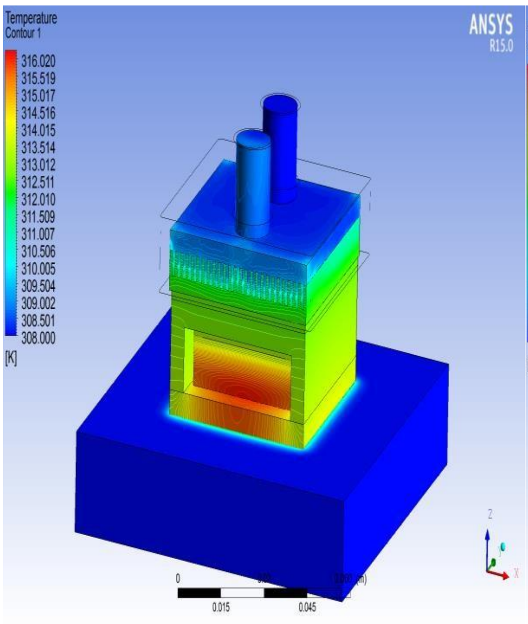
(a) **(b)**

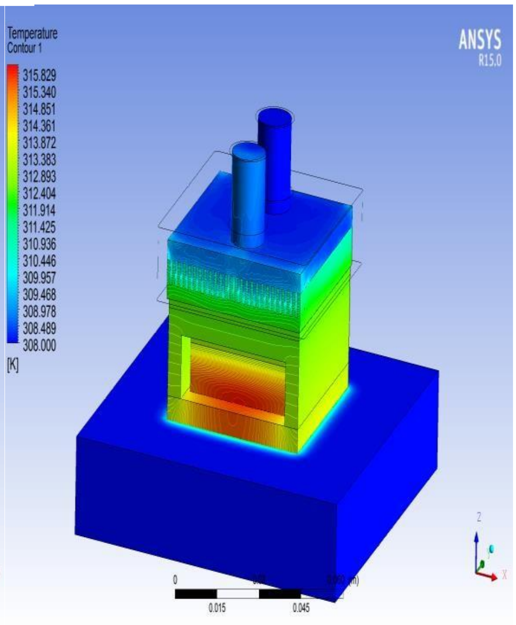




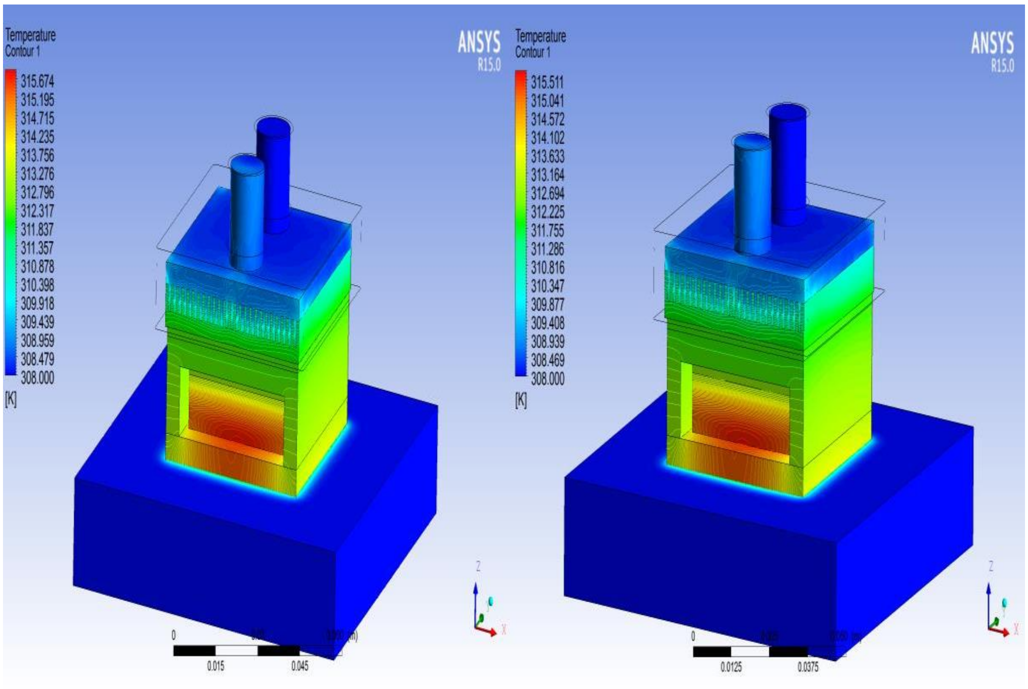
(c) **(d)**

Fig. 12: Temperature profiles of processor chipset for various fluids at 0.04kg/s for TDP of 95W, (a) Water, (b) Water- Alumina 0.1%, (c) Water- Alumina 0.15%, (d) Water- Alumina 0.2%





(a) **(b)**



(c) (d)

Fig. 13: Temperature profiles of processor chipset for various fluids at 0.04kg/s for TDP of 95W, (a) Water (b) Water- Graphene 0.1%, (c) Water- Graphene 0.15%, (d) Water- Graphene 0.2%

5. CONCLUSIONS

From the results it is clear that the processor temperature is decreased up to 8°C lower than maximum allowable temperature by using aluminium minichannel heat sink with Alumina and Graphene nanofluids flowing through it. The inclusion of nanoparticles enhances the thermo physical properties of the base fluid to some extent.

A better performance is obtained using Graphene and Alumina nanofluids, it successfully attained to minimize and hold the wall temperature of the processor at a constant level. For TDP of 95W, the decrement in processor temperature while using Graphene and Alumina nanofluids is 3.22% and 2.04% respectively.

At the highest volume fraction alumina nanofluid gave around 27.70% higher value of convective heat transfer coefficient with comparison to the deionized water. The Graphene nanofluid gave around 36.08% higher value of convective heat transfer coefficient with comparison to the deionized water.

The convective thermal resistance is also minimized in a significant manner, at the highest volume fraction of Alumina nanofluid gave a decrement of 21.69% in convective thermal resistance with the comparison to the deionized water. The Graphene nanofluid gave around a decrement of 26.52%.

6. REFERENCES

[1] Bui Hung Thang, Pham Van Trinh, Le Dinh Quang (2014) 'Heat Dissipation for the Intel Core i5 Processor Using Multiwalled Carbon-nanotube-based Ethylene Glycol', Journal of the Korean Physical Society, Vol. 65, pp. 312-316.
[2] Godson.L, Raja.B, Mohan Lal.D, Wongwises (2010) 'Enhancement of heat transfer using nanofluids – an overview', Renew. Sustain. Energy Rev, pp.629–641.
[3] Kays A. Al-Tae'y, Eqbal Hussain Ali, Manal Naser Jebur (2017) 'Experimental Investigation of Water Cooled Minichannel Heat Sink for Computer Processing Unit Cooling', Int. Journal of Engineering Research and Application, Vol. 7, Issue 8, (Part-1), pp. 38-49.
[4] Nguyen C.T, Roy.G, Gauthier.C, Galanis.N (2007), 'Heat transfer enhancement using Al_2O_3–water nanofluid for an electronic liquid cooling system', pp. 1501–1506.
[5] Prasad Mangalkar, Dr. V.M.Kriplani (2017), 'A Review on Heat Transfer Enhancement using Nanofluid for Cooling of Electronic Components', International Journal of Engineering Science and Computing, pp.1201-1205.
[6] Roberts.N.A, Walker.D.G (2010), 'Convective performance of nanofluids in commercial electronics cooling systems', Appl. Therm. Eng, vol.30, pp. 2499– 2504.
[7] Selvam.C , Balaji.T , Mohan Lal.D , Sivasankaran Harish (2017), 'Convective heat transfer coefficient and pressure drop of water-ethylene glycol mixture with graphene nanoplatelets', Experimental Thermal and Fluid Science, vol.80 , pp. 67–76.
[8] Shekhar D. Thakre, V. B. Swami, Prateek D. Malwe (2014), 'Cooling System of Electronic Devices using Microchannel Heat Sink', International Journal of Thermal Technologies, Vol.4, pp.1201-1206.
[9] Sohel.M.R, Khaleduzzaman.S.S, Saidur.R , Hepbasli.A , Sabri.M.F.M, Mahbubul.I.M (2014), 'An experimental investigation of heat transfer enhancement of a minichannel heat sink using Al_2O_3-H_2O nanofluid', pp. 164-172.
[10] Sohel.M.R, Saidur.R, Sabri.M.F.M, Kamalisarvestani.M, Elias.M.M, Ijam.A (2013), 'Investigating the heat transfer performance and thermo physical properties of nanofluids in a circular micro-channel', Int. Commun. Heat Mass Transfer, vol. 42, pp.75–81.

[11] Sudheer kumar Reddy.R, Dr .k. Govinda Rajulu , Dr. S.M. Jameel Basha , E. Vijay Gowd , P. Veera Prathap, C.N. Vishnu Vandhan.A (2017), 'Thermal Analysis of Pin Fin with Different Shape Forms using ANSYS', International Journal of Engineering Science and Computing, pp.94-99.
[12] Twinkal M bhavsar, Manish maisuria (2014), 'Flow and heat transfer simulation in mini channel', International journal of Mechanical Engineering and Robotics research, vol.3, pp.56-59.