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Computational and Thermal Analysis For Finding Heat Transfer Through An Annular Bend Tube For Various Nano Fluids

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Abstract - Heat transfer by convection is extremely necessary for several industrial heating and cooling applications. The warmth convection will passively be increased by dynamic flow pure mathematics, boundary conditions or by enhancing fluid thermo physical properties. A mixture of nano-sized particles in an exceedingly base fluid, referred to as nanofluids, staggeringly enhances the warmth transfer characteristics of the first fluid, and is ideally fitted to sensible applications as a result of its marvelous characteristics.In this project, totally different nano fluids are analyzed for his or her thermal behavior passing through associate ringed bend tube with turbulence flow. The nano fluids thought of during this project area unit nanofluids made up of base fluid water, tri-cloroethylene gycols, copper nano fluid, atomic number 13 nano fluid and carbide nanofluid. Thermal and CFD analysis is performed to work out the thermal behavior victimization finite component analysis package Ansys. 3D modeling is finished in Pro/Engineer.

I. INTRODUCTION

In the simplest of terms, the discipline of heat transfer is concerned with only two things: temperature, and the flow of heat. Temperature represents the amount of thermal energy available, whereas heat flow represents the movement of thermal energy from place to place. On a microscopic scale, thermal energy is related to the kinetic energy of molecules [1]. The greater a material's temperature, the greater the thermal agitation of its constituent molecules (manifested both in linear motion and vibrational modes). It is natural for regions containing greater molecular kinetic energy to pass this energy to regions with less kinetic energy. Several material properties serve to modulate the heat transferred between two regions at differing temperatures. Examples include thermal conductivities, specific heats, material densities, fluid velocities, fluid viscosities, surface emissivity, and more. Taken together, these properties serve to make the solution of many heat transfer problems an involved process. Heat transfer is categorized into three broad classes known as conduction, convection and radiation.

1.1 CONCEPT OF NANO FLUIDS

ZigBee Nanofluids are fluids containing nanoparticles (nanometer-sized particles of metals, oxides, carbides, nitrides, or nanotubes). Nanofluids exhibit enhanced thermal properties, amongst them; higher thermal conductivity and heat transfer coefficients compared to the base fluid. Simulations of the cooling system of a large truck engine indicate that replacement of the conventional engine coolant (ethylene glycol-water mixture) by a nanofluid would provide considerable benefits by removing more heat from the engine [7-10]. Additionally, a calculation has shown that a graphite based nanofluid developed jointly by Argonne and Valvoline could be used to eliminate one heat exchanger for cooling power electronics in a hybrid electric vehicle. This would obviously reduce weight, and allow the power electronics to operate more efficiently. The benefits for transportation would be Radiator size reduction, Pump size, Possible of elimination of one heat exchanger for hybrid-electric vehicles and Increased fuel efficiency. Using silicon carbide nanoparticles from partner Saint Gobain, the team has created an ethylene glycol/water fluid with silicon carbide nanoparticles that carries heat away 15 percent more effectively than conventional fluids. And working with industrial partner Valvoline, they've developed a graphite-based nanofluid that has an enhanced thermal conductivity of 50 percent greater than the base fluid, which would, under specific conditions, eliminate the need for a second heat exchanger for cooling power electronics. Nanofluids are dilute liquid suspensions of nanoparticles with at least one of their principal dimensions smaller than 100 nm. From previous investigations, nanofluids have been found to possess enhanced thermophysical properties such as thermal conductivity, thermal diffusivity, viscosity and convective heat transfer coefficients compared to those of base fluids like oil or water. From the current review, it can be seen that nanofluids clearly exhibit enhanced thermal conductivity, which goes up with increasing volumetric fraction of nanoparticles. The current review does concentrate on this relatively new class of fluids and not on colloids which are nanofluids because the latter have been used for a long time. Review of experimental studies clearly showed a lack of consistency in the reported results of different research groups regarding thermal properties. The effects of several important factors such as particle size and shapes, clustering of particles, temperature of the fluid, and dissociation of surfactant on the effective thermal conductivity of nanofluids have not been studied adequately. It is important to do more research so as to ascertain the effects of these factors on the thermal conductivity of wide range of nanofluids. Classical models cannot be used to explain adequately the observed enhanced thermal conductivity of nanofluids.

Recently most developed models only include one or two postulated mechanisms of nanofluids heat transfer. For instance, there has not been much fundamental work reported on the determination of the effective thermal diffusivity of nanofluids nor heat transfer coefficients for nanofluids in natural convection. There is a growth is the use of colloids which are nanofluids in the biomedical industry for sensing and imaging purposes. This is directly related to the ability to design novel materials at the nanoscale level alongside recent innovations in analytical and imaging technologies for measuring and manipulating nanomaterials. This has led to the fast development of commercial applications which use a wide variety of manufactured nanoparticles. The production, use and disposal of manufactured nanoparticles will lead to discharges to air, soils and water systems. Negative effects are likely and quantification and minimization of these effects on environmental health is necessary. True knowledge of concentration and physicochemical properties of manufactured nanoparticles under realistic conditions is important to predicting their fate, behavior and toxicity in the natural aquatic environment. The aquatic colloid and atmospheric ultrafine particle literature both offer evidence as to the likely behavior and impacts of manufactured nanoparticles, and there is no pretense that a review duplicating similar literature about the use of colloids which are also nanofluids is attempted in the current review. Owing to their enhanced properties as thermal transfer fluids for instance, nanofluids can be used in a plethora of engineering applications ranging from use in the automotive industry to the medical arena to use in power plant cooling systems as well as computers.

II. INTRODUCTION TO COMPUTATIONAL FLUID DYNAMICS

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial experimental validation of such software is performed using a wind tunnel with the final validation coming in full-scale testing, e.g. flight tests.

2.1 Methodology

In all of these approaches the same basic procedure is followed.

- During preprocessing
- The geometry (physical bounds) of the problem is defined.
- The volume occupied by the fluid is divided into discrete cells (the mesh). The mesh may be uniform or non-uniform.
- The physical modeling is defined – for example, the equations of motion + enthalpy + radiation + species conservation
- Boundary conditions are defined. This involves specifying the fluid behavior and properties at the boundaries of the problem. For transient problems, the initial conditions are also defined.
- The simulation is started and the equations are solved iteratively as a steady-state or transient.

Finally a postprocessor is used for the analysis and visualization of the resulting solution.

III. CALCULATION OF PROPERTIES FOR NANO FLUIDS

Density of Nano Fluid

$\rho_{nf} = \text{Ø}\rho_s + (1-\text{Ø})\,\rho_w$

Specific Heat

$c_{pnf} = \text{Ø}(\rho_s c_{ps}) + (1-\text{Ø})\,\rho_w c_{pw}$

Viscocity

$\mu_{nf} = \mu_w\,(1+2.5\,\text{Ø})$

Ø = volume fraction = 0.03

μ_w = water specific heat = 4.186 KJ/kgK

μ_w = water viscosity = 0.894 kg/m-s

3.1 Aluminum Nano Fluid

ρ_s= nano fluid density = 3890 kg/m^3

ρ_w = water density = 1000 kg/m^3

c_{ps}= nano fluid specific heat = 1.05 KJ/kgK

c_{pw} = water specific heat = 4.186 KJ/kgK

Density of Nano Fluid

@ Ø = 0.03

$$\rho_{nf} = \text{Ø}\rho_s + (1-\text{Ø})\,\rho_w$$
$$= (0.03\times3890) + (1-0.03)\times1000$$
$$= 1083.7 \text{ kg/m}^3$$

Specific Heat

@ Ø = 0.03

$c_{pnf} = \varnothing(\rho_s c_{ps}) + (1-\varnothing)\rho_w c_{pw}$

= (0.03×3890×1.05) + (1-0.03)(1000×4.186) = 4182..95 J/kg K

Viscocity

$\mu_{nf} = \mu_w (1+2.5\,\varnothing)$

@ Ø = 0.03

= 0.894(1+2.5×0.03) = 0.0961 kg/m-s

3.2 Silicon Nanofluid

ρ_s = nano fluid density = 2316 kg/m^3

c_{ps} = nano fluid specific heat = 0.0021 KJ/kgK

Density of Nano Fluid

@ Ø = 0.03

$\rho_{nf} = \varnothing\rho_s + (1-\varnothing)\rho_w$

= (0.03×2316) + (1- 0.03)×1000

= 1039.7 kg/m^3

Specific Heat

@ Ø = 0.03

$c_{pnf} = \varnothing(\rho_s c_{ps}) + (1-\varnothing)\rho_w c_{pw}$

= (0.03×2316×0.0021) + (1-0.03)(1000×4.186) = 4060.42 J/kg K

Viscocity

$\mu_{nf} = \mu_w (1+2.5\,\varnothing)$

@ Ø = 0.03

= 0.894(1+2.5×0.03) = 0.0961 kg/m-s

3.3 Tri Ethylene Glycol

ρ_s = nano fluid density =1111 kg/m^3

c_{ps} = nano fluid specific heat = 8.96 KJ/kgK

Density of Nano Fluid

@ Ø = 0.03

$\rho_{nf} = \varnothing\rho_s + (1-\varnothing)\rho_w$

= (0.03×1111) + (1-0.03)×1000

= 1003.830 kg/m^3

Specific Heat

@ Ø = 0.03

$c_{pnf} = \varnothing(\rho_s c_{ps}) + (1-\varnothing)\rho_w c_{pw}$

= (0.03×1111×8.96) + (1-0.03) (1000×4.186) = 4060.7186 J/kg K

Viscosity

$\mu_{nf} = \mu_w (1+2.5\,\varnothing)$

@ Ø = 0.03

= 0.0961 kg/m-s

3.4 Copper Oxide

ρ_s = nano fluid density = 8933 kg/m^3

c_{ps} = nano fluid specific heat =0.385 KJ/kgK

Density of Nano Fluid

@ Ø = 0.03

$\rho_{nf} = \varnothing\rho_s + (1-\varnothing)\rho_w$

= (0.03×8933) + (1-0.03)×1000

= 1061.21 kg/m^3

Specific Heat

@ Ø = 0.03

$c_{pnf} = \varnothing(\rho_s c_{ps}) + (1-\varnothing)\rho_w c_{pw}$

= (0.03×0.385×89331) + (1-0.03)(1000×4.186) = 4411.8865 J/kg K

Viscocity

$\mu_{nf} = \mu_w (1+2.5\,\varnothing)$

@ Ø = 0.03

= 0.894(1+2.5×0.03) = 0.0961

Thermal conductivity

$$k_{nf} = \left(\frac{k_s + 2k_w + 2(k_s - k_w)(1+\beta)^3\varnothing}{k_s + 2k_w - (k_s - k_w)(1+\beta)^3\varnothing}\right)k_w$$

Ks = thermal; conductivity of nano partical (w/mk) = 25

Kw = thermal conductivity of water (w/mk) = 0.563

B=0.1

@ Ø=0.03

Aluminum nanofluid

$= \left(\frac{25+2(0.563)+2(25-0.563)(1+0.1)3*0.03}{25+2(0.563)-(25-0.563)(1+0.1)3*0.03}\right)0.563 = 0.6285$ (w/mk)

Silicon

$= \left(\frac{120+2(0.563)+2(120-0.563)(1+0.1)3*0.03}{120+2(0.563)-(120-0.563)(1+0.1)3*0.03}\right)0.563 = 0.7021$ (w/mk)

Tri Ethylene Glycol

$= \left(\frac{0.0163+2(0.563)+2(0.0163-0.563)(1+0.1)3*0.03}{0.0163+2(0.563)-(0.0163-0.563)(1+0.1)3*0.03}\right)0.563 =$ 0.5261 (w/mk)

Copper

$= \left(\frac{0.385+2(0.563)+2(0.385-0.563)(1+0.1)3*0.03}{0.385+2(0.563)-(0.385-0.563)(1+0.1)3*0.03}\right)0.563 =$ (w/mk)

IV. RESULTS

The results pertaining to the proposed model are presented in this section. The proposed model is divided into two sections A and B. In section A the CFD and Thermal analysis of the 3D model of the annular tube without contact and in section B with contact are presented here.

A. Without Contact

The proposed model is as shown in the fig.1. The mesh model, inlet and outlet are given in the fig.2, 3 and fig.4.

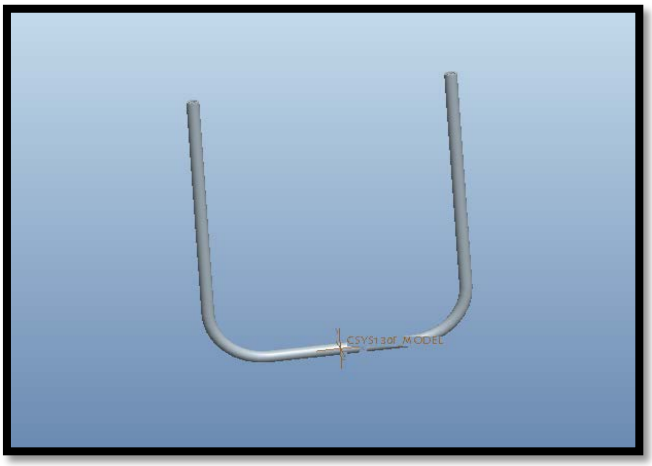

Fig.1. 3D model of the proposed geometry.

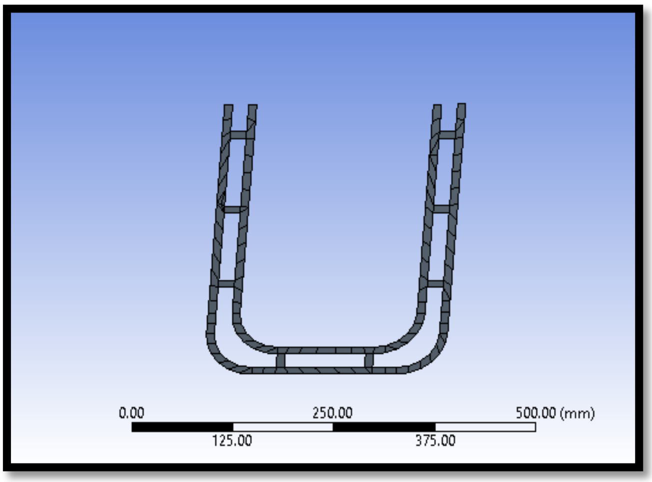

Fig: 2 Meshed Model

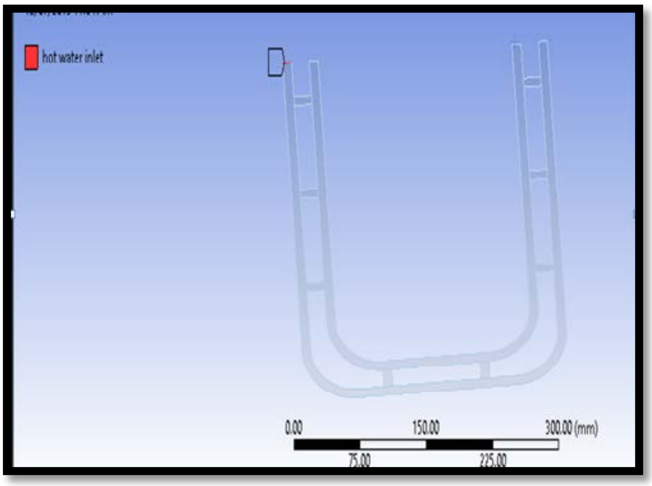

Fig: 3 Hot water inlet

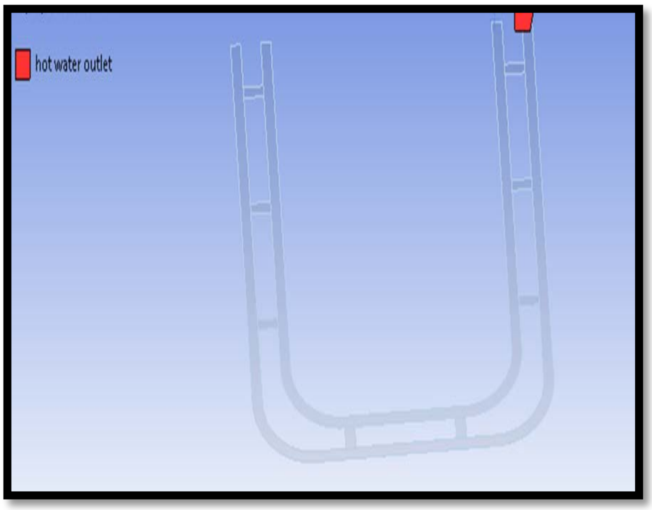

Fig: 4 Hot water outlet

B. With Contact

The proposed model is as shown in the fig.5. The mesh model and graphs are given in the fig.6 and fig.7 to 8.

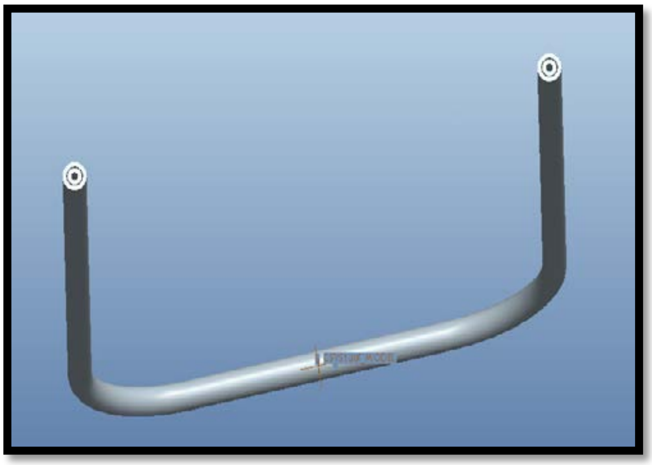

Fig.5 3D model of the proposed geometry.

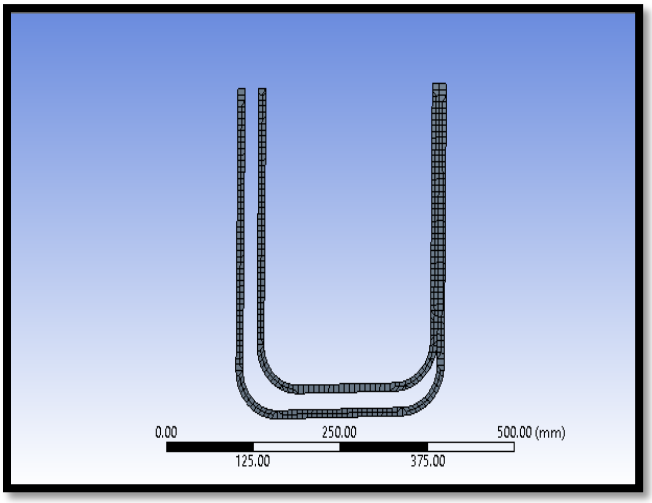

Fig: 6 Meshed Model

CFD Analysis Results

Table 1 Without Contact

	Pressure(Pa)	Temperature(K)	Heat transfer coefficient (w/m^2k)	Heat transfer Rate(w)
Aluminium nanofluid	1.73e+04	3.82e+02	7.81e+02	28.25
Copper nano fluid	1.50e+04	3.82e+02	9.12e+02	18.10
Silicon carbide	1.68e+04	3.82e+02	6.75e+02	9.25
Tri-cloroethylene glycol	1.62e+04	3.82e+02	8.23e+02	39.78

Graphs

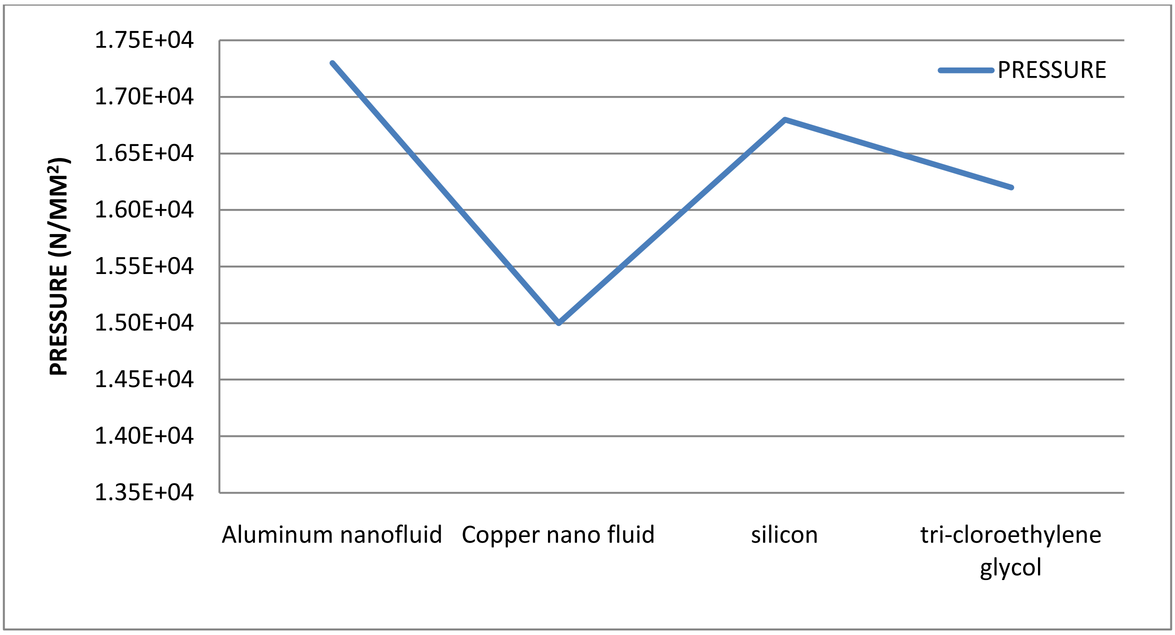

Fig: 7 Pressure

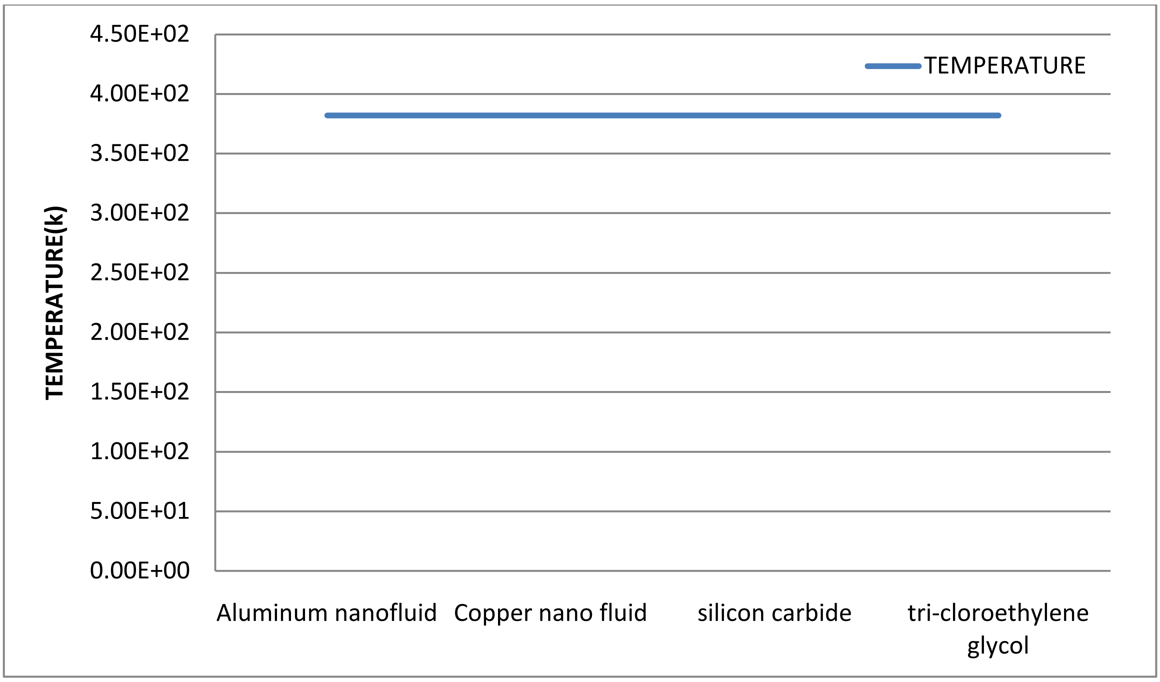

Fig: 8 Temperature

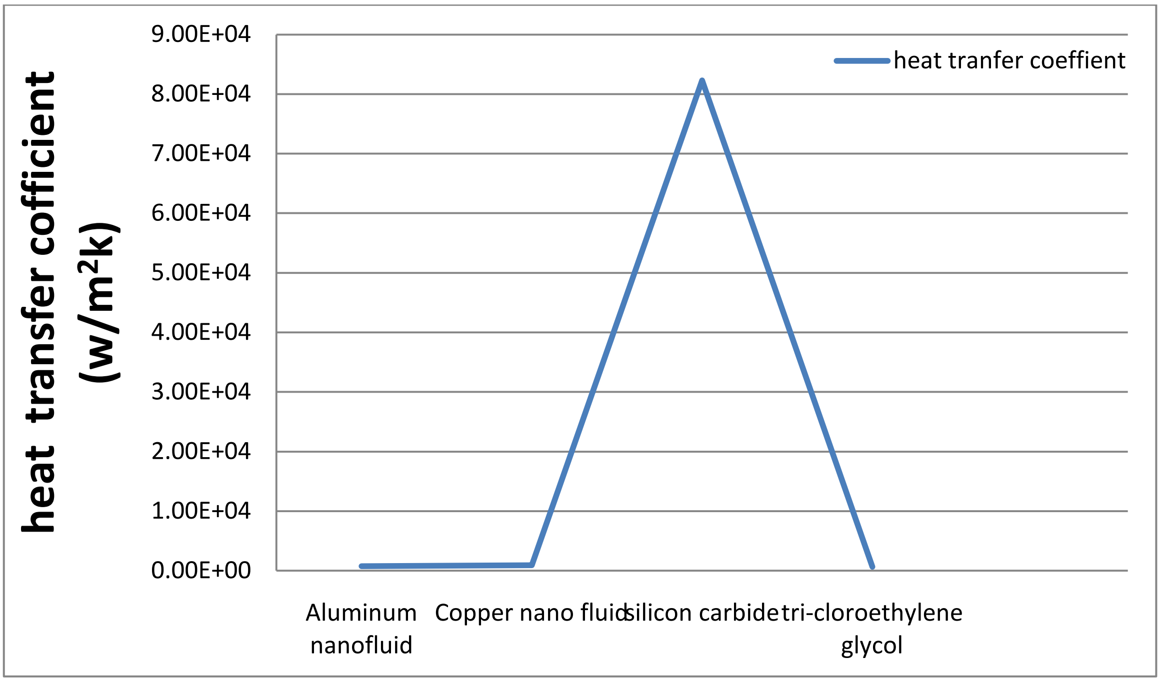

Fig:9 Heat Transfer Coefficient

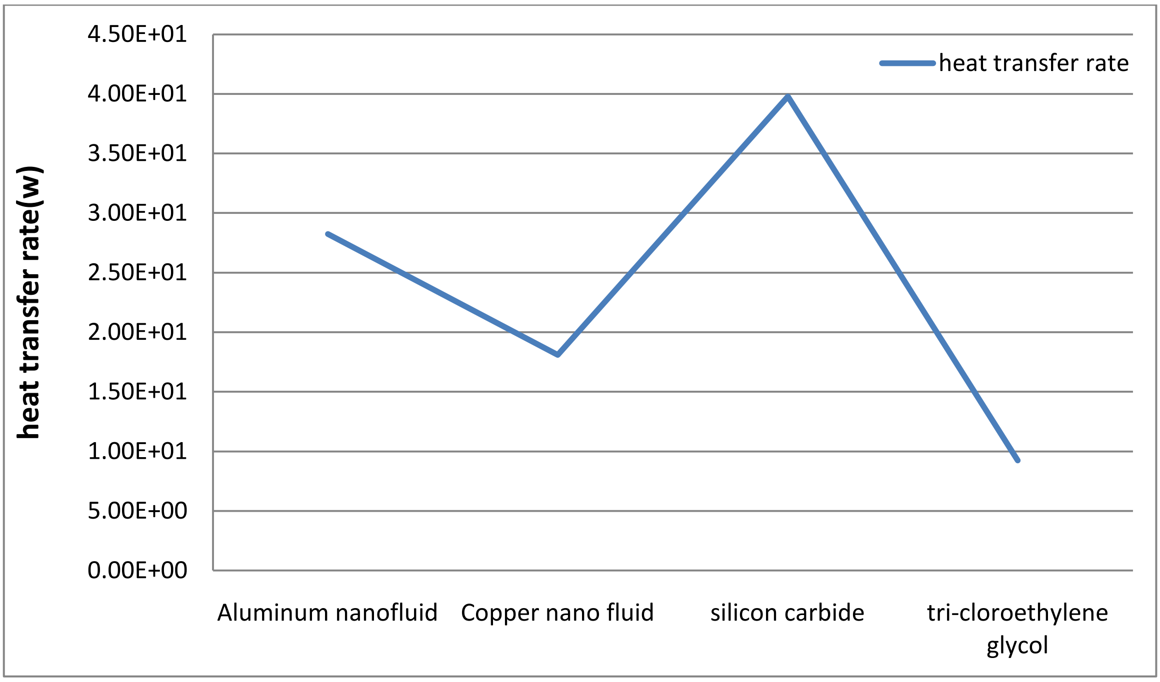

Fig: 10 Heat Transfer Rate

Table 2 With Contact

	Pressure(Pa)	Temperature(K)	Heat transfer coefficient (W/m^2K)	Heat transfer Rate(W)
Aluminum nanofluid	2.00e+04	3.82e+02	1.22e+03	344
Copper nano fluid	1.53e+04	3.82e+02	1.45e+03	308
Silicon carbide	1.97e+04	3.82e+02	1.05e+03	289.75
Tri-cloroethylene glycol	1.87e+04	3.82e+02	1.28e+03	367.5

Graphs

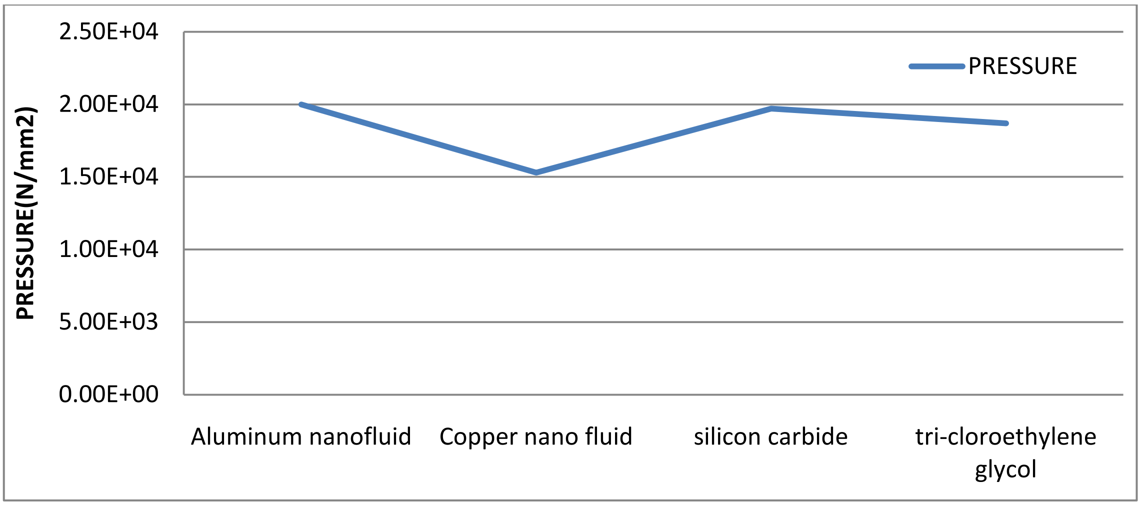

Fig: 11 Pressure

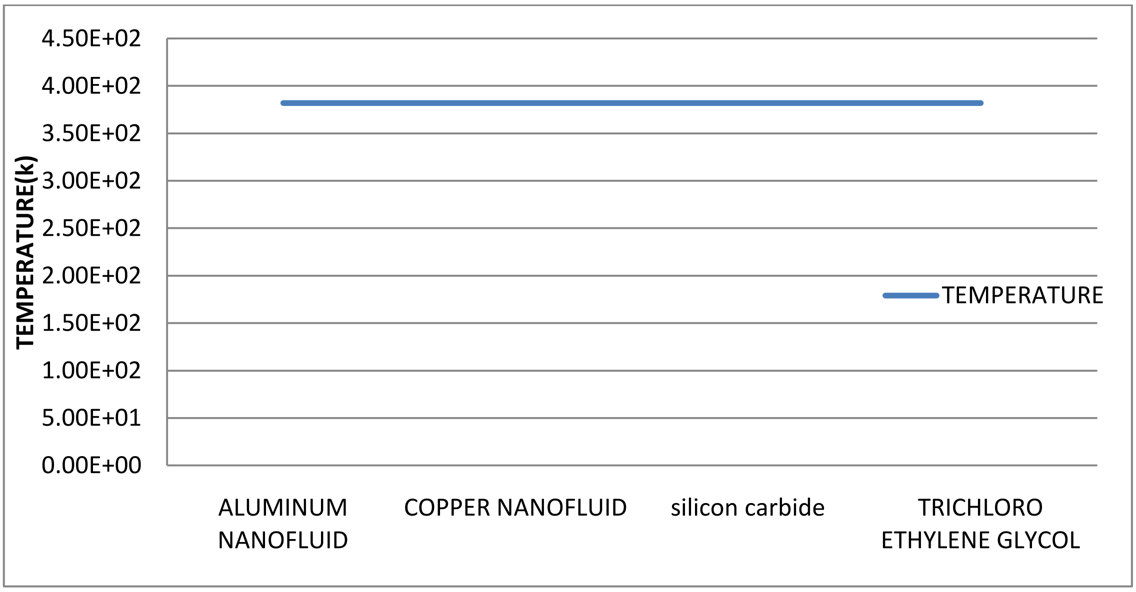

Fig: 12 Temperature

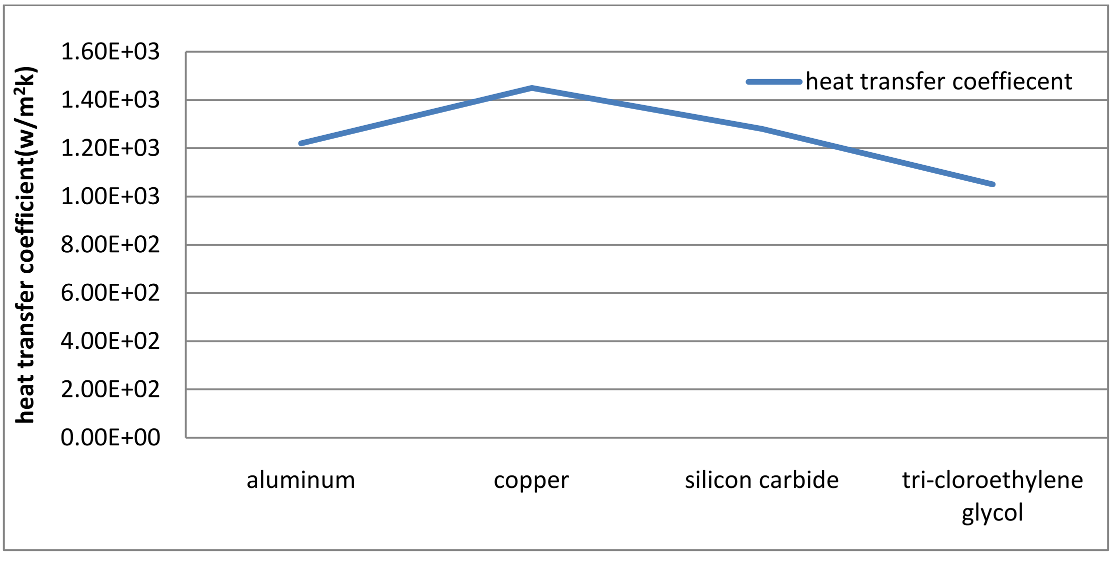

Fig: 13 Heat Transfer Coefficient

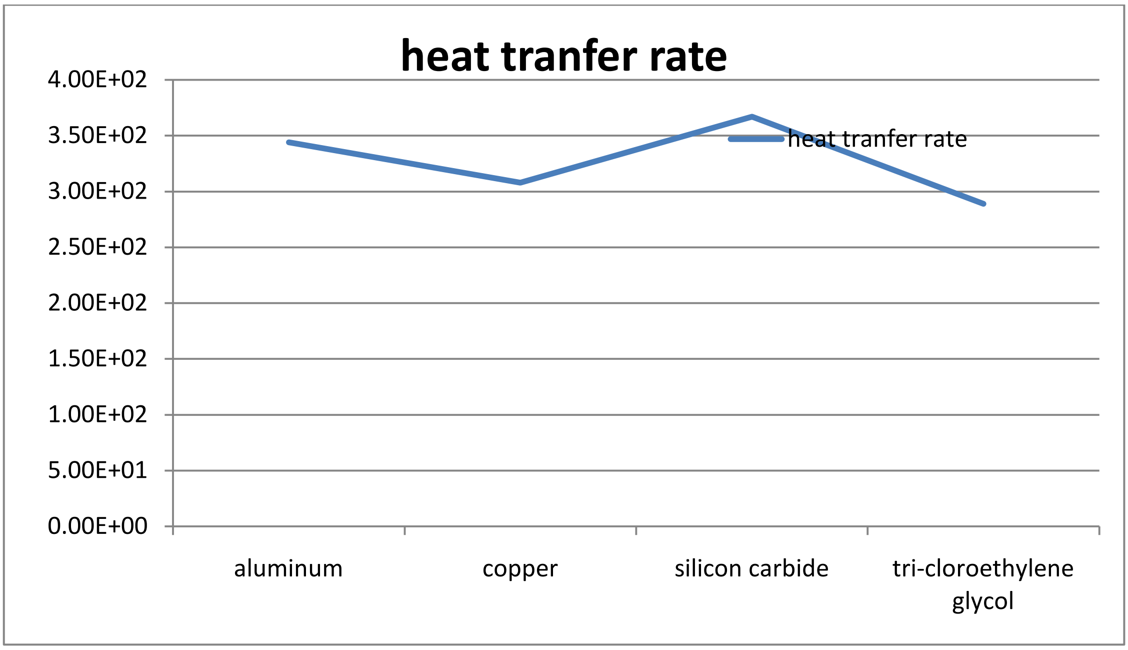

Fig: 14 Heat Transfer Rate

Thermal Analysis

Table 3 Without Contact

	Nodal Temperature (K)	Thermal Gradient (K/Mm)	Thermal Flux (W/Mm^2)
Aluminum Nanofluid	353	92.0705	16.5727
Copper Nanofluid	353	6.036135	1.08658
Silicon Carbide	353	132	25.246
Trichloro Ethylene Glycol	353	8.01495	1.422269

GRAPHS

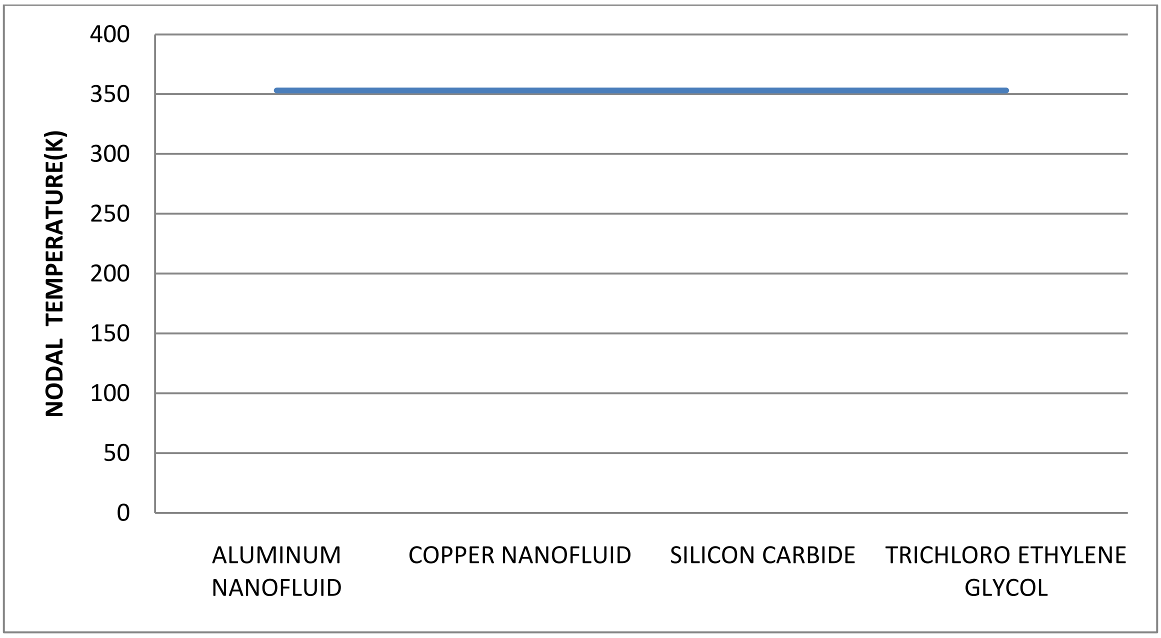

Fig: 15 Nodal Temperature

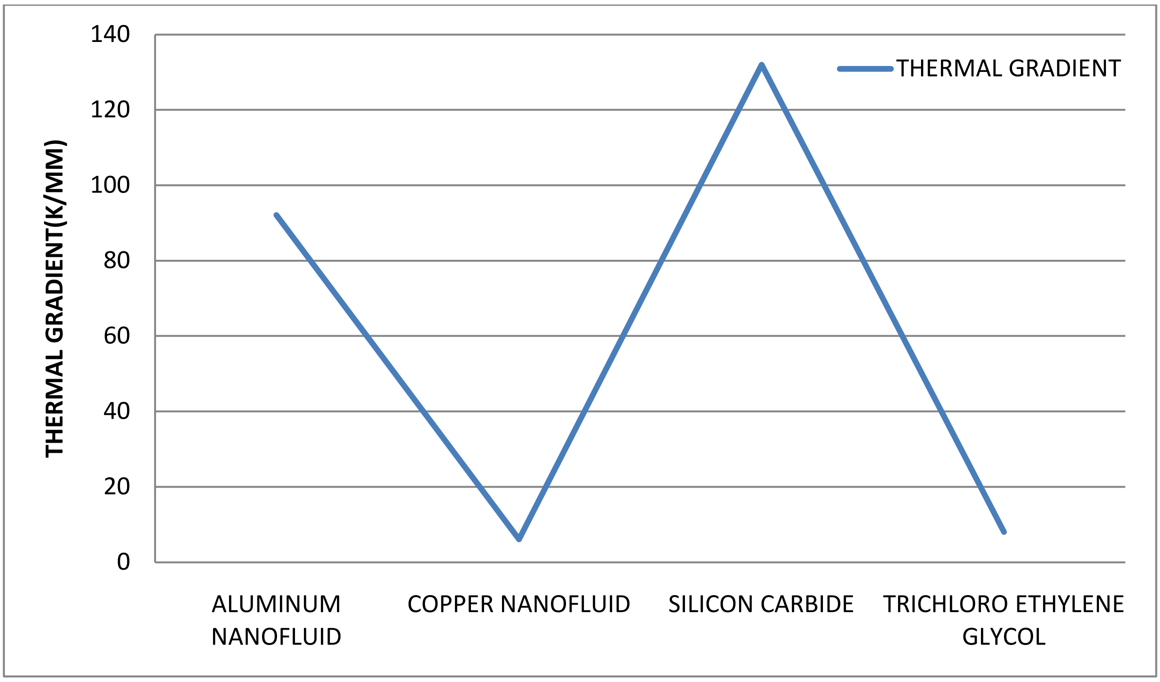

Fig: 16 Thermal Gradient

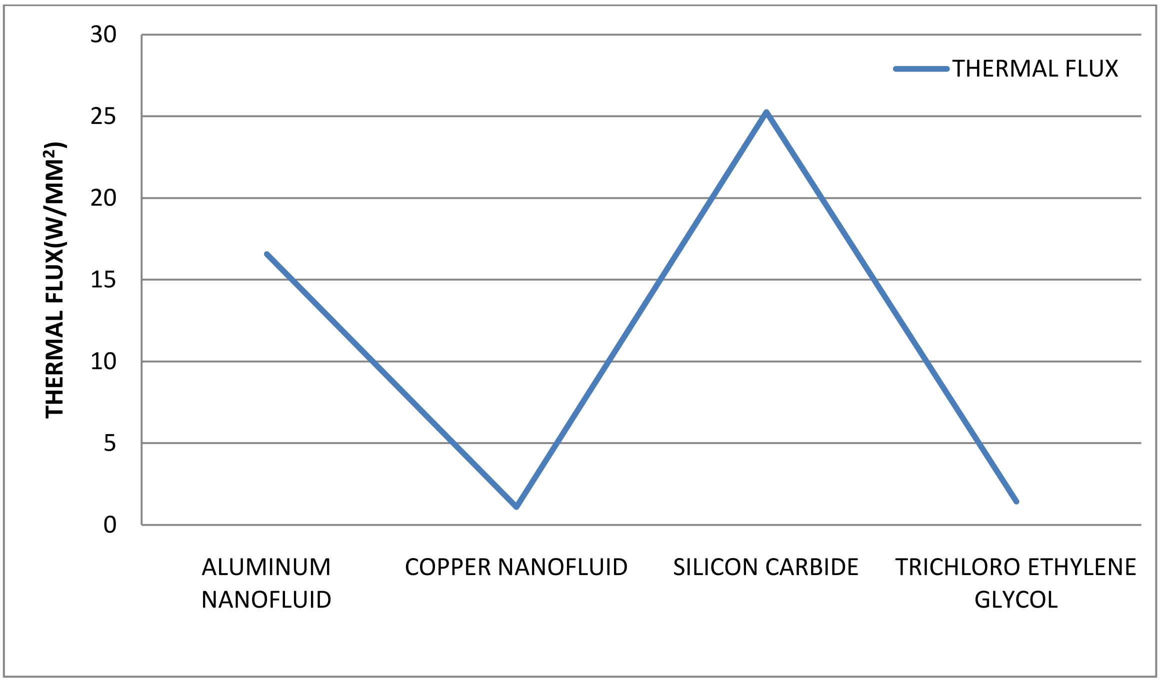

Fig: 17 Thermal Flux

Table 4 With Contact

	Nodal Temperature (K)	Thermal Gradient (K/Mm)	Thermal Flux (W/Mm^2)
Aluminum Nanofluid	353	10.2043	1.83678
Copper Nanofluid	353	11.5837	2.08506
Silicon Carbide	353	450.499	81.0899
Trichloro Ethylene Glycol	353	3.73487	0.672276

GRAPHS

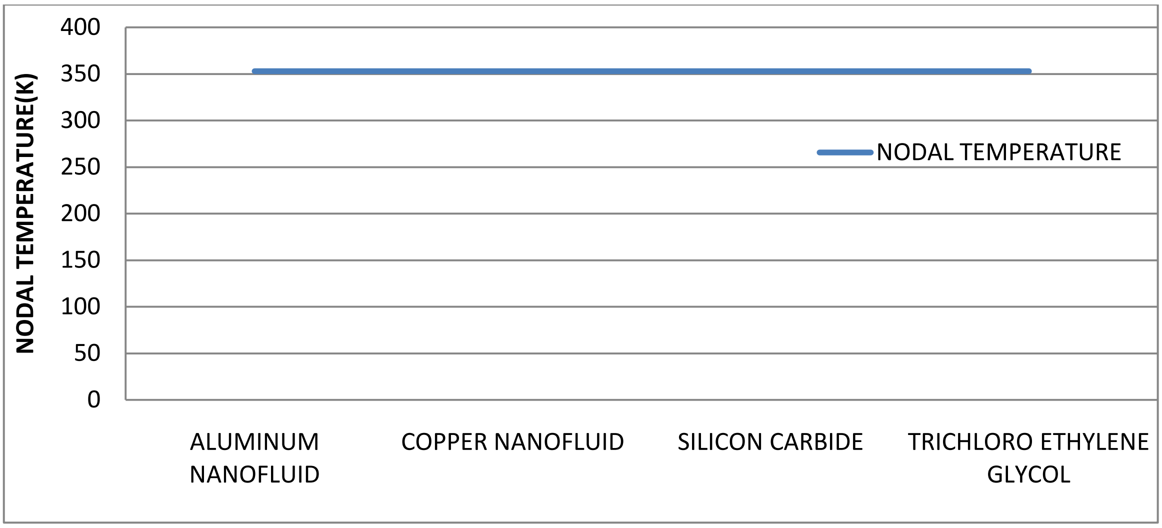

Fig: 18 Nodal Temperature

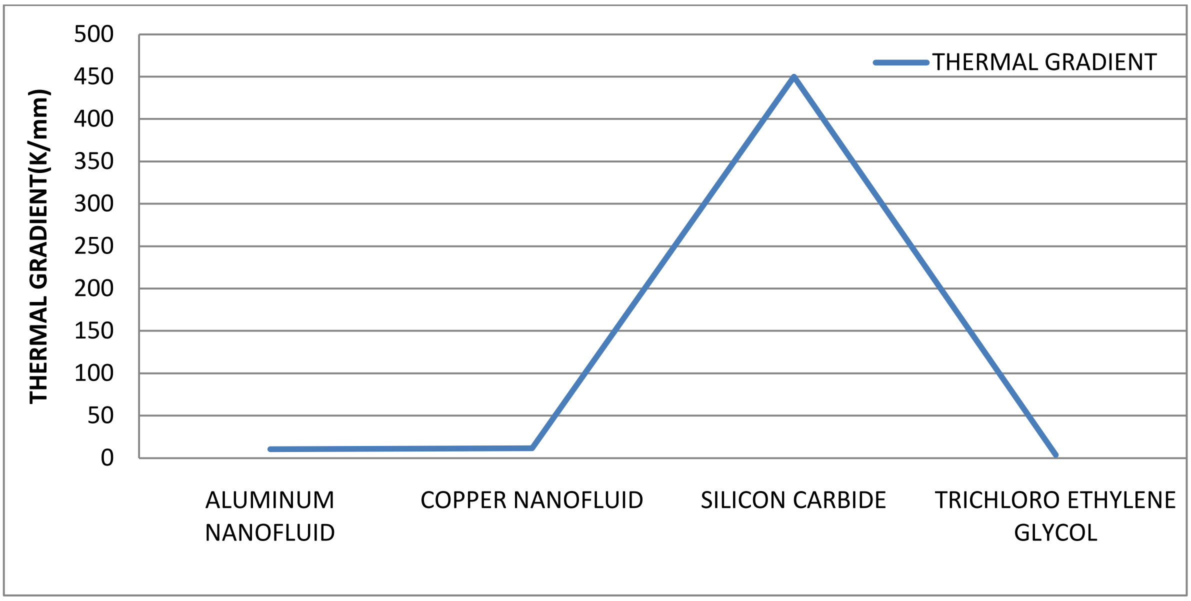

Fig: 19 Thermal Gradient

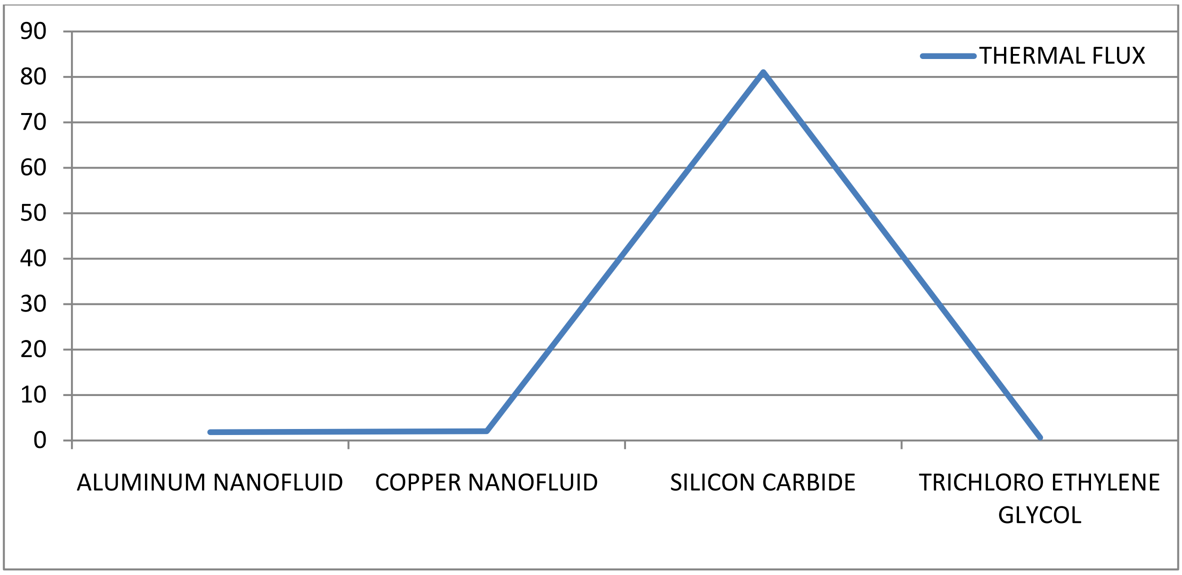

Fig: 20 Thermal Flux

V. CONCLUSION

In this project, different nano fluids will be analyzed for their thermal behavior passing through an annular bend tube with turbulence flow in an hairpin heat pin, which is a double tube heat exchanger. The nano fluids considered in this thesis are nanofluids made from base fluid water, silicon carbide, tri-cloroethylene gycols, copper nano fluid and aluminum nano fluid. 3D modeling is done in Pro/Engineer.

CFD analysis is done to verify the outlet pressure, velocity etc in Fluid Flow Fluent. By observing the results for without contact, and with contact, heat transfer rate is more for with contact.

The heat transfer rate is more when Silicon Carbide nanofluid is used.

Thermal analysis is performed to determine the thermal behavior using finite element analysis software Ansys. By observing the thermal analysis results of annular bend tubes without contact and with contact, the heat transfer rate is more for with contact and silicon carbide nano fluid is used.

So it can be concluded that annular bend tubes with contact yields better results than without contact and using silicon carbide nanofluid is better

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