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Aluminum Alloy Engine Block Heat Transfer Analysis by Varying the Cooling Fluids

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Abstract -- To control the engine temperature cooling system is needed. Usage of good cooling fluid is one of important element in cooling system. Faulty selections of cooling fluid leads shorten the engine life and, over heating of engine, and required more pump work for circulating cooling fluid. Hence by selecting correct cooling fluid we eradicate such problems. The present era of technology was Nano fluids because they have very good heat transfer capacity as compared to conventional fluids. The present Work is mainly focused on effectiveness of Nano fluids when used as cooling fluids. Cooling fluids chosen for analysis are Aluminum Oxide, Silicon Carbide, Titanium Oxide and Copper Oxide at volume fraction of 0.4.the properties of Nano fluids are calculated theoretically by considering it as a homogenous mixture.3D model of the engine block is done in Pro/Engineer. CFD analysis is done on the engine block using all Nano-fluids and Thermal analysis is done on the Aluminum alloy engine block.
Keywords: Engine Heat Transfer, cooling system, cooling fluid, CFD Analysis, Thermal Analysis

I. INTRODUCTION

The Conventional fluids, such as water, engine oil, and ethylene glycol are normally used as heat transfer fluids. Although various techniques are applied to enhance the heat transfer, the low heat transfer performance of these conventional fluids obstructs the performance enhancement and the compactness of heat exchangers. The use of solid particles as an additive suspended into the base fluid is technique for the heat transfer enhancement. Improving the thermal conductivity is the key idea to improve the heat transfer characteristics of conventional fluids. Since a solid metal has a larger thermal conductivity than a base fluid, suspending metallic solid fine particles into the base fluid is expected to improve the thermal conductivity of that fluid. The enhancement of thermal conductivity of conventional fluids by the suspension of solid particles, such as millimeter-or micrometer- sized particles, has been well-known for many years

However, they have not been of interest for practical applications due to problems such as sedimentation leading to increased pressure drop in the flow channel. The recent advance in material technology has made it possible to produce innovative heat transfer fluids by suspending Nanometer-sized particles in base fluids which can change the transport and thermal properties of the base fluid. Nano fluids are solid-liquid composite materials consisting of solid Nanoparticles or Nano fibers with sizes typically of 1 to 100 nm suspended in liquid. The Nano fluid is not a simple liquid-solid mixture; the most important criterion of Nano fluid is agglomerate-free stable suspension for long durations without causing any chemical changes in the base fluid. This can be achieved by minimizing the Density between solids and liquids or by increasing the viscosity of the liquid; by using Nanometer- sized particles and by preventing particles from agglomeration, the settling of particles can be avoided. Nano fluids have attracted great interest recently because of reports of enhanced thermal properties.

Temperatures in the combustion chamber of the engine can reach 4,500 F (2,500 C), so cooling the area around the cylinders is critical. Areas around the exhaust valves are especially crucial, and almost all of the space inside the cylinder head around the valves that is not needed for structure is filled with coolant. If the engine goes without cooling for very long, it can seize. When this happens, the metal has actually gotten hot enough for the piston to weld itself to the cylinder. This usually means the complete destruction of the engine

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II. MODELING AND CALCULATIONS

A. Modeling

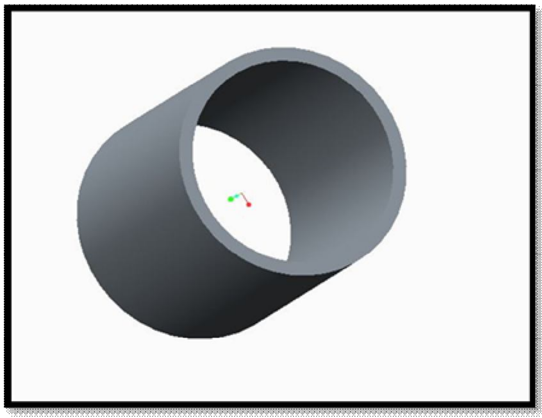

Fig. 1 3D-Model

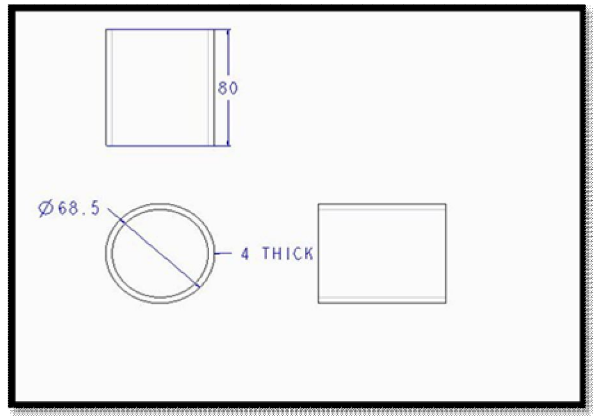

Fig. 2 2D-Model

B. Calculations of Properties for Nano Fluids:

1) Aluminum Oxide Nano Fluid

Ø= Volume fraction =0.4

Density

@ Ø=0.4

$$\rho nf = \text{Ø}\rho s + (1-\text{Ø})\,\rho w = (0.4*3700)+(1-0.4)*1000$$

$$=2083\ Kg/m^3$$

Specific Heat

@ Ø=0.4

$$cpnf = \text{Ø}(\rho scps) + (1-\text{Ø})\,\rho wcpw$$

$$=(0.4*3700*0.775)+(1-0.4)(1000*8.96)$$

$$= 6523\ KJ/Kg\ K$$

Viscosity

$$\mu nf = \mu_f\left(1-\frac{\phi a}{\phi m}\right)^{-\eta(\phi m)}$$

$$=0.038\left(1-\frac{0.4}{0.6}\right)^{-2.5(0.6)}$$

$$=0.19745\ Kg/\ ms$$

Thermal Conductivity

$$K_{nf} = \frac{Ks+2Kw+2(Ks-Kw)(1+\beta)^3\times\phi}{Ks+2Kw-(Ks-Kw)(1+\beta)^3\times\phi} \times k_w$$

Knf=1.094868W/m.K

2) Copper Nano Fluid

Density

@ Ø=0.4

$$\rho\ nf = \text{Ø}\rho s + (1-\text{Ø})\,\rho w$$

$$= (0.4*8933) + (1-0.4)*1000$$

$$=4173.2\ Kg/m^3$$

Specific Heat

@ Ø=0.4

$$cpnf = \text{Ø}(\rho scps) + (1-\text{Ø})\,\rho wcpw$$

$$=(0.4*0.385*8933)+(1-0.4)(1000*8.96) = 6751.682\ KJ/Kg\ K$$

Viscosity

$$\mu nf = \mu_f\left(1-\frac{\phi a}{\phi m}\right)^{-\eta(\phi m)}$$

$$=0.061\left(1-\frac{0.4}{0.6}\right)^{-2.5(0.6)}$$

$$=0.3169 \text{ Kg/ms}$$

Thermal Conductivity

$$K_{nf} = \frac{Ks+2Kw+2(Ks-Kw)(1+\beta)^3\times\phi}{Ks+2Kw-(Ks-Kw)(1+\beta)^3\times\phi}\times k_w$$

Knf=0.4074 W/m.K

3) Titanium Di-Oxide (Tio$_2$)

Density

@ Ø=0.4

ρ nf =Øρs + (1-Ø) ρw

=(0.4*4050)+(1-0.4)*1000

= 2220 Kg/m^3

Specific Heat

@ Ø=0.4

cpnf = Ø(ρs*cps) +(1-Ø) ρw*cpw

=(0.4*4050*0.697)+(1-0.4)(1000*8.96) = 6505.14 KJ/Kg K

Viscosity

$$\mu nf = \mu_f\left(1-\frac{\phi a}{\phi m}\right)^{-\eta(\phi m)}$$

$$=0.043\left(1-\frac{0.4}{0.6}\right)^{-2.5(0.6)}$$

=0.2234 Kg/ ms

Thermal Conductivity

$$K_{nf} = \frac{Ks+2Kw+2(Ks-Kw)(1+\beta)^3\times\phi}{Ks+2Kw-(Ks-Kw)(1+\beta)^3\times\phi}\times k_w$$ Knf= 0.5567 W/m.K

4) Silicon Carbide Nano Fluid

Density

@ Ø=0.4

ρ nf =Ø*ρs + (1-Ø)*ρw

=(0.4*2316)+(1-0.4)*1000

=1526.4 Kg/m^3

Specific Heat

@ Ø=0.4

cpnf = Ø*(ρs*cps) +(1-Ø) ρw *cpw

=(0.4*2316*0.0021)+(1-0.4)(1000*8.96) =5395.4544 KJ/Kg K

Viscosity

$$\mu nf = \mu_f\left(1-\frac{\phi a}{\phi m}\right)^{-\eta(\phi m)}$$

$$=0.091\left(1-\frac{0.4}{0.6}\right)^{-2.5(0.6)}$$

=0.4728 Kg/ms

Thermal Conductivity

$$K_{nf} = \frac{Ks+2Kw+2(Ks-Kw)(1+\beta)^3\times\phi}{Ks+2Kw-(Ks-Kw)(1+\beta)^3\times\phi}\times k_w$$ Knf=1.112W/m.K

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III. CFD ANALYSIS OF ENGINE BLOCK

A. FLUID- Al_2O_3

1) After Importing Mesh Model

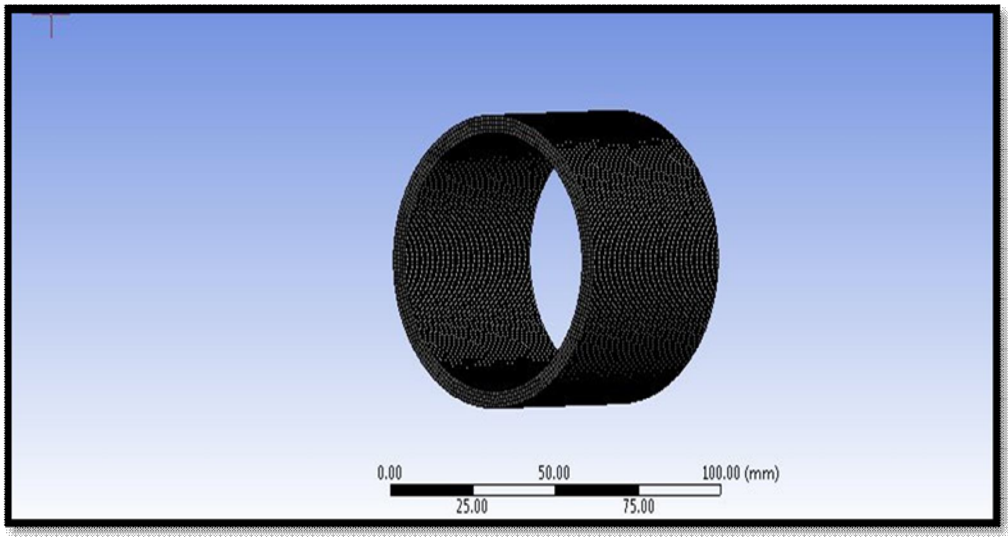

Fig. 3 Imported Mesh Model

2) Static Temperature

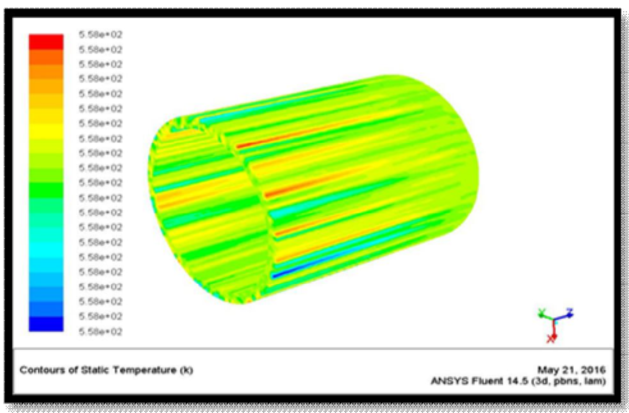

Fig. 4 Static Temperature

3) Heat transfer coefficient

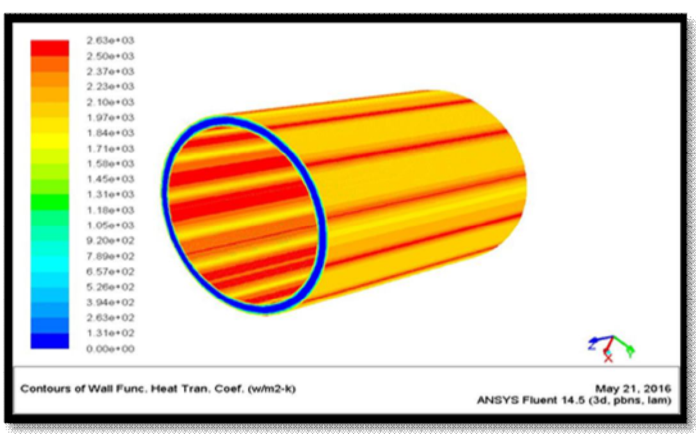

Fig. 5 Heat Transfer Coefficient

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B. FLUID - CuO

1) Static Temperature

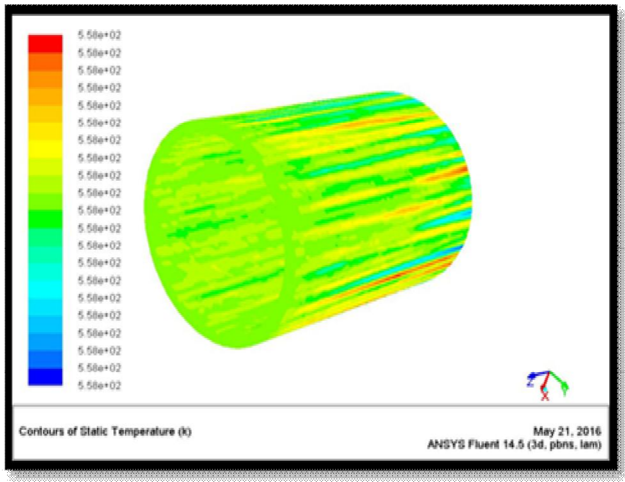

Fig. 6 static Temperature-Cuo

2) Heat transfer coefficient

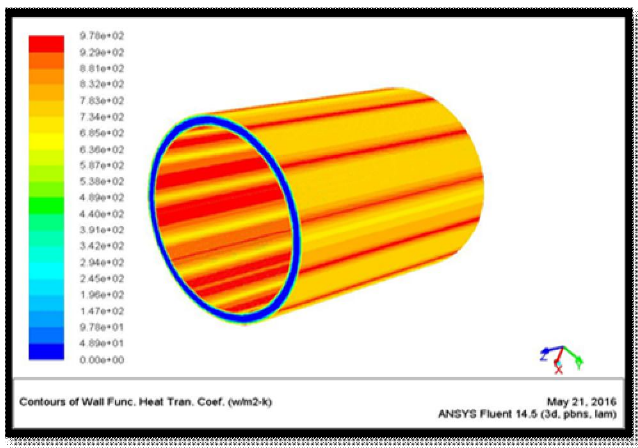

Fig. 7 Heat Transfer Coefficient-Cuo

C. FLUID - SiC

1) Static Temperature

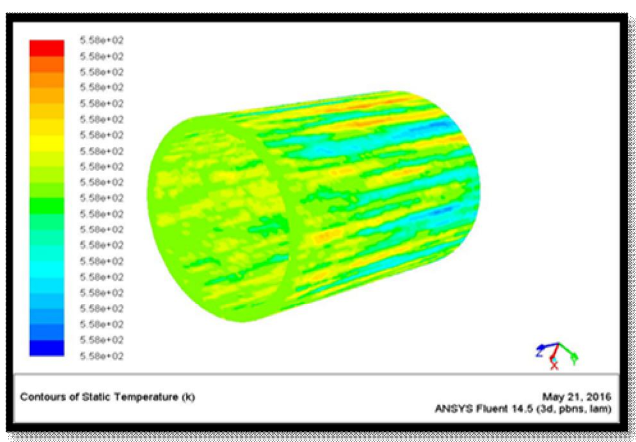

Fig. 8 static Temperature-SiC

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2) Heat transfer coefficient

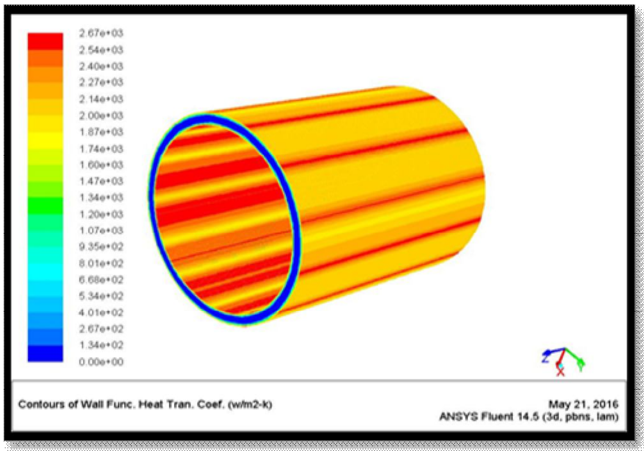

Fig. 9 Heat Transfer Coefficient-sic

D. FLUID –TiO_2

1) Static Temperature

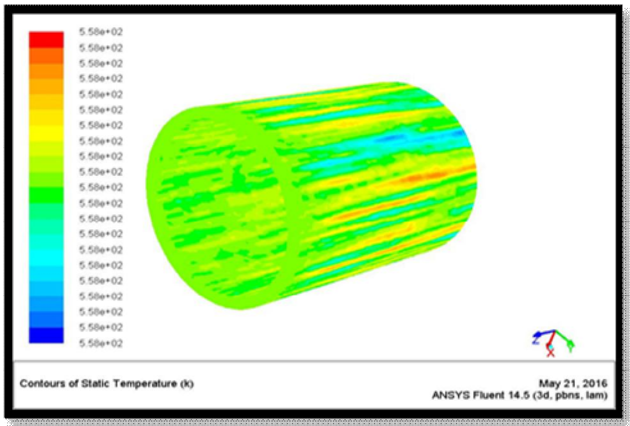

Fig. 10 static Temperature-TiO_2

2) Heat transfer coefficient

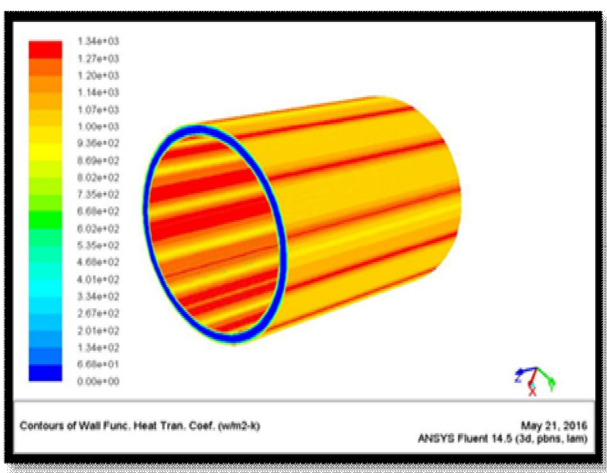

Fig. 11 Heat Transfer Coefficient- TiO_2

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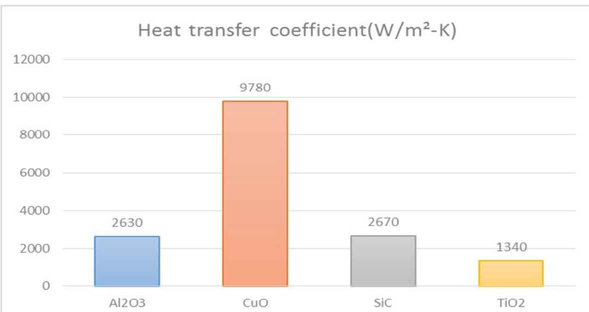
III. RESULTS TABLE

A. CFD ANALYSIS

Fluid	Temperature (K)	Heat transfer coefficient (W/m^2-K)	Heat transfer rate (W)	Mass flow rate (Kg/s)
Al_2O_3	5.58E+02	2.63E+03	-44.5	-5.9127808E-05
CuO	5.58E+02	9.78E+02	-0.026367188	-5.531311E-05
SiC	5.58E+02	2.67E+03	-0.0078125	-5.2452087E-06
TiO_2	5.58E+02	1.34E+03	-0.036621094	-4.1007996E-05

B. Graphical Representation of Results



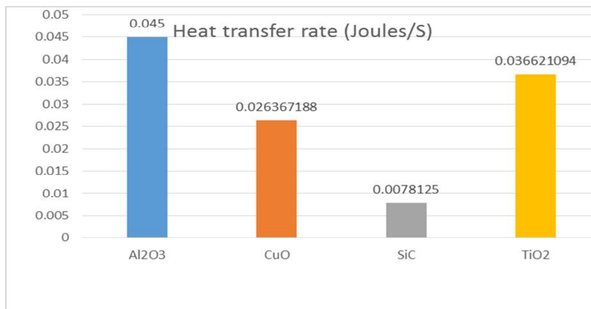


Fig. 12 Comparison of Heat Transfer Coefficient Values for All Nano Fluids
Fig. 13 Comparisons of Heat Transfer Rate Values for All Nano Fluids

IV. THERMAL ANALYSIS OF ENGINE BLOCK MATERIAL – ALUMINUM

A. Fluid – Aluminum Oxide

Thermal conductivity: 210 W/mK
Film coefficient value→ 2630 $W/m^{2\,0}C$ (taken from cfd-al_2o_3)

1) After Importing Meshed model

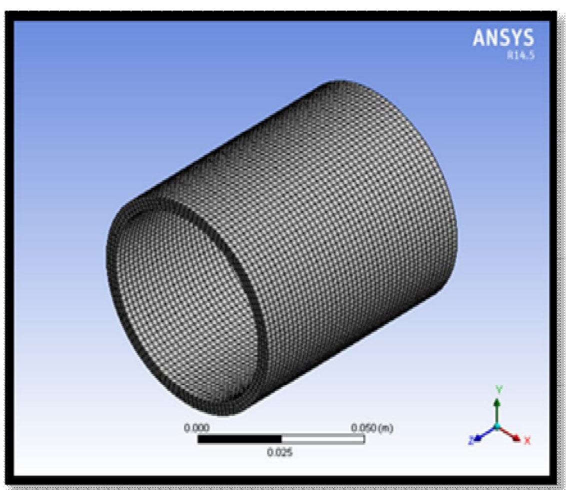


Fig. 14 Importing Meshed model

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2) Convection – AL_2O_3

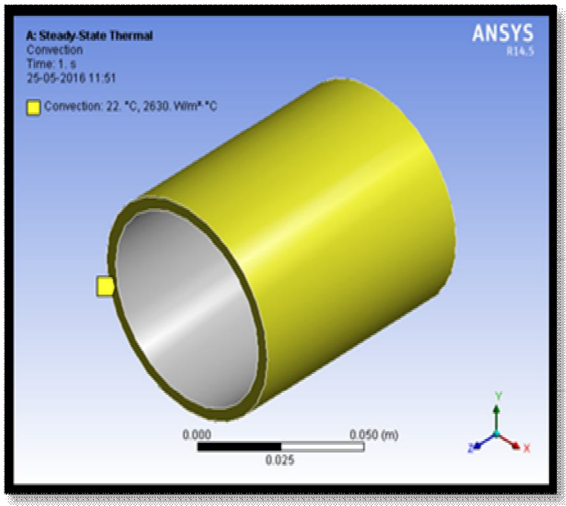

Fig. 15 Convention- AL_2O_3

3) Temperature

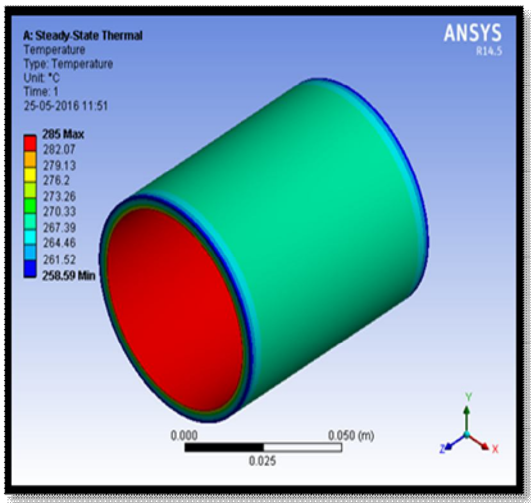

Fig. 16 Temperature- AL_2O_3

4) Heatflux

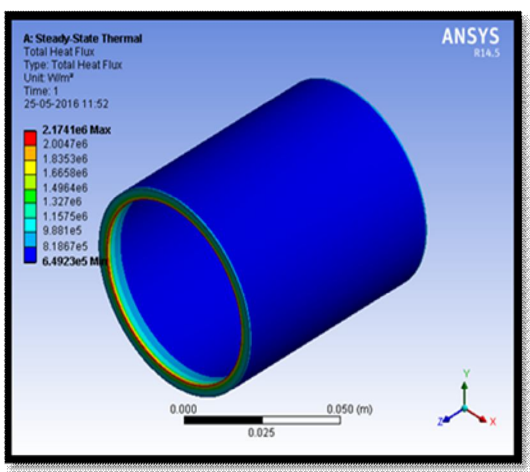

Fig. 17 Heat Flux- AL_2O_3

B. Fluid – Silicon Carbide

Convection film coefficient value→ 2670 W/m^{2} ^{0}C (taken from cfd-sic)

1) Convection 2) Temperature 3) Heat flux

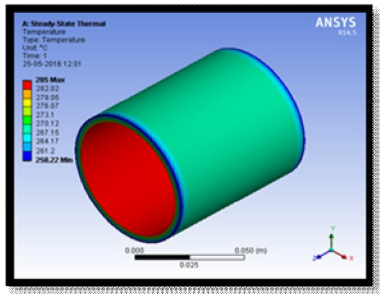

Fig.18Convection-SiC

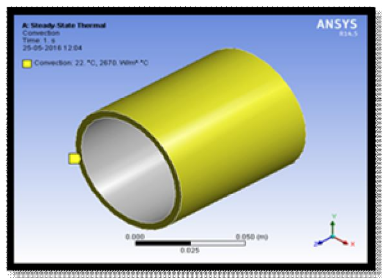

Fig. 19 Temperature-SiC

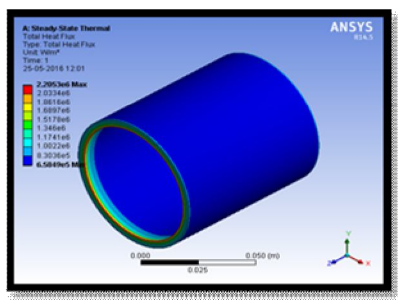

Fig. 20 Heat Flux-SiC

C. Fluid – Titanium Oxide

Convection film coefficient value→ 1340 W/m^{2} ^{0}C (taken from cfd- TiO_2)

1) Convection *2) Temperature* *3) Heat flux*

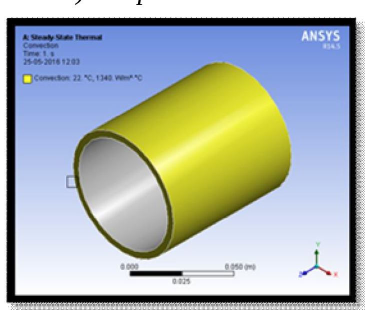

Fig.21 Convection- TiO_2

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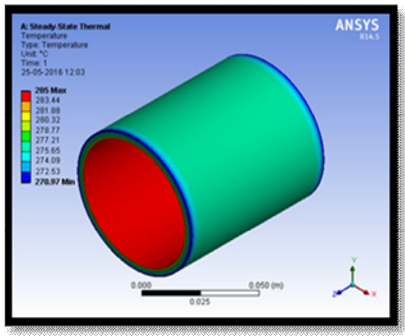

Fig. 22 Temperature- TiO_2

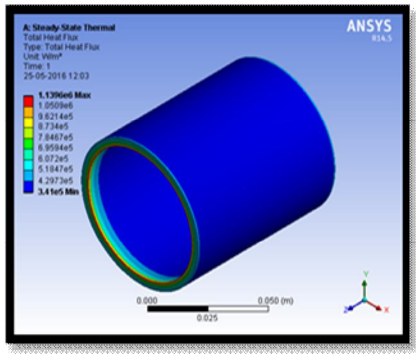

Fig. 23 Heat Flux- TiO_2

2) Fluid – Copper Oxide

Convection film coefficient value→ 978 W/m^2 ^{0}C (taken from cfd- Cuo)

1) Convection *2) Temperature* *3) Heat flux*

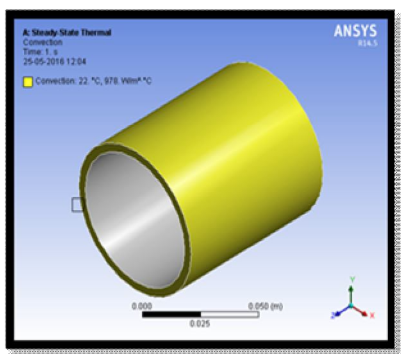

Fig.24 Convection-Cuo

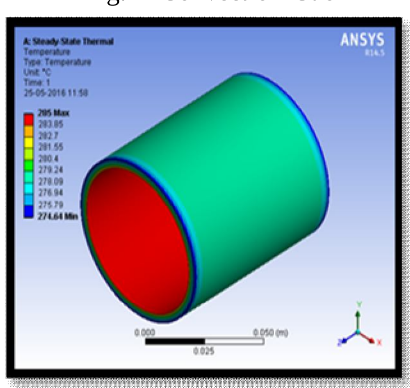

Fig. 25 Temperature-Cuo

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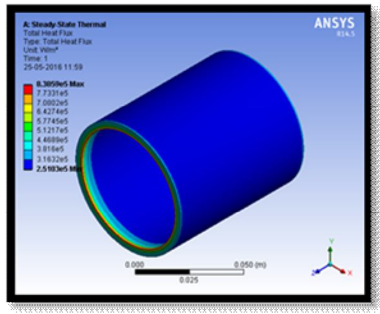

Fig. 26 Heat Flux- Cuo

V. RESULTS TABLE THERMAL ANALYSIS

Cylinder Material	Convection	Temperature (^{0}C)	Heat flux (W/m^2)
	Al_2O_3	285	2.1741e6
	SiC	285	2.2053e6
	TiO_2	285	1.1396e6
Aluminum	CuO	285	8.3859e5

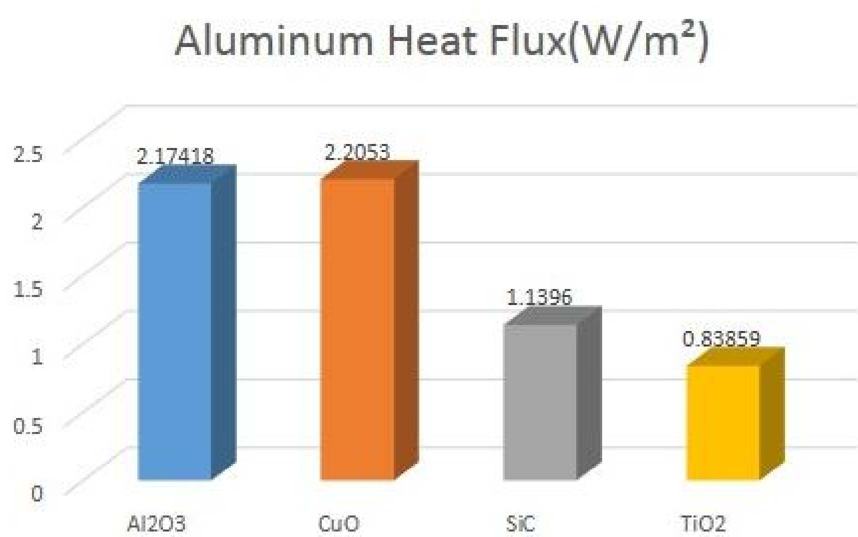

Fig.27 Comparison of Heat Flux for All Nano Fluids of Al

VI. CONCLUSION

In this thesis CFD and thermal analysis is performed on the engine block of a car using Nano Fluids. Different types of fluids mixed with base fluid water considered in this thesis Aluminum Oxide, Silicon Carbide, Titanium Oxide and Copper Oxide at volume fraction of 0.4. the properties of the Nano Fluids are calculated theoretically.

A. By observing the CFD analysis results, the heat transfer coefficient and mass flow rate are more for silicon oxide than other Nano Fluids. The heat transfer rate is more for Aluminum oxide.

B. By observing the thermal analysis results, taking Aluminum as engine block material and fluid is silicon carbide ,gives better heat flux (i.e) heat transfer rate is more

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