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Enhancement of Heat Transfer in Automobile Radiator Using Nano Fluids through CFD Analysis

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ABSTRACT:

An efficient cooling system can prevent engine from overheating and assists the vehicle running at its optimal performance. In this thesis, different nano fluids mixed with base fluid water are analyzed for their performance in the radiator. The nano fluids are Aluminium Oxide and Titanium carbide for two volume fractions 0.2, 0.3. Theoretical calculations are done to determine the properties for nano fluids and those properties are used as inputs for analysis.3D model of the radiator is done in Pro/Engineer. CFD analysis is done on the radiator for all nano fluids and volume fraction and thermal analysis is done in Ansys for two materials Aluminium and Copper for better fluid at better volume fraction from CFD analysis.

1. INTRODUCTION TO AUTOMOBILE RADIATOR:

Radiators are heat exchangers used to transfer thermal energy from one medium to another for the purpose of cooling and heating. The majority of radiators are constructed to function in automobiles, buildings, and electronics. The radiator is always a source of heat to its environment, although this may be for either the purpose of heating this environment, or for cooling the fluid or coolant supplied to it, as for engine cooling. Despite the name, radiators generally transfer the bulk of their heat via convection, not by thermal radiation, though the term "convector" is used more narrowly.

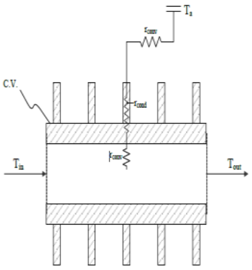
Fig. 1.1 Water-air convective cooling radiator

In practice, the term "radiator" refers to any of a number of devices in which a liquid circulates through exposed pipes (often with fins or other means of increasing surface area), notwithstanding that such devices tend to transfer heat mainly by convection and might logically be called convectors. The term "convector" refers to a class of devices in which the source of heat is not directly exposed.

1.1 Working of Automobile Radiators:

Almost all automobiles in the market today have a type of heat exchanger called a radiator. The radiator is part of the cooling system of the engine as shown in Figure below. As you can see in the figure, the radiator is just one of the many components of the complex cooling system. Most modern cars use aluminium radiators. These radiators are made by brazing thin aluminium fins to flattened aluminium tubes. The coolant flows from the inlet to the outlet through many tubes mounted in a parallel arrangement. The fins conduct the heat from the tubes and transfer it to the air flowing through the radiator. The tubes sometimes have a type of fin inserted into them called a turbulator**,** which increases the turbulence of the fluid flowing through the tubes. If the fluid flowed very smoothly through the tubes, only the fluid actually touching the tubes would be cooled directly. The amount of heat transferred to the tubes from the fluid running through them depends on the difference in temperature between the tube and the fluid touching it. So if the fluid that is in contact with the tube cools down quickly, less heat will be transferred. By creating turbulence inside the tube, all of the fluid mixes together, keeping the temperature of the fluid touching the tubes up so that more heat can be extracted, and all of the fluid inside the tube is used effectively.Radiators usually have a tank on each side, and inside the tank is a transmission cooler.

In the picture above, you can see the inlet and outlet where the oil from the transmission enters the cooler. The transmission cooler is like a radiator within a radiator, except instead of exchanging heat with the air, the oil exchanges heat with the coolant in the radiator.



$$r_{cond} = \frac{R_{cond}}{L_{pipe}} \quad \text{(Eq. 1)}$$

$$R_{cond} = \frac{L_{fin}}{k_{fin} A_{fin}} \quad \text{(Eq. 2)}$$

$$r_{conv} = \frac{R_{conv}}{L_{pipe}} \quad \text{(Eq. 3)}$$

$$R_{conv} = \frac{1}{h A_{S.A.}} \quad \text{(Eq. 4)}$$

Figure : A control volume thermal circuit diagram

Fig. 1.2 control volume thermal circuit diagram

1.2 NANO FLUIDS:

Nanoscience and nanotechnology primarily deal with the synthesis; characterization, exploration, and exploitation of nanostructure materials.A wide variety of industrial processes involve the transfer of heat energy. Throughout any industrial facility, heat must be added, removed, or moved from one process stream to another and it has become a major task for industrial necessity. These processes provide a source for energy recovery and process fluid heating/cooling.The enhancement of heating or cooling in an industrial process may create a saving in energy, reduce process time, raise thermal rating and lengthen the working life of equipment. Some processes are even affected qualitatively by the action of enhanced heat transfer. The development of high performance thermal systems for heat transfer enhancement has become popular nowadays. Thus the advent of high heat flow processes has created significant demand for new technologies to enhance heat transfer. There are several methods to improve the heat transfer efficiency.Heat transfer efficiency can also be improved by increasing the thermal conductivity of the working fluid. Commonly used heat transfer fluids such as water, ethylene glycol, and engine oil have relatively low thermal conductivities, when compared to the thermal conductivity of solids. High thermal conductivity of solids can be used to increase the thermal conductivity of a fluid by adding small solid particles to that fluid.

2. LITERATURE SURVEY:

The literature review in this thesis is taken from paper done by Junjanna G.C in which the study uses the computational analysis tool ANSYS Fluent 13.0 to perform a numerical study on a compact heat exchanger. The computational domain is identified from literature and validation of present numerical approach is established first. Later the numerical analysis is extended by modifying chosen geometrical and flow parameters like louver pitch, air flow rate, water flow rate, fin and louver thickness, by varying one parameter at a time and the results are compared. Recommendations has been made on the optimal values and settings based on the variables tested, for the chosen compact heat exchanger. In paper by JP Yadav and Bharat Raj Singh in which a complete set of numerical parametric studies on automotive radiator has been presented in detail in this study. The modeling of radiator has been described by two methods, one is finite difference method and the other is thermal resistance concept.

In the performance evaluation, a radiator is installed into a test-setup and the various parameters including mass flow rate of coolant, inlet coolant temperature; etc. are varied. A comparative analysis between different coolants is also shown. One coolant as water and other as mixture of water in propylene glycol in a ratio of 40:60 is used. It is observed that that the water is still the best coolant but its limitation is that it is corrosive and contains dissolved salts that degrade the coolant flow passage. In the paper performed by Durgesh Kumar Chavan and Ashok T. Pise experimental tests of forced convective heat transfer in an Al_2O_3/water nanofluid has experimentally been compared to that of pure water in automobile radiator. Five different concentrations of nanofluids in the range of 0–1.0 vol. % have been prepared by the addition ofAl_2O_3 nanoparticles into the water.

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The test fluid flows through the automobile radiator consisted of 33 vertical tubes with elliptical cross section and air makes a cross flow inside the tube bank with constant speed. The test fluid flow rate has been changed in the range of 3 l/min to 8 l/min to have fully turbulent regime.. The application of the Nano fluid with low concentration can enhance heat transfer efficiency up to 40–45% in comparison with pure water. In the paper by Paresh Machhar, FalgunAdroja, forced convective heat transfer in a water based nanofluid will experimentally be compared to that of pure water in an automobile radiator. Five different concentrations of nanofluids in the range of 0.1 - 1 vol. % will be prepared by the addition of TiO2 nanoparticles into the water. The test liquid flows through the radiator consisted of 34 vertical tubes with elliptical cross section and air makes a cross flow inside the tube bank with constant speed. Liquid flow rate will be changed in the range of 2 - 5 l/min.

3. INTRODUCTION TO CAD:

From history of our industrial society, many inventions have been patented and whole new technologies have evolved. Perhaps the single development that has impacted manufacturing more quickly and significantly than any previous technology is the digital computer. Computers are being used increasingly for both design and detailing of engineering components in the drawing office. Computer-aided design (CAD) is defined as the application of computers and graphics software to aid or enhance the product design from conceptualization to documentation. Computer-aided design systems are powerful tools and in the mechanical design and geometric modeling of products and components. There are several good reasons for using a CAD system to support the engineering design. Software allows the human user to turn a hardware configuration into a powerful design and manufacturing system. CAD/CAM software falls into two broad categories, 2-D and 3-D, Based on the number of dimensions are called 2-D representations of 3-D objects is inherently confusing. Equally problem has been the inability of manufacturing personnel to properly read and interpret complicated 2-D representations of objects. 3-D software permits the parts to be viewed with the 3-D planes-height, width, and depth-visible. The trend in CAD/CAM is toward3-D representation of graphic images. Such representation approximates the actual shape and appearance of the object to be produced; therefore, they are easier to read and understand.

Fig. 1.3 3D Model of the Radiator

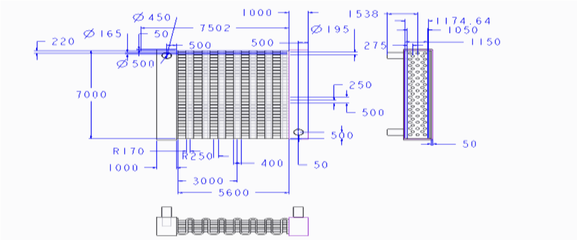

Fig. 1.4 Drafting Of Model of the Radiator

4. INTRODUCTION TO FEA:

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M.J.Turner, R.W. Clough, H C.Martin, and L.J.Top established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures". By the early 70's, FEA was limited to expensive mainframe computers generally owned by the aeronautics, automotive, defense, and nuclear industries. Since the rapid decline in the cost of computers and the phenomenal increase in computing power, FEA has been developed to an incredible precision.

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Present day supercomputers are now able to produce accurate results for all kinds of parameters.FEA consists of a computer model of a material or design that is stressed and analyzed for specific results.There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture. FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. To perform CFD analysis for various fluids, the properties of fluids are calculated and tabulated as below.

Fluid	**v_f**	**K (w/m-k)**	**C (J/kg-k)**	**ρ (kg/m^3)**	**ν(kg/m-s)**
Al_2O_3	0.2	1.532	2569.44	1574.56	0.00151
	0.3	5.00	2137.37	1862.74	0.00176
TiC	0.2	1.182	2016.37	1784.56	0.00151
	0.3	1.698	1824.69	2177.74	0.00152

Table 4.1: Properties of Nano Fluids

5.CFD ANALYSIS ON AUTOMOTIVE RADIATOR

5.1 Radiator without Louvered Fin

To facilitate CFD analysis of radiator, we take 2D CFD model to obtain the values for different fluids at different volume fractions. The fluids are water based

a) Aluminium oxide(ϕ= 0.2,0.3)
b) Titanium carbide(ϕ= 0.2,0.3)

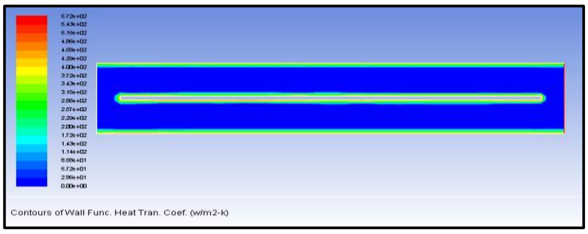

Fig.5.1 CFD analysis – heat transfer coefficient (Al_2O_3, 0.2)

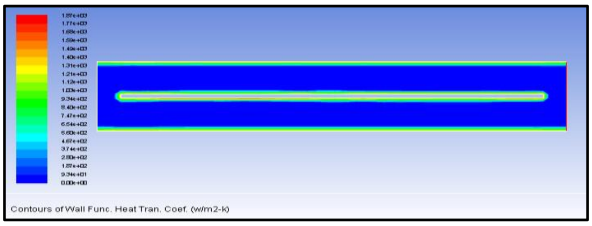

Fig.5.2 CFD analysis – heat transfer coefficient (Al_2O_3, 0.3)

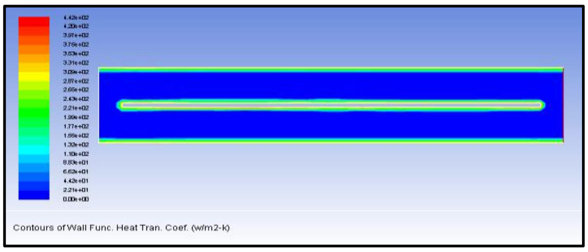

Fig 5.3 CFD analysis – heat transfer coefficient (TiC, 0.2)

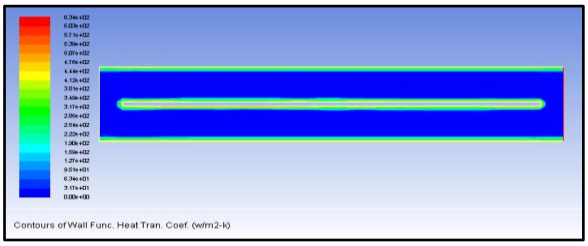

Fig 5.4 CFD analysis – heat transfer coefficient (TiC, 0.3)

5.2 Radiator with Louvered Fin (Pitch =10 mm)

The thesis is to improvise heat transfer rate of the fin, we create louvered fin. This is to improve the contact surface area with air. This louver concept is applied for two different pitches i.e. for 10mm and 15mm.

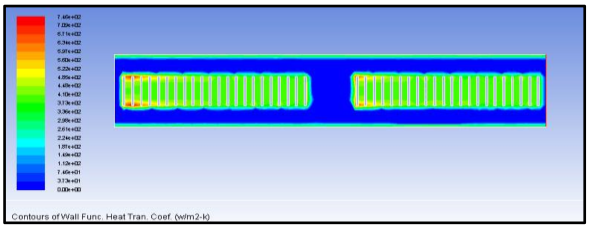

Fig.5.5 CFD analysis – heat transfer coefficient (Al_2O_3, 0.2)

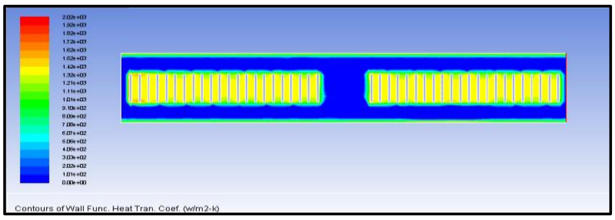

Fig. 5.6 CFD analysis – heat transfer co-efficient (Al_2O_3, 0.3)

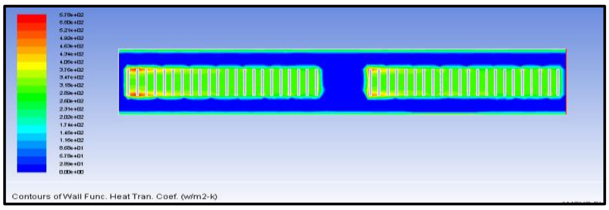

Fig 5.7 CFD analysis – heat transfer coefficient (TiC, 0.2)

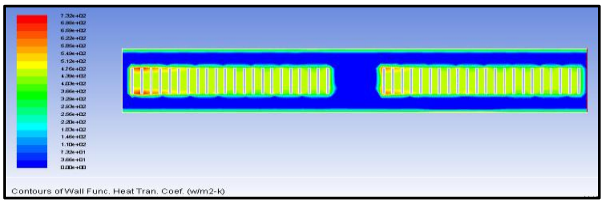

Fig 5.8 CFD analysis – heat transfer coefficient (TiC, 0.3)

5.3 Radiator with Louvered Fin Pitch=15mm

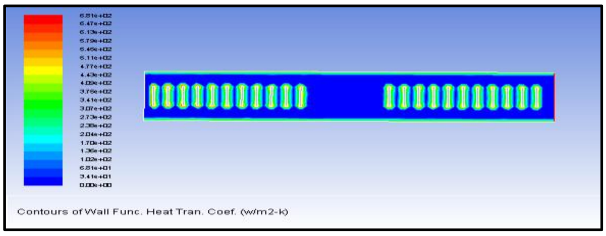

Fig. 5.9 CFD analysis – heat transfer co-efficient (Al_2O_3, 0.2)

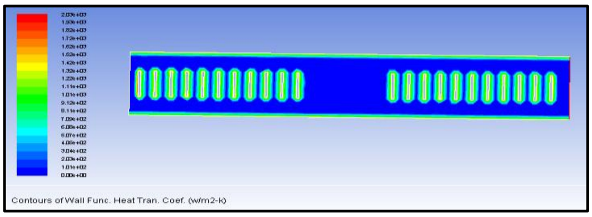

Fig 5.10 CFD analysis – heat transfer coefficient (Al_2O_3, 0.3)

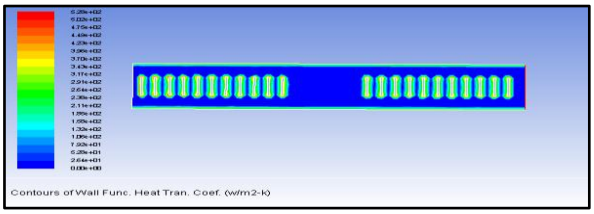

Fig 5.11 CFD analysis – heat transfer coefficient (TiC, 0.2)

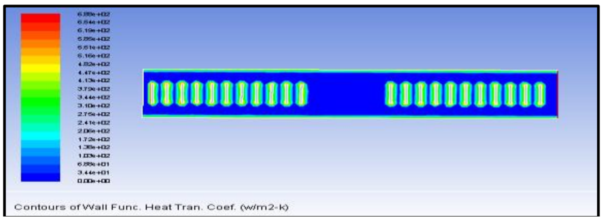

Fig. 5.12 CFD analysis – heat transfer coefficient (TiC, 0.3)

Model	**fluid**	v_f	**h (W/m^2-k).**	**Q (w)**
without louvered fin	Al_2O_3	0.2	5.72E+02	3.22
		0.3	1.87E+03	357.73
	TiC	0.2	4.42E+02	3.7519
		0.3	6.34E+02	16.22
with louvered fin 10mm	Al_2O_3	0.2	7.46E+02	241.004
		0.3	2.023E+03	490.594
	TiC	0.2	5.28E+02	220.88
		0.3	7.32E+02	389.77
with louvered fin 15mm	Al_2O_3	0.2	6.81E+02	561.42
		0.3	2.03E+03	543.5
	TiC	0.2	5.28E+02	446.039
		0.3	6.88E+02	150.309

Table 5.1CFD Analysis Results Table

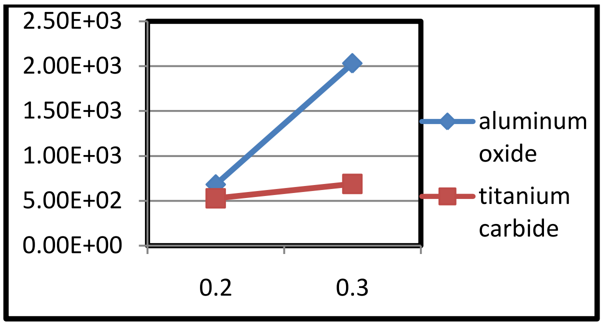

Fig 5.13 CFD analysis – heat transfer coefficient graph

6. THERMAL ANALYSIS OF RADIATOR:

Thermal analysis is carried out on the radiator from the values using the heat transfer co-efficient value that is attained in CFDanalysis. Thermal analysis is carried out for two materials, namely

1. Aluminium
2. Copper

By performing thermal analysis for two materials, we can get the values for temperature distribution and heat flux through the radiator for conditions without louver fin and with louver fin for pitches 10 mm and 15 mm.

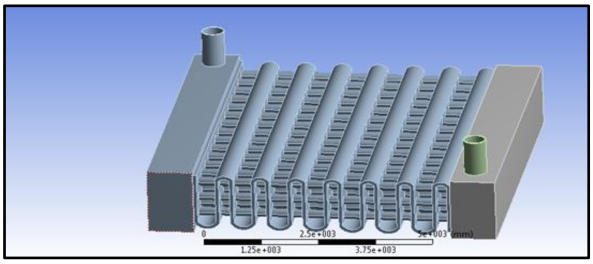

Fig. 6.1 Imported 3D Model

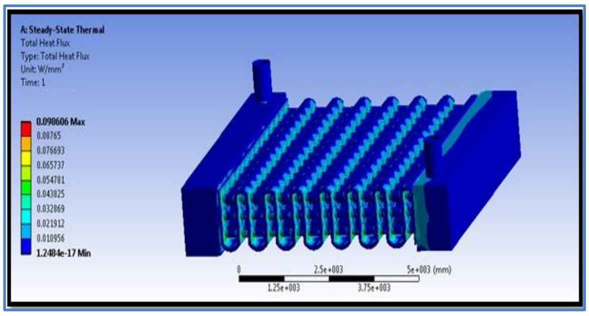

Fig. 6.2heat flux-3D Model

By analyzing the fin we attain heat transfer for fin, then for the louver fins for the pitches 10mm and 15mm. from the calculation we determine the best fin for best material.

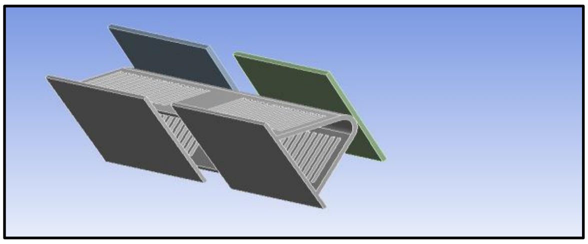

Fig 6.3 Imported Model (louvered fin, 10mm)

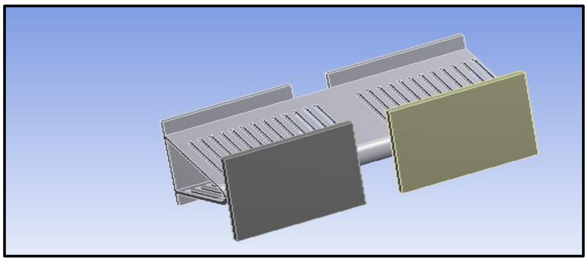

Fig. 6.4Imported Model (louvered fin, 15mm)

Models	Material	Heat flux(w/mm 2)
Radiator	Aluminium alloy	0.072436
	Copper alloy	0.098606
Without Louver Fin	Aluminium alloy	3.735
	Copper alloy	8.8745
With Louver Fin (pitch 10mm)	Aluminium alloy	3.8789
	Copper alloy	8.9747
With Louver Fin (pitch 15mm)	Aluminium alloy	3.958
	Copper alloy	9.2134

Table 6.1Thermal Analysis Results Table

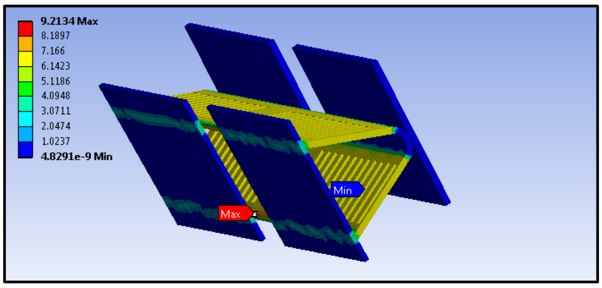

Fig. 6.5 Heat flux (louvered fin, 15mm, Cu)

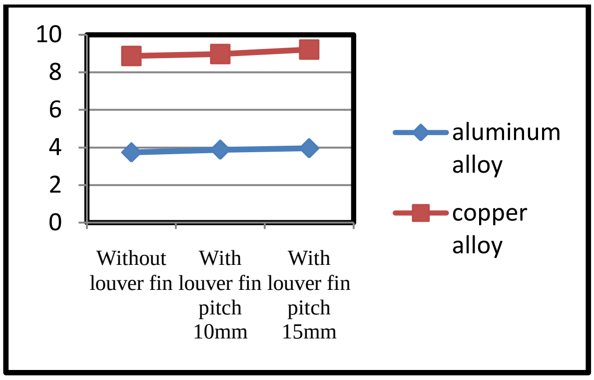

Fig. 6.7 Heat flux graph

7. CONCLUSION:

In this thesis, different nano fluids mixed with base fluidwater are analyzed for their performance in the radiator. The nano fluids are Aluminium Oxide and Titanium carbide for two volume fractions 0.2, 0.3.3D model of the radiator is done in Pro/Engineer. CFD analysis is done on the radiator for all nano fluids Aluminium Oxide and Titanium Carbide and at different volume fractions 0.2, 0.3. By observing the CFD analysis results, the pressure is more for AluminiumOxide at volume fraction of 0.2 and mass flow rate is more for titanium carbide at volume fraction of 0.3. The heat transfer coefficient and heat transfer rate are more for Aluminium oxide at volume fraction of 0.3.Thermal analysis is done for two materials Aluminium and Copper taking heat transfer coefficient value of Aluminium oxide at 0.3 volume fractions from CFD analysis. By observing thermal analysis results, heat flux is more when Copper is used than when Aluminium alloy is used.

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