CFD Analysis of Helical Tube Automobile Radiator Considering Different Coolants

Pradeep Pandey*
Patel College of science and Technology, Indore (M.P), India

Mr. Devendra Singh Sikarwar, Mr. Ashish Patidar
Patel College of science and Technology, Indore (M.P), India

Abstract
Increasing the rate of heat dissipation in automotive radiators is in great demand due to the use of more powerful engines in relatively small space. Insufficient rate of heat dissipation can result in overheating of the engine, and that causes corrosion and metal weakening of engine parts. The aim of this project is to design radiator for thermal stability of engine with increasing the rate of heat transfer and decreases the computational cost dramatically and leads the way to obtain hydrodynamic and thermal performance of a fin-and-helical tube type radiator by using CFD analysis. By adopting this methodology, the thermal performance of a complete radiator design can be obtained within a reasonable computational time and a CFD model with the proposed methodology can be implemented as a design tool for the radiator design which would lead to more optimized radiator designs. Overall heat transfer is calculated for each design. Different type of nano fluids Ethanol, Methanol, Al_2O_3/water2%, Al_2O_3/water3% and CuO/water and other coolants are taken into consideration while running the analysis. By The Varying turbulence model and surface Nusselt number, the contours of temperature, energy (pressure drop), and mass flow rate were calculated and plotted using ANSYS FLUENT 14.5. The purpose of this study is to minimize the stress on the engine and lighten automotive component because of heat generation, and to make automotive radiators more compact while maintaining important level of heat performance. Compactness plays significant role in heat exchanger performance; economy in manufacturing and operating costs, energy conservation and for ecological reasons.
Keywords: Helical Tube type Radiator, Nano Fluid, CFD

INTRODUCTION:

Cooling is one of the top technical challenges to obtain the best automotive design in multiple aspects (performance, fuel consumption, etc.). Automotive radiator is an important part of the engine cooling system. Radiator is a heat exchanger that removes heat from engine coolant passing through it. Heat is exchanged from hot coolant to outside air. Radiator gathering comprises of three primary parts centre, intake tank and outlet tank as appeared in fig.1.1 Centre has two arrangements of entry, an arrangement of tubes and an arrangement of fins. Coolant courses through tubes and wind streams between fins. The hot coolant sends warm through tubes to balances. Outside air going between balances pickups and diverts warm as appeared in fig 1.2. Because of constrained space at the front of the motor, the extent of the radiator is limited and can't be basically expanded. In this manner, it is important to expand the warmth exchange abilities of working liquids, for example, water and ethylene glycol in radiators on account of their low warm conductivity and furthermore the territory of warmth exchange is expanded by using the broadened surfaces as balances joined to dividers and surfaces.

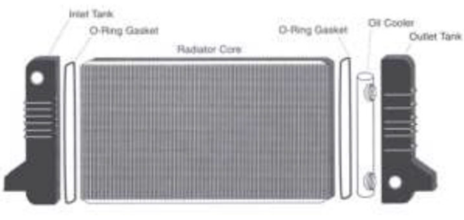


Figure 1.1: Components of Automotive Radiator

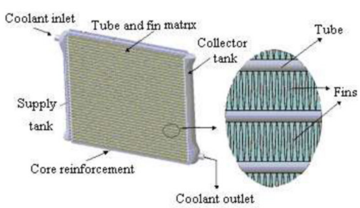


Figure 1.2: Automotive Radiator fluid flow Circuit

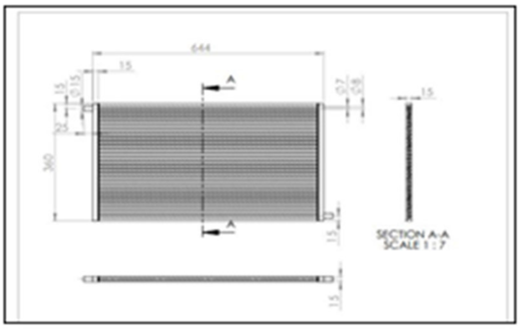


Figure 1.3: Dimension Drawing Sheet of Automotive Radiator

Methodology & Theoretical Orientation: Heat transfer increases as we redesign the tube of radiator and increase the surface area of the fins with the use of nano fluids. Modern design (Varying turbulence model) can dissipate the same and/or more heat by using vortex generators in tubs of radiator. Helical tube disturbs the flow field and provides swirling flow which causes high rate of heat exchange of core and wall fluid.

Findings: Vortex generators in helical tube decrease the wake region size and increase the intensity of secondary flow. The fins with the helical tube increases the heat transfer performance of radiator about 55.8% compared to existing radiator.

Analysis is done in ANSYS - 14.5 software with using CFX. The analysis is done on both helical tube and straight tube radiator model and then performance comparison is done to understand importance of particular configuration with help of ANSYS software.

Objectives of the Present Work: The objective of the work:

1) To analyze and to compare heat transfer of car radiator with and without nano fluids using computational results.
2) To analyze and to compare heat transfer of car radiator with different nano fluids with different base fluid, nano particles and concentration.

Proposed Design:

The proposed design of radiator is done as per the standard designing procedure for our project work.

It includes the design of radiator model on 3D modelling mechanical software (CREO and CATIA), its manual calculations, CFD analysis on ANSYS software and its results.

The designed model of radiator is made with the help of CREO software as per dimensions and calculations carried out for our project work. Figure 1.4 shows the 3D model of radiator.

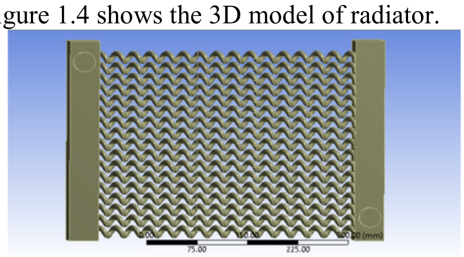


Figure1.4: CREO model of Helical tube Radiator

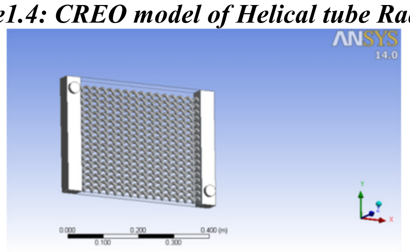


Figure1.5: ANSYS model of Helical tube Radiator

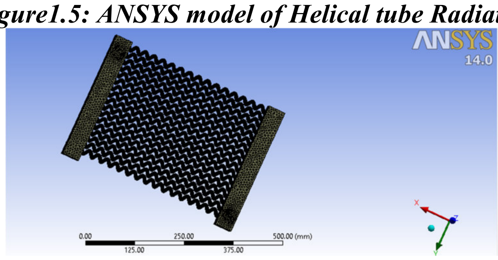


Figure1.6: ANSYS meshed model of Helical tube Radiator

Input Data

Air inlet velocity	: 4.4 m/s
Air inlet temp	: ambient temp
Coolant in let temp	: 358.15K
Outside temperature	: 298K
Coolant mass flow	: 2.3 kg/sec.
Flow region	: Laminar
Mass & Momentum	: Free slip wall

Overall heat transfer co efficient across the radiator ranges from 75 to 560 W/ m^2-K

Radiator Specification for Helical Type Tubes:

Number of tubes	: 29
Helical type tube mean diameter	: 8mm
Pitch	: 15mm & 20mm

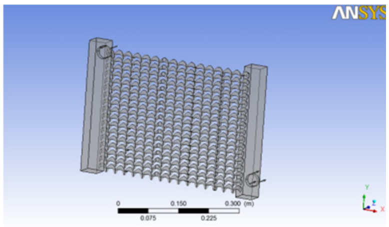


Figure 1.7: Helical tube radiator in ANSYS

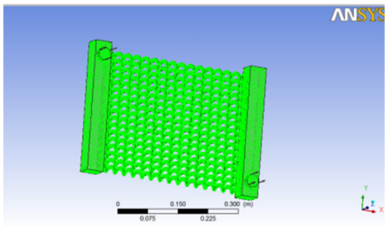


Figure 1.8: Helical tube radiator in ANSYS, CFX

Assumptions: In order to solve the analytical model, the following assumptions are made:

Coolant flow rate is constant and there is no phase change in the coolant. Heat conduction through the walls of the coolant tube is negligible. Heat loss by coolant was just exchanged to the cooling air, in this manner no other heat exchange mode, for example, radiation was considered. Coolant liquid stream is in a completely created condition in each tube. All measurements are uniform all through the radiator and the heat exchange surface zone is predictable and distributed consistently. The heat conductivity of the radiator material is thought to be consistent. There are no heat sources and sinks inside the radiator. There is no liquid stratification, misfortunes and flow non distribution. Force condition: Tube divider is stationary.

Case-I: Analysis of Radiator with Helical Tubes Using Coolant: Water

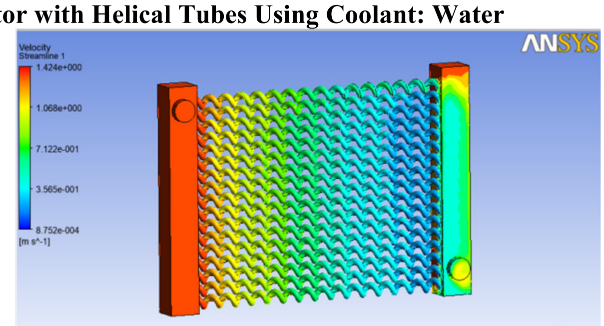


Figure 1.9: Velocity Streamline diagram of helical tubes used in Radiator. (Water)

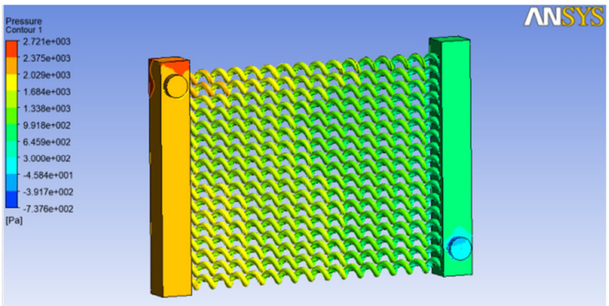


Figure 1.10: Pressure Contour diagram of helical tubes used in Radiator. (Water)

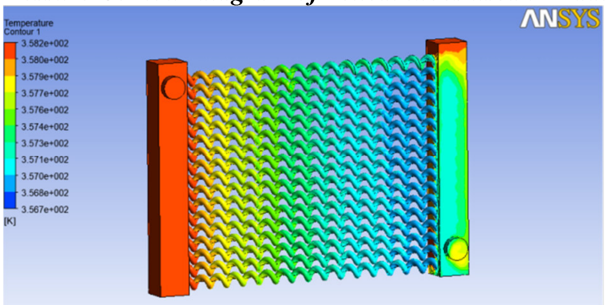
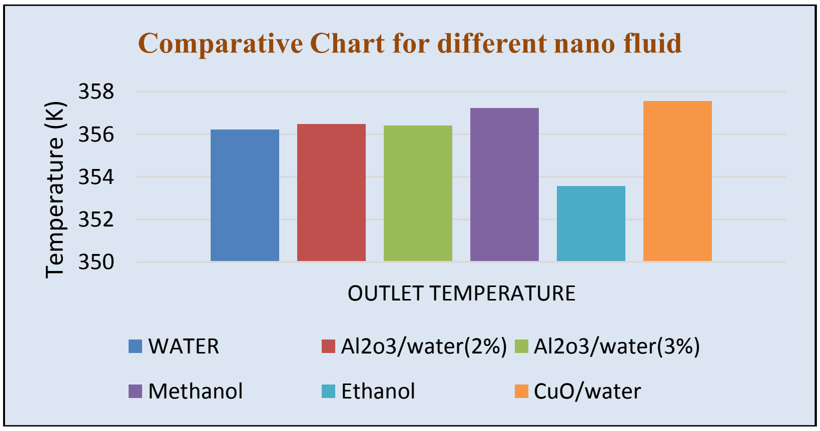
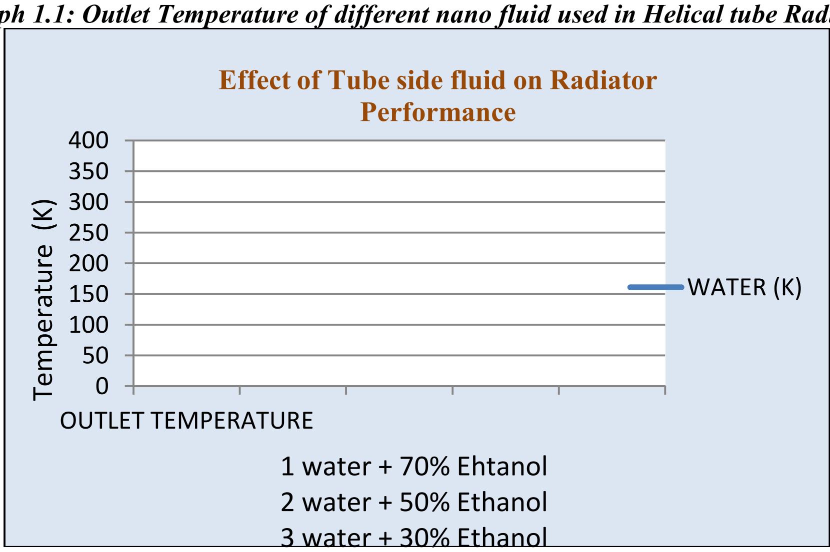


Figure 1.11: Temperature diagram of helical tubes used in Radiator. (Water)

Coolant in temp(k)	**Coolant out temp(k)**	**Temperature difference(k)**
358.15	356.21	1.94

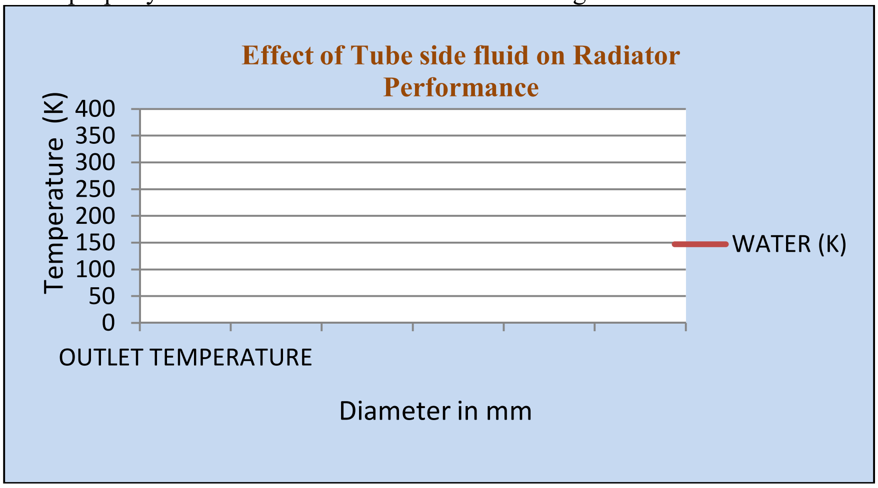


Graph 1.1: Outlet Temperature of different nano fluid used in Helical tube Radiator



Graph 1.2: Effect of percentage Ethanol on Tube Side Fluid of Helical tube

Also from the other comparison, we can conclude that by fixing the water proportion and taking the reading with different coolant (IE. Like Methanol, AL2O3, Ethanol) in 30 % mixing ration with the water, then the Ethanol gives the least outlet temperature of 349 K among all the mixtures and Ethanol gives the highest outlet temperature as 355 K. So from the result, it is desirable to use Ethanol with water, which gives better performance but the difference is not much more between all the coolants and that's why by sometimes seeing the toxicity and other property Ethanol is more desirable to use among all the coolants.



Graph 1.3: Effect of Tube Diameter on Radiator Performance

Graph 1.3 show the result for effect of tube diameter on radiator performance if we are decreasing the tube diameter, then the tube side outlet temperature will be increasing in the radiator 359K. As we are decreasing here the tube diameter, so as the diameter is decreasing the friction force acting at the extreme fiber of the intersection zone of inner fluid and the solid will be increasing and due to those phenomena the temperature rise in the small diameter tube and which is not desirable, it leads to poor performance.

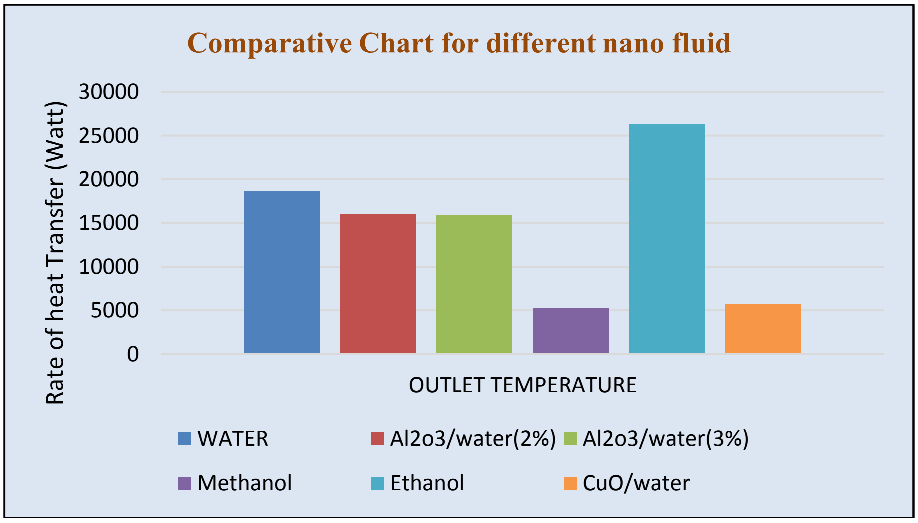
As discussed for the small scale radiator, again the flow is not distributed among tubes as seen in Figure 1.9. This non-uniformity also contributes to the temperature gradient among the tubes in the x-direction. According to the simulation, the average outlet coolant temperature was found as a result, According to this temperature drop, the total heat capacity of the radiator was calculated for different type of coolant;

$$Q = m\, C_p \Delta T$$

According to the Ansys CFD results for various nano fluid used in helical tube type radiator, the outlet temperature of nano fluid is determined and numerically determined outlet temperatures, which is quite acceptable. The heat capacity of the radiator is determined as by the calculations using the relation given above.

Table: 1.1 Rate of Heat dissipation through helical tube radiator

Coolant Used in Radiator	**Mass flow rate m (Kg/Sec)**	**Specific Heat C_p (KJ/KgK)**	**Temperature difference ΔT (k)**	**Rate of Heat dissipation $Q = m\, C_p \Delta T$ (Watt)**
Water	2.3	4181.7	1.94	18658.7
Al2o3 water nano fluid 2%:	2.3	4120.5	1.69	16016.38
Al2o3 water nano fluid 3%:	2.3	4086.2	1.69	15883.05
Methanol (CH4O)	2.3	2500	0.91	5232.5
Ethanol C2H6O	2.3	2500	4.58	26335
CuO/water	2.3	4150.9	0.6	5728.24



Graph 1.4: Rate of Heat dissipation through Helical tube Radiator

Summary And Conclusions: To remunerate every one of these elements radiator centre size required might be extensive. In this study approach has been made to increase the value of air flow rate which in turn takes care of the size of the radiator.

- We can conclude that by fixing the water proportion and taking the reading with different coolant (i.e. Like Ethanol, Methanol, Al_2O_3/water2%, Al_2O_3/water3% and CuO/water) in 30 % mixing ration with the water, then the CuO/water gives the highest outlet temperature 357.55K among all the mixtures and ethanol gives the least outlet temperature 353.57K. So from the result, it is desirable to use ethanol with water, which gives better performance but the difference is not much more between all the coolants and that's why by sometimes seeing the toxicity and other property Ethanol is more desirable to use among all the coolants, it gives the low temperature at the outlet.
- We are increasing the water in the mixture tube side outlet temperature will be decreasing in the radiator, So as the higher mixing ration of the water is desirable for achieving better performance of the radiator.
- Also from the other comparison, if we are decreasing the tube diameter up to 2mm, then the tube side outlet temperature will be increasing in the radiator 359K. As we are decreasing here the tube diameter, so as the diameter is decreasing the friction force acting at the extreme fibre of the intersection zone of inner fluid and the solid will be increasing and due to those phenomena the temperature rise in the small diameter tube and which is not desirable, it leads to poor performance.
- For helical tubes Radiator; there are used four coolants Ethanol, Methanol, Al_2O_3/water2%, Al_2O_3/water3% and CuO/water; Ethanol maximum temperature drop compared to other coolant. So, there is Ethanol which is best among four coolants, related to heat dissipation.

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