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Design and Performance Analysis of Louvered Fin Automotive Radiator using CAE Tools

Vishwa Deepak Dwivedi
Scholar of Master of Technology,
Mechanical Engineering Department,
UCER, Allahabad, India

Ranjeet Rai
Assistant Professor,
Mechanical Engineering Department,
UCER, Allahabad, India

***Abstract*--Researches in heat transfer have been carried out over the previous several decades, leading to the development of the currently used heat transfer enhancement techniques. The water and ethylene glycol as conventional coolant have been widely used in an automotive radiator in many years. With the advancement of nanotechnology, a coolant are invented which is known as "nanofluids". The Researchers found that these fluids offer higher thermal conductivity compared to that of conventional coolants. The study is focused on the performance evaluation of the louvered fin based tube automotive radiator using nanofluids as coolant. The compact radiator is basically used in automotive vehicles. In the present work, relevant input data, nanofluid properties and empirical correlations is taken from previous literatures and is analyzed the fluid flow and cooling capacity characteristics of a compact automotive radiator operated with the use of nano fluid like Si C based fluid.**

An automotive radiator (louvered fin type) model is modeled on modeling software CATIA V5 and performance evaluation is done on pre-processing software ANSYS 14.0. Present study outline that the nano fluids may effectively use as coolant in automotive radiators to improve the performance. The temperature and velocity distribution of coolant and air are analyzed by using Computational fluid dynamics environment software CFX. Results have shown that the rate of heat transfer is better when nano fluid (Si C + water) is used as coolant, than the conventional coolant.

Keywords-- Automotive radiator, Nanofluid, Louvered fin and Circular tube geometry, performance parameters.

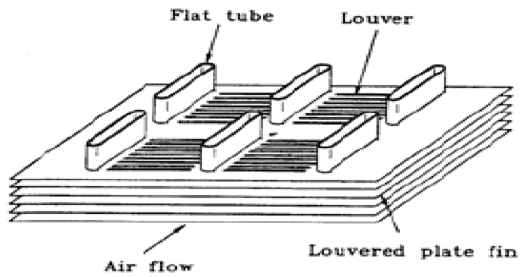
I. INTRODUCTION

The growth of technology found in high tech industries, such as automobiles, microelectronics, transportation, and manufacturing has created a specific way for scientific advances that would have wide ranging effects on many obstacles facing today's scientific world such as system efficiency, reliability and pollution. However, many factors are underlined in the development of the automotive industries among them as one point is the ability to rapid cooling of the products. Cooling is one of the important process for maintaining and enhancing the operational performance of the system as a result caused by the increase in power and reduces in sizes and weight in future products. Thus researchers are starting to invest more specific way to efficient and effective heat transfer processes.

Continuous technological development in automotive industries has demand for high efficiency engines. A high efficiency engine is not only based on the performance of radiator but also depends on better fuel economy and less emission rate. Reducing the vehicle weight by optimizing design and size of a radiator is a capital feature. Addition of fins is one of the approaches to increase the heat transfer rate of radiator, provides greater heat transfer area and enhances the air convective heat transfer coefficient.

Recently there has been considerable research outlining superior heat transfer performances of nano fluids in automotive radiator. As per need, there is a new and innovative heat transfer fluid, known as "Nanofluid" (a suspension of nanometer-sized metallic particles less than 100nm in a base fluid) for improving the heat transfer rate in an automotive radiator. Nanofluids are superior as a heat transfer agent over conventional fluid (Water + EG). The idea behind development of nanofluids is to improve the heat transfer coefficient and to minimize the size of heat transfer equipments for conservation of material and energy. Nanofluids have invented a new path in the field of thermal engineering and are taken to be a new generation fluid for dissipation of heat in many fields such as transportation, electronics, medical, nuclear, food, space vehicles and manufacturing of many other products. With the use of nano fluids, there be about 10-20% of heat transfer enhancement can be achieved. It provides better aerodynamic characteristics for design of an automotive vehicle.

The purpose of the paper is to predict the flow behaviour and temperature distribution of a louvered type fin tube cooling units with nanofluids (Si C based fluid) and to calculate and compare the loss in temperature in conventional and nanofluids (Si C based fluid) as coolant in the radiator model with CFX analysis.



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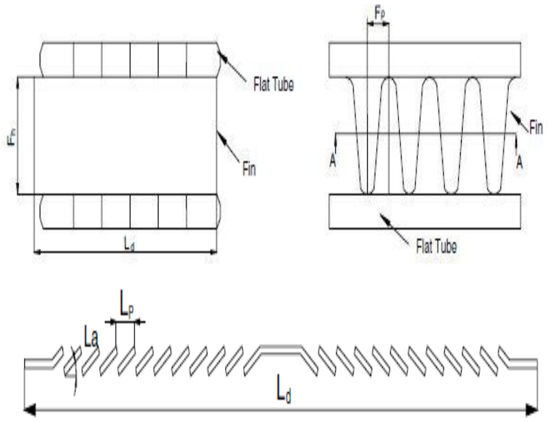

Fig.1. Louvered fin geometry

II. MATHEMATICAL MODELLING

A. Problem geometry

The automotive radiator is a type of compact heat exchanger, is made of four major components as coolant inlet tank, outlet tank, pressure cap and core. The main subcomponents of the core are coolant tubes and fins. Circular tubes are more effective for automotive engine applications due to their low drag compared with elliptical tubes.

The design is a circular tube and louvered fin based compact automotive radiator which is designed for getting high cooling rate with nanofluids. There are 644 circular tubes which are arranged in parallel design use for the support of 346 fins as well as contain the necessary volume of coolant.

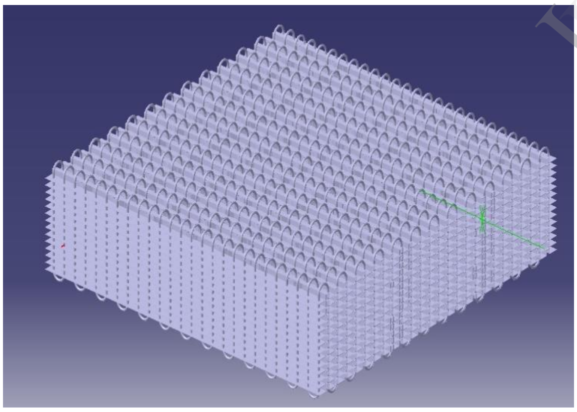

Fig.2. Isometric view of automotive radiator on CATIA

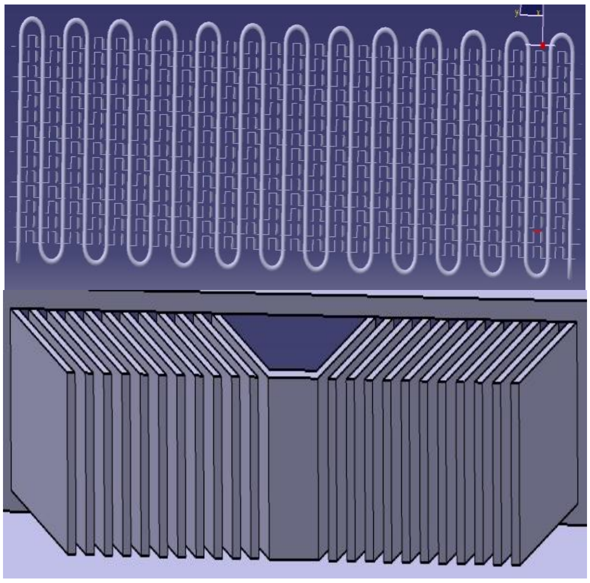

Fig.3. Front view of circular tubes and multi louvered fin

The governing equations

The governing equations are assumed to be steady state for in compressible fluid and the fluid inside the tube has Newtonian behaviour. The density of the water and ethylene glycol-based nanofluids is almost constant under pressure. Ambient temperature and an air velocity through the air cooled exchanger are assumed to constant. Inlet velocity and temperature of the circular tube is uniform. Thermal equilibrium is established between the Nanoparticles and the base fluid. The wall resistance and fouling factors are taken as negligible. The following assumptions have been made for analysis:

- Properties of nanofluid as well as air assumed to be constant.
- Steady state process.
- All the heat rejected from nanofluid absorbed by air flow through radiator.

III. INPUT PARAMETERS

The radiator which is considered, is mounted on the present turbo-charged diesel engine is cross flow compact heat exchanger with unmixed fluids. Radiator consists of 644 tubes make of brass (Thermal conductivity is considered as 120 W/m K) and 346 continuous fins made of aluminum alloy (thermal conductivity is considered as 177 W/m K). For designing and performance analyses of compact automotive radiator (louvered fin type) using nanofluid as coolant (Si C + water) whose thermal conductivity is 350 W/m K. The following parameters are given as;

TABLE I. Fluid parameters and Normal Operating conditions

S. No.	*Description*	*Air*	*Coolant*
1.	Fluid mass rate	20 Kg/s	6 Kg/s
2.	Fluid inlet temperature	35 ℃	95 ℃
3.	Core Width	0.6m	
4.	Core height	0.6 m	
5.	Core depth	0.017m	

TABLE II. Surface core geometry of flat tubes

S. No.	*Description*	*Air side*	*Coolant side*
1.	Fin pitch	0.0446 fin/m	
2.	Fin metal thickness	0.00025 m	
3.	Hydraulic diameter	0.00351 m	0.00373 m
4.	Fin area	0.845	

TABLE III. Specification of louvered fin parameters

S. No.	*Description*	*Fin Dimension*
1.	Louver angle (L_a)	28°
2.	Fin pitch (F_p)	0.002 m
3.	Louver pitch (L_p)	0.0012 m
4.	Fin height (F_h)	0.008 m
5.	Louver height (L_h)	0.0065 m
6.	Louver length (L_d)	0.0366 m

IV. SIMULATION PROCESS

For implementing the analysis, pre-processing software ANSYS 14.0 is used for the compact heat exchanger. This software is useful in analyzing the fluid properties at operating temperatures is estimating the velocity and temperature distribution of coolant and air of cross flow automotive radiator.

Numerical simulation approach is adopted using the theory of three-dimensional computational fluid dynamics and flow direction is studied with the help of CFX. With this approach, it was able to generate three dimensional patterns for temperature and pressure of coolant and air, inside and outside the radiator respectively.

As the model analysis is difficult with available resources, 644 tubes model is reduced to 15 tubes model which gives the same result, in the specific ratio. The radiator model is imported from CATIA to ANSYS through a neutral file format STEP. Imported model contains only single volume of radiator with fins. For the analysis of the radiator model, we need volume of coolant and air flow.

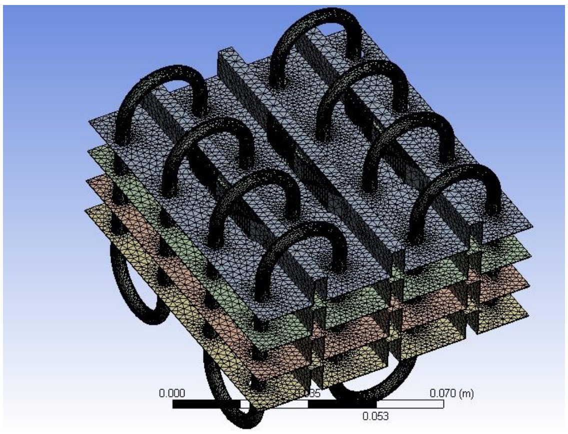

Fig.4. Meshing of a section of radiator on ANSYS

RESULTS AND DISCUSSION

The simulation results obtained show reasonable variation in the temperature as expected. A drop in temperature of the coolant (Si C) from 375 K to 351 K.

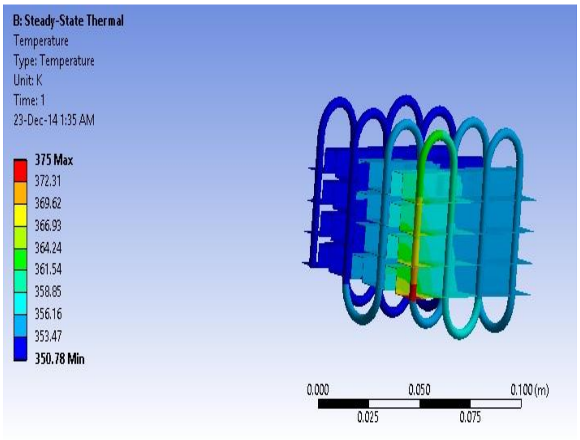

Fig.5.The variation of coolant (Si C) temperature (K)

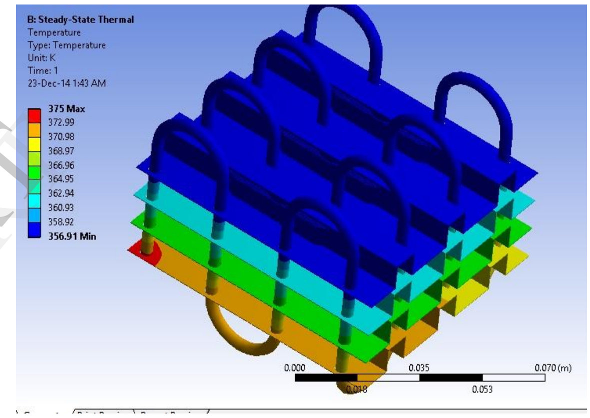

Fig.6.The variation of coolant (water) temperature (K)

The loss in temperature across the tube length for the water as coolant and nano fluid as coolant are shown below. Where the drop in temperature with water as coolant is from 375 to 357 i.e. 18°C and with nano fluid as coolant, it is 375 to 351 i.e. 24°C. So by this it has been shown that heat transfer of nano fluid is better than that of water as coolant in compact radiator.

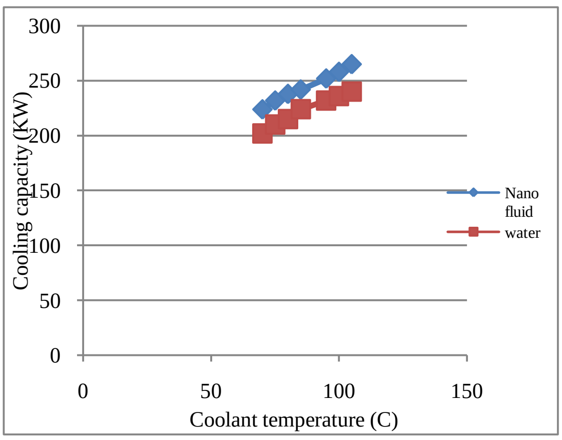

Fig.7. Effect of coolant temperature on cooling capacity

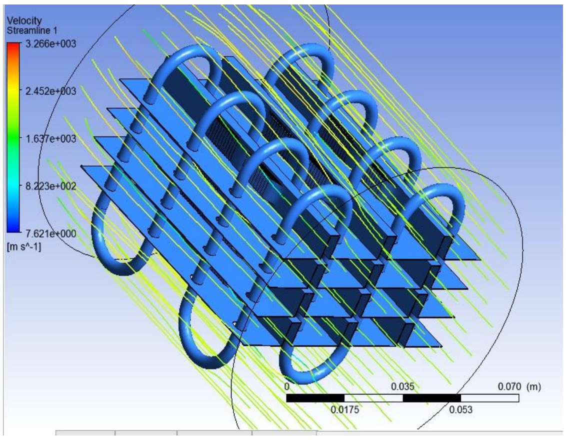

Fig.8. Air flow variation through the radiator

As heat transfer rate is more in tubes when coolant just enters. As the air flow rate is very less in between the tubes, heat transfer rate is less in the centre tubes when compared to that of end tubes.

Due to friction in the tubes, there will be loss of pressure across the tubes. As there are number of tubes and in each tube input pressure and output pressure vary from each other, we get a graph of pressure variation along the tube length.

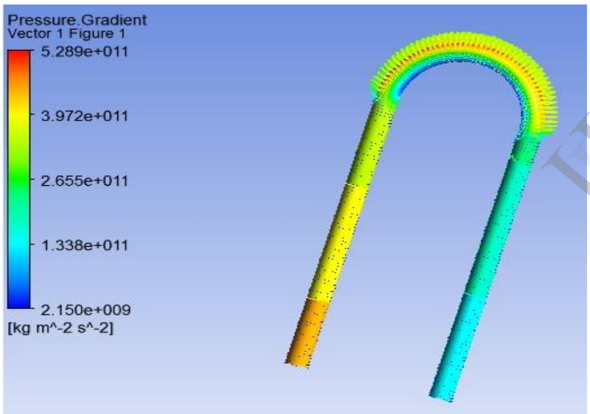

Fig.9. Pressure distribution of the coolant through tube length

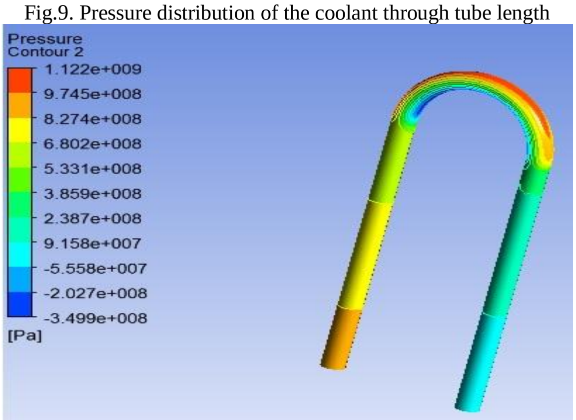

Fig.10. Contours of pressure distribution of coolant through tube

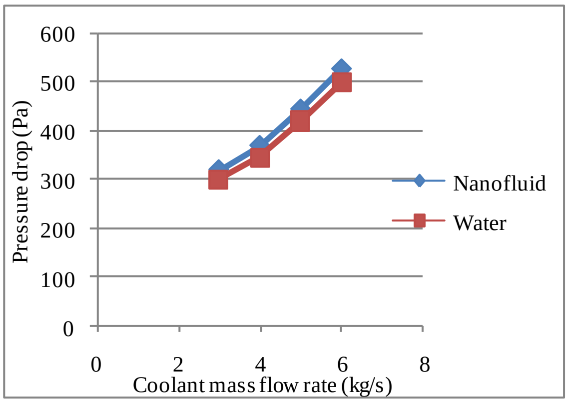

Fig.11. Effect of mass flow rate of coolant on Pressure drop

V. CONCLUSION

The fluid flow and heat transfer analysis of the automotive radiator (louver fin) with nano fluid is successfully carried out. The variations in the pressure, temperature and velocity in the direction of coolant flow and air flow is analyzed. With the computational time and available resources, the results obtained are to be satisfied. It is obtained that temperature drop of conventional coolant is 18℃ and for nanofluid as coolant, is 24℃ and pressure drop of 500 Pa. So when compared for conventional coolant (water), the heat transfer rate is higher when nanofluid is used as coolant on same radiator model.

As we can find that we can reduce the size of the radiator by using nanofluid as coolant to obtain higher cooling capacity by which we can optimize the size, weight and cost of automotive vehicles in recent years.

Based on results and comparisons, following conclusions are obtained;

- Cooling capacity increases with increase in mass flow rate of air and coolant.
- Reduction in cooling capacity with the increase in inlet air temperature while cooling capacity increases with the increase in inlet coolant temperature.
- The pressure drop also increases with the increase in air and coolant mass flow rate through radiator.
- About 6% increment in cooling capacity with the use of louver fin heat exchanger with nanofluid as compared to conventional coolant with the same model.

However, a continued study in various aspects for a better design of the radiator is suggested as;

- Experimental set up will be prepared for different fin geometry and comparison of this result will be done with experimental data.

Nomenclature

A	total heat transfer area (m^2)
A_f	fin area
C	heat capacity rate (W/K)
c_p	specific heat (J/kg K)
C*	heat capacity ratio
D_h	hydraulic diameter (m)
f	friction factor
F_h	fin height (m)
F_p	fin pitch (m)

h heat transfer coefficient (W/m^2 K)
k thermal conductivity (W/m K)
L_a louver angle (degree)
L_d fin length (m)
L_h louver height (m)
L_p louver pitch (m)
Nu Nusselt number
Pr Prandtl number
Q heat transfer rate (W)
Re Reynolds number
t fin thickness (m)
T Temperature (K)
u fluid velocity (m/s)
U overall heat transfer coefficient (W/m^2 K)
$\dot{m}$ mass flow rate (kg/s)
ΔP pressure drop (Pa)
η_f fin efficiency
μ dynamic viscosity (Ns/m^2)
ρ density (kg/m^3)
σ minimum free flow area/frontal area
ε heat exchanger effectiveness

REFERENCES

1) J. Dong, J. Chen, Z. Chen, W. Zhang and Y. Zhou {2007} 'Heat transfer and pressure drop correlations for the multi-louvered fin compact heat exchangers, Energy Conversion and Management, Vol. 48, pp.1506-1515.
2) Gunnasegaran, shuaib N.H., Abdul Jalala, M.F. and Sandhita {2012} 'Numerical Study of Fluid Dynamic and Heat Transfer in a Compact Heat Exchanger Using Nanofluids', ISRN Mechanical Engineering , Vol.2012, Article ID 585496.
3) J. Koo and C. Kleinstreuer {2004} 'A new thermal conductivity model for nanofluids', Journal Nano particle Research, Vol. 6, pp. 577-588.
4) K.Y. Leong, R. Saidur, S.N. Kazi and A. H. Mamun, {2010} 'Performance investigation of an automotive car radiator operated with nanofluid – based coolants (nanofluid as a coolant in a radiator)', Applied Thermal Engineering, Vol. 30, pp. 2685-2692.
5) S.M. Peyghambarzadeh, S.H. Hashemabadi, S.M. Hoseini, and M. Seifi Jamnani, {2011} 'Improving the cooling performance of automobile radiator with Al_2O_3/water nanofluid', Applied Thermal Engineering, Vol. 31, pp. 1833-1838.
6) R. Tarodiya, J. Sarkar and J. V. Tirkey {2012} 'Preformance of flat fin tube automotive radiator using nanofluids as coolants, Emerging trends in mechanical engineering ETME 422-429.
7) R. Strandberg and D.K. Das {2010} 'Finned tube performance evaluation with nanofluids and conventional heat transfer fluids', International Journal Thermal Sciences, Vol. 49, pp. 580-588.
8) R. S. Vajjha, D.K. Das, and P. K. Namburu, P.K.{2010} 'Numerical Study of fluid dynamic and heat transfer performance of Al_2O_3 and Cu O nanofluids in the flat tubes of a radiator', International Journal Heat fluid Flow, Vol. 31, pp. 613-621.
9) Deepak Chintakayal and Rajamanickam C S {2013} 'CFD analysis of fluid flow and heat transfer of an automotive radiator with nanofluid', Auto Vertical, L& T IES.
10) Adnan M. Hussein, R. K. Bakar, K. Kadirgama and K.V. Sharma {2014} 'Heat transfer enhancement using nanofluids in an automotive cooling system', International communications in heat and mass transfer Vol. 53, pp. 195-202.
11) Vahid Delavari and Seyed Hassan Hashemabadi {2014} 'CFD simulation of heat transfer enhancement of Al_2O_3/water and Al_2O_3/ethylene glycol nanofluids in a car radiator' Applied Thermal Engineering, Vol. 73, pp. 378-388.