A review on Performance evaluation of different coolants used in car radiator: A Finite Element Analysis

Rohit Kumar Namdeo[1], Prof K.K. Jain[2]
[1] *Research Scholar, department of mechanical Engg. SRIT, Jabalpur (M.P)*
[2] *Professor, department of mechanical Engg. SRIT, Jabalpur (M.P)*

Abstract- **In automobile industry continuous expanded the need of superior, best economy, ideal outline of motor. Radiator is utilized like a cooling segment of motor, and for the most part water is utilized as coolant. In fluid cooled framework, warm is isolates by means of coolant blending in the radiator. The coolant is move through pumps and the warmth is diverted by means of radiator. Optimization of outline and size of radiator is important for the effective cooling rate.**

This objective of the present review paper is "to evaluate the performance of the heat transfer characteristics of water/anti-freezing based fluid as a coolant for car radiator" based on previous research paper.

Index Terms- **; radiator, heat transfer rate, CFD, FEA approach etc.**

I. INTRODUCTION

1.1 General

In an automobile, fuel and air deliver power inside the engine through ignition. Just a segment of the aggregate generated power really supplies the automobile with power - the rest is squandered as fumes and warmth. On the off chance that this abundance warm isn't expelled, the engine temperature turns out to be too high which brings about overheating and viscosity breakdown of the lubricating oil, metal debilitating of the overheated engine parts, and worry between engine parts bringing about faster wear, in addition to other things.

A cooling system is utilized to evacuate this abundance warm. Most car cooling systems comprises of the accompanying components: radiator, water pump, electric cooling fan, radiator weight top, and thermostat. Of these components, the radiator is the most prominent piece of the system since it exchanges warm.

As coolant goes through the engine's cylinder block, it amasses warm. Once the coolant temperature increments over a specific edge esteem, the vehicle's thermostat triggers a valve which powers the coolant to move through the radiator.

As the coolant flows through the tubes of the radiator, warm is exchanged through the balances and tube dividers to the air by conduction and convection

HEAT TRANSFER THEORY

Heat transfer is the thermal energy in transit caused by a temperature difference. Heat transfer can occur basically in three different ways, namely – Conduction, Convection and Radiation. It can occur either alone or in combination depending on the object under consideration. When the object under study is stationary and there is a temperature gradient in it, heat transfer through conduction takes place. Similarly, the heat transfer which will occur between a moving fluid and a stationary object is significantly convection. Although in reality, convection doesn't exist alone and some amount of heat transfer takes place through radiation.

Conduction

''Conduction is the transfer of energy from high-energy particles of a substance to the adjacent low-energy particles as a result of interactions between the particles. In solids, conduction is the result of the vibrations of molecules and the energy transport by free electrons. The amount of energy transferred depends on the internal temperature difference in the volume, cross section area and thermal conductivity of the material. The heat transfer rate can be described by

$$Q_{cond} = kA \frac{dT}{dx} \quad \ldots\ldots\ldots\ldots \quad (1.1)$$

Where Q_{cond} is the rate of heat transfer, k is the thermal conductivity, A is the cross section area, is the temperature difference between the layers and is the distance between them.

Convection

''Convection is the energy transfer between a solid surface and an adjacent fluid that is in motion; it is the combined effect of conduction and fluid motion. Convection can be natural or forced. Natural convection is a form of conduction between the volume and the stationary fluid and occurs because of the density differences due to temperature change in the fluid. Natural convection can be described by

$Q_{conv} = hA_s(T - T_{00})$ ………… (1.2)

Where $Q_{conv}$the heat transfer rate, h is the convection heat transfer coefficient, As is the surface area, T is the volume temperature and T_{00} is the fluid temperature.

Radiation

''All bodies with a temperature above absolute zero emit thermal radiation. The energy emitted is in the form of electromagnetic waves and transfers heat from the volume to the surrounding environment. Radiation depends on the surface area of the volume, the temperature difference between the volume and the surrounding environment and the emissivity of the material. The emissivity is a measure of how close the material is to an ideal surface in terms of a maximum radiation rate. The net heat transferred by radiation can be described by

$Q_{rad} = \varepsilon\sigma A_s(T^4 - {T_{00}}^4)$ ………… (1.3)

Where Q_{rad} is the net heat transfer rate, ε is the emissivity, σ is the Stefan-Boltzmann constant, As is the surface area, T is the volume temperature and T_{00} is the surrounding air temperature.

1.2 The Cooling systems

When gasoline is combusted in an engine only 30 % of the chemical energy in the fuel is converted to useful work. The remaining energy is transformed to heat which must be removed from the engine in order to prevent the engine parts from overheating. To expand the heat dismissal from the engine a cooling system is used keeping in mind the end goal to exchange produced heat to the encompassing air. The cooling system in a cutting edge auto fundamentally comprises of three noteworthy subsystems, isolated by the distinction in cooling fluid, which is straightforwardly or in a roundabout way associated with the engine (Figure 1.1). These subsystems redirect around 50 % of the created heat in the engine and exchange it to the particular cooling fluid

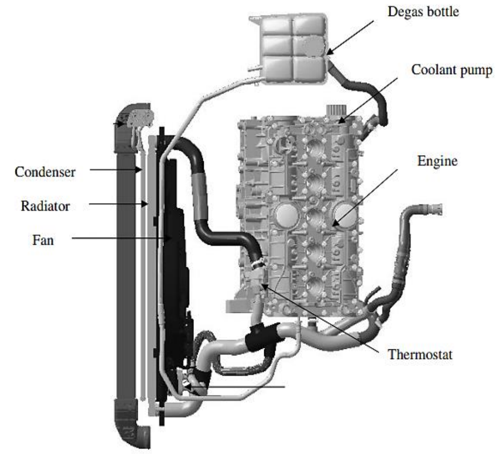

Figure 1.1 Cooling System

Radiator

The radiator is a component used to transfer heat from the coolant to the ambient air. The coolant flows in tubes from side to side, and the air flows in the transverse direction forced by the vehicle speed and under some circumstances by the fan. To increase the heat transfer, flat metal pieces known as fins are attached to the tubes. This increases the area where heat transfer can take place. Depending on gearbox selection, two different configurations of the radiator exists.

As the coolant flow through the components in the Low Temperature circuit it will accumulate heat before it reaches the radiator where the coolant is cooled itself. The radiator is a type of heat exchanger located in the front of the vehicle (behind the grille) utilizing ambient air to cool the coolant flowing through its finned heat exchanger tubes [2].

The heat transfer between the coolant and air occurs by conduction through the tube walls and fins as well as by convection [2]. As with all heat transfer, the temperature difference between the coolant and the air is an important aspect determining the heat transfer rate in the radiator. Two other important aspects of the radiator cooling power is coolant flow and air flow, which in contrast to the temperature difference can be controlled.

In order to avoid overcooling of the coolant, keeping the coolant temperature optimal, the coolant flow is sometimes directed past the radiator [3]. This is controlled by a self-regulating wax thermostat which opening area is determined by the temperature of the coolant.

Generally the air flow through the radiator is determined by the vehicle speed. However, the air flow can be controlled by using radiator shutters (grille shutter and spoiler shutter) and a radiator fan. The radiator shutters are vanes that blocks air flow through the grille and spoilers, this is done both in order to control the temperature of the coolant but also to reduce drag (improve fuel economy) [3]. The radiator fan is placed behind the heat exchangers to regulate the air flow, this is particularly useful when idling since the "natural" air flow caused by driving then is close to zero.

II-LITERATURE REVIEW

The various researchers have been study the cooling performance of radiators some of them are:

“Experimental investigation of heat transfer potential of Al2O3/ Water-Mono Ethylene Glycol nanofluids as a car radiator coolant”, Dattatraya G. Subhedar, Bharat M. Ramani, Akhilesh Gupta, 2018, Case Studies in Thermal Engineering 11 (2018) 26–34

In this examination, the heat transfer potential of Al_2O_3/Water-Mono Ethylene Glycol nano-fluids is explored tentatively as a coolant for auto radiators. The base liquid was the blend of water and mono ethylene glycol with 50:50 extents by volume. The stable nano-fluids got by ultra-sonication are utilized as a part of all trials. In this study nanoparticle volume fraction, coolant flow rate, inlet temperature used in the ranges of 0.2–0.8%, 4–9 l per minute and 65–85 °C.

The results show that the heat transfer performance of radiator is enhanced by using nano-fluids compared to conventional coolant. Nano-fluid with lowest 0.2% volume fraction 30% rise in heat transfer is observed. Also the estimation of reduction in frontal area of radiator if base fluid is replaced by Nano-fluid is done which will make lighter cooling system, produce less drag and save the fuel cost.

“Thermos-physical properties and heat transfer characteristics of water/anti-freezing and Al_2O_3/CuO based nanofluid as a coolant for car radiator” Alhassan Salami Tijani, Ahmad Suhail bin Sudirman, 2018, International Journal of Heat and Mass Transfer 118 (2018) 48–57

In this paper the performance of the heat transfer characteristics were evaluated based on certain parameters which are the heat transfer coefficient, thermal conductivity, Nusselt number, and rate of heat transfer of the nano-fluids. It was found that the nanofluid that exhibited the highest heat transfer performance was the CuO nanofluid.

“Full vehicle CFD investigations on the influence of front-end configuration on radiator performance and cooling drag”, Chunhui Zhang, Mesbah Uddin, Clay Robinson, Lee Foster, 2017, Applied Thermal Engineering (2017)

It is demonstrated in this study that by properly manipulating the cooling air flow pattern, simultaneous improvement of radiator performance and total vehicle drag can be achieved. The cooling air stream not just purposes drag specifically, the communication of under-body stream with other vehicle parts may prompt more obstruction drag. This paper presents computational examinations to explore underhood air stream highlights related with radiator execution and cooling drag. Moreover, examination of the effect of the front grille opening size and underhood aloof streamlined gadgets on the cooling drag and radiator execution are introduced in view of full vehicle CFD simulations carried out using a model of Hyundai Veloster.

“Heat transfer enhancement of Al_2O_3-EG nanofluid in a car radiator with wire coil inserts”, 2017, K. Goudarzia1 and H. Jamali, Applied Thermal Engineering (2017)

In this exploratory examination, Aluminums Oxide (Al_2O_3) in Ethylene Glycol (EG) as nanofluid was utilized for warm move upgrade in auto radiator together with wire loop embeds. Two wire coils embeds with various geometry and nanofluids with volume centralizations of 0.08%, 0.5% and 1% were examined. The results indicated that the use of coils inserts enhanced heat transfer rates up to 9 %. In addition, the simultaneous use of the coils inserts with the nanofluid with concentration of 0.08%, 0.5% and 1% resulted the thermal performance enhancement up to 5% as compared to the use of coils inserts alone.

“CFD Analysis of Radiator”, 2016, C. Uma Maheswari, C. Suresh Reddy, C, Rajeshwara Reddy, A.T. Kiran Sai Naidu, C. Saradhi, A. Chenna kesavulu

This paper manages the warm and CFD investigation of vehicle radiator. The hypothetical figuring has been done in MAT Lab by differing the mass flow rate of coolant. Displaying has been done in Solidworks and sent out to Ansys for CFD investigation. The temperature distribution, heat transfer rate for different velocities of coolant to has been done for different tube materials such as copper, aluminium and stainless steel. The numerical results were compared and found that copper has best heat transfer rate and has better efficiency than the others.

3 MODELLING AND SIMULATION

There are a few methods for acquiring the numerical formulation of a heat conduction issue, for example, the finite distinction technique, the finite element strategy, the limit element technique, and the energy adjust (or control volume) strategy. The flow of thermal energy from issue possessing one region in space to issue involving an alternate region in space is known as heat transfer. Heat transfer can occur by three main methods: conduction, convection, and radiation. The fluid flow and heat transfer are effective and complex parameters in radiator flattened tube. CFD simulation depends upon many factors. Geometry modeling and its boundary condition, grid generation, choice of fluent parameters are significantly affect the simulation process.

Ansys Fluent 15.0 is a fluid analysis software of Ansys workbench platform. Ansys combines the cad modeling, complex mesh generation, algorithm solution and post processing facility.

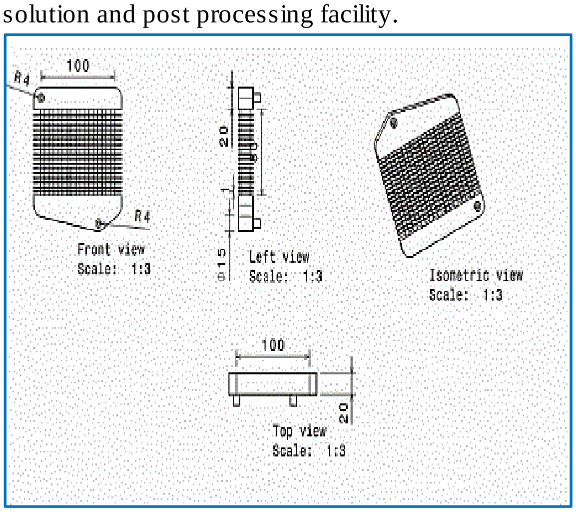

Figure 3.2 Geometry of Radiator

IV CONCLUSION

The heat transfer performance of both Al_2O_3 and CuO contained Water fluid were determined and compared against each other. Both fluids were also compared to the base fluid water to determine the best fluid to be used as coolant in the car radiator.

The following results have been obtained based on previous study

- It is observed that the temperature difference is higher while increasing the coolant inlet temperature.
- There is close relation in between temperature difference and fluid inlet temperature as maximum value of R^2 can be obtained and the curve varies linearly.

The addition of Al_2O_3 and CuO particles to the water as coolant fluid of the car radiator enhanced the heat transfer performance, with an increase in the thermal conductivity, heat transfer coefficient and Nusselt number.

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