Review of Problems of Heat Transfer in Car Radiator and Suggested Solutions

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***Abstract* - As demand of more powerful engines in smaller hood space has created problem of insufficient rate of heat dissipation in automobile radiator. As result, many radiators are redesigned more compactly but having the same rate of heat transfer dissipation. There are several different approaches that can be used to optimize heat transfer performance of smaller radiator design. These are 1) Changing the fin design 2) Increasing the core depth 3) Changing the tube type 4) Changing the flow arrangement 5) Changing the fin material 6) Increasing the surface area to coolant ratio 7) Changing the different types of fluid and mixture concentration. For heat transfer enhancement in radiator design there is limitation on increasing number of fins and current technology gets it at maximize level. So there is need to look in something new technology which have large potential of heat transfer enhancement. It is seen that nano fluid is potential candidate for automobile sector. Heat transfer coefficient of nanofluid is higher than water or water - ethylene glycol mixture. As heat transfer can be improved by number of different ways (one of emerging is use of nanofluid) in Automobile radiators can be made energy efficient and compact. Reduced or compact shape may results in reduced drag, increase the fuel economy, and reduces the weight of vehicle. So it is Possible to design the more powerful engine of a car in smaller hood space.**

***Keywords*: Heat transfer problem, Radiator, Nano fluid**

I. INTRODUCTION

Radiators are heat exchanger which is used to transfer heat and thermal energy from one medium to another for the cooling or heating purpose. In automobile radiator is used to cool the automotive in which heat from engine is transfer to the fluid in radiator which further transfer to the outside air. The demand of more powerful engine in smaller hood spaces has created problem of insufficient rates of heat dissipation in automotive radiator. In an automobile engine, fuel an air produces power in the engine by combustion. Only some portion of generated power supplies to automobile as power the rest is wasted in the form of exhaust and heat. Radiator assembly consist of radiator, electric cooling fan, water pump, thermostat and radiator pressure cap. Insufficient heat dissipation in car radiator results in overheating of engine, cylinder deformation and wear between engine parts. To overcome this problem of high power generation and less radiator size, the automotive radiator must be redesigned to become more compact but still maintaining high level of heat transfer performance.

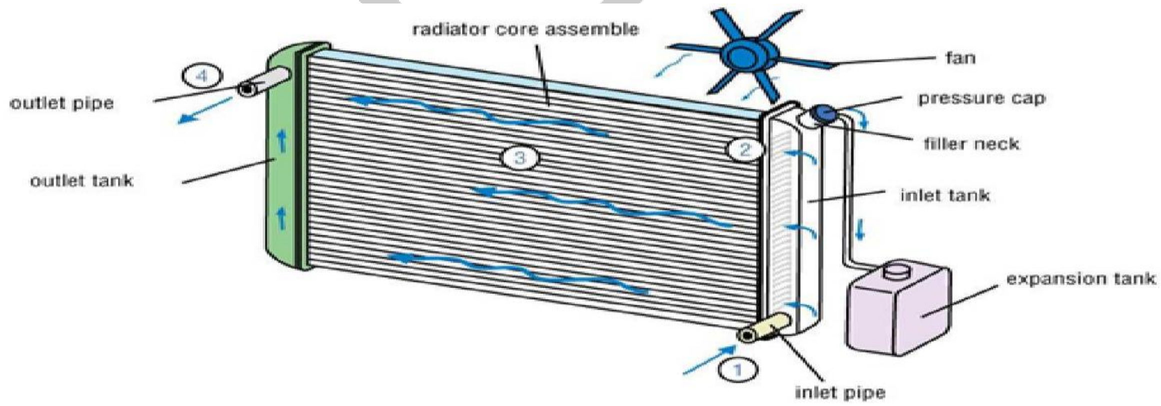

Figure 1: Components within an automobile cooling system

II. LITERATURE REVIEW

Yiding Cao et al.[1] They introduce application of heat pipe in automobile industry. In this application heat pipe is introduced in the automotive radiator to enhance heat transfer. The use of heat pipe increases the automobile radiator efficiency and reduces cooling fan power consumption. Heat pipes are wickless heat pipes and basically two- phase closed thermosyphons. The working fluids inside the heat pipe are different than the engine coolant. The effectiveness of heat pipe are hundred times higher than the copper. The gravity is used to assist the return fluid. Air is evocated from container and container is sealed. Heat was applied to the evaporator section, which causes the liquid to vaporize. The vapor then flows from the hotter section due to the higher vapor pressure to the colder section of the heat pipe, where it was condensed. The liquid condensate then returns to the evaporator section from the condenser section under the assistance of gravity.

Efeovbokhan et al. [2] The cooling properties of a locally formulated coolant (sample c) its boiling characterized and specific heat capacity were investigated along with common coolant water(as sample A) and a commercial coolant (sample B). The results off investigation showed that sample C gave the best performance compared to other two samples A and B. The boiling point of sample B is higher than sample A and C is higher than B. This means that the possibility of a boil-out of sample C from the radiator is littlecompared to samples A and B. Also, for the same quantity of coolant more heat would be required to raisesample C to its boiling point than for samples A and B. The better cooling is achieved using sample C.

Oliet et al. [3]Studied different factors which influences the radiator performance. It includes air, fin density, coolant flow and air inlet temperature. The radiator performance depends upon air and coolant mass flow rate. When air and coolant flow rates increases the efficiency of radiator also increases. When inlet air temperature increases the cooling capacity decreases.Smaller fin spacing and greater louver fin angle have higher heat transfer. Fin density may be increased till it blocks the air flow and heat transfer rate reduced.

Jama et al. [4]The air flow distribution and non-uniformity across the radiator of full size Australian made ford falcon was tested in industrial wind tunnel. The cooling air intake of the vehicle were shielded by a quarter, one half and three quarter and fully blocked. The best method to shield front end is to employ horizontal method. This shielding method produces the more uniform cooling airflow distribution compared to other methods. Non uniformity index increased significantly as the front end air intake area was shielded. It is reduced the cooling capacity of the vehicle. These shielding methods also produced higher average velocity across the radiator which is analogous to better cooling.

Sadik Kakac, et al [5] In his literature survey showed that nanofluids significantly improve the heat transfer capability of conventional heat transfer fluids such as oil or water by suspending nanoparticles in these base liquids. The understanding of the fundamentals of heat transfer and wall friction is prime importance for developing nanofluids for a wide range of heat transfer application. He concluded that although there are recent developments in the study of heat transfer with nanofluids, more experimental results and the theoretical understanding of the mechanisms of the particle movements are needed to understand heat transfer and fluid flow behavior of nanofluids.

D. Chintakayala et al. [6] In the present study a Nano fluid is used as a coolant in a radiator model and radiator model is modeled in CATIA modeling software and is meshed using a pre-processing software GAMBIT. It is analyzed and presented by using a Computational Fluid Dynamics (CFD) environment software FLUENT. In results velocity distribution graphs shown that the radiator design have to be optimized to eliminate water stagnation. To account for the variation of the inlet conditions with time as in practical cases, transient analysis can be done.

A. Sing [7] Nano fluid is the suspensions of nano particle in base fluid. Nano fluid are the unique feature which is different from conventional liquid solid mixture in which nm or μm sized particle are added in the base fluid to enhance the heat transfer rate. Most system/process whose performance is affected by the heat transfer disepetationnanao fluid provides very important role in such case. It is evident that the effects of viscosity and thermal conductivity should be considered together.

D. Sandhya [8] The performance of ethylene glycol and water based TiO_2 nano fluid as an automobile radiator coolant is determined experimentally.The preparation of nanofluid is as 40% ethylene glycol and 60% water with volume concentration of 0.1%, 0.3%, and 0.5% of TiO_2 nano powder.The degree of heat transfer enhancement is depends on quantity of nanoparticle added in the base fluid. At the concentration of 0.5%, the heat transfer enhancement of 35% compared to base fluid was observed. The increase in flow rate of working fluid enhance the heat transfer coefficient for both water and nanofluidconsiderably the variation of fluid inlet temperature to the radiator slightly influence the heat transfer rate. Brownian motion of nanoparticles may one of the major factor in heat transfer enhancement.

S. Heris [9] They study the effect of water ethylene glycol mixture base nanofluid in a car radiator. Significant enhancements in heat transfer rate are observed using this mixture. The highest Nu number enhancement up to 55% was obtained in 0.8 % volume concentration of CuO and water ethylene glycol mixture. As increase in inlet temperature the Nu number is increased.

III. PROBLEM DESCRIPTION

From the law of thermodynamics, we know that as we increase the area of radiator the heat transfer enhancement also increases. But as demand of more powerful engines in smaller hood space has created problem of insufficient rate of heat dissipation in automobile radiator. As result, many radiators are redesigned more compactly but having the same rate of heat transfer dissipation.

Methods

Heat transfer enhancement methods are generally classified into three categories:

1) Active method 2) Passive method 3) Compound method

Active Method
Active heat transfer enhancement methods require external power input, it is done using the mechanical aids.

Passive Method
While in passive method of heat transfer enhancement does not require any external power input. One of the ways in passive method to enhance heat transfer is to increase the effective surface area and resistance time of the heat transfer fluid.

Compound method
When both active technique and passive technique are used simultaneously for increasing heat transfer of any devices, which is greater than by using any one method at a time, then this term is known as the compound method. Uses both external power sources and geometry design changes[11]

Methods of heat transfer enhancement in radiator
There are several different approaches that can be used to optimize heat transfer performance of smaller radiator design. These are 1) Changing the fin design 2) Increasing the core depth 3) Changing the tube type 4) Changing the flow arrangement 5) Changing the fin material 6) Increasing the surface area to coolant ratio 7) Changing the different types of fluid and mixture concentration.

Among the methods mentioned above any one method can be used to enhance the heat transfer rate and then to minimize the radiator size. The selection of method is done as per the application requirement and utilizing range. The changing fin design and increase the number of fins can reached at certain level and there is certain limitation on number of new fins. So its need to look in something new technology which can wide scope of heat transfer enhancement process. Among all it is convenient to use the last method that is changing the different types of fluid and mixture concentration. It does not require to any geometrical change in radiator fin design. The use of nanofluid is one of them.[10]

Nanofluid
The currently water or mixture of water- ethylene glycol is used as radiator coolant. The concept of nanofluid is firstly proposed by choi.Nano fluid contains nanometer sized particles, called nanoparticles. These nano particles are added in the base fluid. The nanoparticles of nanofluids are typically made of metals, carbides, oxides or carbon nanotubes. The water or mixture of water – ethylene glycol are used as a base fluid. By using the nano particle in radiator it increases the heat transfer coefficient compared to base fluid.

Important Formulae
According to Newton's law of cooling heat transfer coefficient and corresponding Nu number can be calculated as [12]

$$Q = h\ A\ \Delta T = h\ As\ (Tb\text{-}Ts) \quad (1)$$

As is the surface area of the tube, Tb is the bulk temperature,

$$Tb = (Tin + Tout) / 2 \quad (2)$$

Tin and Tout are inlet and outlet temperatures respectively and Ts is the tube wall temperature which is the mean value by two surface thermocouples as

$$Ts = (T1 + \ldots\ldots.+Tn) / n \quad (3)$$

And heat transfer rate calculated by

$$Q = m^*C\ \Delta T = m^*C\ (Tin - Tout) \quad (4)$$

$m^*$is mass flow rate which is determined as

$$m^* = \rho\ V^* \quad (5)$$

The heat transfer coefficient can be evaluated by combining eqs. 1 and eqs. 4

$$hexp = m^*C\ (Tin - Tout) / As\ (Tb - Ts) \quad (6)$$

and the Nusselt number can be calculated as

$$Nu = hexp\ Dh / k \quad (7)$$

Dh is the hydraulic diameter

$$Dh = 4\times\ Area / perimeter. \quad (8)$$

Reynolds number (Re) is determined as

$$ReD = \rho nf\ Dh\ u / \mu nf \quad (9)$$

Experimental Review on Car Radiator

Table 1: Experimental Review

Author	Nano Particle	Working Conditions	Result/Conclusion
Adan Hussein [12]	SiO2	Four different Concenration1-2.5%	1. Heat transfer rate increases with concentration. 2. Friction Factor increases.

		Flow rate 2 to 8 lpm	Heat transfer rate increases with increase in flow rate.
		Reynolds number 500-1750	Friction factor decreases with increase in flow rate.
		Inlet temperature	Nusselt number increases.
S.M. Hoseini [13]	Al2O3 + Water	Concentration	Heat transfer rate increases with increase in volume concentration.
		Flow rate	With increase in flow rate heat
M. Naraki [13]	CuO /Water	Concentration 0-0.4%	Overall heat transfer coefficientincreases with increase in concentration.
		Inlet temperature 50-80˚C	Heat transfer rate decreases with increase in inlet temperature.
Peyghamba- rzadeh [14]	CuO And Fe2O3	Nano particle CuO,Fe2O3	Fe2O3 has high heat transfer capacity
		Concentration	Heat transfer rate increases with Increase in concentration.
		Inlet temperature	With increase in inlet temperature heat transfer decreases.
		Air velocity	With increase in air velocity heat transfer rate increases.
		Flow rate	Heat transfer rate increases with flow rate.
Ravi Adwani [15]	Al_2O_3	Concentration 2%,4%,6%	With increase Concentration heat transfer increases.
		Different Load Condition	With increase in load, heat increases transfer

IV. Conclusion

- Efficiency of radiator increases by inserting heat pipe in radiator core.
- For heat transfer enhancement in radiator design there is limitation on increasing number of fins and current technology gets it at maximize level.
- It is seen that nano fluid is potential candidate for automobile sector. Heat transfer coefficient of nanofluid is higher than water or water - ethylene glycol mixture.
- Heat transfer rate increases of Nano fluid is affected by number of parameters like volume concentration, flow rate, Inlet temperaturespecific heat capacity ofparticle, density,viscosity,thermal conductivity, Size and Shape of Nano particle.
- As heat transfer can be improved by number of different ways (one of emerging is use of nanofluid) in Automobile radiators can be made energy efficient and compact. Reduced or compact shape may results in reduced drag , increase the fuel economy, reduce the weight of vehicle.
- Possible to design the more powerful engine of a car in smaller hood space**.**

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