Heat Transfer Enhancement in Automobile Radiator Using Nanofluids: A Review

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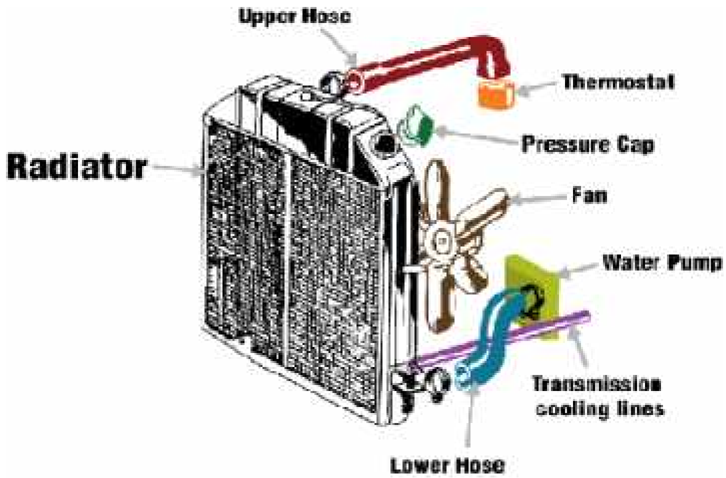
ABSTRACT:
In today's world one of the most important tasks is to handle the energy available and to minimize the heat losses. Talking about the automobile sector, engine is the prime energy source. Cooling system in any automobile system is of utmost importance as it carries the heat from the engine and dispenses it to the atmosphere. It also enhances the fuel economy and heat transfer rate which in turn helps in maximizing the engine performance.
Keywords*: Radiator, Nanofluids, Nanoparticles, Ethylene Glycol, Propylene Glycol, thermal conductivity, heat transfer coefficient, effectiveness.*

INTRODUCTION:

High performance cooling is the need of the hour. Most internal combustion engines are fluid cooled either air or liquid cooled in which case a liquid coolant is made to flow through a heat exchanger commonly known as radiator. The heat transfer rate can be enhanced by different ways and means. Extended surfaces also called as fins are provided to the radiator which increases the surface area for heat transfer and thus give a comparatively higher heat transfer as compared to one without fins. The performance of radiator strongly depends upon different parameters like fluid thermal conductivity, Reynolds number nusselt number prandtl number.

Various coolants are being used in automobile radiator to serve the purpose of heat transfer. Different fluids have different thermal properties and hence perform in different ways. Water being available readily is the prime coolant used in automobile radiators. However, some other fluids are often mixed with water in required proportion to get desirable heat transfer characteristics. Ethylene glycol is one such coolant mixed with water.



A typical car radiator assembly with fan mounted at back

Now a days a new type of coolants are being tested and researches have been carried out to study the enhanced heat transfer rate of a radiator by using nanofluids. Nanofluids are those fluids which carry some additional very small sized solid particles typically of order of nanometer in the base fluid coolants. Addition of such nano particles increases the effective surface area which increases the heat transfer rate ultimately. The added advantage of using this method is that it does not require any design changes to the existing radiator design. Such fluids have a high efficiency heat transfer characteristics as compared to conventional fluids as these have higher thermal conductivity than other fluids. Some typical nano particles made up of pure metals are iron (Fe), Copper (Cu), Gold (Au), silver (Ag). Nano particles of metal oxides likes copper oxide(CuO), Ferro ferric oxide(Fe_3O_4),silicon dioxide (SiO_2), Zinc oxide(ZnO), Titanium dioxide (TiO_2), aluminum oxide (Al_2O_3) are also used. Silicon carbides, titanium carbides, silicon nitrides and aluminum nitrides are the common carbides and nitrides used as nanoparticles. The characteristics of nanofluid are given by its various properties like average particle size, specific surface area and thermal conductivity.

The governing heat transfer equation of a heat exchanger is Q=mCp(Tin-Tout) where, Q= amount of heat transferred, m= mass flow rate, Cp= Specific heat of Fluid and Tin and Tout are inlet and outlet temperature of flowing fluid. There are two fluids flowing through a heat exchanger namely hot and cold fluid. The hot fluid transfer heat to the cold fluid as it flows. The overall heat balance equation for a heat exchanger is Qhot=Qcold i.e. the amount of heat absorbed by the cold fluid is same as that being liberated by hot fluid. Qcold=mcCpc(Tcout - Tcin) where mc= mass flow rate of cold fluid, Cpc = Specific heat of cold fluid, Tcin, Tcout are inlet and outlet temperatures of cold fluid respectively.

Another thing that determines the heat exchanger performance is the effectiveness of heat exchanger which is defined as ratio of actual heat transfer to the maximum possible heat transfer.

Effectiveness=Qactual / Qmax

LITERATURE REVIEW:

Rahul Bhagore et.al performed and experiment on an automobile radiator with Al2O3 nanofluid they observed that with increase in volume concentration of nanoparticles (ranging from 0% to 1%) heat transfer rate is increased. He observed that by adding of 1% Al2O3 nanoparticles at constant air Reynolds number of 84391 and constant mass flow rate (0.05 Kg/s), an increase of about 40% heat transfer was achieved . Also overall heat transfer based on air side was found to be increased by about 36% with addition of 1% Al2O3 nanoparticles by volume fraction than the base fluid at constant air Reynolds number and constant mass flow rate. He also noted that at the same particle volume fraction, mass flow rate and air Reynolds number, effectiveness of the radiator increased up to 40%.[1]

Golakiya Satyamkumar et.al studied the heat transfer in an automobile radiator. He found out that by adding 4% volume fraction of Al2O3 in water heat transfer rate increases by 17% further, addition of 8% volume fraction of Al2O3 in water the effective heat transfer increase is of about 26% in as compared to water as coolant.[2]

J.R. Patel, A.M. Mavani et.al studied the fluid flow in an automobile radiator on CFD analysis using STAR CCM+ software. by using CuO /water nanofluid as a coolant at a constant mass flow rate of 4 Kg/s. He concluded that CFD Analysis results fairly matches with the experimental results which show that CFD analysis is a good tool for avoiding costly and time consuming experimental work.[3]

Parashurama M S et.al performed an experimental investigation to study the use of CuO-water nanofluid as a coolant in a radiator of army tanker diesel engine. The heat transfer rate for a 10% volume fraction of CuO-water nanofluid was studied. It was found that the overall heat transfer coefficient of nanofluid is higher than that of water alone and hence the total heat transfer area of the radiator can be reduced. However, the associated pumping power was found to increase which may impose some limitations on the efficient use of this type of nanofluid in automotive diesel engine radiators.[4]

Navid Bozorgan et.al in a study did numerical investigation of the use of CuO-water nanofluid as a coolant in a radiator of Chevrolet Suburban diesel engine with a given heat ex- change capacity. The local convective and overall heat transfer coefficients and pumping power for CuO-water nanofluid at different volume fractions (0.1% - 2%) were studied under turbulent flow conditions. He also considered the effects of the coolant Reynolds number and the vehicle speed on the radiator performance in his work. The simulation results indicate that the overall heat transfer coefficient of nanofluid was found to be higher than that of water alone and therefore the total heat transfer area of the radiator can be reduced. He also found out that associated pumping power also increases which might reduce the efficiency of radiator to some extent.[5]

JP Yadav and Bharat Raj Singh performed a comparative study between different coolants viz water and mixture of water and propylene glycol in a ratio of 40:60. He found out a high difference in the cooling capacity of the radiator when the flowing coolant was changed from water to water-propylene glycol mixture. He concluded that this is on the account of a very high value of specific heat of water in comparison to the mixture. It therefore can be concluded that the water is still the best coolant but its corrosive properties and the fact that water contains dissolved salts which in turn obstructs the coolant flow passage.

On the basis of his study he further concluded that:-

1. The cooling capacity and the effectiveness are directly proportional to the inlet temperature of hot coolant i.e. as the value of inlet coolant temperature

increases the cooling capacity & the effectiveness of the radiator increases respectively.

2. The cooling capacity and the effectiveness are also directly proportional to the mass flow rate of the coolant.[6]

V. L. Bhimani et.al In his experimental work heat transfer coefficients in the automobile radiator have been measured with two distinct working liquids: pure water and water based nanofluid (small amount of TiO2 nanoparticle in water) at different concentrations and temperatures and concluded as follows:

1. The presence of TiO2 nanoparticle in water at the concentration of 1 vol. %, the heat transfer enhancement of 40-45% compared to pure water was recorded.

2. Increasing the flow rate of working fluid (or equally Re) enhances the heat transfer coefficient for both pure water and nanofluid considerably.

3. In the study he also found out that the increase in the effective thermal conductivity and the variations of the other physical properties does not affect the heat transfer enhancement on a large extent. Brownian motion of nanoparticles maybe one of the factors in the enhancement of heat transfer.[7]

Hardikkumar B Patel performed a CFD analysis of a car radiator from a comparative study he concluded that by fixing the water proportion and taking the reading with different coolant (IE. Like Methanol, Propanol, Ethanol) in 50 % mixing ration with the water, then the Ethanol gives the highest outlet temperature of 351.3 C among all the mixtures and Methanol gives the Least outlet temperature as 350.1 C. So from the result, it is desirable to use Methanol with water, which gives better performance however is other coolants have similar properties and hence sometimes it is seen that other fluids are used as well keeping in mind the toxicity and other properties Ethanol is more desirable to use among all the coolants even it gives the high temperature at the outlet.[8]

S.P. Venkatesanet.al conducted an experiment on automobile radiator at constant air Reynolds number (84391) and constant mass flow rate (0.08 Kg/s). With the increase in volume fraction of Al2O3 particles dynamic viscosity of nanofluid was found to be increased. An overall heat transfer coefficient 490 W/m2K was achieved for 1% Al2O3 in mixture of EG/water (50% volume concentration) nanofluid coolant compared 305 W/m2K for base fluid which is about 60% increase. By increasing the volume concentration of Al2O3 nanoparticles in the base fluid keeping air Reynolds number and mass flow rate constant, it increases the total heat transfer and effectiveness of the radiator. An increase of volume concentration of the Al2O3 particles in the base fluids within the optimal level of 1% will increases the effectiveness of the radiator up to 40% .[9]

P.K.Trivedi et.al performed a CFD analysis to study heat transfer analysis of an automotive radiator. Results Showed that the heat transfer rate as well as efficiency can be increased by increasing the air mass flow rate.[10]

P. Sai Sasank et.al in an experiment, by using water as base fluid and Al2O3 nanofluid in different concentrations 0.025%, 0.05%, 0.1% as test fluids found out that the enhancement in heat transfer has increased by augmentation in the concentrations of nanoparticle, Improvement in the heat transfer rate was about 12.4% for 0.1% Al2O3 nanofluid at 80ºC.[11]

Archit Deshpande et.al conducted experiments using MWCNT-water nanofluid and Water as engine coolants at varied temperatures (50ºC, 60ºC, 70ºC). Keeping the particle concentration of nanofluid at 0.2% gm/litre. The thermal capacity was observed to be 19.26 kW at 50ºC. also with a rise in temperature to 60ºC There was a rise of 53.27% in capacity. The capacity further enhanced to 37.45 kW at 70ºC. Thus he concluded that as the temperature increases there is an increase in thermal capacity. Similar experiments were performed using water as coolant and the results were found to be 14.547kW, 26.137kW & 31.748kW at 50ºC, 60ºC and 70ºC respectively. It can be observed that with MWCNT nanofluid higher heat transfer capacities can be attained in all cases.[12]

Aditya choure et.al with his experimental setup found out thatdecrease in mass flow rate results in higher temperature difference between the inlet and outlet temperature of the coolant which could be due to the fact that coolant is gets more time to absorb heat from the heat source. Also among all fluids, Al2O3 nanofluid is having better temperature difference.[13]

Murat Unverdi et.al studied the The fluctuation of the nano particles and their effects on the fluid to find out that it leads to the change of the flow structure, especially at higher Reynolds numbers. He also calculated the Nusslet numbers and pressure drops of the nanofluids for the flow rate of

90 kg/h of hot water, Reynolds number was varied between 600 and 1900 and the volume concentration of Al2O3/water nanofluids in 0.25%, 0.5%, 0.75% and 1%. The highest increase in Nusselt number occurs in 1 % volume concentration. Also increase of about 29.42 %, 24.34 %, 18.02 %, 15.37 %, 11.74 % and 9.43 % respectively for nanofluid flow rates of 90, 120, 150, 180, 240 and 300 kg/h.[14]

Mohammad Hemmat Esfe et.al in his experiment, studied the variations of effective thermal conductivity ofMgO/water–EG (60:40) with temperature and particle concentration and suggested new correlations by using regression at different solid volume fractions and temperatures. He concluded that the thermal conductivity of nanofluid increases with increasing temperature. However the variations of thermal conductivity with temperature were more tangible at higher concentration. On the contrary, he also said that at low solid volume fraction, the thermal conductivity is unaffected by temperature.[15]

Krishna Mundada et.al performed a comparative study of different nano fluids in radiator he found out that with water as base fluids The thermal capacity of the Nano fluids decreases with increase in volume fraction but in case of Ethylene Glycol as base fluids it increases for Al2O3, CuO,TiO2,Fe3O4 nanoparticles with different volume fraction. (EG+water) mixture and nanofluids enhances thermal conductivity almost upto 45% also that using Al2O3 nanoparticles is more benefial than CuO nanoparticles based on the performance index for 1.5- 2%vol. fraction.[16]

Ramjee Singh Prajapati et.al Experimented on an unmixed-unmixed cross flow heat exchanger with different flow rate and different composition of hot fluid and studied the effect of these parameters on outlet temperatures and overall heat transfer coefficient. It was found that with the increase in the mass flow rate of cold fluid the cold fluid outlet temperature decreases. Also for an unmixed-unmixed heat exchanger a noticeable downfall in performance is observed when percentage of coolant in water coolant mixture exceeds 50% as the viscosity becomes higher at higher concentration and the circulation of fluid will affect and heat transfer rate decreases. [17]

V.Niveditha et.al on comparing for all Nano fluids for 0.2 volume fraction in aluminum and copper radiator found out that Heat transfer rate is more for Aluminum Oxide than ethylene Glycol. On performing CFD analysis it was observed that, heat flux is more when Copper is used than Aluminum alloy.[18]

Dr.Syed Amjad Ahmad et.al In an experiment found out that As the concentration of nanofluids increases the heat transfer rate also increases, also it was found to be maximum at 0.30%,but with the further increase in concentration, heat transfer rate declines, maintaining the constant flow rate. As the amount of nanofluids was increased up to 0.50% the heat transfer rate increased initially but then falls to the rate same as at 0.1%, keeping the flow rate constant 11 liters per minute.[19]

Rashmi Rekha Sahoo et.al performed experiment to study energetic as exergetic performance analyses of louvered fin and flat tube automotive radiator using various coolants (water, EG, PG, water-EG brine, water-PG brine, sugar-cane juice and alumina-water nanofluid). She found out that at higher temperatures Sugarcane juice gives better heat transfer and pressure drop characteristics The effectiveness, Heat transfer rate, pumping power increases with coolant mass flow rate. The coolant flow rate and pumping power reduce by 13% and 41% respectively, when sugar cane juice is used in place of water [20]

D.Srinivasu et.al in his study studied the heat transfer phenomena in a louver fin radiator were numerically dissected at constant air flow of 40Kmph and constant flow rate (0.05L/min) has been carried out. nanofluid viscosity was found to increase With increase in the volume fraction of Al2O3 particles dynamic. The overall heat transfer coefficient based on the air side increase in the volume concentration of Al2O3 particles in the base fluid. He also found out that increase of about 78% in heat transfer coefficient can be achieved for 5% Al2O3+mixture of water-EG (50% volume concentration of Ethyl glycol) nanofluid as compared to based fluid. In this process constant air Reynolds number (1046.8) and constant flow rate (0.05L/min.) an exponential increase in heat transfer was observed by increasing the volume fraction of Alumina particles.[21]

P.Prasad et.al compared the rectangular and louvered finned heat exchanger with 50/50 Ethylene glycol and water mixture as working fluid and observed that louvered fins exhibit better heat transfer characteristics as compared to rectangular fins. The heat transfer rate was found to be 49% more for louvered fins as compared to rectangular fins. He also found that the velocity of air was significantly higher for louvered fins which might be a contributing factor for enhanced heat transfer rate in louvered fins.[22]

by using ε–NTU method using 80%water-20%EG-based Cu, SiC, Al2O3 and TiO2 nanofluids as coolant for louvered fin geometry **Jahar Sarkar et.al** did a detailed parametric studies on automotive radiator and found that relatively lower (by about 2%) pumping power is required with the use of nanofluid in radiator one interesting thing that was observed was however the cooling capacity and effectiveness increase by adding nano particle but beyond 1% volume fraction decrement in the effectiveness and cooling capacity was observed.[23]

Sai Kiran .S et.al compared the results of CFD analysis with the experimental results and found them to be in good agreement with each other.According to him,the Brownian motion of the nanoparticles plays a vital role in improvement in heat transfer rate of radiator. As the nanoparticles move randomly in the fluid it results in the decrease of the boundary layer thickness and thus enhancing the heat transfer. It is observed that nanoparticle concentration plays an important role towards heat transfer enhancement.[24]

S no	Nano particle	Base fluid	Particle vol fraction	K enhancement	Heat transfer enhancement	reference
1	Al2O3	Water	6.8%		40%	Nguyen et al. [25]
2	Al2O3	HP COOL GARD	3.5%	10.41 %	-	Kole et al.[26]
3	ZnO	Ethylene Glycol	5%	26.5%	-	Yu et al. [27]
4	CuO	water	.4%	17%	8%	Naraki et al. [28]
5	Cu	Ethylene Glycol	.30%	40%		Eastman et al. [29]
6	Al2O3	Water	.35%	15%	40%	Heris et al. [30]
7	Al2O3	Water	1%	3%	45%	Peyghambarzadeh et al. [31]

CONCLUSION:

From the study of this review it could be concluded that:

1.Heat transfer through radiator is an important aspect in overall performance evaluation of an automobile as better cooling increases the engine performance.

2.There are number of ways in which better heat transfer can be achieved namely extended surfaces as fins which increase the outer heat transfer area and hence the heat transfer capacity.

3.Another method of heat transfer enhancement is by louvering of fins, it is seen that by changing the orientation angle of a fin the velocity of air passing can be increased and as a result better cooling is achieved.

4.By varying the coolant composition by adding some different additives as nano particles the effective heat transfer area on the coolant side can be increased.

5.The major problem with nanofluid is the stability of nanofluids and thus it make it difficult to use.

6.The effect of nanofluid on overall behavior of radiator is still not clear as this technology is in its early phase.

7.The cost of manufacturing nanofluids is quite high.

A number of different combinations of base fluid with different additives could be used accordingly. Addition of small amount of nanoparticle increases the viscosity and thermal conductivity moderately. Also with the increase of mass flow rate the heat transfer rate increases. Higher the particle volume concentration of nanoparticle higher is the thermal conductivity. The addition of nanoparticles increases the heat transfer surface area which in turn increases the pumping power required. so it would be right to say that if we could control fluid properties as per our requirements the efficiency could be increased as well.

FUTURE SCOPE:

This paper presents an outlook of different additives used in radiator and it is clear that a lot of work has been done in this field but there is always scope of improvement. From the review presented it is quite evident that by varying the coolant properties the heat transfer can be enhanced The main conclusions from the review are the heat transfer from the radiator depends on various factors like coolant inlet temperature, thermal conductivity, mass flow rates and air Reynolds number. Addition of different additives such as Ethylene glycol, propylene glycol affects the radiator performance accordingly Ethylene Glycol and Propylene Glycols are used as antifreeze agents where as nanoparticles like Al2O3, CuO, TiO2 increases the heat transfer rate of the radiator. Glycols are known to have antifreeze properties but still there is scope of improvement nanofluids though increase the heat transfer but also the pumping power also there is the problem of stability of nanoparticles in base fluids that makes it difficult to use nano coolants commercially. All these problems needed to be addressed in order to bring nanofluids in common use.

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