A Review on Automobile Radiator to Improve Heat Transfer Rate using Nano-Fluids

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Abstract— In today's world the need of energy consumption is increasing day by day, thus our major tasks is to control the energy available and to increase the heat transfer rate. In automobile sector, for cooling purpose radiator plays an important role in heat exachange. Commonly used coolants like water, ethylene glycol are not efficient enough to improve the car's performance. Therefore with the research in this field with introduction of 'nano-materials' and 'nano-fluids', it is observed that increase in the heat transfer of automobile radiator and the cooling efficiency of the radiator is improved. This paper contains literature survey in which different base fluid is used with nano fluids for cooling of engine.

Keywords: Radiator, Nanofluids, Nanoparticles, Ethylene Glycol, Base Fluids, Heat Transfer, Efficiency

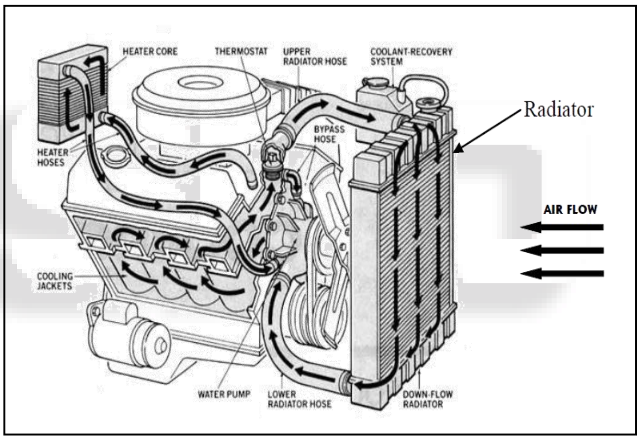
I. INTRODUCTION

Combustion of fuel air mixture in the cylinder of the engine produces considerable amount of heat and high temperatures. Heat is absorbed by the cylinder walls, cylinder heads and pistons. They in turn must be protected by the cooling system so that they do not become overheated. Cooling not only protect engine parts but also prevents oil in the engine parts from breaking down and losing its lubricating properties. While the engine must be cooled, it still needs to operate at temperatures as high as the lubricant will allow. Removing too much heat would lower the engine's thermal efficiency, and useful energy would be lost. This heat can be effectively removed with the help of radiator Figure below [3] [4] [5]

The radiator is a cross flow heat exchanger which transfers the heat from the fluid inside to the air outside, thereby cooling the fluid, which in turn cools the engine. Radiators are also often used to cool automatic transmission fluids, air conditioner refrigerant, intake air, and sometimes to cool motor oil or power steering fluid. Radiators are typically mounted in a position where they receive airflow from the forward movement of the vehicle, such as behind a front grill. Where engines are mid or rear-mounted, it is common to mount the radiator behind a front grill to achieve sufficient airflow, even though this requires long coolant pipes.

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.[7][8]

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 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.[9][10][11]



Overview of Radiator

II. LITERATURE REVIEW

Recent work carried out for experimental and numerical analysis of Radiator with nanofluids reviewed as follows.

A. B. C. Pak et al

Studied turbulent friction and heat transfer behaviors of dispersed fluids (i.e. ultrafine metallic oxide particles suspended in water) in a circular pipe experimentally. Viscosity measurements were also conducted using a Brookfield rotating viscometer. Two different metallic oxide particles, gamma-alumina (Al_2O_3) and titanium dioxide (TiO_2) were used as suspended particles.Therefore, better selection of particles having higher thermal conductivity and larger size is recommended in order to utilize dispersed fluids as a working medium to enhance heat transfer performance. Recent work carried out for experimental and numerical analysis of Radiator with nanofluids reviewed as follows.[1]

B. Heris et al

Presented an investigation of the laminar flow convective heat transfer of Al2O3 water under constant wall temperature with 0.22 volume concentration of nanoparticle for Reynolds number varying between 700 and 2050. The Nusselt number for the nanofluid was found to be greater than that of the base fluid and the heat transfer coefficient increased with an increase in particle concentration. The ratio of the measured heat transfer coefficients increases with the Peclet number as well as with nanoparticle concentrations.[2]

C. Wen et al

Assessed the convective heat transfer of nanofluids in the entrance region under laminar flow conditions. Aqueous based nanofluids containing Al2O3nanoparticle with sodium dodecyl benzene suffocate (SDBS) as the dispersant were tested under a constant heat flux boundary condition. For nanofluids containing 1.6 volume concentration, the local heat transfer coefficient in the entrance region was found to be 41% higher than that of the base fluid at the same flow rate.[3]

D. J.Y. Jung et al

Studied convective heat transfer coefficient and friction factor of nanofluids in rectangular micro channels. An integrated micro system consisting of a single micro channel on one side, and two localized heaters and five polysilicon temperature sensors along the channel on the other side were fabricated.The convective heat transfer coefficient of the Al2O3 nanofluid in laminar flow regime was measured to be increased up to 32% compared to the distilled water at a volume fraction of 1.8 volume percent without major friction loss. The Nusselt number measured increases with increasing the Reynolds number in laminar flow regime.[4]

E. Sharma et al

Experimented to evaluate heat transfer coefficient and friction factor for flow in a tube and with twisted tape inserts in the transition range of flow with Al2O3 nanofluid are conducted. The results showed considerable enhancement of convective heat transfer with Al2O3 nanofluids compared to flow with water.Heat transfer coefficient and pressure drop with nanofluid has been experimentally determined with tapes of different twist ratios and found to deviate with values obtained from equations developed for single-phase flow. A regression equation is developed to estimate the Nusselt number valid for both water and nanofluid flowing in the transition flow Reynolds number range in circular plain tube and with tape inserts.[5]

F. C.T. Nguyen et al

Experimentally investigated the behavior and heat transfer enhancement of a particular nanofluid, Al2O3 nanoparticle–water mixture, flowing inside a closed system for cooling of microprocessors or other electronic components. Experimental data, obtained for turbulent flow regime, have clearly shown that the inclusion of nanoparticles into distilled water has produced a considerable enhancement of the convective heat transfer coefficient. For a particular nanofluid with 6.8% particle volume concentration, heat transfer coefficient has been found to increase as much as 40% compared to that of the base fluid. It has also been found that an increase of particle concentration has produced a clear decrease of the heated component temperature.[6]

G. Gilles Roy et al

Investigated, the problem of laminar forced convection flow of nanofluids for two particular geometrical configurations, namely a uniformly heated tube and a system of parallel, coaxial and heated disks. Numerical results, as obtained for water–Al2O3 and Ethylene Glycol– Al2O3 mixtures, have clearly shown that the inclusion of nanoparticles into the base fluids has produced a considerable augmentation of the heat transfer coefficient that clearly increases with an increase of the particle concentration. However, the presence of such particles has also induced drastic effects on the wall shear stress that increases appreciably with the particle loading. Among the mixtures studied, the Ethylene Glycol– Al2O3 nanofluid appears to offer a better heat transfer enhancement than water– Al2O3 it is also the one that has induced more pronounced adverse effects on the wall shear stress.[7]

H. S. Kalaiselvam et al

This paper presents an experimental investigation of CuO–oleic acid nanofluids as a new phase change material for the thermal energy storage of cooling systems. This paper also presents the preparation of nanofluids, which is solid–liquid composite material consisting of CuO nanoparticles with sizes ranging from 1 to 80 nm dispersed in oleic acid. CuO nanoparticles were synthesized by precipitation method. Sedimentation photograph and particle size distribution of nanofluids prepared by two step method, illustrate the stability and evenness of dispersion.Similarly, complete melting times of nanofluids with 0.5, 1.0, 1.5 and 2 wt% of CuO nanoparticles could be saved by 7.14, 14.28, 25 and 28.57% respectively, than the base fluid. Thus, CuO–oleic acid nanofluids can be recommended as better PCM for cooling thermal energy storage applications.[8]

I. Ying Yang et al

The convective heat transfer coefficients of several nanoparticle-in-liquid dispersions (i.e. nanofluids) have been measured under laminar flow in a horizontal tube heat exchanger. The nanoparticles used in this research were graphitic in nature, with aspect ratios significantly different from one (l/d = 0.02). The graphite nanoparticles increased the static thermal conductivities of the fluid significantly at low weight fraction loadings. However, the experimental heat transfer coefficients showed lower increases than predicted by either the conventional heat transfer correlations for homogeneous fluids.[9]

J. Wenhua Yu et al

Experimented the heat transfer rates measured in the turbulent flow of a potential commercially viable nanofluid consisting of a 3.7% volume of 170-nm silicon carbide particles suspended in water. The properties and characteristics are favorable, and the fluid is available in large quantities. Heat transfer coefficient increase of 50–60% above the base fluid water was obtained when compared on the basis of constant Reynolds number. This enhancement is 14–32% higher than predicted by a standard single-phase turbulent heat transfer correlation pointing to heat transfer mechanisms that involve particle interactions. The data were well predicted by a correlation modified for Prandtl number dependence although experiments in the present study did not support the postulated mechanisms of Brownian diffusion and thermophoresis. This increase in heat transfer rate over prediction is a favorable result for nanofluid heat transfer enhancement.[10]

K. Kleinstreuer et al

In this research work, smaller and lighter high-performance cooling devices, steady laminar liquid nanofluid flow in microchannels was simulated and analyzed. Considering two types of nanofluids, i.e., copperoxide nanospheres at low volume concentrations in water or ethylene glycol, the conjugated heat transfer problem for microheat-sinks had been numerically solved. They employed new models for the effective thermal conductivity and dynamic viscosity of nanofluids, the impact of nanoparticle concentrations in these two mixture flows on the microchannels pressure gradients, temperature profiles and Nusselt numbers were computed, in light of aspect ratio, viscous dissipation, and enhanced temperature effects. Based on these results, recommendations were made for microheat- sink performance improvements: Use of large high-Prandtl number carrier fluids, nanoparticles at high volume concentrations of about 4% with elevated thermal conductivities and dielectric constants very close to that of the carrier fluid, microchannels with high aspect ratios, and treated channel walls to avoid nanoparticle accumulation.[11]

L. Darzi et al

Presented experimental investigation of turbulent heat transfer and flow characteristics ofSiO_2/water nanofluid within helically corrugated tubes. Water and SiO_2 with mean diameter of 30 nm were chosen as base fluid andnano-particles, respectively. Experiments were performed for plain tube and five roughened tube withvarious heights and pitches of corrugations. It shows that adding the nano-particles in tube with high height and small pitch of corrugations augments the heat transfer significantly with negligible pressured drop penalty.[12]

M. Ferrouillat et al

Experimental study has been carried out on water-based SiO2 and ZnO nanofluids flowing inside a horizontal tube whose wall temperature is imposed. Pressure drop and heat transfer coefficients have been measured at two different inlet temperatures (20^0C, 50^0C) in heating and/or cooling conditions at various flow rates (200 < Re< 15,000). The Reynolds and Nusselt numbers have been determined by using thermal conductivity and viscosity measured in the same conditions as those in tests. The results obtained show a small improvement of Nusselt numbers of studied nanofluids compared to those of the base fluid. An energy Performance Evaluation Criterion (PEC) has been defined to compare heat transfer rate to pumping power. Only nanofluid with ZnO nanoparticles having a shape factor greater than 3 appears to reach a PEC as high as that of water.[13]

N. Suresh et al

Presented effect of Al_2O_3–Cu/water hybrid nanofluid in heat transfer. In this experimental work, a fully developed laminar convective heat transfer and pressure drop characteristics through a uniformly heated circular tube using Al_2O_3–Cu/water hybrid nanofluid is presented.The experimental results also show that 0.1% Al_2O_3–Cu/water hybrid nanofluids have slightly higher friction factor when compared to 0.1% Al_2O_3/water nanofluids.[14]

O. D. Madhesh et al

In this study experimental study has been carried out of copper–titania hybrid nanofluids (HyNF).The nanofluids were prepared by dispersing the surface functionalized and crystalline copper–titania hybrid nanocomposite (HyNC) in the base fluid, with volume concentrations ranging from 0.1% to 2.0%. Beyond the volume concentration of 1.0% and up to 2.0%, the reduction in the convective heat transfer potential and the Nusselt number were marginal, which signified the effective thermal conductivity enhancement in HyNF. The functionalized structure and crystalline nature of HyNC acted as extended surfaces within the fluid medium, thereby creating more thermal interfaces for achieving improved thermal conductivity and the heat transfer potential of HyNF.[15]

Summary of maximum measured thermal conductivity enhancement for nanofluids containing metal oxide nanoparticles. The base fluids used are water, ethylene glycol and mineral oils.

Reference	Base fluid	Nanoparticles and Diameter	Maximum Concentration (vol.%)	Maximum Enhancement in *k* (%)
Pak (Pak and Cho 1998)	Water	Al_2O_3, 13 nm	4.3	32
Prasher (Prasher et al. 2005)	Water	Al_2O_3, 10 nm	0.5	100
Eastman (Eastman et al. 1996)	Water	CuO, 36 nm	5	60
Wang (Wang et al. 1999)	Ethylene Glycol	CuO, 23 nm	15	55

Metallic nanoparticles have much higher thermal conductivity than oxides, therefore theoretically much lower concentrations of metallic nanoparticles is needed in order to achieve the same level of thermal conductivity enhancement, or at the same concentration of nanoparticles, much higher enhancement can be obtained than that in those oxide nanofluids. Though not so many studies were conducted on nanofluids containing metallic nanoparticles as those on nanofluids containing oxides, the results have already shown more encouraging results, for example, up to 45% enhancement in thermal conductivity has been observed through the addition of less than 0.055 vol.% of 35 nm Cu particles into pump oil (Eastman et al. 1996). Eastman et al.(Eastman et al. 2001) also found 40% thermal conductivity enhancement in EG containing less than 0.3 vol.% Cu nanoparticles. Xuan et al. (Xuan and Li 2000) prepared nanofluids by directly mixing Cu nanopowders with water and oils. The nanofluids they measured were much more concentrated than those measured by Eastman et al., however, the thermal conductivity enhancement is comparable. At a Cu nanoparticle concentration of 7.5 vol.%, they were able to obtain 75% and 45% enhancements in water and transformer oil based nanofluids, which is summaries in below table.

Reference	Base fluid	Nanoparticles and Diameter	Maximum Concentration (vol.%)	Maximum Enhancement in *k* (%)
Eastman (Eastman et al. 1996)	Pump Oil	Cu, 35 nm	0.055	45
Xuan (Xuan and Li 2000)	Water	Cu, 100 nm	7.5	75
Eastman (Eastman et al. 2001)	Ethylene Glycol	Cu, 10 nm	0.2	40
Hong (Hong et al. 2006; Hong et al. 2005)	Ethylene Glycol	Fe, 10 nm	0.55	18

III. Conclusion

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

- Radiator plays an important role to increase heat transfer rate hence performance of an automobile improves as better cooling increases the engine performance.
- There are different ways by which heat transfer rate can be increased such as extended surfaces as fins which increase the surface area thus increases the heat transfer rate.
- Another method of heat transfer to increase heat transfer rate 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 can be achieved.
- It is observed that 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.
- The major problem with nanofluid is the stability of nanofluids and thus it make it difficult to use..
- The cost of manufacturing nanofluids is quite high.
- The results suggest that Cu nanofluid have high potential for flow and heat transfer enhancement and are highly appropriate to industrial and practical applications

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