COOLING EFFECT ENHANCEMENT OF AUTOMOBILE RADIATOR USING NANOFLUID: A REVIEW

Rahul D. Pande[1], Prof. S. S. Jawre[2], Prof. A. A. Kanaskar[3]

[1] *M. Tech. Scholar, Mechanical Engg. Department, S.S.P.A.C.E-Wardha, Maharashtra, India*
[2] *Assistant Professor, Mechanical Engg. Department, S.S.P.A.C.E-Wardha, Maharashtra, India*
[3] *Assistant Professor, Mechanical Engg. Department, S.S.P.A.C.E-Wardha, Maharashtra, India*

ABSTRACT

In the development of the many modern technology the primary challenge is thermal management. If we are looking towards the automobile sector the thermal management is the most difficult challenge. Nanofluids are suspension of metallic or nonmetallic nanoparticles in the base fluid; it can be used to increase the heat transfer rate of various applications such as internal cooling system of gas turbine blades, cooling system for automobile engine. This paper contains the literature survey which gives the techniques to implementation of the nanofluids in the automobile radiator for the cooling of engine.
Conventionally, water and ethylene glycol are used in automobile radiator as coolants. These coolants offer low thermal conductivity and therefore in the present work, thermal performance of the automobile radiator is carried out experimentally using convectional coolants and nanofluids. A critical literature review is carried out to understand various heat transfer properties of nanofluid. It is observed that thermal conductivity, viscosity depends strongly on concentration, particle size and temperature of nanofluid. There are many nanofluids which are used to improve thermal performance of car radiator.

Keyword : - *heat transfer , automobile radiator , nanofluids, coolants, etc….*

---

1. INTRODUCTION

Radiators also known as compact heat exchanger are classified as plate fin or tube fin heat exchangers. These heat exchangers can provide higher heat transfer coefficient in laminar flow than that offered by a highly turbulent flow in a plain tube situation. Experiments prove that by reducing the coolant flow rate, the time taken for the coolant to absorb heat from engine block and release it in the radiator will be expanded. Then the differential between temperature in and temperature out from the radiator will be at the highest stage. As the result, the heat dissipation from the radiator will be at the maximum point.
Many researchers have extensively investigated heat transfer enhancement by the various enhancement techniques, some of them had carried test using nanofluids in water. Nanofluids possess high specific surface area and therefore more heat transfer surface between particles and fluids, high dispersion stability with predominant Brownian motion of particles, reduced pumping power as compared to pure liquid to achieve equivalent heat transfer augmentation, reduced particle clogging as compared to convention slurries, thus promoting system miniaturization, adjustable properties, including thermal conductivity and surface wet ability, by varying particle concentrations to suit different applications.

1.1 Nanofluids

Nanofluids are a new class of fluids engineered by dispersing nanometer-sized materials (nanoparticles, Nanofibers, Nanotubes, Nanowires, Nanorods, Nanosheet, or droplets) in base fluids. In other words, nanofluids are nanoscale colloidal suspensions containing nanomaterials. They are two-phase systems with one phase (solid phase) in another (liquid phase). Nanofluids have been found to possess enhanced thermo physical properties such as thermal conductivity, thermal diffusivity, viscosity and convective heat transfer coefficients compared to those of base fluids like oil or water. It has demonstrated great potential applications in many fields. For a two-phase system, there are some important issues we have to face. One of the most important issues is the stability of nanofluids and it remains a big challenge to achieve desired stability of nanofluids. In this section we will review the new progress in the methods for preparing stable nanofluids and summarize the stability mechanisms. In recent years, nanofluids have attracted more and more attention.

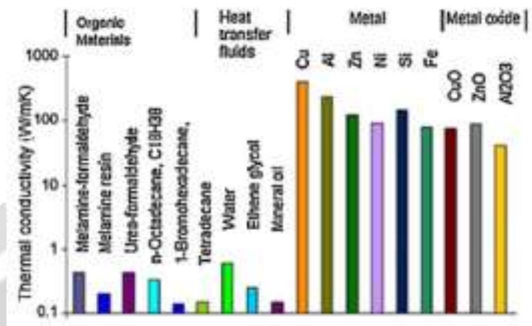

Fig -1: Thermal conductivity of typical materials

Figure 2.4 shows the thermal conductivity of typical materials. Solids have thermal conductivities that are orders of magnitude greater than those of traditional heat transfer fluids.

1.2 Particle Material and Base Fluid

Many different particle materials are used for nanofluid preparation. Al2O3, CuO, TiO2, SiC, TiC, Ag, Au, Cu, and Fe nanoparticles are frequently used in nanofluid research. Carbon nanotubes are also utilized due to their extremely high thermal conductivity in the longitudinal (axial) direction. Base fluids mostly used in the preparation of nanofluids are the common working fluids of heat transfer applications; such as, water, ethylene, glycol and engine oil. In order to improve the stability of nanoparticles inside the base fluid, some additives are added to the mixture in small amounts.

2. LITRATURE SURVEY

B. C. Pak et al. [3] 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 (Al2O3) and titanium dioxide (TiO2) were used as suspended particles. The Reynolds and Prandtl numbers varied in the ranges l04-I05 and 6.5-12.3, respectively. The viscosities of the dispersed fluids with gamma- Al2O3and TiO2 particles at a 10% volume concentration were approximately 200 and 3 times greater than that of water, respectively. These viscosity results were significantly larger than the predictions from the classical theory of suspension rheology. The Nusselt number of the dispersed fluids for fully developed turbulent flow increased with increasing volume concentration as well as the Reynolds number. However, it was found that the convective heat transfer coefficient of the dispersed fluid at a volume concentration of 3% was 12% smaller than that of pure water when compared under the condition of constant average velocity. 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.

Heris et al. [4] 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.

Wen et al. [5] Assessed the convective heat transfer of nanofluids in the entrance region under laminar flow conditions. Aqueous based nanofluids containing Al2O3 nanoparticle 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.

J.Y. Jung et al. [6] 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. Aluminum dioxide (Al2O3) with diameter of 170 nm nanofluids with various particle volume fractions were used in experiments to investigate the effect of the volume fraction of the nanoparticle to the convective heat transfer and fluid flow in micro channels. 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.

Sharma et al. [7] 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. The heat transfer coefficient of nanofluid flowing in a tube with 0.1% volume concentration is 23.7% higher when compared 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.

C.T. Nguyen et al [8] 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.

Gilles Roy et al [9] 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. For the case of tube flow, results have also shown that, in general, the heat transfer enhancement also increases considerably with an augmentation of the flow Reynolds number.

S. Kalaiselvam et al. [10] 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. Using thermal diffusivity analyzer, enhancement of thermal conductivity of nanofluids with different mass fraction of CuO nanoparticles was found to be higher than oleic acid. Based on the test results, complete solidification times of nanofluids with 0.5, 1.0, 1.5 and 2 wt% of CuO nanoparticles could be saved by 10.71, 16.07, 19.64 and 27.67% respectively, than the base fluid. 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.

Ying Yang et al. [11] 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.

Wenhua Yu et al. [12] 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.

Kleinstreuer et al [13] 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., copper oxide 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.

Darzi et al. [14] Presented experimental investigation of turbulent heat transfer and flow characteristics of SiO_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.

Ferrouillat et al. [15] Experimental study has been carried out on water-based SiO_2 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 (200 C, 500C) 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.

Suresh et al. [16] 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 convective heat transfer experimental results showed a maximum enhancement of 13.56% in Nusselt number at a Reynolds number of 1730 when compared to Nusselt number of water. 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.

4. CONCLUSIONS

Literature review reveals that

1. Addition of nanomaterial in the working fluid of automobile radiator can enhance its performance.

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

3. The presence of nanofluid in water can enhance the heat transfer rate of the automobile radiator. The degree of the heat transfer enhancement depends on the amount of nanoparticle added to pure water.

4. Use of Hybrid nanocomposite have contributed to the creation of effective thermal interfaces with the fluid medium enabling achievement in improved thermal conductivity and heat transfer potential of nanofluids

5. Many of the researchers have worked on the nanofluids such as Al_2O_3 and TiO_2, SiC etc.

6. Very few of them have worked on the hybrid nanofluid for radiator.

From above survey it is clear that, use of radiator with nanofluid has better performance. Further theoretical and experimental research investigations are needed to understand the heat transfer characteristics of nanofluids and identify new and unique applications for these fields.

6. REFERENCES

[1]. Moran, M.J. and Shapiro, H.N., ―Fundamentals of Engineering Thermodynamics, 5th Edn,‖ John Wiley & Sons, Hoboken, NJ, USA, 2004, 48-50.

[2]. Z.H. Liu and Y.Y. Li, ―A new frontier of nanofluid research – Application of nanofluids in heat pipes‖, International Journal of Heat and Mass Transfer, vol-55, 6786–6797, (2012)

[3]. B.C. Pak, I.Y. Cho, Hydrodynamic and heat transfer study of dispersed fluids with sub-micron metallic oxide particles, Experimental Heat Transfer11 (1998) 151-170

[4]. S.Z. Heris, M. Nasr Esfahany, S.Gh. Etemad, Experimental investigation of convective heat transfer of Al2O3/water nanofluid in circular tube, International Journal of Heat and Fluid Flow28 (2) (2007) 203-210

[5]. D. Wen, Y. Ding, Experimental investigation into convective heat transfer of nanofluids at the entrance region under laminar flow conditions, International Journal of Heat and Mass Transfer 47 (2004) 5181-5188

[6]. J.Y. Jung, H.S. Oh, H.Y. Kwak, Forced convective heat transfer of nanofluids in microchannels, in: Proceeding of ASME International Mechanical EngineeringCongress and Exposition (IMECE 2006) (2006)

[7]. K.V. Sharma, L. SyamSundar, P.K. Sarma, Estimation of heat transfer coefficient and friction factor in the transition flow with low volume concentrationof Al2O3 nanofluid flowing in a circular tube and with twisted tape insert,International Communications in Heat and Mass Transfer 36 (2009) 503-507

[8]. C.T. Nguyen, G. Roy, C. Gauthier, N. Galanis, Heat transfer enhancement using Al2O3water nanofluid for an electronic liquid cooling system, Applied Thermal Engineering 27 (2007) 1501-1506

[9]. Gilles Roy, Cong Tam Nguyen Heat transfer enhancement with the use of nanofluids in radial flow cooling systems considering temperature-dependent properties, Applied Thermal Engineering 26 (2006) 2209–2218

[10]. S. Kalaiselvam, S. Harikrishnan, Preparation and thermal characteristics of CuO-Oleic acid nanofluids as a phase change material, ThermochimicaActa 533 (2012) 46–55.

[11]. Ying Yang, Z. George Zhang, Eric A. Grulke,William B. Anderson , Gefei Wu Heat Transfer properties of nanoparticle-in-fluid dispersions (nanofluids) in laminar flow. International Journal of Heat and Mass Transfer 48 (2005) 1107–1116

[12]. Wenhua Yu, David M. France, David S. Smith, Dileep Singh, Elena V. Timofeeva, Jules L. Routbort, Heat transfer to a silicon carbide/water nanofluid, International Journal of Heat and Mass Transfer 52 (2009) 3606–3612

[13]. J. Koo, C. Kleinstreuer Laminar nanofluid flow in microheat-sinks,*International Journal of Heat and Mass Transfer 48* (2005) 2652–2661

[14]. R.Darzi, M.Farhadi, K.Sedighi, R.Shafaghat, K.Zabihi, ‗Experimental investigation of turbulent heat transfer and flow characteristics ofSiO_2/water nanofluid within helically corrugated tubes',*International Communications in Heat and Mass Transfer*, Vol. 39(2012) 1425–1434.

[15]. Ferrouillat S, Bontemps A, Ribeiro JP, Gruss JA, Soriano O. Hydraulic and heat transfer study of SiO2/water nanofluids in horizontal tubes with imposed wall temperature boundary conditions. *Int Journal of Heat Fluid Flow* 2011.

[16]. Suresh, K.P. Venkitaraj, P. Selvakumar, M. Chandrasekar Effect of Al_2O_3–Cu/water hybrid nanofluid in heat transfer, *Experimental Thermal and Fluid Science 38* (2012) 54–60.