Heat analysis of radiator using Nanofluid

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ABSTRACT

The objective of this experimental study is to discuss the thermal performance of car radiator using Al_2O_3–nanofluid in temperature ranges from (40-75°C) under different fractions of nanoparticles from 0.5, 1, 1.5% by volume. In this study, the heat transfer with water based nano-fluids was experimentally compared to that of pure water as coolant in an automobile radiator. By varying the amount of Al_2O_3 nano particles blended with base fluid water, three different concentrations of nano-fluid 0.5%, 1%, 1.5% (by vol.) were obtained. The size of nanoparticle used was 100nm. Liquid flow rate has been changed in the range of 50 lph to 200 lph and air velocity in the range of 3.8 m/s to 6.2 m/s. The fluid inlet temperature was varying from 40°C to 75°C to find the optimum inlet condition. Results demonstrate that increasing coolant flow rate can improve the heat transfer performance. Also increasing the air flow rate improves the heat transfer rate. The rate of heat transfer enhancement was found 19% to 42% in comparison with pure water.

Keywords— NanoFluid, Al_2O_3,Radiator, Flow Rate, Cooling Performance, Heat Transfer enhancemnt.

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I. INTRODUCTION

Modern automotive internal combustion engines generate a huge amount of heat. This heat is created when the gasoline and air mixture is ignited in the combustion chamber. This explosion causes the piston to be forced down inside the engine, levering the connecting rods, and turning the crankshaft, creating power. Metal temperatures around the combustion chamber can exceed 538°C. In order to prevent the overheating of the engine oil, cylinder walls, pistons, valves, and other components by these extreme temperatures, it is necessary to effectively dispose of the heat. Approximately 1/3 of the heat in combustion is converted into power to drive the vehicle and its accessories. Another 1/3 of the heat is carried off into the atmosphere through the exhaust system. The remaining 1/3 must be removed from the engine by the cooling system. The use of nanofluids has the potential to improve the engine cooling rates. These improvements can be used to remove engine heat with a reduced size cooling system.Smaller cooling system leads to use of smaller and lighter radiators which in turn will lead to better performance and increased efficiency. Alternatively, improved cooling rates can be used to remove more heat from higher horsepower engines with same size of cooling system.

II. LITERATURE SURVEY

Datta N. Mehtre *et al.*,[14] studied the total heat transfer rate from an automotive radiator is determined using two working fluids: water and water based nanofluid (Al2O3) at three different concentrations 0.5%, 1% and 1.5% on volume basis. From the experimental work, the following conclusions were made. 1)19% rate of heat transfer is increased in car radiator by addition of 0.5% Al2O3 nano powder of 100nm size in pure water at constant coolant flow rate of 200 lph and constant air flow rate of 6.2 m/s. 2) 33% rate of heat transfer is increased in car radiator by addition of 1% Al2O3 nano powder of 100nm size in pure water at constant coolant flow rate of 200 lph and constant air flow rate of 6.2 m/s.3)42% rate of heat transfer is increased in car radiator by addition of 1.5% Al2O3 nano powder of 100nm size in pure water at constant coolant flow rate of 200 lph and constant air flow rate of 6.2 m/s 4)Additon of 0.5% to 1.5% Al2O3 nanopowder in pure water gives 14% to 42 % heat transfer enhancement than pure water.

Sarit Kumar Das *et al.*,[15] studied detailed into investigating the increase of thermal conductivity with temperature for nano fluids with water as base fluid and particles of Al2O3 or CuO as suspension material. A temperature oscillation technique is utilized for the measurement of thermal diffusivity and thermal conductivity is calculated from it. The results indicate an increase of enhancement characteristics with temperature, which makes the nanofluids even more attractive for applications with high energy density. Thus the problems of traditional slurries can be eliminated by reducing the particles to nanometer dimensions. It must be kept in mind that the enhancement that is talked about in the above studies is only that of thermal conductivity. This makes nanofluids a prospective candidate for cooling application such as energy intensive laserand X-ray applications, super conducting magnets, high speed computing systems, fibre manufacturing processes and high-speed lubrication applications.

S.M. Peyghambarzadeh *et al.*, [16] they did experimental analysis of heat transfer enhancement in automobile radiator with water and ethylene glycol based Al2O3 nanofluids. They selected the range of Reynolds number 9000-23000 for water based nanofluids and 1200-2500 for ethylene glycol based nanofluids and ambient air for cooling. They select inlet temperature range from 350-500 for water based nanofluids and 450-600 for ethylene glycol based nanofluid, the fluid flowing range from 2-6 lit/min and the concentration range from 0-1 Vol. %. For avoiding the any changes in fluid property they neglect the addition of the dispersant and stabilizer to the nanofluids. They concluded that the heat transfer behaviors of the nanofluids are highly dependent on the particle concentration and weakly dependent upon the temperature.

Devdatta P. Kulkarni *et al.*,[17] they performed the experiment on Diesel Electrical Generator using the water based Al2O3 nanofluids as a coolant in jacket cooling fluid. They used the nanofluids with various particle concentrations of 0.5%, 1% and 1.5%. The Reynolds number varies from 200-1400, and the fluid inlet temperature varies from 200-700 C. The investigation carried out by them, they shown that applying nanofluids resulted in reduction in cogeneration efficiency due to decrease in specific heat, which influences the waste heat recovery from the engine. From that, they concluded that efficiency of waste heat recovery heat exchanger was increased for nanofluids, due to its large convective heat transfer coefficient.

Durgeshkumar Chavan *et al*.,[18] performed experiment on the automobile radiator with using the Al2O3/ water nanofluid as a cooling fluid. For avoiding the any changes in fluid property they neglect the addition of the dispersant and stabilizer to the nanofluids. They took the five different concentrations in range of the 0-1.0 vol. %. The test fluids flow rate was changed in the range of 3 lit/min to 8 lit/min to obtain the fully turbulent regime having Reynolds number 4000-16000. From the experimental investigation they concluded that with increase in the fluid circulating rate increased th heat transfer rate, with increase in the Reynolds number enhance the heat transfer coefficient of both water and nanofluids considerably and with addition of 1.0 Vol. % of Al2O3 nanoparticles into the pure water, the heat transfer coefficient increased about 40-45% with compare to the pure water.

Yi-Hsuan Hung *et al.*,[19] did the study of the evaluating the feasibility of the alumina (Al2O3)/water nanofluid for the cooling system use in the automobile using the air-cooled heat exchanger for heat dissipation. They prepared the Al2O3/water nanofluid by using the direct synthesis method and mechanical agitations with different weight fraction of nanoparticles. They took the concentration 0, 0.5, 1.0, 1.5 % of weight fraction. The fluid inlet temperature would be 300, 400, 500 and 600. They kept the air flow rate fixed and mass floe rate of liquid side was controlled by input voltage of circulating pump. The operating range would be 1.8, 2.1 and 2.4 lit/min. For decreasing the measurement errors they measured each condition five times. From the experimentation they found result for the concentration of 0.5 % by weight and a temperature range 300-600 C, the thermal conductivity increased by 3.8-17.2%, for a concentration of 1.0 % by weight the thermal conductivity increased by 4.6-19.7%, for a concentration of 1.5 % by weight the thermal conductivity increased by 8.1-20.5% with pure water. They conclude that the maximum enhancement of heat exchange occurred compared with the distilled water was of 40% at high weight fraction (1.5 % by weight) of nanoparticles and low inlet temperature (300 C).

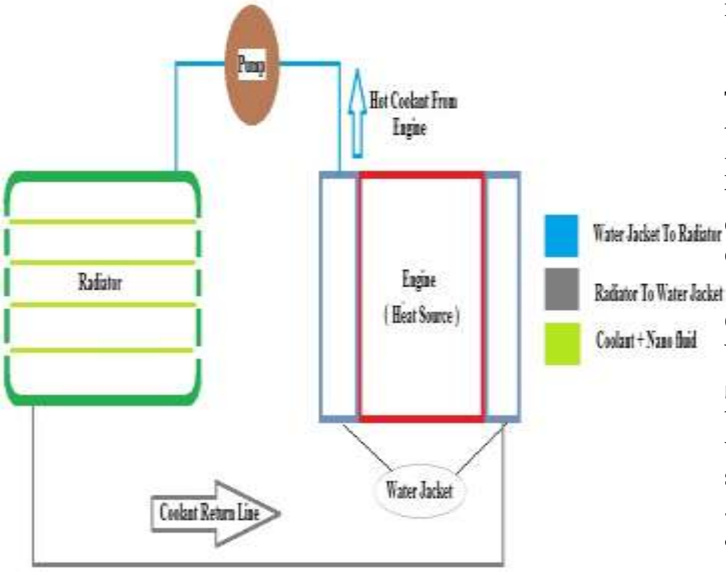
Rahul A. Bhogare, B. S. Kothawale *et al*.,[20] studied effect of adding Al2O3 nanoparticle to base fluid (mixture of EG+Water) in Automobile radiator is investigated experimentally. Improving thermal efficiency of engine leads to increase the engine's performance, decline the fuel consumption and decrease the pollution emissions. Effects of fluid inlet temperature, the flow rate and nano particle volume fraction on heat transfer are considered. Results show that Nusselt number, total heat transfer, effectiveness and overall heat transfer coefficient increases with increase , nano particle volume fraction , air Reynolds number and mass flow rate of coolant flowing through radiator.

III.OBJECTIVES AND SCOPE

An engine coolant is mixture of ethylene glycol and water in various ratios like 30:70, 40:60 and 50:50 respectively are mostly used in auto-mobiles. Water and ethylene glycol as conventional coolants have been widely used in an automotive car radiator for many years. These heat transfer fluids offer low thermal conductivity [1]. An innovative way of improving the heat transfer performance of common fluids is to suspend various types of small solid particles (metallic, nonmetallic and polymeric particles) in conventional fluids to form colloidal [2].Therefore certain alternative engine coolant are required to be used which will reduce the problem associated with suspended particles also it will improve the heat transfer rates, improve engine efficiency and reduce the size of the radiator [2]. The nanofluids project will help to reduce the size and weight of the vehicle cooling systems by greater than 10% despite the cooling demands of higher power engines. Nanofluids can help to enable the potential to allow higher temperature coolants and higher heat rejection in the automotive engines [3]. It is estimated that a higher temperature radiator could reduce the radiator size approximately by 30%. This translates into reduced aerodynamic drag and fluid pumping and fan requirements, leading to perhaps a 10% fuel savings [2]. It is interesting idea in these years which humans involved in the energy and fuel shortage crisis.

IV. EXPERIMENTAL SETUP AND PROCEDURE

Fig shows the test rig, in which coolant is heated in heat source and it is then circulated in the radiator with the help of pump. Rotameter is used to adjust the flow of water in the radiator. Due to forced convection, heat of coolant is rejected to surrounding with the help of radiator fan. The fins provided on radiator improve heat transfer rate. The coolant is again recirculated back to the heat source. Al_2O_3 nanofluid is prepared by two step method because two-step process works well in many cases, especially for oxide and nonmetallic Nanoparticles [9].The preparation starts by adding 25mg of Al_2O_3 nanoparticles to coolant, then the solution is stirred well and placed under UV light in dark room. This will help to disperse nanoparticles properly in solution and avoid sedimentation. The solution is kept for a 5-6 hrs under UV light, then it is ready for use as a coolant.



SPECIFICATIONS

Table 1: The specifications of the equipments used in the experiment are:

Component	Specification
Radiator	Maruti 800 model, single pass cross flow type radiator, 3.5 liter.
Rotameter	Acrylic Body Rotameter, 10 lpm.
Heater	230 V AC, 1.5 KW
Pump	Continuous duty, 220 V, 50 Hz, 0.5 HP, 0.37 KW
Hose	25 mm dia
Collar	Screw fastening
Frame	MS
Thermocouple	Dip type, Digital temperature sensor
Adapter	To increase radiator fan speed
Connector	To connect pump to hose

Table 2: Thermo physical properties of base fluid and nanofluid.

Thermal physical properties	Base fluid+ Ethylene glycol	Air	Al_2O_3
Density(kg/m3)	1064	1.1614	3950
Specific heat (J/kgK)	3370	1005	873.336
Viscosity(N-s/m2)	4.65×10^{-5}	0.00001846	-
Conductivity(W/mK)	0.363	-	31.922

TESTING PROCEDURE:

Ensure all the connections are proper and leak proof. Open the radiator cap and pour clean water in the radiator. Close the radiator cap properly and connect the radiator, pump and heater to power supply. Switch on the supply for Pump and Heater. Open the knob of rotameter to complete 10 lpm. Run the pump and heater for 20 to 30 min until there is sufficient temperature raise. Switch on the supply to radiator, subsequently the radiator fan will start. Adjust the flow of coolant to 10 lpm and take two reading for each flow rate after every 2 min (upto 8 lpm). Observe the inlet and outlet temperature of radiator on thermocouple and note it down. Also measure the outlet temperature of air from radiator.

V.MATHEMATICAL FORMULAE

The characteristics of nanoparticles and base fluid used in this study are summarized in Table 2. The necessary thermo physical properties are density,viscosity, specific heat and thermal conductivity. Xuan [12] paper proposed empirical correlations to calculate density and specific heat capacity of Al_2O_3/water nanofluid which are as follows:

$$\rho nf = (1-\phi)\,\rho bf + \phi\ \rho p,\ kg/m^3 \quad (1)$$

$$Cnf = [\,\phi\,\rho p + (1-\phi)\,\rho nf\ Cbf]/\rho nf,\ J/kgK. \quad (2)$$

Where f is nanoparticle volume concentration and ρp, ρbf and Cnf, Cbf are the densities and the specific heats of the nanoparticles and base fluid, respectively.Also, dynamic viscosity (μnf) for nanofluid have been estimated based on semi-empirical equation presented by M. Eftekhar [13] in 2013 on the basis of a wide variety of experimental date available in the literature as following equations:

$$\mu nf = \mu bf \times 1/(1-\phi)^2,\ Ns/m^2 \quad (3)$$

Heat transfer modelling

Heat transfer rates through water and air can be calculated by the formulas as follows:

$$Qnf = \dot{m}nf\ Cpnf\ (Ti-To),\ W \quad (4)$$

$$Qa = \dot{m}a\ Cpa\ (Toa-Tia),\ W \quad (5)$$

After finding heat transfer rates, find average heat transfer rate by the formula:

$$Qavg = 0.5\ (Qnf+Qa),\ W \quad (6)$$

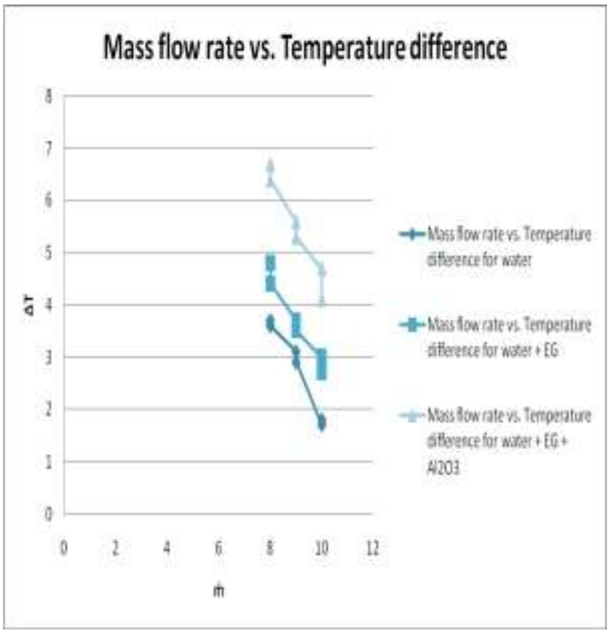
Finally the effectiveness of radiator is given by the formulae:

$$\mathcal{E} = \dot{m}nf\ Cpnf\ (Ti-To)/\dot{m}a\ Cpa\ (Ti-Tai) \quad (7)$$

Compare performance characteristics of water, water + ethylene glycol, water+ethylene glycol & Al_2O_3 Nanofluid.

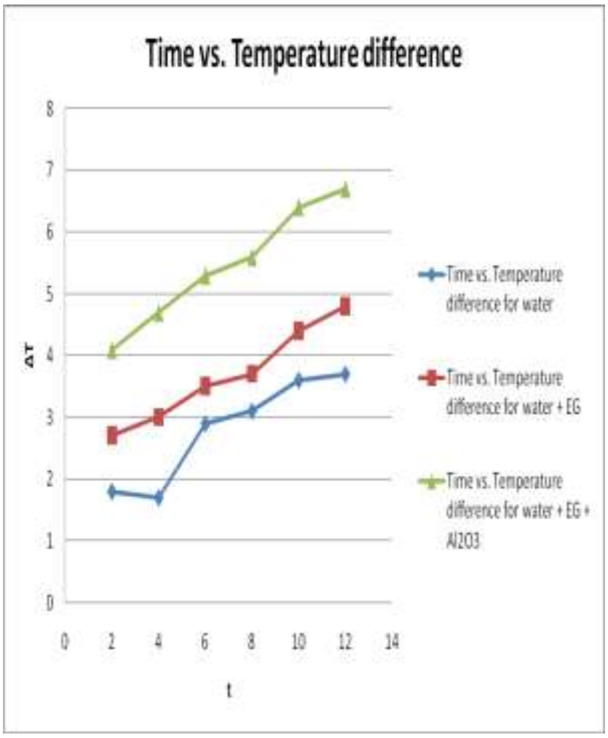
VI.RESULTS AND DISCUSSION

1) Mass flow rate (lpm) vs. Temperature difference (°C)



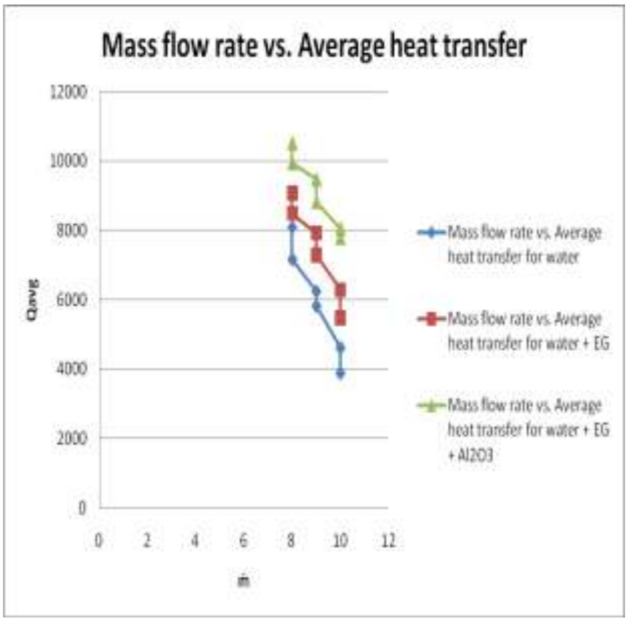
It can be seen in the graph that the with decrease in mass flow rate, temperature difference between the inlet and outlet temperature of the coolant increases as the coolant is getting more time to absorb heat from the heat source. Among all the curves, Al_2O_3 nanofluid is having better temperature difference.

2) Time (min) vs. Temperature difference (°C)



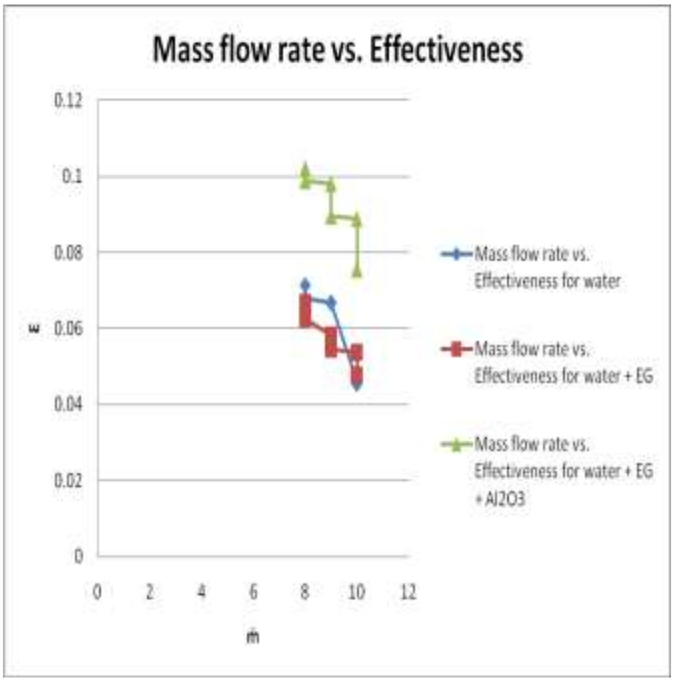
In the graph with increase in time, temperature difference between inlet and outlet temperature of the coolant increases. Among all three curves, Al_2O_3 nanofluid curve is having better temperature difference with time.

3) Mass flow rate (lpm) vs. Average heat transfer (W)



It can be inferred from the graph that with decrease in mass flow rate, average heat transfer rate of coolant and air increases. Among all curves, Al_2O_3 nanofluid curve is having better average heat transfer rate.

4) Mass flow rate (lpm) vs. Effectiveness



Effectiveness of coolant means the capacity or potential to achieve desired results. In technical terms it is the ratio of actual heat transfer rates to the maximum heat transfer rates. From the graph it can be inferred that Al_2O_3 nanofluid is having better effectiveness as compared to water and mixture of water + ethylene glycol.

VII.CONCLUSION

It is concluded that nanofluids are having better heat transfer rate as compared to other coolants and they can be considered as a potential candidate for numerous applications involving heat transfer and their use will continue to grow. It is also found that the use of nanofluids appears promising, but the development of the field faces several challenges. Nanofluid stability and its production cost are major factors in using nanofluids. The problems of nanoparticle aggregation, settling, and erosion all need to be examined in detail in the applications. We can say that once the science and engineering of nanofluids are fully understood and their full potential researched, they can be reproduced on a large scale and used in many applications.

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