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Performance Investigation of Automobile Radiator using Al_2O_3 as base Nanofluid

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ABSTRACT: Cooling system plays important roles to control the temperature of car's engine. One of the important element in car cooling system is the radiator. Radiator plays an important role in heat exchange. Conventional coolants like water, ethylene glycol are not efficient enough to improve the car's performance. Therefore with the development of new technology in the field of 'nano-materials' and 'nano-fluids', it seems to effectively use these technologies in car radiators to improve engine efficiency, reduce weight of vehicle and size of radiator. In this study, effect of adding Al_2O_3 nanoparticle as a base fluid in radiator will be investigated experimentally. Forced convective heat transfer of water and ethylene glycol based nanofluid will be compared experimentally with water, water + ethylene glycol (60:40), water + ethylene glycol + nanoparticles have been carried out. The experimental results show that Al_2O_3 based coolant show better heat transfer as compared to other coolants.

KEYWORDS: Aluminum Oxide, Ethylene Glycol, Nanofluid, Radiator.

I. INTRODUCTION

Automotive radiator is key component of engine cooling system. Radiators are compact heat exchangers optimized and evaluated by considering different working conditions. Coolant surrounding engine after absorbing heat from it passes through radiator. In radiator, coolant gets cooled down and re-circulated into system. It means the radiator is normally used as a cooling system of the engine and generally water is the heat transfer medium. There are various components that make up the cooling system and they are Air blower, Cooling fans, Radiator Parts, Radiators and Water pumps. Each of these components plays essential role. For instance the radiator cools the coolant by forced convection so that it can be reused; the water pumps the coolant through the system via water pipes, the air blower draws air through the radiator to achieve the cooling action etc.

Conventional fluids like water, oil, ethylene glycol etc have poor heat transfer performance therefore high compactness and effectiveness of heat transfer systems are necessary to achieve the required heat transfer.

Recent advances in nanotechnology have allowed development of a new category of fluids termed Nanofluids. Nanofluid is a fluid containing nanometer sized particles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in nanofluids are typically made of metals oxides, carbides, or carbon nanotubes. Common base fluids include water and ethylene glycol. Nanofluids have novel properties that make them potentially useful in many applications like in heat transfer, microelectronics, fuel cells, pharmaceutical processes and hybrid powered engines [4]. Major properties of nanofluids which make it suitable to be used in Radiator coolant are high thermal conductivity, low viscosity, high convective heat transfer coefficient, high area per unit volume. The Nanofluids offer numerous benefits like enhanced heat transfer and stability, micro channel cooling without clogging, reduction in pumping power, reduction in size of the radiator etc. These properties helps to improves the engine efficiency. Thus nanofluids can help to enable the potential to allow higher temperature coolants and higher heat rejection in the automotive engines [5].

II. LITERATURE SURVEY

Peyghambarzadeh et al. [6] have recently investigated the application of Al_2O_3/water nanofluids in the car radiator by calculating the tube side heat transfer coefficient. They have recorded the interesting enhancement of 45% comparing with the pure water application under highly turbulent flow condition. In the other study, Peyghambarzadeh et al. [7] have used different base fluids including pure water, pure ethylene glycol, and their binary mixtures with Al_2O_3 nanoparticles and once again it was proved that nanofluids improves the cooling performance of the car radiator extensively.

Yu, W., France, D.M., Choi, S.U.S. et al, [8] reported that about 15-40% of heat transfer enhancement can be achieved by using various types of Nanofluids. This translates into a better aerodynamic feature for design of an automotive car frontal area. Coefficient of drag can be minimized and fuel efficiency can be savings for the automotive industries through the development of energy efficient nanofluid and smaller and lighter radiators.

D. Wen, Y. Ding et al. [9] investigated the effect of temperature, particle size and volume fraction on thermal conductivity of water based nanofluids of copper oxide and alumina. Authors suggested that thermal characteristics can be enhanced with increase of particles volume fraction, temperature and particle size. Authors found that the smaller the particle size, the greater the effective thermal conductivity of the nanofluids at the same volume fraction. Huaqing Xie et al. [10] performed their experiments in the radiator type heat exchanger and at 6.8 vol. % Al_2O_3 in water obtained 40% increase in heat transfer coefficient. Eastman, J. A., Choi, S. U. S., Li, S., Yu, W et al. [11] measured thermal conductivity of Nano fluids containing Al_2O_3, nanoparticles with two different base fluids: ethylene glycol and pump oil. Results showed a 30 % & 40 % improvement in the thermal conductivity as compared to the corresponding base fluids for 5 vol. % of nanoparticles and the size of the nanoparticles used with both the fluids is 60 nm.

III. OBJECTIVES AND SCOPE OF WORK

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 1 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.

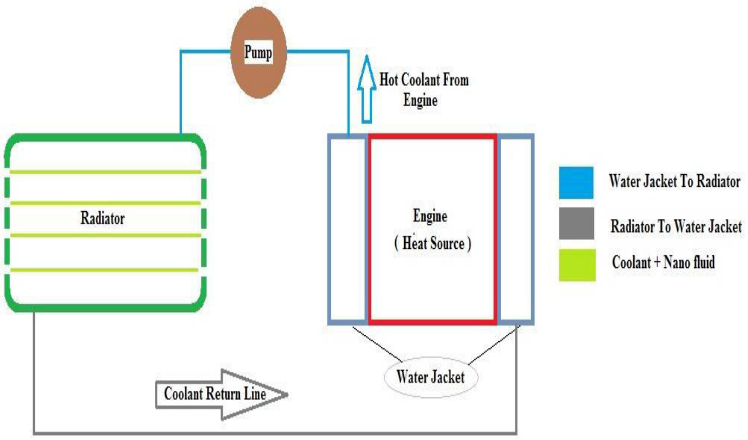

Fig. 1 Experiment test rig

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.

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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

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

Table 2: Thermophysical properties of base fluid and nanoparticles

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

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:

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

$$Cnf = \frac{\phi\, \rho p + (1-\phi)\, \rho nf\, Cbf}{\rho nf}, \ J/kgK. \qquad (2)$$

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:

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

Heat transfer modelling

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

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

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

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

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

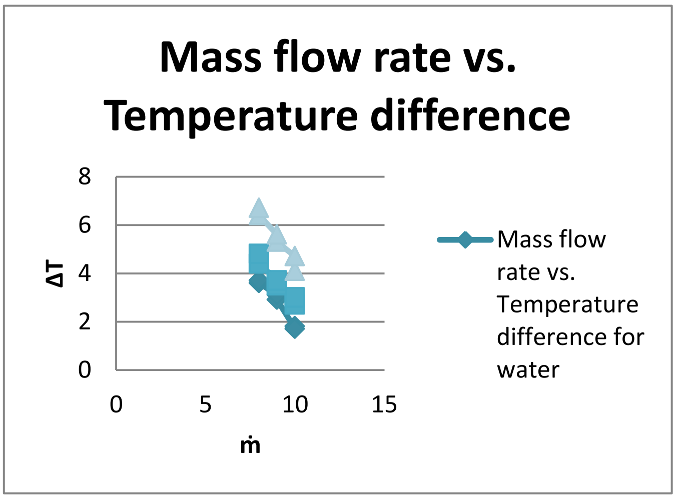
Finally the effectiveness of radiator is given by the formulae:

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

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

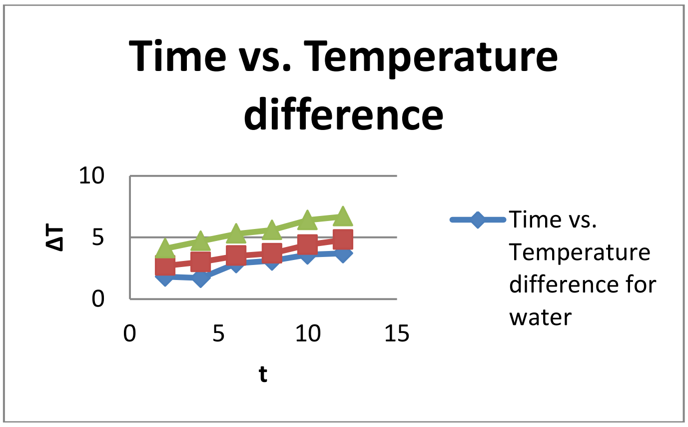
VI. RESULTS AND DISCUSSION

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.

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



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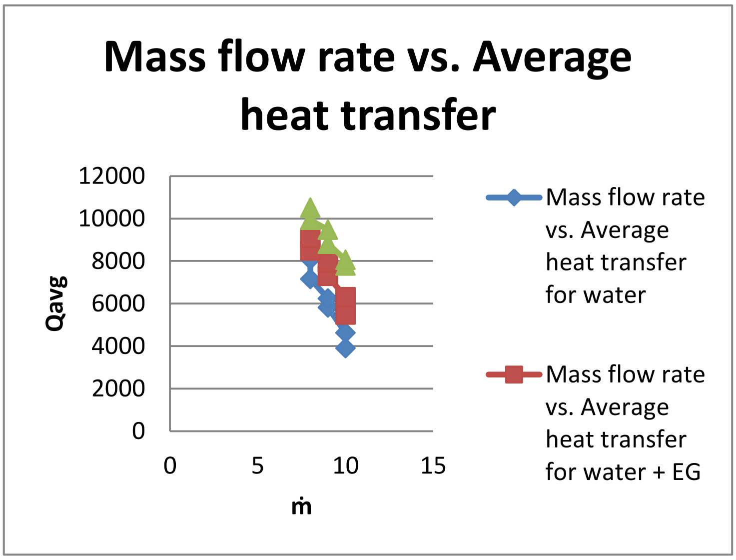
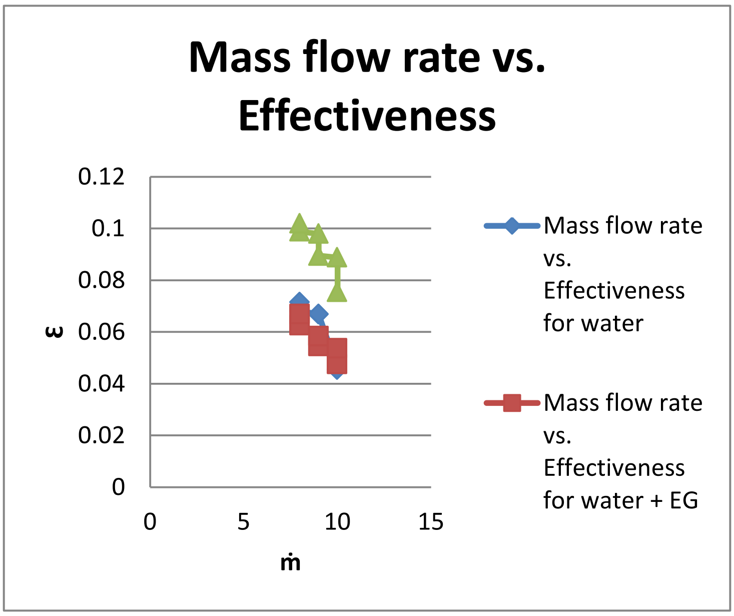
In the graph with increase in time, temperature difference between inlet and outlet temperature of the coolant increases. Among all three curves, Al_2O_3 nanofluid curve is having better temperature difference with time.

2. 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.

3. 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.

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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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