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Experimental investigation of cooling performance of an Automobile radiator using Al_2O_3-Water+ethylene Glycol nanofluid

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Abstract:- In the present study, the enhancement of forced convective heat transfer of Al_2O_3-Water+ ethylene glycol nano fluid in an automobile radiator has been experimentally studied. In this study, different volume fractions of nanofluids in the range of 0.01 to 0.08 % were prepared with the addition of Al_2O_3 nanoparticles into the water and sonicated using ultrasonic sonicator for 2 hours for getting stable suspension. Maximum heat transfer performance for 0.08% volume fraction was found 48 % higher compared to water. The effective thermal conductivity of nanofluid is increased with increase in particle concentration which leads to increase the radiator cooling performance. The coolant flow rate is varied from 3 lpm to 15 lpm. It is observed that with increase in flow rate heat transfer performance increases.

Keywords:- Forced convection heat transfer, nano fluids, Al_2O_3-Water+ethylene glycol.

I. INTRODUCTION

In an automobile lot of heat is produced due to the combustion, only a portion of heat is utilized to produce the power rest of heat is wasted in the form of exhaust heat. If this excess heat is not removed, the engine temperature becomes too high which results in overheating and viscosity breakdown of the lubricating oil, wear of the engine parts, due to thermal stress of the engine components failure may occurs in engine. So that a cooling system is required. The automobile engine utilizes a heat exchanger device, termed as radiator, in order to remove the heat from the cooling jacket of the engine. The radiator considered as an important component
of the cooling system of the engine. Normally, it is used as a cooling system of the engine and generally water is the heat transfer medium .For this liquid-cooled system, the waste heat is removed via the circulating coolant surrounding the devices or entering the cooling channels in devices. The coolant is propelled by pumps and the heat is carried away mainly by radiator. For the purpose of producing high efficiency engine we need look at reducing a vehicle weight by optimizing design and size of a radiator is a necessity for making the new design model of radiator.

Over several years researchers have focused to overcome the limited heat transfer capabilities of conventional heat transfer mediums such as water, engine oil, ethylene glycol (EG). For the need of the high performance cooling, heating efficiency, energy saving, less generation of green house gases nanotechnology is applied to thermal engineering. Nanofluid is nothing but nano meter sized particles suspended in base fluid which was innovated by choi [1]. In this technology requirement is addressed by two means i.e one is geometry which tells the particle size and the second one is fluid being used. Nanofluids have unique features different from convectional solid- liquid mixtures in which mm (or) µm sized particles of metals and non metals are dispersed. Due to their excellent characteristics, nanofluids find wide application in enhancing heat transfer characteristics namely extreme stability, ultra-high thermal conductivity.

Heat transfer surface area increases due to Brownian motion and inter particle forces so that increased thermal conductivity, increased single-phase heat transfer, increased critical heat flux occurs [2]. Nano particles are very small in size, usually < 100 nm. The smallest nano particles, only a few thousand atoms these nano particles can posses properties that are substantially different from their parent materials. Unstability of nano particles in base fluid can occur due to thermodynamics unstable Vander wall forces between nano particles. Preparation of stable nanofluids is the key issue in nanofluids research. For the preparation of stable nanofluids mainly three processes are using namely two-step process, chemical approach, laser ablation method [3].

Nanofluids used many applications like microelectronics, fuel cells, pharmaceutical process, hybrid power engines, engine cooling, vehicle, thermal management, domestic refrigerator, chiller, heat exchangers, in grinding, mashing, boiler flue gas temperature reduction , geothermal extractions of geo thermal power and other energy sources, cryopreservation[3].

Xiaohao Wei et al [4] presented The effect of reactant molar concentration and nanofluid temperature on thermal conductivity. Nano particles shape is (spherical to octahedral)variable by adjusting some synthesis parameters such that enhance thermal conductivity up to 24%. Cu_2O nanofluids can be synthesized by using the chemical solution method. Pooyan Razi et al [5] assessed Nan foluids with different particle weight concentration passing through the flatend copper tubes and heated by an electrical heating coil and created fully developed flow. Study the effect of different parameters on heat transfer coefficient and pressure drop flow is studied. The results shoe down a maximum increase of 16.8% in heat transfer coefficient for a range of Reynolds numbers between 10 to 100 is obtained for nanofluid flow with 2% wt. concentration inside the round tube, while, the increases of 20.5% and 26.4 are obtained for this fluid flow inside the flattened tubes with internal heights of 8.3 and 6.3 mm at nearly the same Reynolds numbers range, respectively.

M.pirhayati et al [6] Studied convective heat transfer of nanofluid flow inside an inclined copper tube and created. Laminar and hydro dynamically fully developed flow inside round tube. different weight fractions of nano fluid and the study of effect of different parameters increasing the heat transfer coefficient. Inclined tube at 30° exhibit most heat transfer enhancement amongst other tube inclination. Weerapun Duangthongsuk et al[7] examined Comparing the heat transfer coefficient and friction factor for different volume % passing through the horizontal double tube counter flow heat exchanger under turbulent flow conditions. Aida Nasiri et al[8] assessed Preparing nanofluids with three different dispersion methods namely ultrasonic bath, ultrasonic probe, functionalization. among three functionalization method gives that the best stability and thermal conductivity. K.B Anoop[9] et al presented Two particle sizes were used one with average particle size of 45nm to 150nm. 45nm particle showed higher heat transfer coefficient than that 150nm particles. Heat transfer coefficient show higher enhancement than in the developed region. S.M.S Murshed et al [10] examined Particle size and shape also have effects on the enhancement of thermal conductivity. The PH value and viscosity of the nanofluids are also characterized.

M. chandrasekar et al [11] implemented nanofluid Prepared by microwave method assisted chemical precipitation method. Different volume concentrations at room temperature were used for investigation conclude that the viscosity increase is substantially higher than the increase in the thermal conductivity. Patricia E [12] studied The effect of particle diffusion in a temperature field on the aggregation and transport and the predicted thermal conductivity and viscosity enhancements are compared to determine the favourability of aggregation nanofluid. Eiyad Abu nada et al [13] performed By taking account the solid particle dispersion the angle of inclination is used as a control parameter for flow and heat transfer varied from o° to 120° the governing equation are solved with finite volume technique. S.k sahu and S. Chougule [14] has been studied experimentally inside an automobile radiator. Heat removal rate of the coolant flowing through the automobile radiators is of great importance for the optimization of fuel consumption. Four different concentrations of nanofluids in the range of 0.15–1 vol. % were prepared with the addition of CNT nanoparticles into water. The CNT nanocoolants are synthesized by functionalization (FCNT) and surface treatment (SCNT) method. The effects of various parameters, namely synthesis method, variation in pH values and nanoparticle concentration on the Nusselt number are examined through the experimental investigation. Nanocoolants exhibit enormous change Nusselt number compared with water. The results of functionalized CNT nanocoolant with 5.5 pH exhibits better performance compared to the nanocoolant with pH value of 6.5 and 9.

II. NANOFLUIDS PREPARATION

Preparation of nanoparticles suspension is the first step in applying nanofluid for heat transfer experiments. In this work the Al_2o_3 –water+ ethylene glycol nanofluid is prepared by a two-step method. The Al_2o_3 nanoparticles with an average size of 30 to 50nm have been provided by NANOLABES. As the provided nanoparticles had a hydrophobic surface, they agglomerated and precipitated when dispersed in water in the absence of a dispersant/surfactant. Moreover, addition of any agent may change the fluid properties. In two step method first we have take 10.5 litres of distilled water and 4.5 litres of ethylene glycol mix with each other this is used as base fluid.

%volume concentration = $(WAl_2o_3 / \rho Al_2o_3) / [(WAl_2o_3 / \rho_{Al2o3}) + (W_{bf} / \rho_{bf})]$

$W\ Al_2o_3$ = Weight of aluminum oxide nano particles.

$\rho\ Al_2o_3$ = Density of aluminum oxide nano particles =3600kg/m$^{3.}$

W_{bf} = Weight of base fluid.

ρ_{bf} = Density of base fluid. =1064kg/m^3

From the volume concentration equation finds out the requirement of nanoparticle to add the base fluid. The resulting mixture was first sonicated at 28 °c for 1 hr using ultrasonic vibration at sound frequency of 20 kHz.

check for the uniform distribution again the suspension were subjected to ultrasonic vibration at 500W and 24 kHz for 3–5 h to obtain uniform suspensions.

Fig 1. Oscar ultra sonicator, Pr-1000

III. NANOFLUIDS PROPERTIES

Before the study of the convective heat transfer performance of the nano fluids the properties of nano fluid must be known accurately. By assuming that the nano particles are well dispersed in the fluid, the concentration of nanoparticles may be considered uniform throughout the tube. Although this assumption may be not true in real systems because of some physical phenomena such as particle migration, it can be a useful tool to evaluate the physical properties of a nano fluid.

The density of nano fluid is calculated by the mixing theory as:

$$\rho = Ø\rho_p + (1-Ø)\,\rho_{bf}$$

The specific heat capacity of nanofluid can be calculated based on the thermal equilibrium model as follows

$$C = (Ø\rho_p c_p + (1-Ø)\,\rho_{bf}\, c_{bf}) / \rho_{nf}$$

Specification of nanoparticles

Chemical name: aluminium oxide
Purity: 99%
Appearance: white
Odour: Alcoholic
Average particle size: 30-50nm
Density: 3.5-3.9 g/cm^3

s.no	Properties	Al_2o_3	Mixture Of Water+Ethylene glycol
1	Density(Kg/m^3)	3950	1064
2	Specific Heat (J/kg K)	873.336	3370
3	Thermal Conductivity(W/mK)	31.992	0.363

Table 1. Thermo physical properties of base fluid and nano particles.

It should be noted that these transport properties are functions of temperature. As a consequence, the properties were calculated by using the mean fluid temperature between the inlet and outlet. The addition of small amount of aluminium oxide nanoparticle can change more or less all the physical properties of the base fluid.

IV. EXPERIMENTAL TEST RIG AND PROCEDURE

As shown in Fig. 2, the experimental system used in this study it includes flow lines, a storage tank, a heater, a centrifugal pump, a flow meter, a forced draft fan and a cross flow heat exchanger (an automobile radiator). The pump gives a variable flow rate of 3-15 l/min. the flow rate to the test section is regulated by appropriate adjusting of a globe valve on the recycle line. The base fluid fills 30% of the storage tank whose total volume is 50 lit. The total volume of the circulating liquid is constant in all the experiments. The circuit includes insulated tubes (Isopipe0.75 inch diameter) have been used as connecting lines.

For heating the working fluid an electric heater of capacity 2000 watt and controller were used to maintain the temperature 50-80°C. Two thermocouples were implemented on the flow line to record the radiator inlet and outlet temperature. Four thermocouples is installed on the radiator to measure the wall temperature of the radiator.

When the experiment started, the location of the thermocouple presented the average value of the readings was selected as a point of average wall temperature. Due to very small thickness and very large thermal conductivity of the tubes, it is reasonable to equate the inside temperature of the tube with the outside one. the temperature were noted through the temperature indicator. Error details was measured from calibration of each thermo couples by comparing the temperature which was measured by thermo meter.

Assumptions for test condition A) Velocity and temperature at the entrance of the radiator core on both air and coolant sides are uniform. B) There are no phase changes (condensation or boiling) in all fluid streams. C) Fluid flow rate is uniformly distributed through the core in each pass on each fluid side. D) The flow condition is characterized by the bulk speed at any cross section. E) The temperature of each fluid is uniform over every flow cross section, so that a single bulk temperature applies to each stream at a given cross section. Heat transfer area is distributed uniformly on each side Both the inner dimension and the outer dimension of the tube are assumed constant. F) The thermal conductivity of the tube material is constant in the axial direction. H) Room temperature is 25°c.

The configuration of the automobile radiator used in this experiment is of the louvered fin-and tube type, with 34 vertical tubes with stadium-shaped cross section. The fins and the tubes are made with aluminum. For cooling the liquid, a forced fan was installed close and face to face to the radiator and consequently air and water have in direct cross flow contact and there is heat exchange between hot water flowing in the tube-side and air across the tube bundle.

Fig 2 Schematic of experimental set up.

V. CALCULATION OF HEAT TRANSFER COEFFICIENT

To obtain heat transfer coefficient and corresponding Nusselt number, the following procedure has been performed. According to Newton's cooling law:

$$Q = hA\Delta T = hA(T_b - T_w)$$

Heat transfer rate can be calculated as follows

$$Q = mC_p\Delta T = mC_p\,(T_{in} - T_{out})$$

Regarding the equality of Q in the above equations

$$Nu = \frac{h_{exp} d_{hy}}{K} = \frac{mc_p(T_{in} - T_{out})}{A(T_b - T_w)}$$

In Eq. (7), Nu is average Nusselt number for the whole radiator, m is mass flow rate which is the product of density and volume flow rate of fluid, Cp is fluid specific heat capacity, A is peripheral area of radiator tubes, T_{in} and T_{out} are inlet and outlet temperatures, Tb is bulk temperature which was assumed to be the average values of inlet and outlet temperature of the fluid moving through the radiator, and T_w is tube wall temperature which is the mean value by two surface thermocouples. In this equation, k is fluid thermal conductivity and d_{hy} is hydraulic diameter of the tube. It should also be mentioned that all the physical properties were calculated at fluid bulk temperature.

VI. RESULTS AND DISCUSSIONS

A) pure water, water ethylene glycol (70:30)

Before conducting systematic experiments on the application of nanofluids in the radiator, some experimental runs with pure water were done in order to check the reliability and accuracy of the experimental setup. shows experimental results for constant inlet temperature of 55°c. also done experiment with water+etyline glycol.

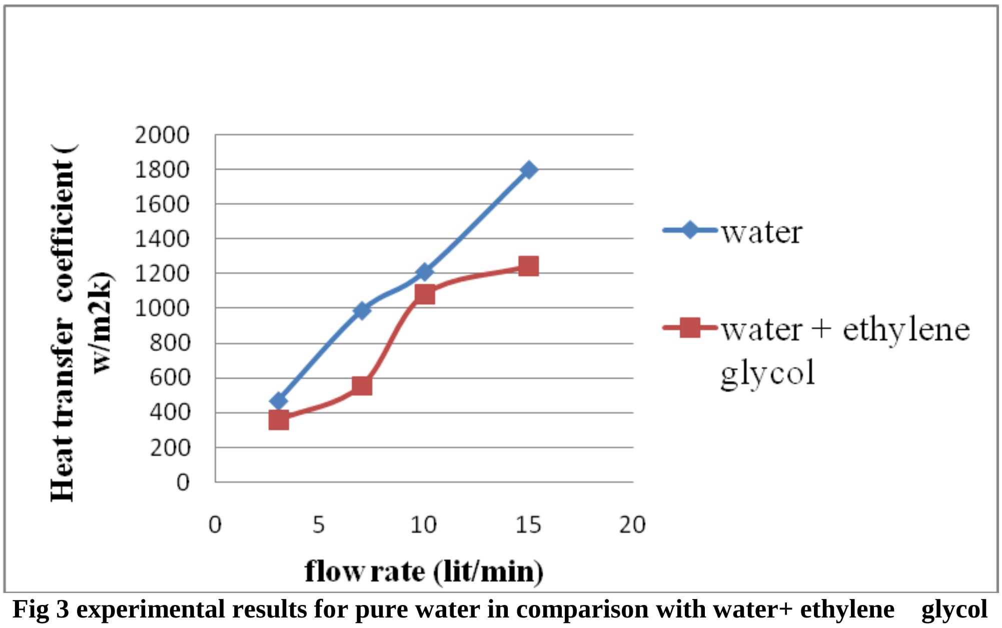

Fig 3 experimental results for pure water in comparison with water+ ethylene glycol

Fig 3 shows experimental results for the pure water and water + ethylene glycol. Compare the results with each other then find out the These fluids posses poor heat transfer performance compared to water because of lower thermal conductivity.

B. nanofluid

The nanofluid is implemented in different Al_2o_3concentrations, i.e. 0.01, 0.02, 0.05 and 0.08 vol. % and at different flow rates of 3,7,10 and 15 l/min were implemented as the base fluid. It is important to mention that from a practical viewpoint for every cooling system, at equal mass flow rate the more reduction in base fluid temperature indicates a better thermal performance of the cooling system. Thermal performance of the automobile radiator at constant air Reynolds number and constant flow rate have been carried out. With increase of the volume concentration of nano particles in the base fluid viscosity of nanofluid has been increased.

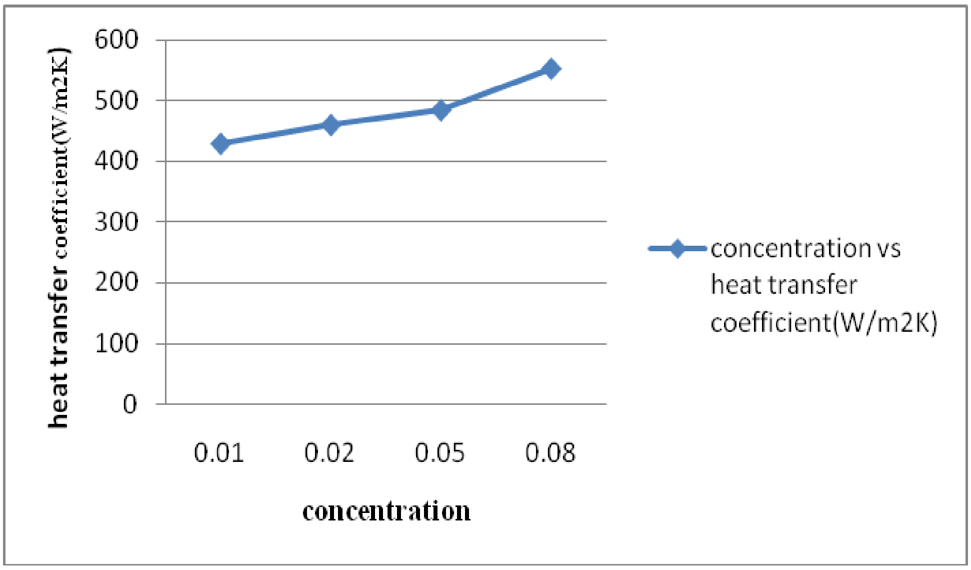

Fig 4 effect of volume concentration of Al_2o_3 nano particles on the heat transfer coefficient at 3 lpm

Fig 4 shows that experimental values of forced convective heat transfer coefficient at the different volume concentrations of Al_2o_3 nano particles. The value is in the range between 430 W/m^2K to 1360 W/m^2K.the results compare with the conventional liquids enhanced up to 4% to 17%.the experiment is carried out at 3 lpm.

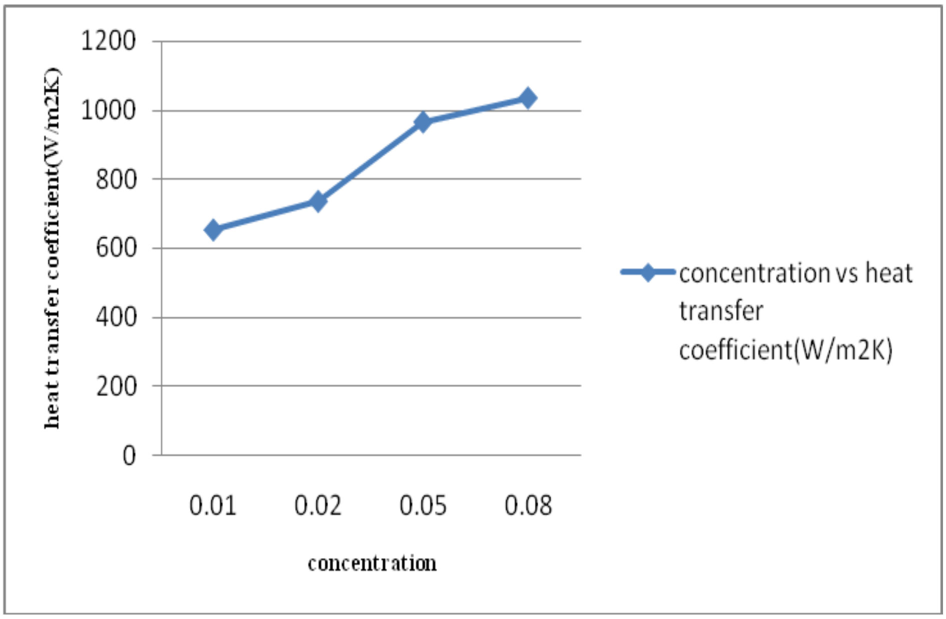

Fig 5 effect of volume concentration of Al_2o_3 nano particles on the heat transfer coefficient at 7 lpm

The concentration of nanoparticle plays an important role in the heat transfer efficiency. Fig 5 shows the heat transfer coefficient values for different volume concentrations at 7 lpm of nanofluid passing through radiator. The enhancement of heat transfer coefficient is in the range of 12% to 24%.

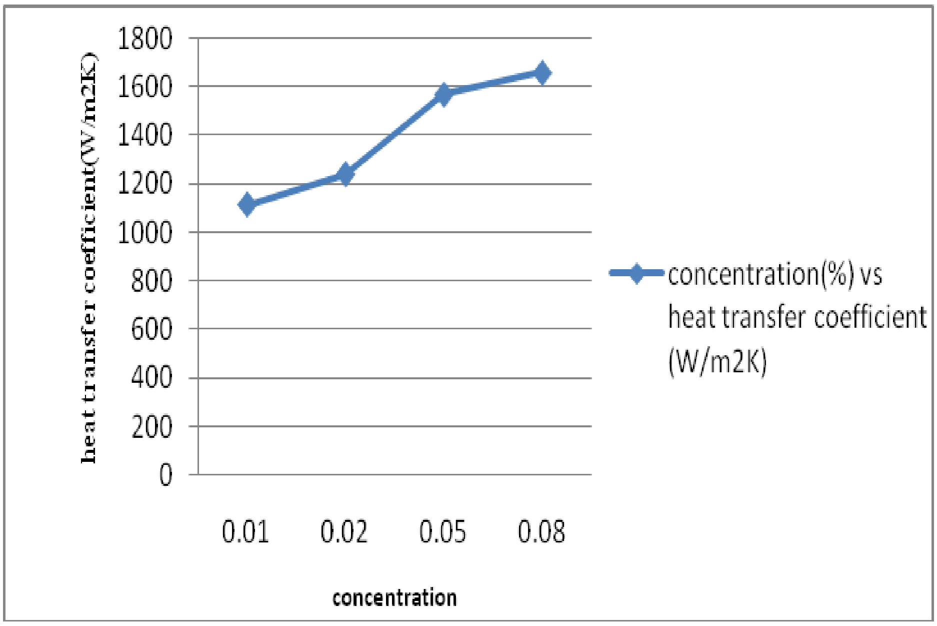

Fig 6 effect of volume concentration of Al_2o_3 nano particles on the heat transfer coefficient at 10 lpm

Fig 6 represents the heat transfer coefficient gradually increasing for increasing the nano particle concentration. the physical properties of nanofluids are slightly different than the base fluid. Density and thermal conductivity increased and specific heat decreased slightly in compare to base fluid. Viscosity increases more markedly, which is unfavorable in heat transfer.

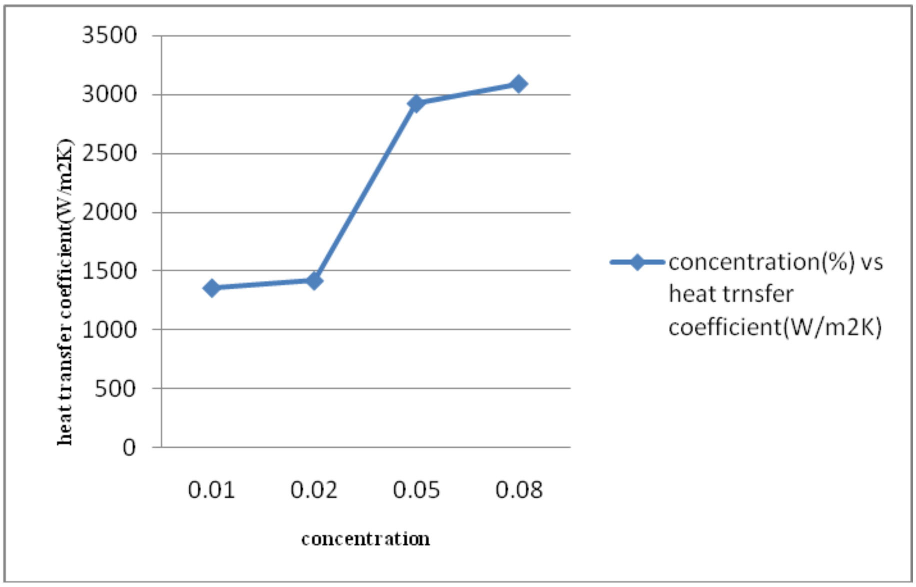

Fig 7 effect of volume concentration of Al_2o_3 nano particles on the heat transfer coefficient at 10 lpm

It can be shown that whenever the concentration becomes greater, heat transfer coefficient becomes larger. By the addition of only 0.08 vol. % of Al_2o_3 nanoparticle into the pure water, an increase of about 55% in comparison with the pure water + ethylene glycol heat transfer coefficient was recorded. The average heat transfer coefficient of nanofluids as a function of volume flow rate for different nanoparticle concentrations is presented in Fig. 8. It is observed that the heat transfer coefficient of all nanofluids is significantly higher than that of the base fluid.

These higher heat transfer coefficients obtained by using nanofluid instead of water allow the working fluid in the automobile radiator to be cooler. The addition of nanoparticles to the water has the potential to improve automotive and heavy-duty engine cooling rates or equally causes to remove the engine heat with a reduced-size coolant system. Smaller coolant systems result in smaller and lighter radiators, which in turn benefit almost every aspect of car and truck performance and lead to increased fuel economy.

VII. CONCLUSION

The presence of Al2O3 nano particles in water + ethylene glycol can enhance the heat transfer rate of automobile radiator. The degree of heat transfer enhancement depends on the amount of the nano particle added to water + ethylene glycol. Ultimately, at the concentration of 0.08 vol % the heat transfer enhancement around 48% compared to the pure water + ethylene glycol recorded.

Increasing the flow rate(3lpm- 15lpm) of base fluid enhance the heat transfer coefficient for both water + ethylene glycol and nano fluid considerably. It seems that the increasing in the effective thermal conductivity and the variation of the other physical properties are not responsible for the large heat transfer enhancement. Brownian motion of nano particles may be one of the factor in the enhancement of the heat transfer.

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