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Experimental Study of Heat Transfer of a Car Radiator with Nano fluid- Al_2O_3/Water mixture as Coolant

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ABSTRACT: Heat transfer in a Car radiator is carried out to cool circulating fluid which regulated of water and a mixture of water and coolant materials like Ethylene glycol (EG). In this Experimental study presented the mixture Ethylene glycol + water (50:50) combination with Al_2O_3 nanoparticle which is called nanofluids in used Car Radiator. In this Experimental Study Volume Concentration used 0.1%, 0.5%, 1% By mixing of Al_2O_3 nanoparticles (size 40 nm). Results of Thermal conductivity, over all heat transfer coefficient, Reynolds number, coolant pressure drop, pumping power have been represented in the present work. It is observed that Overall heat transfer coefficient & heat transfer rate increased different volume concentration by mixing Al_2O_3 particle and flow rate range 2-5 LPM respectively. Thermal conductivity of coolant basefluid (Ethylene Glycol) and nanofluid increases almost linearly with temperature (25 to 45ºC).

KEYWORDS: Nanofluids, Car Radiator, Heat Transfer Enhancement, Magnetic Stirrer, Ethylene glycol, Aluminium oxide Nano particles

I. INTRODUCTION

A wide variety of industrial processes involve the transfer of heat energy. Throughout any industrial facility, heat must be added, removed, or moved from one process stream to another and it has become a major task for industrial necessity. These processes provide a source for energy recovery and process fluid heating/cooling. The enhancement of heating or cooling in an industrial process may create a saving in energy, reduce process time, raise thermal rating and lengthen the working life of equipment. Some processes are even affected qualitatively by the action of enhanced heat transfer. The development of high performance thermal systems for heat transfer enhancement has become popular nowadays. A number of work has been performed to gain an understanding of the heat transfer performance for their practical application to heat transfer enhancement. Thus the advent of high heat flow processes has created significant demand for new technologies to enhance heat transfer there are several methods to improve the heat transfer efficiency.In addition, heat transfer fluids at air and fluid side such as water, ethylene glycol and mixture of ethylene glycol and water (50%+50%) combination exhibit very low thermal conductivity. As a result there is a need for new and innovative heat transfer fluids for improving heat transfer rate in an automobile radiator. Nanofluids seem to be potential replacement of conventional coolants in engine cooling system. Recently there have been considerable research findings highlighting superior heat transfer performances of nanofluids. .A reduction in energy consumption is possible by improving the performance of heat exchange systems and introducing various heat transfer enhancement techniques. [1] Optimal mass characteristics for a heat pipe radiator assembly for space application were investigated by Vlassov et al. [2]. Their results showed that under certain combinations of input parameters, the assembly with acetone HP can be more weight effective than the one with ammonia, in spite of the liquid transport factor criterion indicates an opposite trend.In addition, heat transfer fluids at air and fluid side such as water, ethylene glycol and mixture of ethylene glycol +water (50:50) combination exhibit very low thermal conductivity. As a result there is a need for new and innovative heat transfer fluids for improving heat transfer rate in an automobile radiator. Nanofluids seem to be potential replacement of conventional coolants in engine cooling system. Recently there have been considerable research findings highlighting superior heat transfer performances of nanofluids. Yu et al. [3] reported that about 15-40% of heat transfer enhancement can be achieved by using various types of nanofluids. With these superior characteristics, the size and weight of an automotive car radiator can be reduced without affecting its heat transfer performance. This translates into a better aerodynamic feature for design of an automotive car frontal area. Coefficient of drag can be minimized and fuel consumption efficiency can be improved. Nanofluids have attracted attention as a new generation of heat transfer fluids in building in automotive cooling applications, because of their excellent thermal performance. Recently, there have been considerable research findings highlighting superior heat transfer performances of nanofluids.[9]Therefore, this study attempts to investigate the heat transfer characteristics of an automobile radiator using mixture of ethylene glycol + water (50:50) combination based Al_2O_3 nanofluids as coolants. Thermal performance of an automobile radiator operated with nanofluids is compared with a radiator using conventional coolants. The effect of volume fraction of the Al_2O_3 nanoparticles with base fluids on the thermal performance and potential size reduction of a radiator were also carried out. Al_2O_3 nanoparticles were chosen in this study.

II. NANOFLUID IN ENHANCING THERMAL CONDUCTIVITY

Eastman et al. [4] reported that the thermal conductivity of ethylene glycol nanofluids containing 0.3% volume fraction of copper particles can be enhanced up to 40% compared to that of ethylene glycol base fluid. Hwang et al. [5] found that thermal conductivity of the nanofluids depends on the volume fraction of particles and thermal conductivity of basefluid and particles. Lee et al. [6] measured the thermal conductivity of low volume concentration of aqueous alumina (Al_2O_3) nanofluids produced by two-step method. Authors inferred that the thermal conductivity of aqueous nanofluids increases linearly with the addition of alumina particles. Thermal conductivity of zinc dioxide ethylene glycol (ZnO+EG) based nanofluids was investigated by Yu et al. [7]. They obtained about 26.5% enhancement of thermal conductivity by adding 5% volume fraction of zinc dioxide nanoparticles in ethylene glycol. Present study concluded that size of nanoparticles and viscosity of the nanofluids played a vital role in thermal conductivity enhancement ratio of them. Mintsa et al. [8] 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. Contact surface area of particles with fluid and Brownian motion can be increased when smaller particles are used in the same volume fraction. This consequently increased thermal conductivity of nanofluids.

III. NANOFLUID IN ENHANCING FORCED CONVECTIVE HEAT TRANSFER

Namburu et al. [10] numerically analyzed turbulent flow and heat transfer to three types of nanofluids namely copper oxide (CuO), alumina (Al_2O_3) and silicon dioxide (SiO2) in ethylene glycol and water, flowing through a circular tube under constant heat flux. Results revealed that nanofluids containing smaller diameter of nanoparticles produce higher viscosity and Nusselt number. Nusselt numbers are also increased at higher volume fraction of particles. It is observed that at a constant heat flux (50 W/cm^2) with a constant Reynolds number (20,000), heat transfer coefficient of 6% CuO nanofluid has increased 1.35 times than that of the base fluid. At the same particle volume fraction, CuO nanofluid produced higher heat transfer coefficient compared to that of other types of nanofluids.Ding et al. [11] found that convective heat transfer coefficient of nanofluids has the highest magnitude at the entrance length of a tube. It starts decreasing with axial distance and eventually accomplish at a constant value in the fully developed region. At a given flow and particle concentration, aqueous carbon nanoparticles offer highest improvement. Zeinali et al. [12] experimentally investigated convective heat transfer to alumina water (Al_2O_3/water) nanofluids in laminar flow inside a circular tube with constant wall temperature under different concentrations of nanoparticles. They obtained augmentation of heat transfer coefficient of nanofluid with increase of nanoparticle concentration. They also obtained greater heat transfer coefficient of nanofluid in comparison to that of distilled water base fluid at a constant Peclet number. Authors have reported that the heat transfer augmentation results are much higher in experimental observation than that of predicted results. Yu et al. [13] conducted heat transfer experiments of nanofluids containing 170-nm silicon carbide particles at 3.7% volume concentration. The results showed that heat transfer coefficients of nanofluids are 50-60% greater than those of base fluids at a constant Reynolds number.Kim et al. [14] investigated effect of nanofluids on the performances of convective heat transfer coefficient of a circular straight tube having laminar and turbulent flow with constant heat flux. Authors have found that the convective heat transfer coefficient of alumina nanofluids improved in comparison to base fluid by 15% and 20% in laminar and turbulent flow, respectively. This showed that the thermal boundary layer played a dominant role in laminar flow while thermal conductivity played a dominant role in turbulent flow. However, no improvement in convection heat transfer coefficient was noticed for amorphous particle nanofluids.

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IV. EFFECT OF NANO FLUID ON HEAT TRANSFER (Al_2O_3 NANOPARTICLE)

There are many effect of nanofluid heat transfer such as effect of particle volume fraction, effect of particle material, effect of base fluid, effect of particle size, effect of particle shape, effect of temperature, effect of preparation method followed. They are increasing the thermal conductivity and heat transfer rate compared to base fluid like as water, Ethylene glycol,Engine oil,Acetone,Decene.

V. METHODOLOGY

- **EXPERIMENTAL TEST RIG**

The test rig in Fig. 1 has been used to measure heat transfer coefficient and friction factor in the automotive engine radiator. This experimental setup includes a reservoir plastic tank, electrical heater, a centrifugal pump, a flow meter, tubes, valves, a fan, a DC power supply, Digital thermocouples type K for temperature measurement heat exchanger (Car radiator). An electrical heater (2000W) inside a plastic storage tank (40cm height and 30 cm diameter) put to represent the engine and to heat the fluid .A voltage regular (0–220 V) provided the power to keep the inlet temperature to the radiator from 60 to 80 C. A flow meter (0–30 LPM) and two valves used to measure and control the flowrate .The fluid flows through plastic tubes (0.5in.) by a centrifugal pump (0.5hp) from the tank to the radiator at the flow rate range 2–8 LPM. The total volume of the circulating fluid is 3l and constant in all the experimental steps. Two thermocouples (copper–constantan) types K have been fixed on the flow line for recording the inlet and outlet fluid temperatures. Digital thermocouples type K have been fixed to the radiator surface to ensure more of surface area measurement. Two thermocouples type K also fixed in front of the fan and another side of radiator to measure air temperatures. A hand held (-40 ^{o} C to1000 ^{o} C) digital thermometer with the accuracy of used to read all the temperatures from thermocouples. Calibration of thermocouples and thermometers carried out by using a constant temperature water bath and their accuracy estimated to be 0.15 C .The car radiator has louvered fin and 32 flat vertical Aluminum tubes with flat cross sectional area.The distances among the tube rows filled with thin perpendicular Aluminum fins .For the air side,an axial force fan (1500rpm) installed close on axis line of the radiator .The DC power supply Adaptor convert AC to DC. For heating the working fluid an electric heater of capacity 2000 watt and controller were used to maintain the temperature 40^{o}-80^{o}C. Two K type thermocouples were implemented on the flow line to record the radiator inlet and outlet temperature. Two thermocouples K types is installed in the radiator to measure the wall temperature of the radiator.

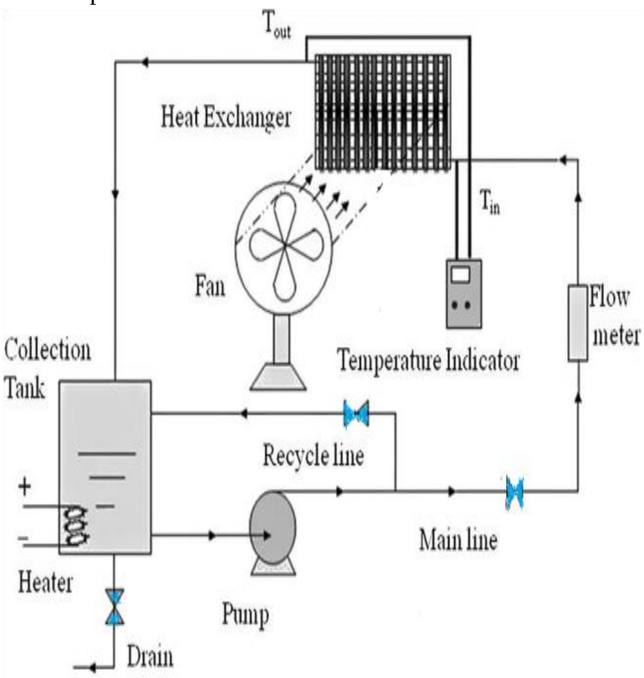

Figure 1 Schematic of experimental set up & Actual picture of Experimental setup

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- **PHYSICAL PROPERTIES Al_2O_3 NANO-PARTICLE**

Mean diameter	Specific Surface m^2/gram	Density (kg/m^3)	Thermal conductivity (W/m k)	Specific Heat (KJ/kgK)	X ray analysis :	particle shape
40 nm	> 40	3700	237	880	ϒ-AlO3 40nm	spherical, elongated

- **CAR RADIATOR SPECIFICATIONS**

S.No.	Description	Air	Coolant
1	Fluid inlet temperature	30 (Assume T_a=24)	85 (Assume Ta= 60)
2	Core width	315 mm	315 mm
3	Core height	315 mm	315 mm
4	Core depth	2 cm	2 cm
5	Tubes	0.7 cm x 30 cm	
6	Fin thickness	0.01 cm	0.01
7	Hydraulic Diameter	7 cm	7 cm
8	Fine types	Ruffled	Ruffled
9	Tubes arrangement	Staggered	Staggered

- **PREPARATION OF NANO-FLUID**

In this experimental study has done prepare nanofluid by magnetic stirrer technique. A magnetic stirrer is a laboratory device that employs a rotating magnetic field to cause a stir bar (magnet) immersed in a liquid to spin very fast and magnetic stirrer also provide heat to the solution. The rotating field may be created either by a rotating magnet. Placed the vessel with liquid on it. Since glass does not affect a magnetic field and most chemical reactions take place in glass vessels, magnetic stir bars work well in glass vessels. On the other hand, the limited size of the bar means that magnetic stirrers can only be used for relatively small experiments. The another advantage of magnetic stirrer to mechanical stirrer is there is no cavitation occur.

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Fig No. 2 Preparation of nanofluid by magnetic stirrer

VI. RESULTS AND DISCUSSION

- **EFFECT OF TEMPERATURE ON thermal CONDUCTIVITY OF NANOFLUID COOLANT WITH Al_2O_3 AS NANO-PARTICLES**

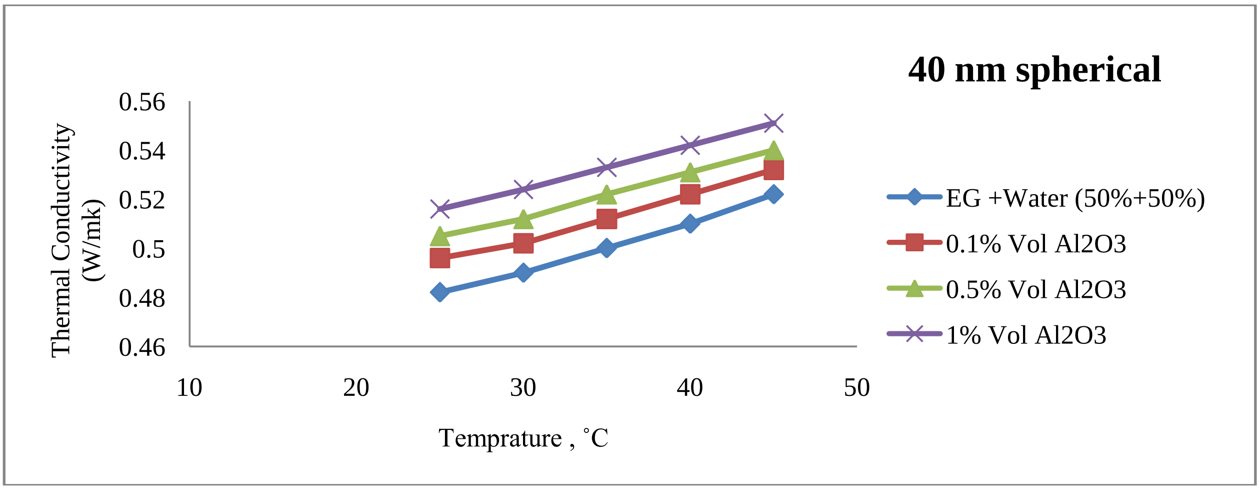

Fig No.3 Temperature on thermal conductivity of nanofluid coolant with Al_2O_3 particles (spherical)

Show in Fig No. 3 it clearly shows that the thermal conductivity of nanofluid is higher than that of base fluid. As the percentage of nanoparticle increases the value of thermal conductivity at constant temperature also increases. Thermal conductivity of both water-ethyl glycol mixture (base fluid) and nano-fluid increased almost linearly with temperature (25 to 45 ºC). At constant volume concentration (0.1%, 0.5% and 1%) of nanoparticles (Al_2O_3) the thermal conductivity increase is almost linear with respect to temperature. At lower temperature increase in thermal conductivity is less, as compared to increases in thermal conductivity at temperatures (35 – 45 º C).

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- **EFFECT OF OVERALL HEAT TRANSFER COEFFICIENT, REYNOLDS NUMBER (AIR), FLOWRATE, PUMPING POWER**

Shown in Fig No 4 Effects of volume fraction of nano-particle on over all heat transfer coefficient of car radiator were observed at constant air Reynolds number (84389) and Constant flow rate 2 LPM. The Overall heat transfer coefficient of 309 W/m2k was obtained for 1% Al2O3 + mixture of EG +water.

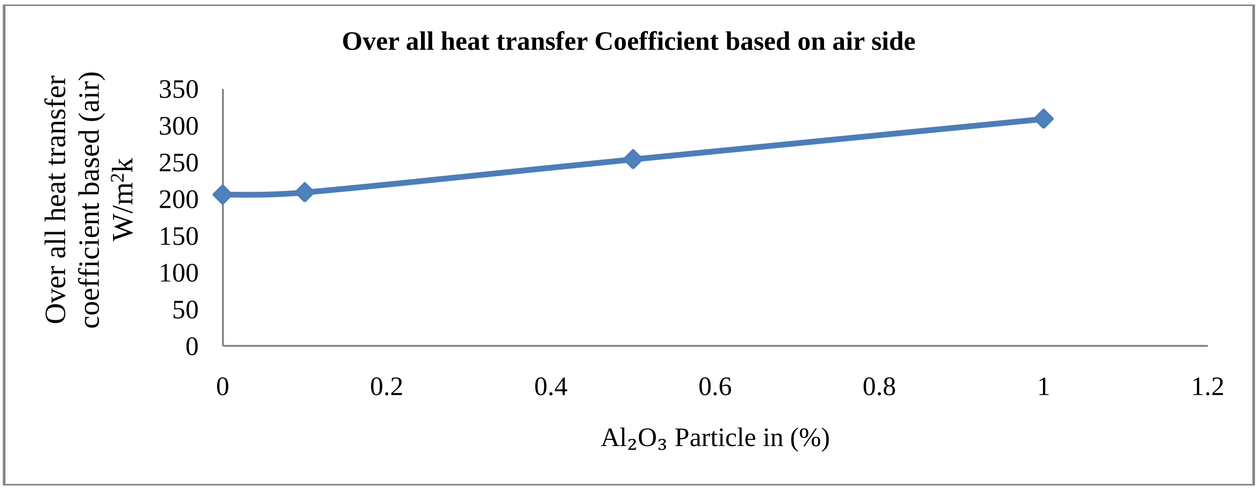

Fig No 4 Effect of volume fraction of nano-particle on over all heat transfer coefficient

Shown in Fig No 5 The Reynolds number affects the thermal performance of car radiator. The coolant mass flow rate was kept constant (2 LPM).

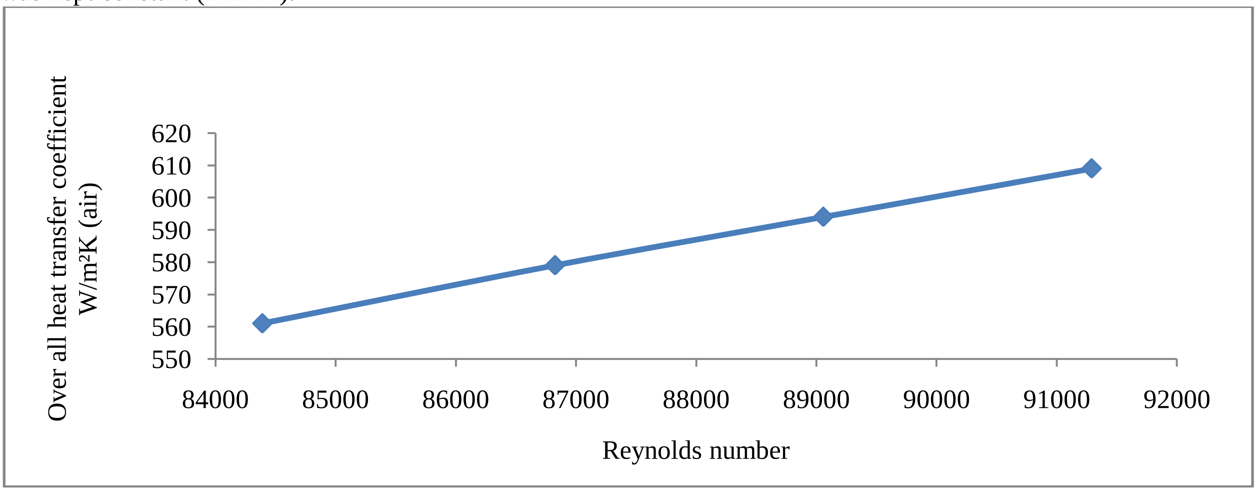

Fig No.5 Effect of Reynolds number with over all heat transfer coefficient

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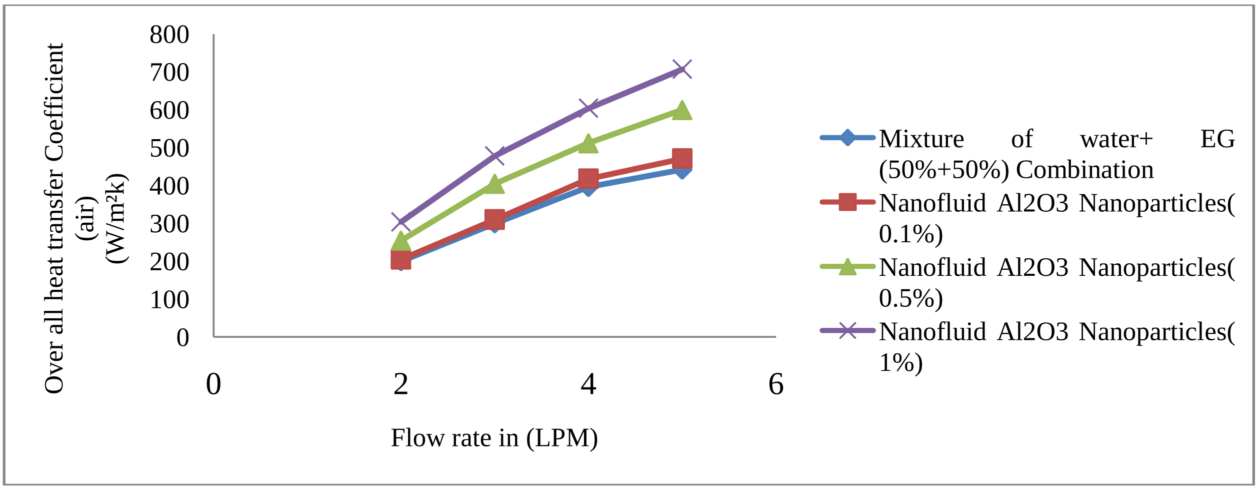

Fig No 6 Effect of flow rate with over all heat transfer Coefficient (% of Al_2O_3 particles)

Show in Fig 6 Overall heat transfer coefficient on air side was increased with flow rate. Heat transfer enhancement was also observed with increase in mass flow rate of the coolant. But it cannot increase beyond certain limit because of constrains in size/flow area of the radiator tubes.

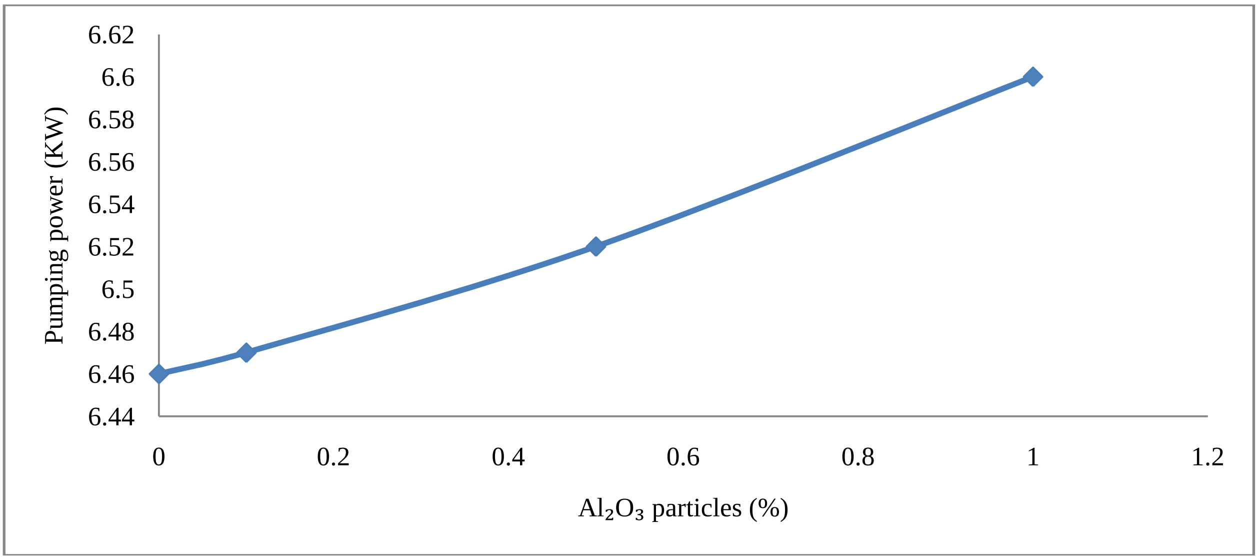

Fig No 7 Percentage of Al_2O_3 to Pumping power

Shown in Fig 7 this Experiment study coolant flow rate was fixed at 5 LPM and air Reynolds number is 91289 but the volume fraction of Al_2O_3 nano particles was varied. Calculated results show that about 3 % increase in pumping power was observed at 1% addition of Al_2O_3 nanofluids compared to EG or Water.

VII. CONCLUSIONS

1) Thermal conductivity of (Ethylene Glycol: water) mixture and nanofluid increases almost linearly with temperature (25 to 45ºC). At a particular value of temperature corresponding enhancement in thermal conductivity is less in the volume concentration range from 0.1 to 0.5%.

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2) Heat transfer rate is increased with increase in volume concentration of nanoparticle (0.1%, 0.5%, and 1%). In this study 3.6% heat transfer enhancement was reached with addition of 1% Al_2O_3 nanoparticle at 84389 Air Reynolds number and constant flow rate 2 LPM.
3) In this experimental Study of the Car radiator using nanofluid, overall heat transfer coefficient is increased with air Reynolds Number. 64 % increment in the Overall heat transfer coefficient and Total heat transfer based on the air side at constant 5 LPM flow rate and range of air Reynolds number (84389-91288) .
4) Extra 3% pumping power is requirement for the radiator using 1% Al_2O_3 nanoparticles with Ethylene Glycol + Water combination (50:50) at 5 LPM coolant flow rate compared to that of using Basefluid same radiator.
5) It is not justified to increase the volume concentration of nanoparticle beyond 1% as it will not only increase the pressure drop/pumping power but also increases the cost of the system although some increase in heat transfer coefficient also increases.

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