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Investigation of Automobile Radiator Using Nanofluid-CuO/Water Mixture as Coolant

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ABSTRACT: In this study water and Ethylene glycol (EG) as conventional coolant have been widely used in automotive car radiator from many times. These heat transfer fluid have low thermal conductivity. In this Experimental study presented the mixture Ethylene glycol + water (50:50) combination with CuO nanoparticle which is called nanofluids in used car radiator. In this Experimental study it was observed the heat transfer enhancement could be achieved with the addition of different Volume Concentration used 0.5%, 1%, 1.5, 2% By mixing of CuO nanoparticles in a base fluid at the Reynolds number of 8000 and 6000 for coolant respectively. Results of thermal Viscosity of nano fluid, Overall heat transfer coefficient, Reynolds number, 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 CuO particle and flow rate range 2-5 LPM respectively.

KEYWORDS: Nanofluids, Car Radiator, Heat Transfer Enhancement, Ethylene Glycol, Copper oxide nanoparticle.

I. INTRODUCTION

In order to improve the thermal properties of various types of liquids, Maxwell's idea to disperse solid particles into liquid, like metals, carbon nano tubes, oxides and other compounds, into a liquid base has been tested already since 19th century. Initially, these particles have micrometric size and they presented several problems due to the tendency to settle down, high pumping power and the wearing effect on the surfaces. Recently, the new development of nanotechnologies offered the possibility to obtain particles with having nano metric size that have supposed to eliminate these problems when dispersed in the liquid .These new suspensions is called Nanofluids.
Nanofluids are fluids containing nanoparticles (nanometre-sized particles of metals, oxides, carbides, nitrides, or nano tubes). Nanofluids exhibit enhanced thermal properties, amongst them; higher thermal conductivity and heat transfer coefficients compared to the base fluid. Simulations of the cooling system of a large truck engine indicate that replacement of the conventional engine coolant (ethylene glycol-water mixture) by a nanofluid would provide considerable benefits by removing more heat from the engine. Additionally, a calculation has shown that a graphite based nanofluid developed jointly by Argonne and Valv oline could be used to eliminate one heat exchanger for cooling power electronics in a hybrid electric vehicle. This would obviously reduce weight, and allow the power electronics to operate more efficiently. The benefits for transportation would be:

- Radiator size reduction
- Pump size
- Possible of elimination of one heat exchanger for hybrid-electric vehicles

Increased fuel efficiency **Sarit k. Das et al. [1]** Nanofluids which are a mixture of nano-sized (1nm-100 nm) particles (nanoparticles) suspended in a base fluid, are used to enhance the heat transfer rate, via its improved thermo physical properties compared to the base fluid. Since solid materials possess higher thermal conductivities than base fluid. Nanofluids have been projected as a next generation fluid capable of superior heat transfer when compared to conventional heat transfer fluids for a given set of conditions. With very small volume fraction of such nanoparticles the thermal conductivity and convective heat transfer capability of these suspensions are significantly enhanced without the problems encountered in various types of slurries such as high pumping power, clogging, erosion, sedimentation. Modern nanotechnology can produce various types of metallicor, non-metallic particles of nanometer sizes. Nanoparticle materials have exclusive chemical properties, mechanical properties, optical, electrical properties, magnetic properties, & thermal properties. Nano fluids (nanoparticle fluid suspensions) is the term invented by **Choi et al. [2]** to describes this new generation of nanotechnology-based heat transfer fluids that exhibited thermal properties

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higher to those of their host fluids or conventional particle fluid suspensions. Nano fluid technology, a new inter disciplinary field of great importance where nano science, nano technology, and thermal engineering encounter, has developed largely over the past decade. The goal of nano fluids is to achieve the highest possible thermal properties at the smallest possible concentrations (preferably < 1% by volume) by uniform dispersion and stable suspension of nanoparticles (preferably < 10 nm) in host fluids. To achieve this goal it is vital to understand how nanoparticles enhance energy transport in liquids. Since Choi conceived the innovative concept of nanofluids in the spring of 1993, talented and thoughtful thermal scientists and engineers in the promptly emergent nanofluids community have made scientific development not only in determining unexpected thermal properties of nanofluids, but also in offering new mechanisms behind enhanced thermal properties of nanofluids, developed alternative models of nanofluids, and identifying unusual prospects to develop next-generation coolants such as smart coolants for computers and anodyne coolants for the nuclear reactor's cooling. As a result, the research matter of nanofluids has been getting increased attention around the worldwide. In the accumulation of increasing number of articles published per year, there are many indicators that give burden to the argument that nanofluid research is getting more and more active and important. Intensifying interest in nanofluids is based on the comprehension that it is possible to develop ultrahigh-performance coolants whose thermal properties are extremely different from those of conventional heat transfer fluids, because in the nanoscale range, necessary properties of nonmaterial such as nanofluids depend strongly on nanoparticle, material, size, shape, and the surface/interface area.

II. PROPERTIES OF NANO -FLUIDS

It may be noted that particle size is an important physical parameter in nanofluids because it can be used to tailor the nanofluid thermal properties as well as the suspension stability of nanoparticles. Researchers in nanofluids have been trying to exploit the unique properties of nano particles to develop stable as well as highly conducting heat transfer fluids. The key building blocks of nanofluids are nanoparticles; so research on nanofluids got accelerated because of the development of nanotechnology in general and availability of nanoparticles in particular. Compared to micrometer sized particles, nanoparticles possess high surface area to volume ratio due to the occupancy of large number of atoms on the boundaries, which make them highly stable in suspensions. Thus the nano suspensions show high thermal conductivity possibly due to enhanced convection between the solid particle and liquid surfaces. Since the properties like the thermal conductivity of the nano sized materials are typically an order of magnitude higher than those of the base fluids, nanofluids show enhancement in their effective thermal properties. Due to the lower dimensions, the dispersed nano -particles can behave like a base fluid molecule in a suspension, which helps us to reduce problems like particle clogging, sedimentation etc. found with micro particle suspensions. The combination of these two features; extra high stability and high conductivity of the dispersed 'nanospecies' make them highly preferable for designing heat transfer fluids. The stable suspensions of small quantities of nano particles will possibly help us to design lighter, high performance thermal management systems. Cooling is indispensable for maintaining the desired performance and reliability of a wide variety of industrial products such as computers, power electronic circuits, car engines, high power lasers, X-ray generators etc. With the unprecedented increase in heat loads and heat fluxes caused by more power in miniaturized products, high tech industries such as microelectronics, transportation, manufacturing, metrology and defence face cooling as one of the top technical challenges. For example, the electronics industry has provided computers with faster speeds, smaller sizes and expanded features, leading to ever increasing heat loads, heat fluxes and localized hot spots at the chip and package levels. Such thermal problems are also found in power electronics, optoelectronic devices etc. So the enhanced heat transfer characteristics of nanofluids may offer the development of high performance, compact, cost effective liquid cooling systems.

III. THERMAL CONDUCTIVITY OF NANOFLUID

Masuda et al. [3] studied the thermo physical properties of Al_2O_3–water, SiO_2–water and TiO_2–water nanofluids. The transient hot-wire method was used to measure the thermal conductivity of nanofluids. They establish that the thermal conductivity of nanofluids increasing by 32 % at the concentration of 4.3 vol. %. They concluded that temperature did not have any effect on the increase of relative thermal conductivity.

Lee et al. [4] conducted an experiment to measure the thermal conductivity of Al_2O_3 and CuO suspended in water and ethylene glycol. Particle sizes of Al_2O_3 and CuO were 23.6 nm and 38.4 nm, respectively. The transient hot-wire method had used to measure the thermal conductivity of nanofluids at a concentration range of 1–4 vol. %. Their results indicated that nanofluids had higher thermal conductivity than the base fluid, and it increased with the increasing level of concentration. When compared the experimental results with prediction from Hamilton and Crosser

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model, it was found that the model could predict thermal conductivity of Al_2O_3 nanofluids, but it could not predict for CuO nanofluids.

Wang et al. [5] studied thermal conductivity of Al_2O_3 and CuO nanofluids with a particle size of 20 nm. Each was suspended in water, vacuum pump oil, engine oil, and ethylene glycol. The steady state method was used to measure thermal conductivity. Their results showed that the thermal conductivity of both nanofluids were higher than that of the base fluids and varying with concentration level. The engine oil and ethylene glycol base fluids yielded higher enhancement than other types of base fluids. When compared with the theoretical model, a thermal conductivity ratio of the nanofluids was found to be higher.

Eastman et al. [6] conducted an experiment to measure the thermal conductivity of Cu– ethylene glycol nanofluid with an average copper particle size of 10 nm and concentration level of 0.6 vol. %. A transient hot-wire method was used for measurement. They found that nanofluids had higher thermal conductivity when the concentration level increased. Moreover, acid-added nanofluids had increased thermal conductivity. At 0.3 vol. % concentration level, thermal conductivity of acid-added Cu nanofluid increased dramatically by 40%. Their experimental results were higher than those obtained from the classical model. The researchers proposed that the shape of particle also had an effect on the increase of thermal conductivity.

Chon and Kihm et al. [7] studied the increase in thermal conductivity of a nanofluid due to Brownian motion. Al_2O_3–water nanofluid at the concentration of 1 vol. % was used in this experiment. The particle sizes used were 11 nm, 47 nm, and 150 nm in a temperature range of 20–70 ºC. They reported the thermal conductivity of the nanofluid increased more than the base fluid and rise with the increase of temperature. They also establish that smaller particle sizes give higher thermal conductivity. They asserted the increase in thermal conductivity of the nanofluid resulted from Brownian motion or micro-convection mechanism. They argued the increase of temperature caused a greater Brownian motion mechanism.

Li and Peterson et al. [8] conducted an experiment on the measurement of thermal conductivity of Al_2O_3 nanofluids with particle sizes of 36 nm and 47 nm. The nanofluids were suspended in distilled water at temperatures of 27 ºC – 37 ºC and concentration levels of 0.5–6.0 vol. %. They used a steady-state method for measurement. Their experimental results showed the thermal conductivity of nanofluids increased more than the base fluid and increased with the rise of concentration level and temperature. However, the increase was nonlinear. They also found that particle size was an important parameter for the increase of thermal conductivity. Smaller particles have higher increase than larger particle. In this experiment, the temperature of 32 ºC and concentration levels of 2 vol. % and 4 vol. % were optimal points that had the highest increase of thermal conductivity.

M. Chopkar et al. [9] studied, Al_2Cu and Ag_2Al nanoparticles dispersing about 0.2–1.5 vol. % these nanoparticles in water and measured the thermal conductivity of nanofluid using modified thermal comparator for thermal conductivity. The results indicate that the present nanofluids records 50–150% improvement in thermal conductivity. The experimental results and analytical study show that the degree of enhancement strongly depends on identity/composition, size, volume fraction and shape (aspect ratio) of the dispersed nanoparticles.

Sundar and Sharma [10] obtained thermal conductivity enhancement of 6.52% with Al_2O_3 nanofluid, 24.6% with CuO nanofluid at 0.8% volume concentration compared to water.

L. Syam Sunder et al. [11] studied, enhancement in viscosity for 1.0% volume concentration of 60:40% EG/W nanofluid is 2.94 times, 40:60 % EG/W nanofluid is 1.61 times and 20:80 % EG/W nanofluid is 1.42 times compared to the same base fluids at a temperature of 50 ºC. The enhancement in viscosity for 1.0 % volume concentration of 60:40 % EG/W nanofluid is 2.13 times, 40:60% EG/W nanofluid is 1.92 times and 20:80 % EG/W nanofluid is 1.4 times compared to the same base fluids at a temperature of 0 ºC. The magnetic nanofluids can comfortably use as heat transfer fluids. The unique advantage of these fluids is having magnetic response even if the nanoparticles are fully dispersed in the base fluid.

K.S. Suganthi et al. [12] performed experiments on preparation of colloidal dispersions of ZnO nanoparticles in propylene glycol to ZnO–propylene glycol nanofluids. Thermal conductivity of nanofluids was measured as a function of nanoparticle concentration (6.2 vol. %), temperature (10–60 ºC) and aggregate size. A strong dependency of thermal conductivity enhancement on temperature with higher enhancements at lower temperatures has been observed. Their results on temperature and aggregation dependence of thermal conductivity enhancement show that the thermal conductivity enhancement in ZnO–propylene glycol nanofluids is attributed to formation of solvation layers (liquid layers) of base fluid on the ZnO nanoparticle surfaces.

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IV. METHODOLOGY

A. EXPERIMENTAL TESTRIG AND PROCEDURE

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 flow rate. 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 C to1000 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 .

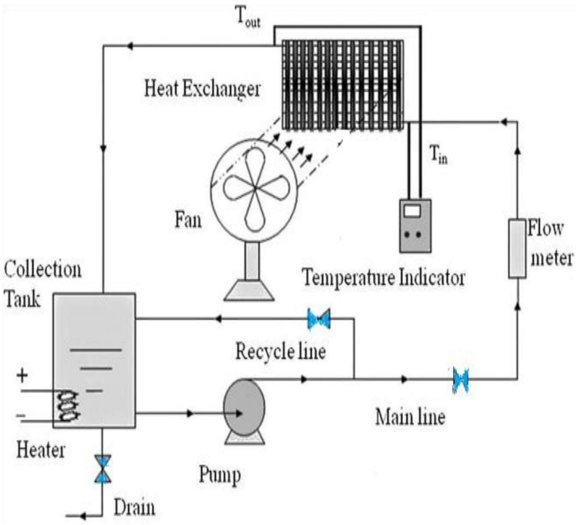

Fig No 1 Schematic of experimental set up Actual picture Experimental set up

The car radiator has louvered fin and 32 flat vertical Aluminium tubes with flat cross sectional area. The distances among the tube rows filled with thin perpendicular Aluminium 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 40o-80oC. 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.

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Table 1 - Radiator specification

Serial number	Description	Air	Coolant
1	Fluid-inlet temperature	20-40 (Assume Ta=24)	50-80 (Assume Ta= 60)
2	Core width	0.35 m	
3	Core height	0.35 m	
4	Core depth	0.016 m	
5	Tubes	0.7cm x 30 cm	
6	Fin thickness	0.01 cm	
7	Hydraulic Diameter	0.0007 m	
8	Fine types	Ruffled	
9	Tubes arrangement	Staggered	

Table 2 Thermo physical Properties of base Fluid and nanoparticles

Sr no	Properties	CuO	Mixture of water +ethylene glycols
1	Density (Kg/m^3)	6510	1064
2	Specific heat (J/kg K)	540	3370
3	Thermal conductivity	18	0.363
4	Viscosity(Ns/m2)	-	4.65 x 10-5

B. **PREPARATION OF NANOFLUID**

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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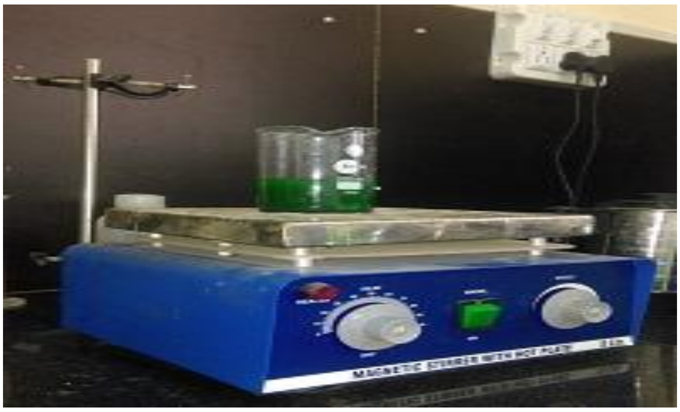

Actual Picture Preparation of Nanofluid Actual Picture Preparation of Nanofluid

C. **MATHMATICAL FORMULATION OF MIXTURE OF WATER + ETHYLENE GLYCOL BASED CuO NANOFLUID IN AN AUTOMOBILE RADIATOR**

The main characteristics of radiator are listed in Table 1 that useful for assessing the radiator performance in this work. However, following assumptions are made:

- The flow is an incompressible, steady state and turbulent.
- The effect of body force is neglected.
- The thermo physical properties of nanofluids are constant.

The characteristics of nanoparticles and base fluid used in this study are summarized in Table 2. The necessary thermo physical properties in this paper are density, viscosity, specific heat and thermal conductivity.
In this paper, density (ρ_{nf}) and special heat capacity (C_{nf}) of CuO/water Nanofluid have been calculated based on empirical correlations proposed by **Pak [13] and Xuan [14]** as follows:

$$\rho_{nf} = (1-\varphi)\rho_{bf} + \varphi\rho_p (1)$$
$$C_{nf} = \frac{\varphi\rho_p + (1-\varphi)\rho_{bf} c_{bf}}{\rho_{nf}} (2)$$

Where f is nanoparticle volume concentration and ρ_p, ρ_{bf} and C_p, C_{bf} are the densities and the specific heats of the nanoparticles and base fluid, respectively. Also, thermal conductivity (k_{nf}) and viscosity (μ_{nf}) for nanofluid have been estimated based on two semi-empirical equations presented by **M. Eftekhar [15]** in 2013 on the basis of a wide variety of experimental date available in the literature as following equations

$$K_{nf} = \frac{K_p + (n-1)K_{bf} - \varphi(n-1)(K_{bf} - K_p)}{K_p + (n-1)K_{bf} - \varphi(n-1)(K_{bf} - K_p)} \times K_{bf} (3)$$
$$\mu_{nf} = \mu_{bf} \times \frac{1}{(1-\varphi)^2} (4)$$

- HEAT TRANSFER MODELING

The rate of heat transferred between nanofluid coolant and airflow in the radiator can be written as follows:
$Q = m_{nf} C_{nf} (T_{nfo} - T_{nfi}) = m_a C_{pa} (T_{ao} - T_{ai}) (5)$
Where nf and ai denote the relevant parameters of nanofluid coolant and air flow The mass flow rates are calculated based on the pump for mixture of water & Ethylene glycol (50% volume concentration) + Nanofluid and the speed and frontal area for the air as follows:
$m_{nf} = \rho_{nf} V_{nf} A_{tube} (6)$
$m_a = \rho_a v_a A_{fr} (7)$
The Effectiveness of the radiator is given below
$\text{Effectivness of the fin} = \frac{\text{Actual Heat transfer}}{\text{maximum Heat Transfer}} (8)$

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$\varepsilon = \frac{m_{nf} C_{nf} (T_{nfo} - T_{nfi})}{m_a C_{pa} (T_{nfo} - T_{ai})}$ (9)

Cmin = ma x Cpa(10)

Total heat transfer in the radiator is given below

$Q_t = \varepsilon C_{min} (T_{nf} - T_{ai})$ (11)

Overall Heat Transfer coefficient based on the air side can be express below

$U = \frac{Q_t}{A_{fr} (T_{nfi} - T_{ai})}$ (12)

Air Heat transfer coefficient can be expressed as follows

$h_a = \frac{J_a G_a C_{pa}}{pr_a^{\frac{2}{3}}}$(13)

Where

$J_a = \frac{0.174}{Re_a^{0.383}}$(14)

$G_a = \frac{Re_a \mu_a}{D_{ha}}$(15)

- PRESSURE DROP MODELING

Pressure drop is given by

$\Delta P_{nf} = \frac{2 \times G_{nf}^2 \times f_{nf} \times H}{\rho_{nf} \times D_{hnf}} \times (\mu_{nf}/\mu_{bf})^{0.25}$(16)

$G_{nf} = \frac{Re_{nf} \times \mu_{nf}}{D_{nf}}$(17)

Pumping Power is given by

$P = V_{nf} \times \Delta P_{nf}$ (18)

V. RESULT AND DISCUSSION

A. VARIATIONS OF VISCOSITY FOR NANOFLUID AT DIFFERENT VOLUME FRACTION

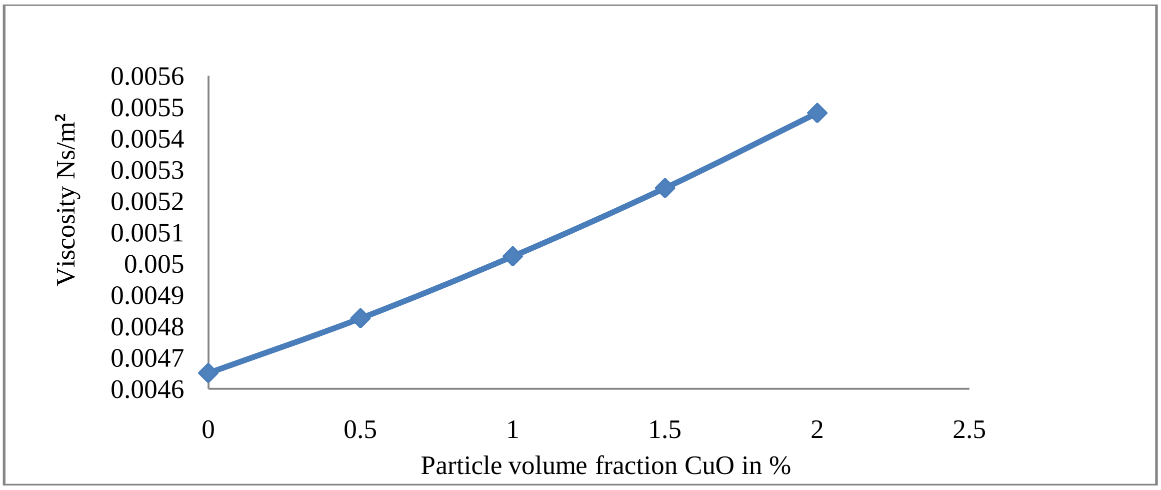

Fig No 2 Variations of Viscosity for Nanofluid at different Particle fraction

In Shown **Figure 2** we have taken particle volume fraction 0.5%,1%,1.5%,2% then we achieved maximum Viscosity 0.005481 Ns/m^2.

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B. **VARIATION OF OVER ALL HEAT TRANSFER COEFFICIENT AT DIFFERENT VOLUME FRACTION**

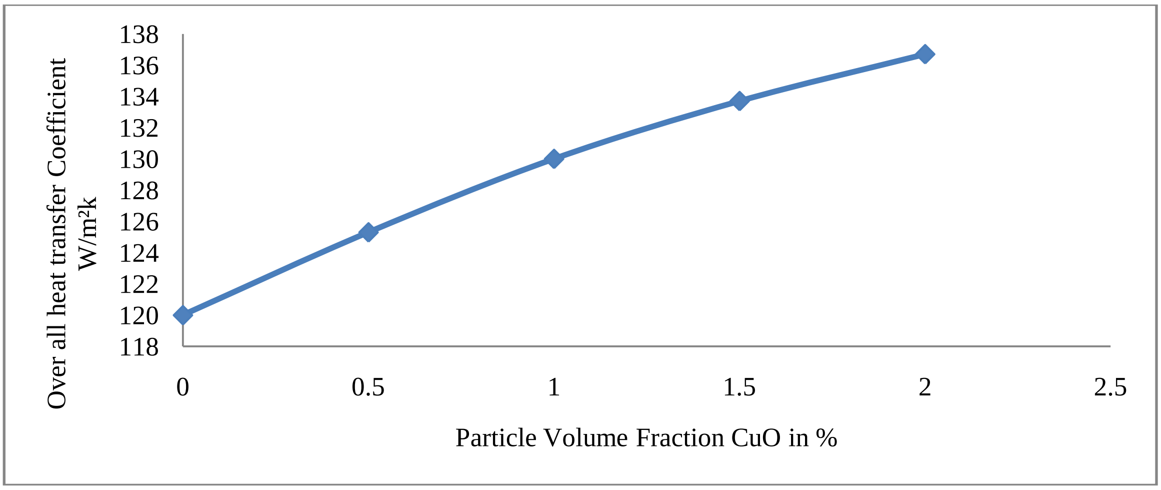

Fig No 3 Variations of Overall heat transfer coefficient for nanofluid at different volume fractions.

Figure 3 shows the overall heat transfer coefficient for CuO-water nanofluid coolant in an automotive radiator that has been calculated by Equation. In this analysis, Reynolds number of the nanofluid is 6000. As shown in this figure, the overall heat transfer coefficient is high when the probability of collision between nanoparticles and the wall of the flat tubes has increased under higher concentration conditions. It confirms that nanofluids have considerable potential to use in the automotive radiator. A further inspection of **Figure 3** shows that the Overall heat transfer coefficient of the CuO-water nano-fluid for volume concentrations in the range of 0.5% to 2% is about 120.6 and 136.7 W/m^2k, respectively.

C. **VARIATION OF OVER ALL HEAT TRANSFER COEFFICIENT AT DIFFERENT FLOWRATE**

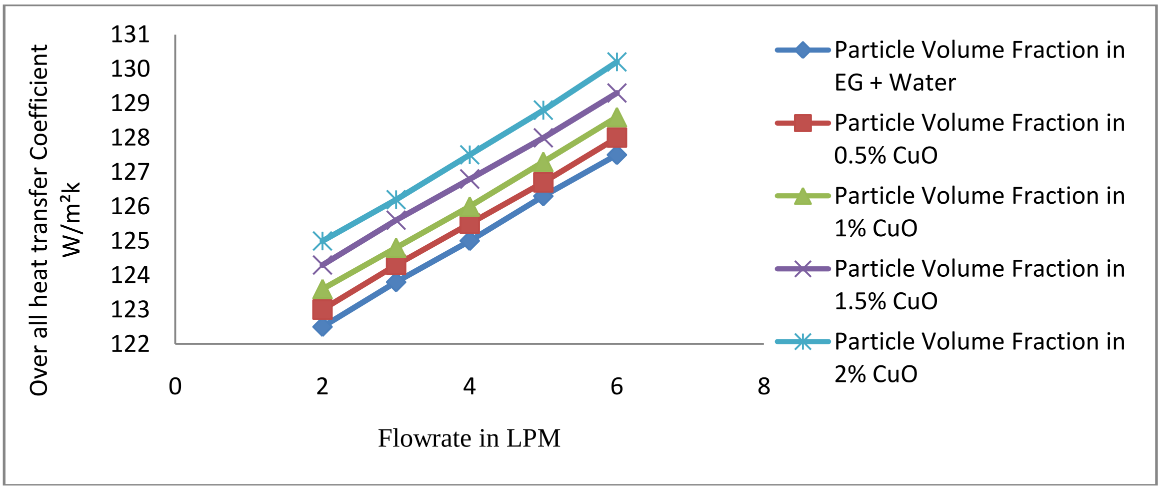

Fig No 4 Variation of Overall heat transfer coefficient for nanofluid at different flowrate in (LPM).

Figure No 4 shows 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. We have taken flowrate 2,3,4,5 and 6 LPM then we achieved maximum over all heat transfer coefficient 130.2 W/m^2K at 6 LPM flowrate.

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D. **VARIATIONS OF PRESSURE DROP, PUMPING POWER FOR NANOFLUID AT DIFFERENT VOLUME FRACTIONS**

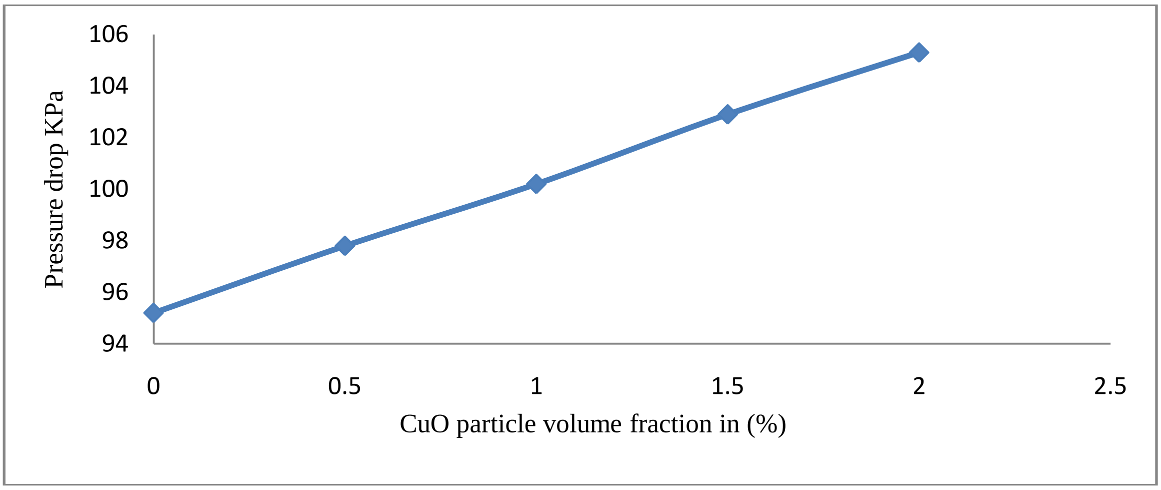

Fig No 5 Variations of Pressure drop for nanofluid at different volume fractions

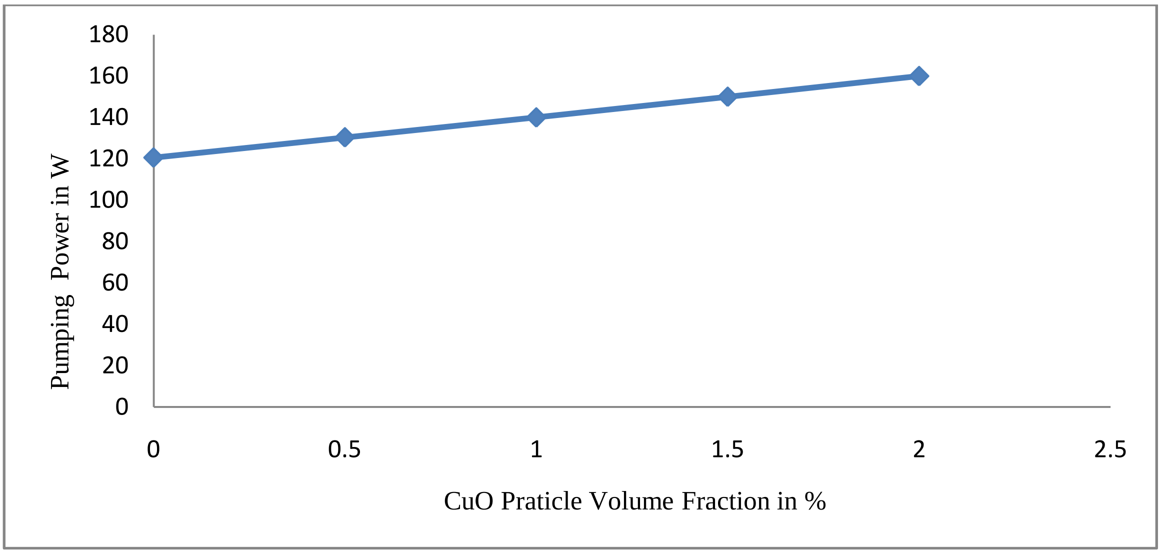

Fig No 6 Variations of Pumping Power for nanofluid at different volume fractions

In order to apply the nanofluids for practical application, in addition to the heat transfer performance it is necessary to study their flow features. With increasing nano- particles loading in the base fluid, viscosity and density of the nanofluids increase and therefore the friction factor and the pressure drop must be increased. Hence, nanofluids generally require the greater pumping power than their base fluid. In the present paper, the pumping power for CuO-water nanofluid coolant flowing in the flat tubes in the various ranges of the coolant Reynolds number.

VI. CONCLUSION

- The density and viscosity of nanofluid is increased with the addition of copper oxide nanoparticle from (0% to 2%) About at 10% nanofluid density & 19.35 viscosity is increased at 2% of CuO in linear way.

- Heat transfer rate is increased with increase in volume concentration of nanoparticle (0.5%, 1%, 1.5%, and 2%). In this study 4.2% heat transfer enhancement was reached with addition of 2% CuO nanoparticle at 6000-8000Reynolds number and constant flow rate 2-5 LPM.
- Extra 14.8% pumping power is requirement for the radiator using 2% CuO nanoparticles with Ethylene Glycol + Water combination (50:50) at 5 LPM coolant flow rate compared to that of using Basefluid same radiator.
- It is not justified to increase the volume concentration of nanoparticle beyond 2% 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.
- It is not justified to increase the mass flow rate beyond certain limit because of fixed sizes/flow are of radiator tubes.

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