COMPARING PERFORMANCE OF NANOFLUIDS OF METAL AND NONMETAL AS COOLANT IN AUTOMOBILE RADIATOR

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ABSTRACT

In this paper research has been carried out to experimentally compare the heat transfer capacity and flow characteristics of copper and titania nanofluids in an automobile radiator. The nanofluids are prepared by dispersing nanoparticles in the base fluid with 0.1% weight concentration. The test liquid flows through radiator consisting of 37 vertical tubes with elliptical cross section. Air cross flows over the tubes with constant speed. The liquid in radiator flows in the range of 1-5 lpm to have Reynolds number in the range of 3000 to 20000. Results show heat transfer comparison and flow characteristics of the individual nanofluids. Also effects of increasing fluid flow rate on the heat transfer performance by keeping inlet fluid temperature constant are discussed.

Keywords*: *Heat Transfer Enhancement, Nanoparticles, Nusselt Number, Thermal Conductivity

I. INTRODUCTION

In the last decade, it has been more concern about the heat removal techniques from an automobile engine. Combustion of fuel in cylinder produces large quantity of heat and increase in temperature of components. Heat is absorbed by various parts such as cylinder, piston, and oil. For the greater power demand there is greater rise in temperature of engine. Overheating of oil used for lubricating may cause it to lose the thermal as well as lubricating properties. Therefore for protecting parts from overheating, they must be cooled by an auxiliary cooling system. This heat energy can be effectively removed with help of radiators. Radiators are crossflow heat exchanger, which transfers heat from the fluid flowing through the tubes to air outside. Thereby cooling the fluid inside which in turn cools engine. Hence generally radiators are mounted in a position to receive air flow from the motion of the vehicle such as behind the front grill.

Conventional coolants used are distilled water or sometimes water is used along with additives such as glycol. For achieving the required heat transfer from radiators, higher effectiveness is needed which is merely possible with the use of such above coolants. Higher size of radiator may cause increase in weight and volume of the whole system.

Many of the researchers are working for higher effectiveness and compactness by using different coolants and their efforts have resulted to application of additives such as nanoparticles to liquids. These researches in nanotechnology invented new type of fluid nanofluids. The nanofluids are the liquid containing metal or non metal particles, where each particle size in the order 10-100 nm. These particles remain suspended when prepared by proper thermo chemical synthesis methods. Now days these fluids are preferred due to their higher thermal conductivity than base fluids and better other thermal properties as compared with base fluids.

There are many other advantages other than higher thermal conductivity such as good stability, negligible rise in pumping power and less wearing of pipe walls. There are many types of nanoparticles available such as metallic particles (Cu, Ag, Au, Fe and Al) and nonmetallic particles (Al_2O_3, CuO, Fe_3O_4, TiO_2 and SiC) and also carbon nanotubes. As it is known that metals have higher thermal conductivity than non metals which is equally true in the case of their respective nanoparticles. Sometimes non metallic nanoparticles are preferred for the reasons as the metallic one are most expensive.

Many of the researchers had worked on the nanofluids through various types of heat exchangers. In spite of low thermal conductivity oxide nanoparticles are studied extensively than metal particles that are because of lower stability of metal particles than oxide nanoparticles.

Nomenclature and letters	Subscripts
C_p : specific heat at constant pressure	b: bulk
f : friction factor	in: inside
h : heat transfer coefficient	nf: nanofluid
m : mass flow rate	p: particle
Q : heat transfer rate	out: outside
T : temperature	w: wall
ρ : density	
μ : dynamic viscosity.	
Φ : volume fraction	

II. LITERATURE REVIEW

Peyghambarzadehassessed [1] the heat transfer of nanofluids in automobile radiator under fully turbulent conditions. Aqueous based nanofluids containing Al_2O_3nanoparticles of the size 20 nm and in the range of concentrations 0.1-1 vol. %. The increase in fluid circulating rate improves heat transfer performance with important drop in fluid outlet temperature.Pak[2] carried an experimental research for the convective turbulent heat transfer attributes of Al_2O_3 nanofluids. Increase in Reynolds number and volume concentration of nanofluids increases convective heat transfer coefficient as well as Nusselt number.Palm and Nguyen [3] studied experimentally as well as numerically laminar forced convection flow of nanofluids in various types of heat exchangers such as uniformly heated tube and the group of parallel, co axial and heated disks.The numerical results matched experimental results which clearly indicated the addition of nanoparticles has produced considerable enlarged heat transfer performance.Murshad[4]measured the thermal conductivity of TiO_2 nanoparticles dispersed in de-ionized water using hot wire apparatus and compared the results with theoretical models available, Hamilton andCrosser [5] and found considerable increase in thermal conductivity of fluid which showed more increase by more addition of nanoparticles.Chein and Chong[6]showed that nanofluids can be used in the micro channel heat sink as a coolants. There is greater energy absorption by nanofluids than pure water at the lower flow rate than at higher flow rate.Ali et al [7]reported numerical research of heat transfer between air and Cu nano particles in falling fin type cross flow heat exchanger. The results showed that the dehumidification and cooling process increased under the low air Reynolds number, a high Cu particle volume fraction. Also, it was found that an increase in Cu volume fraction influence to more stability of the solution.

III. EXPERIMENTAL METHOD

3.1 Experimental Apparatus

Fig. 1 shows, the experimental test apparatus used in this research includes flow pipes, a storage tank, a heater, a centrifugal pump, a flow meter, a forced draft fan and an automobile radiator. The pump gives a constant discharge of 20 liters/min, the flow rate to the test part is adjusted by appropriate adjusting of a globe valve on the recycle line.The fluid used as test fluid fills 25% of the storage tank whose total volume is 25 l. The total volume of the circulating fluid is same in all the experiments. A Rotameter was used to control and regulate the discharge with the accuracy of 0.5 liters/min. For heating the test fluid, an electrical heater used to maintain the temperature between 65 and 70^{0}C. Two thermocouples were used on the pipes to measure radiatorfluid inlet and outlet temperatures.Four thermocouples (K-type) were used for radiator wall temperature measurement.These thermocouples were installed at the equal distance from periphery of the radiator surfaces i.e. four sides.

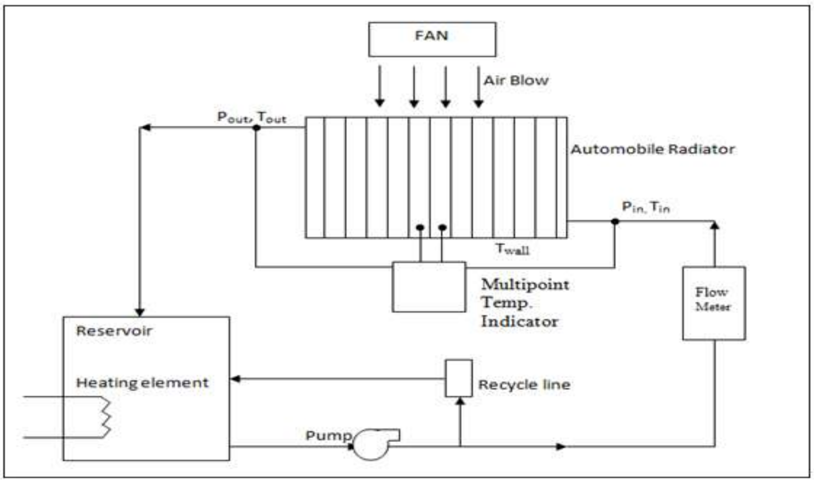

Figure 1 Experimental Setup

The locations of the surface thermocouples have been chosen so that they give the average wall temperature. 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. The radiator wall is constructed with aluminum tubes so the tubes are having high thermal conductivity. The tubes are having very small thickness so that it can be assumed that inside temperature is same asoutside wall temperature. Rotameter also known as flowmeter are calibrated with the standard volume flask. The temperature reading is obtained by digital display with an accuracy of 0.1^{0}C. All thermocouples were calibrated using ice bath and constant temperature water bath.

The configuration of the automobile radiator used in this experiment is of the louvered fin-and-tube type, with 37 vertical tubes with ellipse-shaped cross section. The fins and the tubes are made with aluminum. For cooling the liquid, a forced fan (1400 rpm) was installed close and face to face to the radiator and consequently air and water have indirect cross flow contact and there is heat exchange between hot fluid flowing in the tube-side and air across the tube bundle. Constant velocity and temperature of the air are considered throughout the experiments in order to clearly investigate the internal heat transfer.

The test fluids were water based nanofluids which consist of water and small amount (0.1 wt.%) of copper and titania nanoparticles. The mean particle size of this particle is 20 nm. Sodium Lauryl Sulphate (SLS) was added as dispersant or stabilizer added to nanofluid. This is due to the fact that the addition of dispersant in nanofluid help the particle remains stable in the base fluid. The quantity of dispersant added in the nanofluid is much lesser so that its effect may be neglected. Also, as the whole fluid is in continuous motion and highly turbulent so that it assumed that the particle is well stable in base fluid water.

In this paper forced convection heat transfer coefficients and Nusselt number for pure water, metal nanoparticles (Cu nanoparticles) and oxide nanoparticles (TiO_2nanoparticles) are investigated under fully turbulent conditions. The test section used is automobile radiator with fan for which various parameters are studied.

3.2 Nanofluid Physical Properties

By assuming that the nanoparticles are well dispersed within the base fluid, i.e. the particle concentration can be considered uniform throughout the system; the effective physical properties of the mixtures studied can be evaluated using some classical formulas as usually used for two phase fluids. These relations have been used to predict nanofluid physical properties like density (equation 1), specific heat (equation 2), viscosity(equation 3) and thermal conductivity (equation 4) at different temperatures and concentrations. In this paper, the following correlations[8] [9] were used to calculate these physical properties of nanofluid:

$$\rho_{nf} = \varphi\rho_p + (1-\varphi)\rho_w \qquad \text{(equation 1)}$$

$$(\rho C_p)_{nf} = \varphi(\rho C_p) + (1-\varphi)(\rho C_p)_w \qquad \text{(equation 2)}$$

$$\mu_{nf} = \mu_w(123\varphi^2 + 7.3\varphi + 1) \qquad \text{(equation3)}$$

$$K_{nf} = \frac{K_p + (n-1)K_p - \varphi(n-1)(K_w - K_p)}{K_p + (n-1)K_w + \varphi(K_w - K_p)} Kw \qquad \text{(equation4)}$$

These relations give variations of physical properties of nanofluid when the volume fraction is varied by addition of nanoparticles.

n=3/ψ where ψ is given by particle sphericity. Each particle is considered as spherical in shape. Therefore sphericity is defined as ratio of surface area of a particle, to the volume the particle.

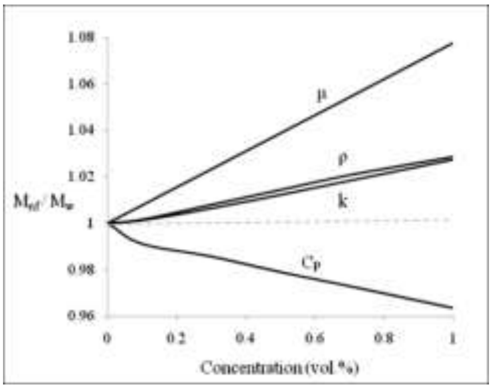

Figure2. Variation of physical properties

Fig. 2 [1] shows the graph for the variation of mass of nanofluid to the variation of the physical properties. Addition of nanomaterials affects the physical properties of the base fluid. With increasing particle concentration, the flow around one particle begins tobe affected by other particles in neighborhood, Solid particles then experience hydrodynamic interactions and the viscosity is linearly dependent on the particle concentration. Therefore fig. shows rise in the viscosity with increase in nanoparticles concentration.

	Copper Nanoparticles	Titanium dioxide Nanoparticle
Average particle size	10-20 nm	10-20 nm
Morphology	spherical	spherical
True density	8.9 g/cm^3	4.01 g/cm^3
Contents (%)	Cu≥99 Sn≤0.1 Fe≤0.02 Ni≤0.04	TiO_2 ≥99 S≤0.1 Si≤0.02 Mg≤0.067 Al≤0.20

Table 1 Characteristics of nanoparticles

Table 1 gives the information of the nanoparticles which is used for the calculations.

3.3 Calculation of Heat Transfer Coefficient

Heat transfer comparison by the nanofluids is analyzed by comparing Nusselt number calculated from respective heat transfer coefficient. To obtain heat transfer coefficient assumption[1] is made that the heat is carried by the air flowing over the tubes of radiator from the nanofluid inside the tubes. Hence by applying Newton's cooling law to the system,

$$Q = hA\Delta T$$

$$= hA(T_b - T_w)$$

And heat transfer from radiator is given as

$$Q = mC_p \Delta T$$

$$= mC_p(T_{in} - T_{out})$$

Hence, h can be given as,

$$h_{experimental} = \frac{mC_p(T_{in}-T_{out})}{A(T_b-T_w)}$$

This h can be used to find Nusselt number,

$$Nu = \frac{hL}{K}$$

Nu is average Nusselt number, L is hydraulic diameter which is calculated for tube of radiator. This Nusselt number is calculated for each nanofluid.

IV. RESULT AND ANALYSIS

For Distilled water: For better results of the research, distilled water was preferred than tap water. Comparison of temperature drop is done with carrying experiment with pure water; it also can be used to study the consistency and accuracy of the research setup. As expected results shows good consistency of outlet temperature when inlet temperature is kept constant at 70^{0}C as the flow rate of water is increased further from 1 to 5 lpm. The validation of the research data was made by using the empirical correlation by Dittus-Boelter[10]. This equation is given by

$$Nu = 0.023Re^{0.8}Pr^{0.3}$$

Friction factor can be formulated by the equation given by Filonenko[11]

$$f = (0.79LnRe - 1.69)^{-2}$$

Actual measurements of Reynolds number used in the Dittus-Boelter equation matches the results of the experimental data.

For Nanofluids

The Copper and Titania nanofluids are used in very little concentration of 0.1% by weight in different flowrates such as 1-5 lpm as the working fluid.The fluid can be considered most efficient when the temperature drop at outlet of radiator is maximum. Similarly it can be taken into consideration that as volumetric flowrate of fluid increases the heat transfer coefficient increases and therefore Nusselt number in all the concentrations has increased by increase in the flow rate of the fluid and consequently Reynolds number. Additionally, the concentration of nanoparticle plays an important role in the heat transfer efficiency. It can be shown that whenever the concentration becomes greater, heat transfer coefficient becomes larger. But increase in concentration affects pressure drop seriously. By the addition of only 0.1% weight shows the enhancement of 10-15% heat transfer coefficient in comparison with pure water.

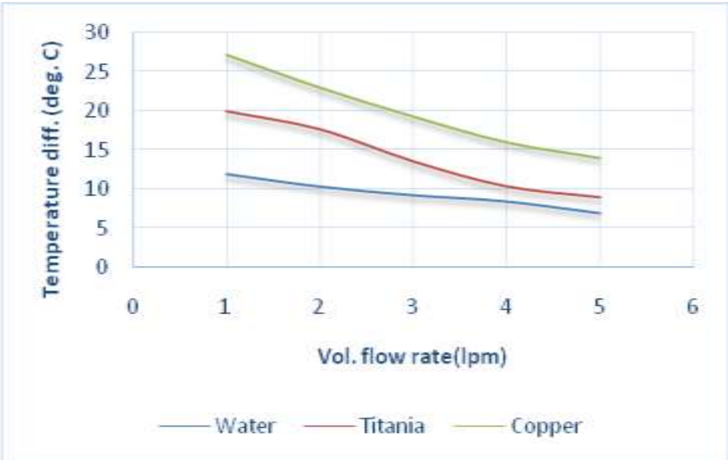

Figure.3 Radiator Cooling Comparison of Pure Water with Nanofluids

Here fig. 3 shows comparision of temperature difference between inlet and outlet of radiator with nanofluids.Physical properties of nanofluids like density, thermal conductivity increases significantly as compared with base fluid due addition of nanoparticles. Nanoparticles in the base fluid act as the extended surfaces for the heat carrying with them. Addition of nanoparticles affects viscosity too, which increases noticeable. The rise in viscosity may lead to an adverse outcome for a heat exchanger. For this research increase is only 4% which is negotiable when heat transfer enhancement is of the greater range. The phenomenon related to the Brownian motion and the clustering effect of the suspended nanoparticles in the base fluid plays an important role in the enhancement of the thermal conductivity of the base fluid, apart from the effects known due to high surface to volume ratio nanoparticles. Therefore, the nanofluids to show better heat transfer characteristics when compared to the conventional heat transfer fluids. The precipitation, aggregation and sedimentation of nanoparticles that may occur above a certain addition to base fluid, would obstruct the process of heat transfer in nanofluids, in spite of getting noticeable enhancement in heat transfer coefficient[12][13].

When each nanofluid is compared when the mean grain size of the nanoparticles of copper and Titania are same, copper nanofluid shows higher heat transfer enhancement in heat transfer coefficient than titania. The only reason could be stated as the thermal conductivity of copper is much higher than titania. Other physical properties are less invariant. The enhancement of copper nanofluid is greater than titania nanofluid. These higher heat transfer coefficients obtained by using copper nanofluid instead of titania nanofluid, water allow the working fluid in the automobile radiator to be cooler, so that it is more compact, spacious. The addition of nanoparticles with large thermal conductivity to the water has the ability to improve automotive engine cooling capacity rates also equally helps 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.

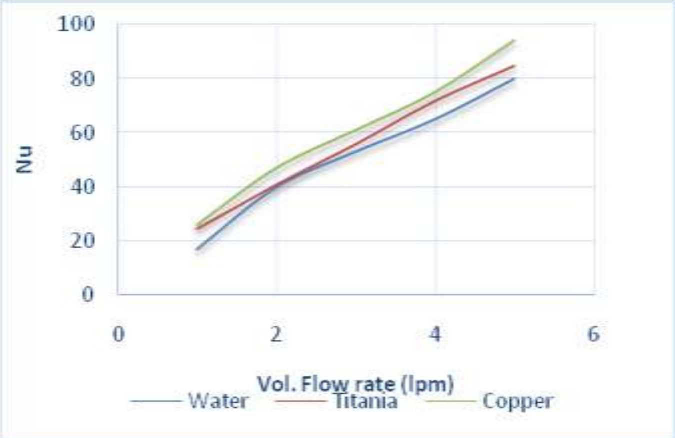

Figure 4. Effect of vol. Flow Rate (lpm) Over the Nusselt number

V. HEAT TRANSFER ENHANCEMENT STUDY

The Nusselt number and Reynolds number were obtained from the research data. Fig. 4 shows rise in Nusselt number with increase in volumetric flow through tubes. From the comparison of results by each nanofluid, it clearly shows that use of nanomaterials in the base fluids augmented Nusselt number even for such lower concentration of 0.1% of weight concentration which in same cause as previous literature reveal.

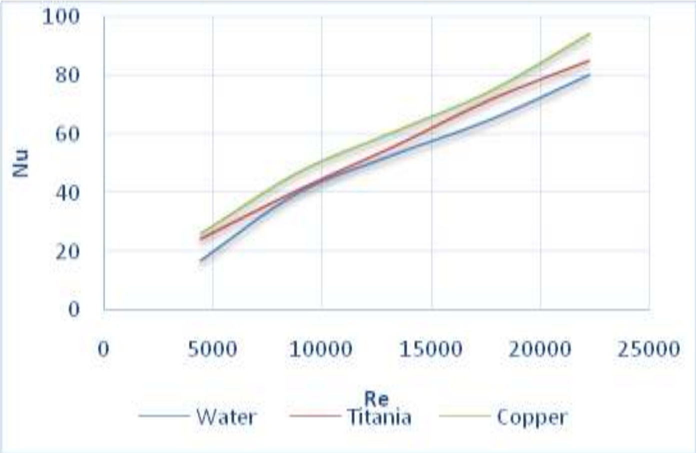

Figure 5 Variation of Nusselt number over Reynolds number

The reason for augmentation in heat transfer can be agreed to the point as the heat transfer coefficient is directly proportional to thermal conductivity. Addition of nanoparticles enhances the effective thermal conductivity.

Therefore above work proves that increased heat transfer from the radiator is the effect of addition of nanomaterials in base fluid which would be expected by increased thermal conductivity alone. From fig.5 it can be seen that heat transfer is enhanced with increase in Reynolds number. In addition thermal conductivity in motion is much higher than in stable condition.

VI. CONCLUSION

In this research paper, heat transfer coefficients of two different nanofluids are compared with water. Following results are discussed.

1. Nanomaterial in the water behaves as the extended surfaces which act as thermal interacting phase which augment the thermal conductivity of the base fluid. The heat transfer depends upon thermal conductivity of nanoparticles.
2. The convective heat transfer coefficient of nanofluids increased with the Reynolds number. For the copper nanofluid with very little weight concentration of up to 0.1%, the convective heat transfer coefficient, Nusselt number, overall heat transfer coefficient were enhanced by 7%, 15% and 5% respectively. For the Titania nanofluid with 0.1 % weight concentration, the convective heat transfer coefficient, Nusselt number, overall heat transfer coefficient were enhanced by 6%, 13% and 3% respectively.
3. The friction factor and pressure drop for both the type of nanofluids are nearly same, but are more than water, which makes increase in pumping power.The friction factor decreases with increasing of volume flow rate.
4. The results suggest that Cu nanofluid have high potential for flow and heat transfer enhancement and are highly appropriate to industrial and practical applications.

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