EXPERIMENTAL INVESTIGATION ON IMPROVING THE COOLING PERFORMANCE OF AUTOMOBILE RADIATOR BY USING CuO NANOFLUID

A.N. Phani deepthi
Assistant Professor, Dept., of Mechanical engineering, VR Siddhartha Engineering College, Vijayawada, India

Mekuri Dharmaiah
PG Student Thermal Engineering, V R Siddhartha Engineering College, Vijayawada, India

ABSTRACT

The convective heat transfer rate inside a flat tube radiator of an automobile using CuO-Water nanofluids were investigated experimentally and numerically. Nanofluid of 0.1%, 0.2%, 0.3% volume concentrations were prepared using CuO nanoparticle with water as base fluid. The effect of mass flow rate, volume concentration inlet temperature on heat transfer rate with varied coolant mass flow rate ranging from 6LPM, 8LPM, 10LPM were examined. Results shows that heat transfer rate linearly increases with increase in mass flow rate and volume concentration, the best heat transfer rate is achieved at 0.3% volume fraction of CuO at 10LPM. A maximum enhancement of 35% in heat transfer rate is obtained for 0.3% concentration of CuO nanofluid.

Key words: Nano particles, Heat Transfer Coefficient, Heat transfer rate, Reynolds Number, radiator, volume concentration


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1. INTRODUCTION

Today, there is a need for dimensions and weight reduction of heat transfer system in automobiles. Better cooling system obtained by using different fin type and microchannel, various tubes insert or rough surface show some efforts made for increasing the cooling rate of radiators.

Another way is changing the working fluid of radiators. Outside air passing through between fins pickups and carries away heat. Small particles are adding to the working fluid gives better performance than conventional fluid. This new fluid is called nanofluid.
Nanoparticles, the additive of nanofluid play an important role in changing the thermal transport properties of nanofluid and also changing the fluid characteristics because thermal conductivity of nanoparticles is higher than the ordinary fluid.

**Sobin Alosious** et al Experimental and numerical study on heat transfer enhancement of flat tube radiator using Al$_2$O$_3$ and CuO nanofluids, In this paper the working fluid is circulated through an automobile radiator with flat tubes at constant inlet temperature of 90$^\circ$C. Experiment is conducted by using water and nano fluid. The flat tube of the radiator with given dimensions were modeled and numerically studied the heat transfer. The model includes the thickness of tube wall and also considers the effect of fins in the radiator. Numerical studies were carried out for different volume concentrations from 0.05% to 1% and Reynolds number varied between 136 and 816 for both nano fluids. Enhancement in heat transfer coefficient and effectiveness of radiator with increase in Reynolds number and volume concentration are observed. A maximum enhancement of 13.2% and 16.4% in inside heat transfer coefficient were obtained for 1% concentration of CuO and Al$_2$O$_3$ nanofluids respectively. However increasing the volume concentration causes an increase in viscosity and density, which leads to an increase in pumping power.

**Navid Bozorgan** et al (2012) Numerical Study on Application of CuO-Water Nanofluid in Automotive Diesel Engine Radiator, This paper presented a numerical investigation of the use of CuO-water nanofluid as a coolant in a radiator of Chevrolet Suburban diesel engine with a given heat exchanger capacity. The local convective and overall heat transfer coefficients and pumping power for CuO-water nanofluid at different volume fractions (0.1% - 2%) was studied under turbulent flow conditions. Also, the effects of the coolant Reynolds number and the automotive speed on the radiator performance are considered in this work. The simulation results indicate that the overall heat transfer coefficient of nanofluid is greater than that of water alone and therefore the total heat transfer area of the radiator can be reduced. However, the considerable increase in associated pumping power may impose some limitations on the efficient use of this type of nanofluid in automotive diesel engine radiators.

**Peyghambarzadeh** et al. [2] investigated experimentally the convective heat transfer enhancement of water and EG based nanofluids consisting of Al$_2$O$_3$ nanoparticles up 1% volume concentration as the coolants inside flat aluminum tubes of the car radiator under laminar and turbulent flows. The results show that the heat transfer enhances about 40% compared with the base fluids in the best conditions.

**Ollivier** et al. investigated the use of nanofluids as a jacket water coolant in a gas spark ignition engine. They numerically simulated the unsteady heat transfer through the cylinder and inside the coolant flow and reported that because of higher thermal diffusivity of nanofluids, the thermal signal variations for knock detection increased by 15% over the predicted using pure water.

**Vajjha** et al. numerically investigated the heat transfer augmentation by application of two different nanofluids consisting of Al$_2$O$_3$ and CuO nanoparticles in an ethylene glycol and water mixture circulating through the flat tubes of an automobile radiator. The numerical results showed that at a Reynolds number of 2000, the percentage increase in the average heat transfer coefficient over the base fluid for a 10% Al$_2$O$_3$ nanofluid was 94% and that for a 6% CuO nanofluid was 89%. Also the average heat transfer coefficient increases with the Reynolds number and also with the particle volumetric concentration.

**Leong** et al. have studied the application of nanofluids as working fluids in shell and tube heat recovery exchangers in a biomass heating plant and showed that about 7.8% of the heat transfer enhancement could be achieved with the addition of 1% copper nanoparticles in
ethylene glycol based fluid at 26.3 kg/s and 111.6 kg/s mass flow rate for flue gas and coolant, respectively.

Ijam et al. theoretically analyzed a minichannel heat sink with a 20 × 20 cm bottom for SiC-water and TiO$_2$-water nanofluids as the coolants through hydraulic diameters under turbulent flow. Their results showed a maximum enhancement of 12.44% in thermal conductivity for SiC-water and 9.99% for TiO$_2$-water at 4% of volume fraction. Also the maximum improvement in heat flux by using SiC-water and TiO$_2$-water nanofluids at 4% of volume fraction for inlet velocities of 2 and 6 m/s is calculated by ~7.63%, 12.43% and 7.25%, 12.43%, respectively.

Saeed-inia et al. In 2012 applied CuO-base oil particles varying in the range of 0.2% - 2% inside a circular tube and showed that the CuO nanoparticles suspended in base-oil increases the heat transfer coefficient even for a very low particle concentration of 0.2% volume concentration. They found a maximum heat transfer coefficient enhancement of 12.7% for 2% CuO nanofluid.

Shafahi et al. used a two-dimensional analysis to study the thermal performance of a cylindrical heat pipe utilizing Al$_2$O$_3$, CuO and TiO$_2$ nanofluids. Their results confirmed that the thermal performance of a heat pipe is improved and temperature gradient along the heat pipe and thermal resistance across the heat pipe are reduced and maximum capillary heat transfer of the heat pipe is observed when nanofluids are utilized as the working fluid. In the present paper, 20 nm-CuO/water nanofluid with concentration up to 2 vol% has been numerically studied as a coolant in a radiator of Chevrolet Suburban diesel engine with a given heat exchange capacity. It shall be noted that metal oxides such as CuO nanoparticles are chemically more stable than their metallic counterparts.

Shah and London (1978) summarized many analytical and some experimental results for laminar flow characteristics and heat transfer with a single-phase fluid in flat tubes. Park and Pak (2002) present results from laminar flow computations in flat tubes of different shape and dimension for a mixture of ethyleneglycol and water. They ran their computations in the range of Reynolds number from 10 to 200, which covers the fluid flow rate in the radiator from 18 to 75 l/min. for an engine with an exhaust displacement of 1800 cc. In our computations, we have run the simulations at much higher Reynolds numbers, ranging from 100 to 2000, to cover the entire laminar range. Laminar flow modeling for circular tubes carrying nanofluids has been conducted by the following researchers, although not for a radiator tube geometry. Yang et al. (2005) presented laminar heat transfer experimental results with graphite nanoparticles and compared the Nusselt numbers’ variation with the Graetz numbers. Akbarinia and Behzadmehr (2007) presented a numerical study of nanofluids under mixed laminar convection in a curved tube. They compared the variations of Nusselt numbers with Grashof numbers for various volumetric concentrations of Al$_2$O$_3$ nanoparticles in water. They found that the skin friction decreased for all concentrations with an increase in the Grashof number.

Maiga et al. (2005) studied Al$_2$O$_3$ nanofluid flow under forced laminar convection in circular tubes and between parallel disks. For a range of Reynolds numbers from 250 to 1000, they concluded that the heat transfer enhancement is much more pronounced with an increase in particle concentration. However, they observed an adverse effect on wall shear stress in comparison to the base fluid. For the analysis of flow between discs, they found an insignificant effect on heat transfer with the variation of gap between the discs. Experimental work with the flow of nano fluids in flat tube geometries are currently not available and is highly recommended as a research topic in the future.
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2. EXPERIMENTAL SETUP

Fig shows the test rig for the investigation. The experimental set up consists of storage tank, heaters, a centrifugal pump, flow controller radiator, fan, thermometers and temperature indicators. Coolant is heated in heat source and it is then circulated in the radiator with the help of pump. Pump gives the constant rate which can be regulated by globe valve. The piping in the text section is strictly insulated by asbestos rope. 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 recirculating back to the heat source.

![Figure 1](image)

**Figure 1** Shows the photograph of the experimental setup

3. NANOFLUID PREPARATION

The CuO Nanofluids samples are kept for observation and no particle settlement was observed at the bottom of the flask containing CuO nanofluids even after four hours. The photographic view of nanofluid suspension prepared after magnetic stirring and sonication process is shown. Nanofluids prepared are assumed to be an isentropic, newtonian in behavior and their thermo physical properties are uniform and constant with time all through the fluid sample.

<table>
<thead>
<tr>
<th>Table 1 CuO Thermal Properties</th>
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<tr>
<td>Thermal properties</td>
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<tr>
<td>$C_p$ (J/kg·K)</td>
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<tr>
<td>$\rho$ (kg/m$^3$)</td>
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<td>$k$ (W/mK)</td>
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**Mathematical Approach:**

Density of Nano fluid= 995.41 kg/m$^3$

$\rho_{nf} = (1 - \varphi)\rho_{bf} + \varphi\rho_{nf}$

$\rho_{bf}$ = Density of nanofluid

$\rho_{bf}$ = Density of water
Where \( \varphi = \) volume concentration

Specific heat of the nanofluid

\[
\frac{C_{nf}}{\rho_{nf}} = \frac{(1-\varphi)(\rho C)_b + \varphi(\rho C)_p}{\rho_{nf}}
\]

Viscosity

\[
\mu_{nf} = \frac{\mu_b}{(1-\varphi)^{2.5}}
\]

Reynolds number

\[
Re = \frac{\rho_{nf} V_{nf} D_H}{\mu_{nf}}
\]

The heat transfer rate was calculated by following procedure.

From the newton’s law of cooling heat transfer rate is

\[
Q = \dot{m}_{nf} C_{pf} \Delta T
\]

where

\( \dot{m}_{nf} = \) mass flow rate in kg/s

\( C_{pf} = \) specific heat in j/kg k

\( T_{in} = \) coolant inlet temperature

\( T_{out} = \) coolant outlet temperature

4. RESULTS & DISCUSSION

The experimental work was carried out for three different mass flow rates (6LPM, 8LPM, 10LPM) with different volume concentrations as 0.1%, 0.2%, 0.3% of coolant. Velocity of the air keeps constant at radiator entire experiment. Comparison of three different volume concentrations represented on graph and it is clearly seen that the heat transfer rates.

Effect of flow rate on heat transfer rate
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The results show that the heat transfer rate linearly increases with an increase in mass flow rate and as well as inlet temperature. We can observe from the graph that an increase in volume concentration of Nano fluid as 0.1%, 0.2%, 0.3% is directly proportional to the heat transfer rate. The highest heat transfer rate was achieved at 0.3% volume concentration compared to 0.1%, 0.2%. This shows the effect of volume concentration on heat transfer capability.

5. NUMERICAL VALIDATIONS:

5.1. Density of nanofluid.

Density of nanofluid \( (\rho_{nf}) \) Kg/m\(^3\)

\[
\rho_{nf} = (1 - \varphi)\rho_{bf} + \varphi\rho_{bf}
\]

Where

\( \rho_{nf} \) = Density of nanofluid

\( \rho_{bf} \) = Density of water

\[
= \left(1 - 0.1\right) 990 + 0.1 \times 6400
\]

\[
= 989.01 + 64
\]

\[
= 995.41 \text{ kg/m}^3
\]

Density of nanofluid at 50\(^\circ\) C, 60\(^\circ\) C, 70\(^\circ\) C and 80\(^\circ\) C temperatures and 0.1%, 0.2%, 0.3% volume concentration

![Temperature Vs Density](image)

**Figure 6:** Changing the density with temperature

Density of nanofluid linearly decreases with an increase in the temperature of nanofluid as the density of the nanofluid is higher than base (water) fluid.

5.2. Specific heat of the nanofluid

Specific heat can be defined and the energy required to rise the temperature of a unit mass of a nanofluid by one degree. Specific heat of nanofluid \( (c_{p_{nf}}) \) in J/kg K

\[
c_{p_{nf}} = \frac{(1-\varphi)(\rho C_p)_f + \varphi(\rho C_p)_{bf}}{\rho_{nf}}
\]

Where

\( c_{p_{nf}} \) = specific heat of nano fluid in j/kg K
$C_{bf} =$ specific heat of base fluid in j/kg k

$\rho_{nf} =$ density of nano fluid in kg/m$^3$

$\rho_{bf} =$ density of base fluid in kg/m$^3$

$\Phi =$ volume concentration of nano particle

$$= (1 - \frac{0.1}{100})(990 \times 4185.5) + \frac{0.1}{100} (6400 \times 540)$$

$$= \frac{413455.6305+3456}{995.41}$$

$$= 4157.09 \text{ J/kg k}$$

Specific heat of nanofluid at 50$^0$C, 60$^0$C, 70$^0$C and 80$^0$C temperatures and 0.1%, 0.2%, 0.3% volume fractions

![Temperature vs Cp](image_url)

As the base fluid (water) has more specific heat than nanofluid. We can see in the above graph the specific heat increases with increase in temperatures from 50$^0$C to 80$^0$C like water.

6. CONCLUSION

The experimental investigation concludes that nanofluids are having better heat transfer rate as compared to base coolant. At the volume concentration of 0.3%, the heat transfer enhancement of 35% compared with base fluid. Increase the flow rate of working fluid enhance the heat transfer rate for both base fluid (water) and nanofluid consider while the variation of coolant inlet temperature to the radiator slightly influences the heat transfer performance. This heat transfer enhancement may be leads to smaller and lighter radiators which in turn lead to the lower capital and running cost.

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Experimental Investigation on Improving the Cooling Performance of Automobile Radiator by Using CuO Nanofluid


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