Examine the Performance of an Automotive Radiator Using Ethylene Glycol and Copper oxide Nano fluid as a Coolant

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Abstract- **The nanoparticles like Al2O3, Sic, CuO and TiO2 are the very commonly used in thermal systems heat exchangers. An experimental study on performance of automotive radiator using water and Copper oxide nano fluid was studied in the present work. The CuO nanoparticles were tested in automotive radiator by varying the percentage of nanoparticles mix with water with glycol. As a reference case, pure water is mixed with glycol at standred proprations 70:30,60:40 and 50:50 mixture is used in an automotive radiator and its performance was studied. CuO nanoparticles are mixed in water in 0.025%, 0.05%, 0.1% and the performance of nanofluid is tested. The performance comparison will be made between pure water and nanofluids tested in an automotive radiator. Finally the recommendations are made and conclusions are drawn based on the improved performance of nanofluids in an automotive radiator. The heat transfer enhancement value of water-glycol mixture with copper oxide nanofliud are better than when compare with pure water, water-glycol mixture. All parameters like thermal conductivity, friction factor and heat transfer rate better values obtained. Finally the recommendations are made and conclusions are drawn based on the improved performance of nanofluids in an automotive radiator.**

Index Terms- **Nanofluids, Heat Transfer, CuO Nano Particles.**

1. INTRODUCTION

Heat transfer fluids such as water, minerals oil and ethylene glycol play an important role in many industrial sectors including power generation, chemical production, air-conditioning, transportation and microelectronics. The performance of these conventional heat transfer fluids is often limited by their low thermal conductivities. According to industrial needs of process intensification and device miniaturization, development of high performance heat transfer fluids has been a subject of numerous investigations in the past few decades.

It is well known that at room temperature, metallic solids possess an order-of-magnitude higher thermal conductivity than fluids. For example, the thermal conductivity of copper at room temperature is about 700 times greater than that of water and about 3000 times greater than that of engine oil.

Therefore, the thermal conductivities of fluids containing suspended solid metallic or nonmetallic (Metallic oxide) particles would be expected to be significantly higher than those of conventional heat transfer fluids.An inventive way of improving the heat transfer performance of common fluids is to suspend various types of small solid particles, such as metallic, nonmetallic and polymeric particles, in conventional fluids to form colloidal. However, suspended particles of the order of μm (micrometer) or even mm (millimeter) may cause some problems in the flow channels, increasing pressure drop, causing the particles to quickly settle out of suspension.

In recent years, modern nanotechnology has been discovered. Particles of nanometer dimensions dispersed in base liquids are called nanofluids. This term was first introduced by Choi in 1995 at the Argonne National Laboratory.

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Compared with millimeter or micrometer sized particle suspensions, nanofluids have shown a number of potential advantages such as better long-term stability and rheological properties, and can have significantly higher thermal conductivities.

A number of researchers have researched and reported the correlations for predicting the thermal conductivity, density, viscosity and specific heat of the nanofluids. Understanding the physical and thermal properties of nanofluid is important before using nanofluids in practical applications. There are a few important correlations for predicting the thermo physical properties of nanofluids that are often cited by a number of researchers. Their works have both experimentally and theoretically investigated the heat transfer behavior of the nanofluids.

The use of nanofluids is one of the most effective mechanisms of increasing the amount of heat transfer in heat exchangers. The use of flat tubes, in which the fluid flow has a lower thermal resistance, is another way of improving the rate of heat transfer in tubes. The subject of the present paper is combining of the two mentioned methods for increase of heat transfer and parametric study of thermal and hydrodynamic performances of flow field.

The word nanofluid refers to a mixture in which solid particles of nano size (generally less than 100 nm) are added to a base fluid and cause the increase of heat transfer in that mixture nanofluids are engineered by dispersion of fine metallic and non metallic particles of nanometer dimension in traditional host liquids which include water, ethylene glycol, propylene glycol, oil etc. Use of such nanoparticles in the base fluids increase their thermal conductivity and heat transfer performance of nanofluids. Nanofluids are new generation heat transfer fluids and can be used for heat transfer augmentations. Nanofluids have high heat transport capability and can replace traditional thermo fluids normally used for heat transfer applications in heat exchangers, chemical process plants, manufacturing processes, automotives and cooling of electronic components. Nanofluids are used in micro channel cooling without any clogging and sedimentation problems. The nanofluids can also be employed in high heat flux applications where single phase pure fluids are not capable of transferring the heat at desired rate.

Nanofluids conserve energy and hence preferred over conventional base fluids. Heat transfer augmentation using nanofluids is one of the emerging areas of research. Generally conventional single phase fluids have low thermal conductivities when compared to metals and their oxides. The fluids with suspended particles of metals and metal oxides are supposed to exhibit better heat transfer properties than the conventional fluids without solid particles. Particles clogging, sedimentation and erosion are some of the common problems associated with the use of micro or millimeter sized solid particles when suspended in the host fluids. Such problems can be minimized by replacing micrometer sized particles by nano sized particles.

Heat transfer enhancement in fluids can be effected primarily by two techniques viz. passive heat transfer technique and active heat transfer technique. Passive heat transfer techniques can be employed by provision of rough and extended surfaces tubes and creation of swirl in the flow using inserts of certain geometrical shape. Active heat transfer techniques include applying of electric/magnetic fields, inducing vibrations in the heated surface, injection and jet impingement of fluids etc. The above techniques can hardly meet the requirements of high heat transfer performance desired by present day modern heat exchanger. Compact heat exchangers with higher performance demand fluids having better heat transfer capabilities. Such devices results in material saving, energy conservation and hence low cost of heat exchangers. Nanofluids improve thermal conductivity of host fluids and now become important area of research attracting the attention of many researchers across the world. The nanofluids will quench the thirst of investigators who are in quest to engineer better heat transfer fluids.

Heat transfer coefficient and friction factor are two important parameters associated with thermo fluids. Many experimental as well as theoretical investigations have been carried out to study heat transfer and pressure drop characteristics of pure fluids. Use of two phase nanofluids for heat transfer enhancement has boosted the research interest among many research groups across the globe.

Literature confirmed that nanofluids give higher heat transfer coefficient compared to the base fluid. The investigation results on nanofluids indicated that heat transfer coefficient increases with the increase of nanoparticle concentration in the base fluid.

Most of the research works done so far on nanofluids are experimental studies and confined either to laminar or turbulent flow conditions. The host or base fluid is water in majority of the cases. In severe cold climatic conditions glycols are added to water in different proportions to reduce the freezing point of heat transfer liquids. Glycol based fluids are used in base board heaters, automobile radiators and process plants particularly in cold countries where the ambient temperatures are below zero degree Celsius.

II.PREPARATION AND ESTIMATION OF NANOFLUID

The idea behind development of nanofluids is to use them as thermo fluids in heat exchangers for enhancement of heat transfer coefficient and thus to minimize the size of heat transfer equipments. Nanofluids help in conserving heat energy and heat exchanger material. The important parameters which influence the heat transfer characteristics of nanofluids are its properties which include thermal conductivity, viscosity, specific heat and density. The thermo physical properties of nanofluids also depend on operating temperature of nanofluids. Hence, the accurate measurement of temperature dependent properties of nanofluids is essential. Thermo physical properties of nanofluids are pre requisites for estimation of heat transfer coefficient and the Nusselt number.

A. Estimation of Nanoparticle Volume Concentration

The amount of CuO nanoparticles required for preparation of nanofluids is calculated using the law of mixture formula. A sensitive balance with a 0.1mg resolution is used to weigh the CuO nanoparticles very accurately. The weight of the nanoparticles required for preparation of 5 liters of CuO nanofluid of a particular volume concentration, using water base fluid is calculated by using the following relation

% volume concentration = $$\frac{\frac{W_p}{\rho_p}}{\frac{W_p}{\rho_p}+\frac{W_f}{\rho_f}}$$

Where,

w_p = weight of the nanoparticle (grams)

ρ_p = density of nanoparticle (kg/m^3)

w_f = weight of the base fluid (liters)

ρ_f = density of the base fluid(kg/m^3)

Copper oxide nanofluids of three different volume concentrations in range of 0.025, 0.05 and 0.1 % are prepared in the present work. Normally agglomeration of nanoparticles takes place when nanoparticles are suspended in the base fluid. All the test samples of CuO nanofluids used subsequently for estimation of their properties were subjected to stirring process for about 5 hours. The CuO nanofluids samples thus prepared are kept for observation and no particle settlement was observed at the bottom of the tank containing CuO nanofluids even after four hours.

III EXPERIMENTAL SETUP AND PROCEDURE

In the performance evaluation of radiator a test apparatus is prepared which consists of a radiator, fan, flow meter, heating element, pump, two thermocouples, tank are used.

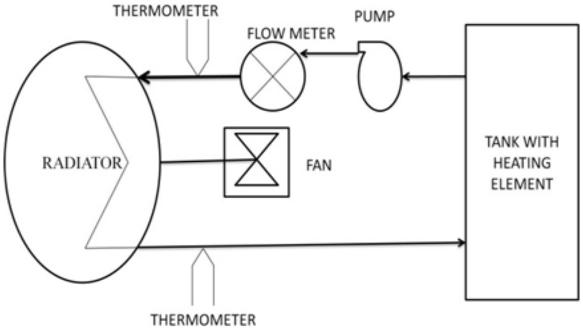


Fig.1: Schematic diagram of test setup

A. Testing Procedure

In the test apparatus the heating element will be acting as a source of heat which will act just like an engine in an automobile. This heating element will heat up the coolant to a temperature range of 60ºC - 80ºC. After heating, the hot water is pumped with the help of a pump in to the radiator. At the outlet of the pump a flow meter is installed to measure the mass flow rate of the hot coolant. The flow to flow meter is controlled by a controlling valve, which helps in obtaining different mass flow rate of the hot coolant. Then the inlet temperature to radiator is calculated by installing one thermocouple at inlet and is digitalized by one digital meter.

The hot water then flows through the radiator core. Here with the help of a fan cold air is sucked in, which helps in decreasing the temperature of the coolant flowing through the radiator. Then, the temperature at outlet is measured by a second thermocouple. After this the coolant from outlet is returned to the reservoir where it again becomes hot by the action of heating element and is re-circulated in the flow circuit to maintain the continuity of flow.

During testing, firstly water is taken as a coolant. It is circulated at a different mass flow rate of 4 LPM (liter per minute), 6 LPM and 8 LPM. The fan is rotated at a speed of 2300 rpm. After this the temperature of hot coolant at the outlet is recorded at particular inlet coolant temperatures. The temperature of inlet coolant is maintained at 60ºC.The temperature of inlet coolant is changed to 70ºC and the process is repeated. And again the temperature of inlet coolant is changed to 80ºC and the process is repeated. The readings are taken at outlet coolant at 60ºC, 70ºC, 80ºC. After this first round of data recording the coolant is changed.

This time water is replaced with a 0.025% of nanofluid. Here the mass flow rate is maintained at the same level as before and the fan is also circulated with the same speed of 2300 rpm. The temperature of the hot coolant at the inlet is also maintained at the previous values and the corresponding temperature values of the hot coolant at the outlet are recorded. At these varying mass flow rates the corresponding outlet temperature values of the hot coolant is recorded. After the process of 0.025% nanofluid at the different mass flow rates and at different temperatures the coolant is replaced by 0.05% nanofluid.

The readings are recorded for 0.05% coolant as previous process at different temperatures and different flow rates. After that the coolant is replaced by third concentration of nanofluid i.e., 0.1% nanofluid. The readings are recorded at different temperatures and by changing the flow rates also the readings of inlet and outlet temperatures are recorded. Now by the readings the heat transfer rate, Nusselt number (Nu), Reynolds number (Re), friction factor and heat transfer enhancement are calculated for all process at the different temperatures and at the different flow rates.

IV RESULTS AND DISCUSSION

The fabricated model of radiator was run at three different flow rates (4 liters/min, 6 liters/min and 8 liters/min) at an inlet fluid temperature of 60ºC, 70ºC, 80°C. A temperature difference (ΔT) was recorded for each flow rate, respectively. These obtained results are drawn graphically.

Before conducting systematic experiments on the application of nanofluids in the radiator, some experimental runs with pure water was carried out in order to check the reliability and accuracy of the experimental setup.

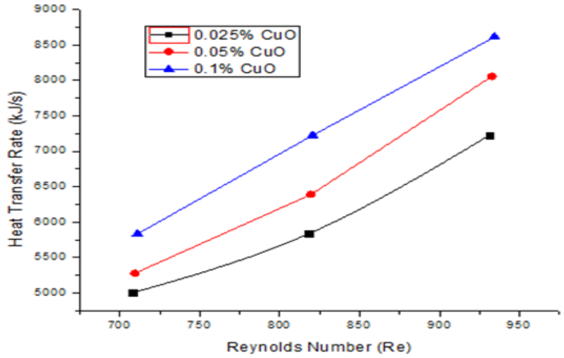


Fig.2: Variation of Heat transfer rate for different Reynolds number at 4lts/min

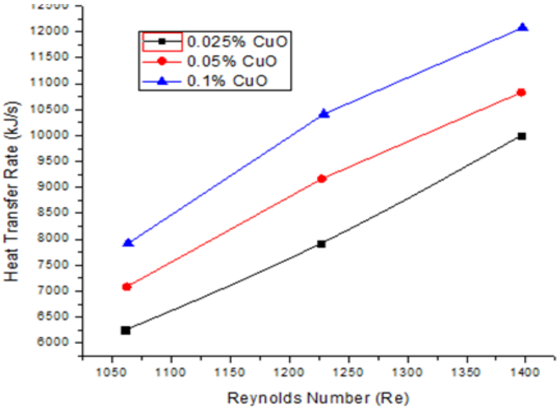


Fig.3: Variation of Heat transfer rate for different Reynolds number at 6lts/min

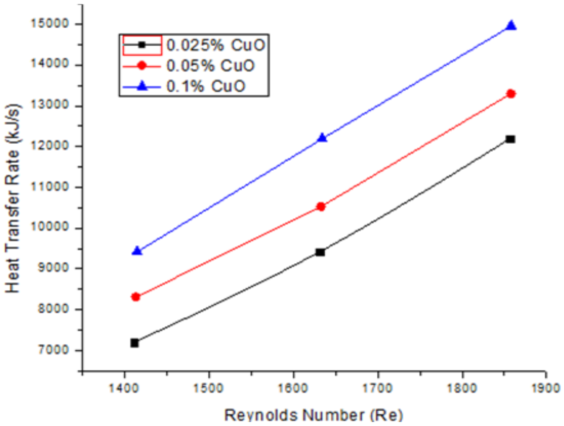


Fig.4: Variation of Heat transfer rate for different Reynolds number at 8lts/min

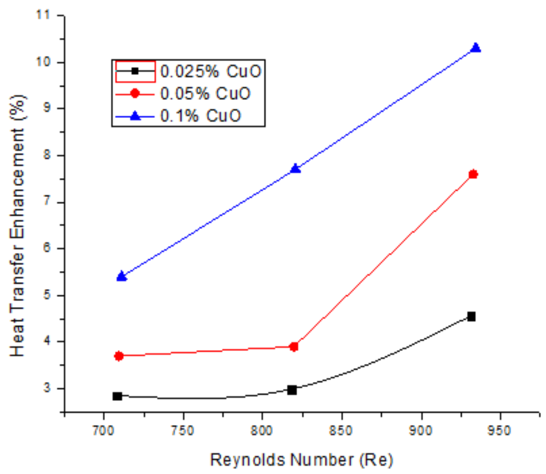


Fig.5:Effects of the Reynolds number on heat transfer enhancement at 4lts/min

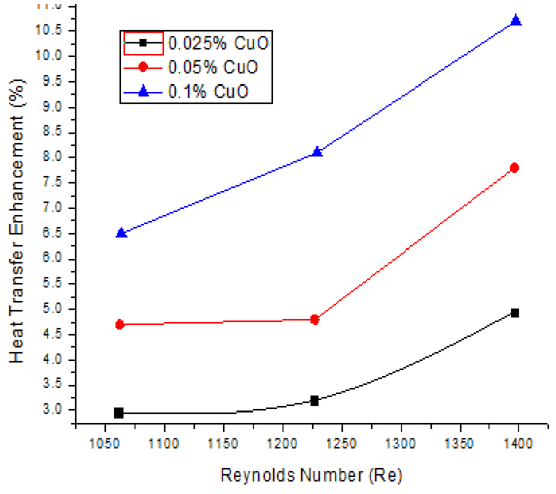
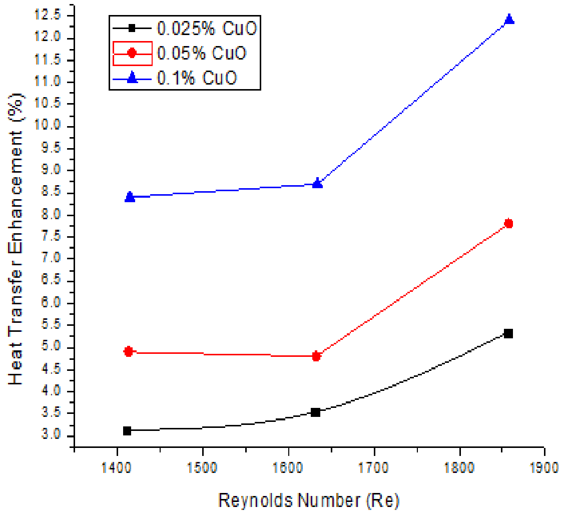


Fig.6: Effects of the Reynolds number on heat transfer enhancement at 6lts/min



Fig,7: Effects of the Reynolds number on heat transfer enhancement at 8lts/min

Effects of the Reynolds number, nanoparticle volume fraction and fluid inlet temperature on enhancement in heat transfer are shown in Figures above. The enhancement in heat transfer has increased by augmentation in the concentrations of nanoparticle, Reynolds number and fluid inlet temperature. For the water based nanofluid it is obvious that E increases with Reynolds number and in higher concentrations of nanoparticle the effect of Reynolds number becomes pronounced.

V CONCLUSION

The convective heat transfer performance and flow characteristics of CuO nanofluid flowing in an automotive radiator have been experimentally investigated. Significant increase in heat transfer was observed with the used different volume concentrations of nanoparticles mixed with water. The results showed that the variation of the friction factor and Nusselt number of the nanofluids were highly depended on the volume concentration and Reynolds number.

The friction factor decreases with increasing of volume flow rate and the inlet temperature of nanofluid. The experimental results have shown that the Nusselt number behavior of the nanofluids was highly depended on the volume concentration and the volume flow rate. The heat transfer enhancement was about 4.56% for 0.05% CuO nanofluid at 80ºC and this is about 12.4% for 0.1% CuO nanofluid at 80ºC.The results have shown that CuO nanofluid has a high potential for hydrodynamic flow and heat transfer enhancement in an automotive radiator.

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