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Investigation on Thermal Properties and Thermal Performance of Car Radiator with Binary Mixture based Al2O3-Cu Hybrid Nano Fluid

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Now a days hybrid nano fluid are most preferable nano fluid for heat exchanger applications for better heat transfer rate. Thermal conductivity of water and air is very less as compare to metallic nano fluids. In these study we have prepared hybrid nano fluid Al2O3- Cu with base fluid water using two step method and compare the cooling performances of different composition of hybrid nano fluid with water and ethylene glycol. Experimental set up has been constructed using car radiator as a heat exchanger. Hybrid nano fluid Al2O3-Cu of different concentration (0.1%, 0.2%, 0.3%, 0.4%) have been utilized in car radiator set up at two different inlet temperatures 40ºC and 50º to study thermal performance behavior. It has been found that heat transfer rate in case of hybrid nano fluid is very high as compare to traditional cooling fluids such as water and ethylene glycol.

1. Introduction

Conventional fluids commonly used in heat transfer applications, such as deionized water (DI) or ethylene glycol (EG), have inherently low thermal conductivity compared to metals and metal oxides. The traditional approach of using fins and micro-channels to improve cooling rates has reached its maximum effectiveness [1-4]. To enhance their thermal conductivity, nanoparticles are introduced into these fluids. This resulting suspension is known as a nanofluid, a term coined by Choi in 1995 [5]. The engine cooling system relies on coolant to remove heat generated by the engine, which is then dissipated into the atmosphere via the radiator. Enhanced heat extraction from the engine is crucial for maintaining energy efficiency, as inadequate heat dissipation can lead to overheating issues. Therefore, developing alternative coolants with improved thermo physical properties is necessary to make cooling systems more efficient, portable, and cost-effective [6].

Goudarzi et al. [7] investigated heat transfer rates using two-wire coils of various geometries filled with ethylene glycol (EG) nanofluids infused with aluminum oxide (Al2O3). They varied the Al2O3 concentration at volume fractions of 0.08%, 0.5%, and 1%. Their findings showed a 9% improvement in heat transfer rates. Furthermore, using coil inserts with the same nanofluid concentration led to a thermal performance enhancement of up to 5% compared to using coil inserts alone. Researchers explored the parametric behavior of geometric and hybrid fluid domains through both experimentation and computational fluid dynamics (CFD) simulations [8-9]. Raising the concentration of smaller nano particles in the base fluid enhances the heat transfer rate.

2. Material and methods

The choice of Nano fluid material for the proposed research was primarily guided by a comprehensive review of the literature. Upon examining numerous research papers, the initial focus was on identifying which nano particles are commonly utilized and the underlying reasons for their popularity [10]. Among the nano particles considered, Al2O3, ZnO, and Cu stood out due to their favorable cost-effectiveness and properties compared to others. Specifically, CuO nano fluid exhibited a linear conductivity behavior, distinguishing it in this regard.

2.1 Nano fluid Preparation

In the present study, Al2O3 and Cu nanoparticles in suspended form were procured from Vedayukt India Pvt. Ltd. (India). These nanoparticles were mixed with water as the base fluid at weight concentrations of 0.1%, 0.2%, 0.3%, and 0.4%, respectively. Equation (1) was used to calculate the initial volume concentration of Al2O3 and Cu nanofluids. The nanoparticles were initially suspended in deionized (DI) water using mechanical stirring for 1 hour at 1400 rpm, followed by a probe sonication process. Typically, sonication equipment is utilized to effectively disperse particles and minimize their agglomeration. Stabilization is crucial in preparing nanofluids for experimentation because it enables biphasic heat transfer. According to a study by M. Naraki et al. on the heat transfer coefficient of CuO in water [11], the nanofluid was stabilized by increasing the sonication time.

$$\varphi = \frac{\frac{w_p}{\rho_p}}{\frac{w_{bf}}{\rho_{bf}} + \frac{w_p}{\rho_p}} \qquad (1)$$

Nano fluid samples have been prepared using two step method. Stability of the nano fluid samples have been observed using normal visualisation method. It is observed from various observation that nano particles are not precipitated after three days of visualisation. It is shown in figure 1.

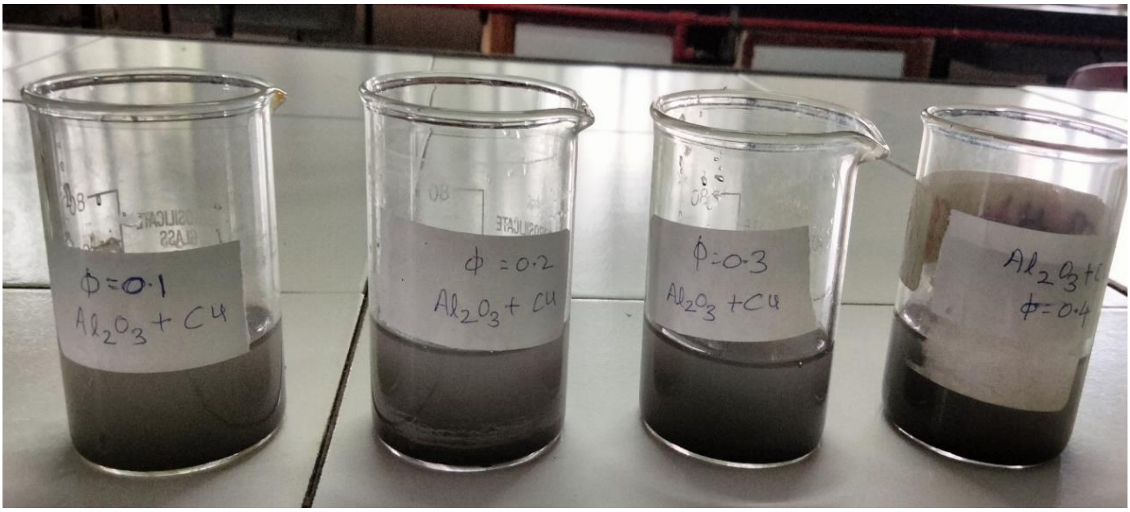

Figure 1 hybrid Nano fluid sample of Al2O3 with Copper nano particle and base fluid water

3. Experimental Set up and calculation

3.1 Experimental set up

A schematic of the experimental configuration is depicted in Figure 2. The volumetric flow rate was determined using a rotameter, and five thermocouples were utilized for temperature measurement. Specifically, two thermocouples were employed for measuring the inlet nanofluid and inlet air temperature of the radiator, while another two thermocouples were used for measuring the outlet nanofluid and outlet air temperatures, respectively. The nanofluid was heated to a specific temperature by the heater before flowing through the pipes to the radiator. The circulation of the heat transfer fluid was arranged under a constant heat load condition, with the heater positioned in the tank for a constant heat load, as in the case of an automobile engine. A forced convection fan was used to cool the heat transfer surface of the radiator. The flow control mechanism was governed by the bypass valve arrangement, which was positioned before the rotameter. As we adjusted the bypass valve, the flow rate correspondingly varied. The heat transfer rate, water flow rate, and airflow were investigated in the experimental setup. To model the operating conditions, four different volume concentrations and four flow rates were studied. The inlet coolant fluid temperature of the radiator was maintained at 80°C until a steady-state regime was achieved using a heat bath.

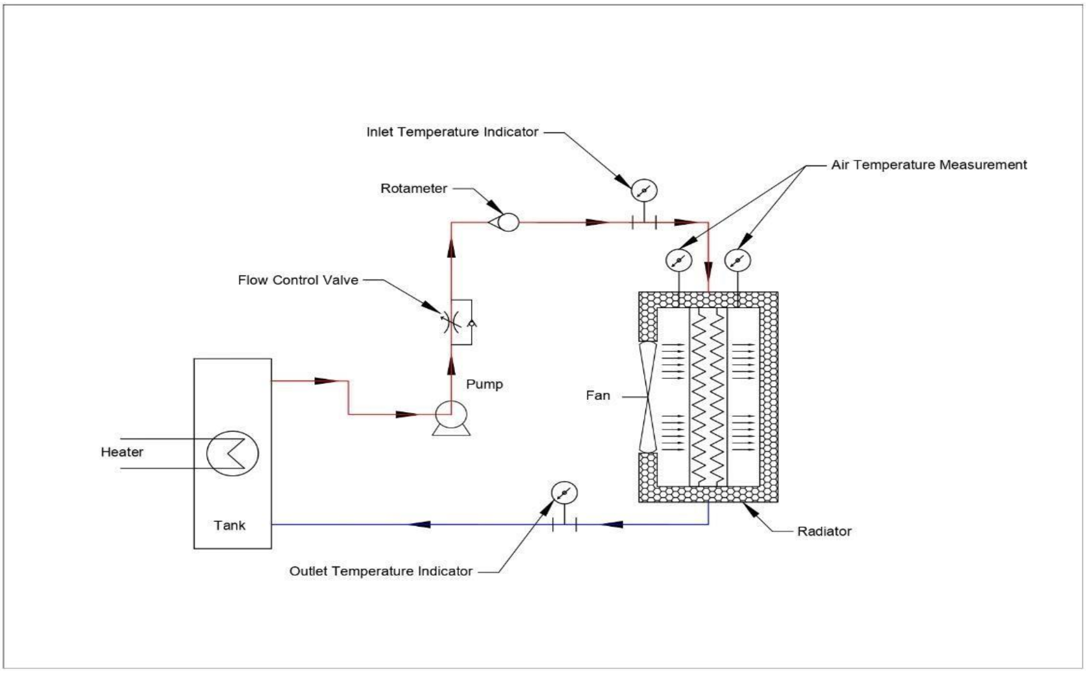

Figure 2 Experimental line diagram for radiator cooling

Data Reduction

The overall heat transfer coefficient, convective heat transfer coefficient, heat transfer rate and Nusselt number of nano fluid for various concentration of nano particles are calculated using various experimental results. The heat transfer rate for nano fluid can be calculated using following equation.

$$Q_{nf} = m_{nf} \times C_{p(nf)} \times (T_{out} - T_{in})_{nf}$$

In above equation m_{nf} indicates mass flow rate of nano fluid (i.e. hot fluid). T_{out} and T_{in} are outlet nano fluid temperature and inlet nano fluid temperature respectively. $C_{p(nf)}$ indicates specific heat at constant pressure of hot nano fluid. Similarly for cold fluid heat transfer rate following equation is used

$$Q_{cfw} = m_{cfw} \times C_{p(cfw)} \times (T_{in} - T_{out})_{cfw}$$

In the above equation m_{cfw} indicates mass flow rate of cold water. T_{out} and T_{in} are outlet cold water temperature and inlet cold water temperature respectively.

The density of nano fluid can be calculated using below equation.

$$\rho_{nf} = (1 - \varphi)\, \rho_f + \varphi\, \rho_p$$

Subscripts f, p and nf indicates the base fluid, nano particles and nano fluid sample respectively. Similarly specific heat of nano fluid sample can be calculated using below equation.

$$(\rho C_p)_{nf} = (1 - \varphi)\, (\rho C_p)_f + \varphi\, (\rho C_p)_p$$

4. Result and Discussion

To evaluate the heat transfer coefficient and effectiveness of flowing nano fluid various readings have been observed in experimental set up for different volume fraction of nano particles of Al2O3 , Copper and hybrid combination of Al2O3 and Copper nano particles. It is observed that as we increase the volume concentration of nano particles in nano fluid the heat transfer coefficient value and effectiveness value will increases (fig. 3 and 4). Also as we increase the flow rate of nano fluid the high volume fraction nano particles will enhances the heat transfer rate of radiator nano fluid very rapidly.

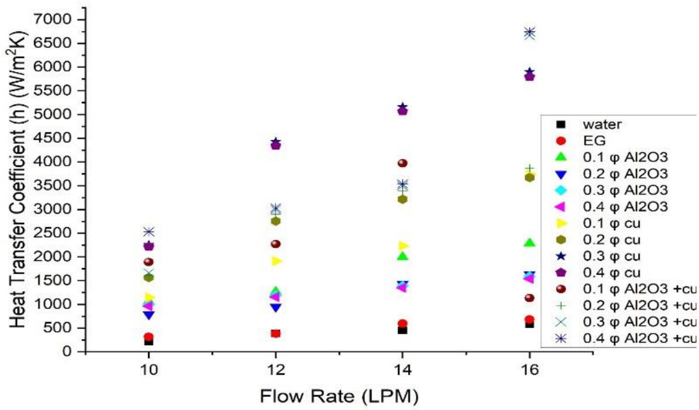

Figure 3 Variation of heat transfer coefficient (W/m2) with respect to flow rate(LPM) for diffrent volume fraction of nano fluid

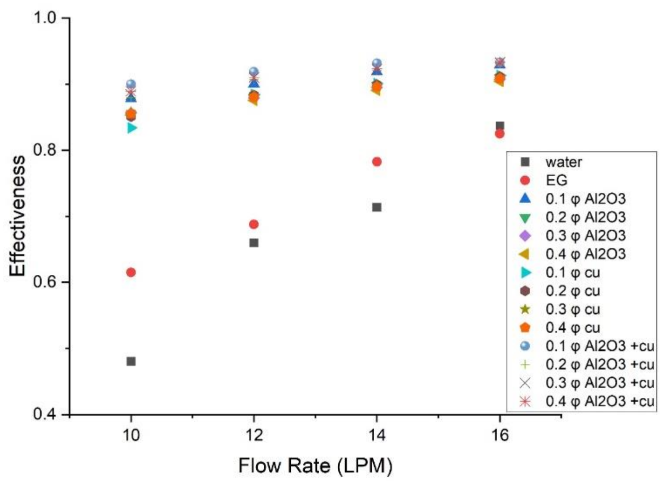

Figure 4 Variation of effectiveness of nano fluid with respect to Flow rate (LPM) for different volume fraction of nano fluid

5. Conclusion

As the growing demand of efficient heat transfer cooling fluid is necessity of time. The nano fluid is one of the best option for cooling enhancement in radiator. The various research work have been conducted on radiator heat transfer enhancement but most of the work based on mono nano fluid with low flow rates. In these paper mono nano fluid have been compared with hybrid nano fluid with different volume fraction and different flow rate and it has been observed that with increasing flow rate with moderate volume fraction we can enhance heat transfer rate optimistically. Because as we increase the volume fraction stability issue will arises which again decreases the heat transfer rate of nano fluid.

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