Experimental investigation of radiator heat transfer efficiency using Water + Ethylene Glycol based Al$_2$O$_3$, SiC nanofluids

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Abstract. The experimental work to boost forced heat transfer performance in an Al$_2$O$_3$, SiC-Water+ethylene glycol nanofluid radiator was discussed in this paper. In this analysis, different volume fractions of nanofluids in the range of 0.01 to 0.1 percent were prepared and sonicated for 2 hours using an ultrasonic sonicator to achieve stable suspension with the incorporation of Al$_2$O$_3$, Sic nanoparticles into the water. The maximum-performable heat transfer was found to be 50 percent higher than water at a fraction of 0.1 per cent. The effective thermal conductivity of the nanofluid is increased with increased particle concentration, which helps to boost radiator heating efficiency. The rate of heat flow ranges from 3 to 12 lpm. It is noted that the efficiency of heat transfer has increased with an increase in flow rate.

Keywords: Forced convective heat transfer, Radiator, Heat exchanger, Nano fluids, Al$_2$O$_3$, SiC – Water + ethylene glycol.

1. Introduction

Radiators are thermal exchangers which are used to transfer thermal energy from one medium to another for cooling and heating purposes. The majority of radiators are designed to work in automobiles, houses, and appliances. The radiator is also an environmentally friendly source of heat, and this can be either for the purpose of heating the environment or for the purpose of cooling the fluid or coolant supplied, as is the case for cooling the vehicle's engines. Such liquids are colloidal nanoparticle concentrations shaped in a working fluids. Nanofluids can be viewed as single-phase fluids in studies such as computational fluid dynamics. Near to all recent research papers are using a two-phase premise. The classical theory of single-phase fluids, where the physical properties of nanofluids are taken as a function of the properties and concentrations of both constituents, can be applied. Using a two-component model, an alternative technique simulates nanofluids. Thermodynamic and mechanical heat transfer measures the rate of heat transfer, the proportionality between the heat flux and the thermodynamic mass transfer coefficient for the heat flow. The heat flux is a quantitative definition of the Victoria heat flow over a surface. Over several years, researchers have concentrated on overcoming the restricted heat transfer capacities of traditional means of heat transfer, such as liquid, motor oil, and ethylene glycol (EG). Nanofluid is a particle sized nano metre, nothing but S.M.Peyghambarzadeh et al [1] measured the capacity of heat EG / Al$_2$O$_3$ nanofluids and has been measured experimentally and a 40 percent increase in temperature capacitance has been
observed compared to the base 1 percent of fluids by volume. ChilamkurthiLvsr Prasad et al [2] found lubricant friction coupled with Al$_2$O$_3$ nanopowder and noted a 46.35 percent increase in the heat flow rate and a 16.85 percent decrease in the coefficient of friction at room temperature (35 °C) with 0.5 percent volume fraction. Kole and Dey et al [3] Sonication has been used to prepare ZnO-ethylene glycol nanofluids. In thermal conductivity, there was a maximum gain of 40 percent for 3.75 percent vol as opposed to base fluid with clusters of ZnO in ethylene glycol. Dattatraya Subhedar and Bharat Ramani et al [4] observed a linear rise in the thermal conductivity of nanofluid as the volume concentration rises, with an 8.5 percent increase in the volume fraction of Al$_2$O$_3$ nanoparticles of 20 nm size in water / MEG base fluid. It is observed in heat capacity. K.B Anoop et al [5] stated that, two volume fraction were used with a mean particle size varying from 45 nm to 150 nm. The coefficient of heat transfer of particles of 45 nm was greater than that of particles of 150 nm. The coefficient of heat transfer indicate greater enhancement than in the developed region. Neguen et al. [6] Using Al$_2$O$_3$ water nanofluid, instead of water base fluid, they studied the overall heat transfer behaviour of a traditional cooling system. Compared to the 6.8 percent base fluid, the heat transfer coefficient increased by more than 40 percent, they revealed. Yu et al [7] claimed that using various types of nanofluids it was possible to achieve around 15-40 percent of the heat transfer enhancement. With all these superior features, the size and weight of an automotive car radiator can be decreased without compromising its heat transfer effectiveness. Pak and Cho et al. [8] performed an investigation of convective turbulent nanofluid (Al$_2$O$_3$-water) heat transfer characteristics of 1-3 percent vol. with increased volume concentration and Reynolds number, the Nusselt number for nanofluids increases. Lai et al. [9] estimated the flow behaviour of nanofluids (Al$_2$O$_3$-water; 20 nm) in a millimetre-stainless steel test tube under constant wall heat flux and low Reynolds (Re < 270) was examined. Nusselt’s overall nanofluid enhancement of 8 per cent at 1 vol. Percentage reported. Guo et al. [10] determined convective co-efficient increase in heat transfer was achieved by 60 % compared to (60/40) ethylene glycol / water base fluid with 2 vol percent nanofluid under circular convective tube fluid flow. Sundar et al. [11] made an observation with turbulent Fe$_3$O$_4$ / water nanofluid flow at 0-0.6 vol. in a single circular tube. Percent concentrations were reported and the coefficient of convective heat transfer enhancement factor increased by 30.96 percent and 10.01 percent compared to water at 22,000 Reynolds. Devireddy Sandhya et al. [12] appealed that, the development of vehicle radiators was experimentally tested with 40 percent ethylene glycol and 60 percent water based TiO$_2$ nanofluids at volume concentrations of 0.1 percent, 0.3 percent and 0.5 percent. Their findings showed that, at small concentrations, the heat transfer increased by up to 37 percent compared to water. Ravikanth et al. [13] claimed that, in the flat tubes of the radiator, the heat transfer properties of ethylene glycol and water mixtures based on Al$_2$O$_3$ and CuO nanofluids were numerically analysed. Their findings showed that thermal energy efficiency improved with increasing the volumetric concentration of nanofluids in particles. R.Saidur et al.[14] claimed that by adding 2 percent copper nanoparticles to ethylene glycol, around 3.8 percent of the heat transfer increase could be achieved. Bhogare et al.[15] conducted experimental tests on the thermal efficiency of 0-1 Vol percent Al$_2$O$_3$ / water-EG nanofluids in a car radiator have been conducted. The analyses were carried with the air side Reynolds number ranging from 83491-91290. 0.54 percent and 3.8 percent at 1 Vol percent and 83491 air side Reynolds number were reported as the highest improvement in efficiency and heat transfer.

2. Preparation of Nanofluid

A first step in evaluating nanofluid to heat transfer studies is the readying of suspension nanoparticles. Throughout this research, the nanofluid Al$_2$O$_3$ -SiC -water+ glycol is prepared using a two-step process. One is process of one stage and the other is the process of two stages. Al$_2$O$_3$ nanoparticles with an average size of 30 to 50 nm and SiC nanoparticles with an average size of 10 to 200 nm were developed by Nanolabs. In the absence of a dispersant or surfactant, Since the nanoparticles in question had a rough nature when spread in water, we were agglomerating or precipitating. Addition, adding any agent can change the properties of the fluid. Lastly, in two
measures, 10 litres of distilled water and 4 litres of ethylene glycol mixture are taken together as the base fluid.

Figure 1: Ultra sonicator Pr-1000

Figure 2: Schematic diagram of nanofluid

3. Properties of Nanofluids
Before examining the radiative efficiency of heat transfer of nano fluids, proper understanding of the effect of nano fluid is required. The concentration of nanoparticles in the tube can be called uniform, assuming the nano particles in the fluid are well distributed. While this statement may not be valid in actual systems due to certain physical processes such as particle movement, this can be a useful method for evaluating a nano fluid's physical properties.

The mixing principle measures the density of nano fluids:

$$\rho = \alpha \rho_p + (1-\alpha)\rho_{bf}$$

In accordance with the thermal equilibrium model, the total heat ability of nanofluids can be calculated:

$$c = (\alpha \rho_p c_p + (1-\alpha)\rho_{bf} c_{bf})/\rho_{nf}$$
Table 1. Nanoparticulate specifications

| Name of chemical | Aluminium oxide | Silicon Caride |
|------------------|-----------------|----------------|
| Absolute Purity  | 99%             | 99%            |
| Outlook          | White           | Black          |
| Smell            | Alcoholic       | No Smell       |
| Mean Amount of particles | 30-50nm       | 20-100nm       |
| Density          | 3.5-3.9g/cm³ | 3.16g/cm³       |

Table 2. The physical thermal properties of water, water+EG(3:1)

| Base fluid | Density (kg/m³) | Thermal conductivity (W/mK) | Specific heat (J/KgK) | Thermal Expansion coefficient (K⁻¹) | Dynamic viscosity |
|------------|----------------|-----------------------------|-----------------------|-------------------------------------|------------------|
| Water      | 998            | 0.61                        | 4178                  | 0.31×10⁻³                          | 0.808×10⁻³       |
| Water+EG   | 1025           | 0.52                        | 3530                  | 0.40×10⁻³                          | 0.96×10⁻³       |

Table 3. Nanoparticulate thermo-physical properties

| S No | Properties               | Al₂O₃  | SiC  |
|------|--------------------------|--------|------|
| 1    | Mass density (Kg/m³)     | 3160   | 3580 |
| 2    | Relevant heat (J/Kg k)   | 773    | 1340 |
| 3    | Thermal Conductivity(W/m K) | 40     | 350  |

Note that these transport properties are temperature functions. Consequently, the properties were determined using the mean liquid temperature between the inlet and outlet. Using small quantities of aluminium oxide and nanoparticles from Silicon Carbide can more or less all of the basic fluid's physical properties.

4 Experimental setup

Schematic diagram and configuration of experimental test system. The experimental setup includes Pipelines, Centrifugal pump, Automobile radiator, Storage tank, Forced draft fan, temperature indicator, magnetic stirrer, Heater, Thermostat and Thermocouples. The operating fluid is filled up to 33 per cent of the storage tank in all tests. The car radiator used in our research is automobile, consists of 48 capsules cross-sectional. Table 4 defines the specifications for vertical formed tubes made of aluminium and for automotive radiators.

Table 4. Requirements of the Automobile Radiator

| Length of Tube | 38cm |
| Width of Tube  | 1.1cm |
| Thickness of Tube | 0.5mm |
| The radius of a tube semicircle | 0.00381 m |
| Number of total of Tubes | 48 |
| Maximum surface area | 0.5731 m |
Nanofluid is heated by a 3 KW electric heater which has a thermostat-based temperature control system for conducting experiments at various temperatures. A total of 7 thermocouples to calculate the temperature around the radiator (K Type) was set. Two thermocouples control the temperature of inlet and outlet, and the remaining 5 thermocouples are used to denote the radiator tubes outside the wall temperature. More focus is placed on the transfer coefficient of fluid side heat in the present research work, which can be determined by the temperatures in the inner wall. After all, the inside pipe temperature profile is believed to be equal to the outside surface wall temperature, as the thickness of the surface of the radiator tube is insignificantly thin. All experiments were carried out by varying the inlet of the radiator Temperature and flow rates vary from 50-70 ° C to 3-12 l / min respectively.
6.1 Base Fluid
The tests were performed by the base fluid (Water+EG) to verify the experimental test rig before conducting the experiments with nanocoolants. Figure 3 provides experimental results at constant reservoir of radiator 85°C temperature. An increase in the number of nussels was observed based on the results, with an increase in the number of Reynolds. The conclusions of the experiments are compared with the theoretical data from the Dittus-Boelter\[16\] eq(10) equation and the Gnielinsky\[17\] eq(11) correlation for the validation of the experimental configuration.

$$\text{Nu} = 0.026 \text{Re}^{0.8} \text{Pr}^{0.3}$$

$$\text{Nu}=\frac{f/8(\text{Re}-1000)\text{Pr}}{(1+12.7 (f/8)^{0.5} (\text{Pr}^{2/3} -1))}$$

Where $f = (\ln \text{Re} - 1.69)^2$

![Nusselt Number Variation with Reynold Number Variation](image.png)

**Figure 4:** Nusselt Number Variation with Reynold Number Variation

On the basis of the above plots, the experimental data was found to agree with conceptual information gathered from correlation of Dittus-Boelter with a maximum error of 5 percent. Then we need to verify the precision of the experimental test rig and the results calculated.

6.2 Nano Fluid

Using the nanofluids prepared at different volumetric concentrations (0.1% to 0.3%), the nanofluid was circulated through the radiator tubes at various flow rates (3-12lit/min) and temperatures (60°C) for each concentration. The heat transfer convection mode takes place between the nanofluids and the radiator walls as the nanofluid moves through the radiator and then, through the forced convection, the heat absorbed by the radiator walls is rejected into the atmosphere using a draught fan.
At different volume concentrations of nano-particles of Al2o3, SiC, the experimental values of the coefficient of forced convective heat transfer. The Nusslet number will give 30.05 at the flow rate of 3lpm, just as the flow rate of 6lpm the Nusslet number will give 56.84 similarly at 9lpm the Nusslet number value 80.47 and finally at 12 lpm the Nusslet number gives the value 104.6.

To understand the thermal efficiency of an automotive radiator, tests were carried out at varying temperatures from 60 ° C to 90 ° C. Figure 6 shows that difference in the nussel number with the temperatures of the inlet radiator. Improvement in the number of nussels is observed with rising working fluid temperatures, based on the findings. The same pattern is noted for all nanofluid concentrations. At 0.3 vol percent concentration, 21 percent improvement in Nu with various working fluid temperatures between 60 °C to 90 °C with a flow rate of 12L/min was recorded.

7. Conclusion

The involvement of alumina SiC nanoparticles in water+ glycol will increase heat transfer efficiency from radiators. The amount of thermal energy improvement depends on the amount of nano particles added to water + glycol. Finally, as opposed to pure Water + Etylene Glycol, the rise in thermal energy was found at a level of 0.1vol per cent around 50 per cent.
Through the growing base fluid flow rate (3-12lpm), the heat transfer coefficient for both liquid + ethyl alcohol and nanofluids is greatly increased. The improvement of efficient heat capacity does not appear to be responsible for the production of the great heat transfer variety of the other mechanical properties.

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