EXAMINING THE NANOFLUID'S HEAT TRANSFER PROPERTIES IN AN AUTOMOTIVE RADIATOR

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Abstract.

An experimental investigation on heat transfer utilizing nanofluid coolants in engines is presented in this research. Due to its strong conductive property, which is observed to grow with concentration, Al2O3 has been shown in earlier tests to be more effective in heat transmission. The particles that are highly unstable in solution and have low thermal conductivities create severe friction and clogging in the flow section. Their diameters range from 10-3 to 10-6 m. Nanoparticles on the other hand are easily dispersed and cause minimal clogging or friction in the flow. In the present work, ethylene glycol-water solution is taken as a base fluid for nanoparticle dispersion. The ratio of water to ethylene glycol used is 80:20 and it has been noted out that heat conduction improved with increasing fraction of ethylene glycol. The experiments were conducted with flow rate of 4,5,6 and 7 L/min and the air flow rate inside the duct was kept constant at 4.9 m/s. The temperature of water in the reservoir is kept at 70°C. The nanoparticles used in this experiment are Cu and TiO2 having particle size less than 80nm. Result shows that there is an improvement of 24.5% in the overall heat transfer coefficient and there was also an increase of 13.9% in the heat transfer rate compared to the base fluid (80:20 Water: EG solution).

Key Word-: Nanofluid, Ethylene glycol-water solution,

1. Introduction

Recently, the automotive industry has placed a lot of emphasis on weight reduction because it lowers operating costs and increases vehicle fuel economy. The system that allows for weight reduction is the engine cooling system. Additionally, recent technology advancements raise thermal loads, necessitating quicker cooling. Fins and microchannels, the conventional techniques for accelerating the cooling rate, have already reached their limit. In order to achieve this high-performance cooling, new and creative coolants are desperately needed. Thermal conductivities of conventional engine coolants (lubricants and water) are low. Certain parameters of an automobile like engine performance, fuel efficiency, and emissions are heavily affected by convective heat transfer. The amount of heat produced during the combustion is important in enhancing the engine lifespan, oil cooling system and climate regulation. Developed thermal systems for modern vehicles need more compact heat exchangers, innovative heat transfer schemes and eco-friendly fluids with better heat transfer characteristics. The modern coolants with their enhanced thermal performance will cut down the overall size of heat exchanger (radiator) and may lessen the vehicle fuel consumption. To increase the heat transfer from heat exchanger and engine cooling system, several methods are adopted such as helically twisted tapes[1,2,3] nanotubes surface coatings[4] electric field and nanofluids in coolants[5] which in turn reduce the weight with the same given power.

1.1. Nanofluids

With the advancement of nanotechnology, nanofluids can be thought of as a coolant in heat exchangers[6, 7, and 8]. Nanofluids are liquid with suspensions of nanoparticles with at least one of their principal dimensions smaller than 100 nm. From previous investigations, nanofluids have been found to possess enhanced thermo physical properties such as thermal conductivity, thermal diusivity and viscosity. Convective heat transfer coecients of nanofluids are greater, compared to those of base fluids like ethylene glycol or water due to the increase in particle volume fraction, temperature and higher thermal conductivity of the nanoparticle that is dispersed in the fluid. The nanoparticle used include stable metals such as copper, gold and silver, metal oxides

such as alumina, bismuth oxide, silica, titania and zirconia and allotropes of carbon such as diamond, single-walled and multi-walled carbon nanotubes and fullerenes [9-12]. Nanofluids are also used in micro channel cooling without any clogging and sedimentation problems.

2. Methods and Materials

Two methods are used for the preparation of nanofluids as documented in the literature[20]. In the present work, two-step process is adopted. In this process, nanoparticles are prepared and are dispersedin the base fluids with the help of mechanical agitation (stirring) or ultra-sonication method. The nanofluids are emulsified with or without the help of surfactants depending on the boundary propertiesof nanoparticles and the base fluids

2.1. Preparation of Nanofluids

The following steps are involved in preparation of Cu and TiO_2 based hybrid nanofluids.

- Initially the base fluid having distilled water and ethylene glycol in the ratio 80:20 (water 80% and ethylene glycol 20% by volume) is taken and mechanically stirred for mixing of the two fluids.

- The second step involves measuring the quantity of nanoparticles containing Cu (~50 nm) in the ratio of 0.3% (wt by vol) and TiO_2 (~20 nm)in the ratio of 0.4%(wt/vol) and adding it to thebase fluid step by step while the base fluid is being stirred in the magnetic stirrer.

- Then the surfactant (CTAB) is added to the base fluid.

- The nanofluid is magnetically stirred for an hour to ensure proper dispersion of the nanoparticlesin the base fluid.

- The next step involves conducting stability and sedimentation tests on the nanofluid prepared using KD2 PRO Thermal Analyzer (Decagon)

The forced convective heat transfer experiment was conducted using three different fluids (1)distilledwater, (2) base fluid and (3) nanofluids and their heat transfer characteristics are compared.

Table 1. Properties of TiO_2 nanoparticles

Material	Titanium oxide, Anatase (TiO2)
Appearance	White powder, no odour
Purity	99.9%
Particle size density	~40 nm (from SEM & BET surface area)Specific
surface area	40 m^2/g

Table 2. Properties of copper nanoparticles

Material	Copper (Cu)
Appearance	Black powder
Purity	99.9%
Particle size density	~50 nm (from SEM & BET surface area)

2.2. Experimental Setup

The schematic diagram of experimental setup is shown in figure 1. Initially the experiment was conducted using distilled water with the flow rate at 4,5,6 and 7 L/min. The air flow rate inside the ductwas kept constant at 4.9 m/s throughout the experiment and was measured using pitot tube. The water in the reservoir tank (15 liters) was heated to 70ºC using electric heater. Once this temperature was achieved, the water is then circulated throughout the system while temperature was recorded at variouspoints like water inlet, air inlet, water outlet, air outlet by using Data Accusation Card (DAC). The procedure was repeated for the base fluid (water and

ethylene glycol) by taking 12 liters of distilled water and 3 liters of ethylene glycol in the reservoir tank. Similarly, for the nanofluids, Cu and TiO₂ nanoparticles were taken in the ratio of 0.3% and 0.4% wt/vol concentration and they were dispersed inthe base fluid and the procedure was repeated. The formulas used for the calculation of the results are given in appendix A.
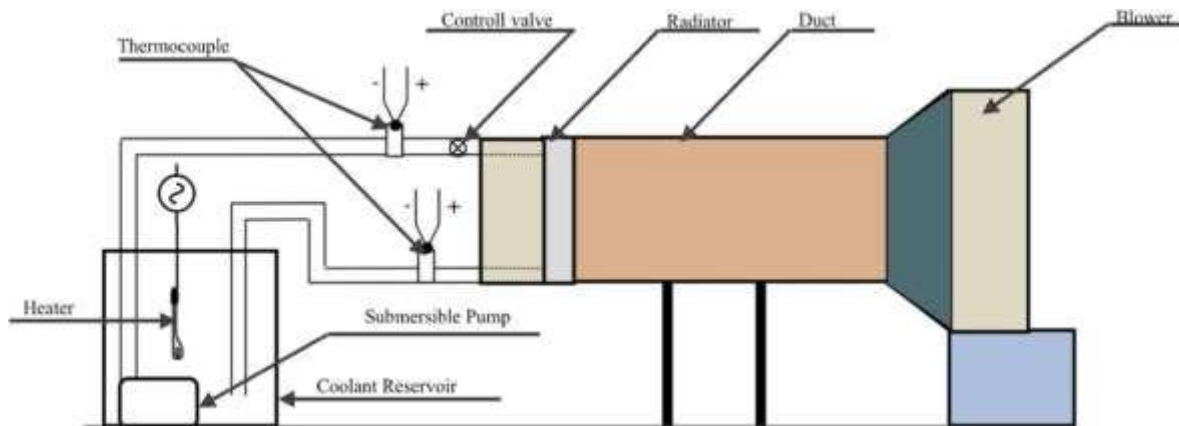

Figure 1 Schematic diagram of the experimental setup

3. Result and Discussion

3.1. Heat Transfer with Nanofluids

Heat transfer enhancement is associated with the collision among nanoparticles, collision between the nanoparticles and the tube wall of the automobile radiator. It can also be improved by increasing the concentration, Brownian motion and the energy exchange rate of nanoparticles.
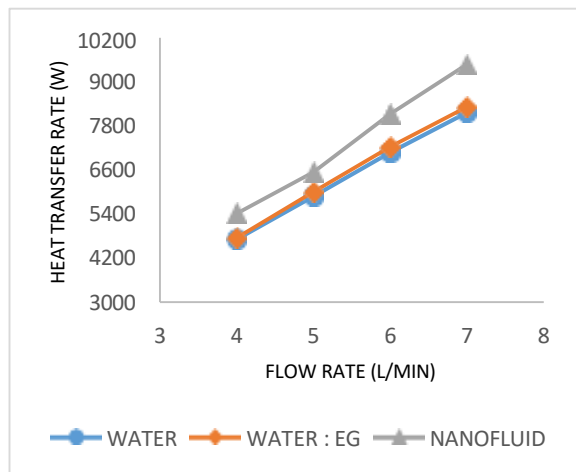

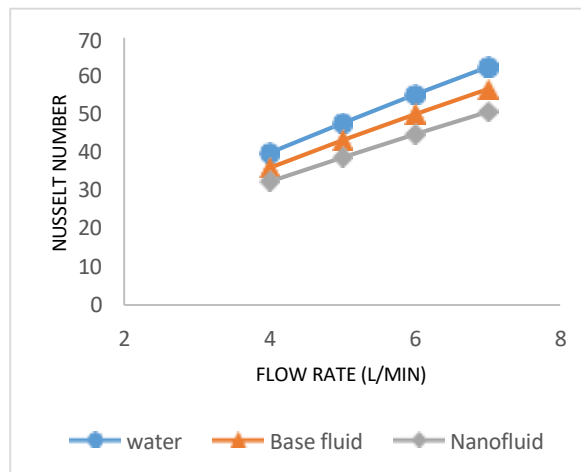Figure 2 Heat transfer rate Vs flow rate

Figure 3 Nusselt number Vs flow rate

Figure 2 shows the heat transfer rate with the flow rate for water, water : EG and nanofluid. It is notedthat the heat transfer rate is greater for the nanofluid compared to other liquids. This type of higher heattransfer rate is attributed to the large surface area of the nanoparticle and higher thermal conductivity ofnanofluids. From the fig., it is observed that there is an increase of 13.9% in heat transfer rate for nanofluids when compared to the base fluid. Eastman et. al [13] noted 40% increase in the 0.3% coppernanoparticle dispersed nanofluid compared to the ethylene glycol base fluid. Similarly Liu et. al [14] noted an increase of 23.8% in the thermal conductivity by adding 0.1% volume fraction of copper nanoparticle in water prepared by chemical reduction method. Yoo

et. al[16] suggested that the surfaceto volume ratio is the dominant factor in enhancing the thermal conductivity rather than the thermal conductivity of the nanoparticle and the base fluid.

Figure 3 shows the variation in Nusselt number with different coolant flow rate of various coolants. It is observed that the Nusselt number increases with the increase in the coolant flow rate, thereby increases the heat transfer. This may be due to the fact that the enhanced thermal conductivity of nanofluids increases the heat transfer performance[17]. Figure 4 shows the variation of the Nusselt number with Reynolds number. The experimental results exhibited good agreement with Dittus Boelter equation [18].The results show that the Nusselt number increases with the increase in the Reynolds number.

The overall heat transfer coefficient and Nusselt number increased with the flow rate. The overall heat transfer coefficient and Reynolds number is observed to increase with the flow rate which could beascribed to the improved heat transfer properties of nanofluids, compared to that of the base fluid. From the figure 5, it is observed that there is an increase of 24.5% in the overall heat transfer rate for nanofluidswhen compared to the base fluid. This is due to the improved thermal conductivity of these particles, and the reduced thermal resistance offered by the flowing nanofluid on the wall surface of the inner tube. It is noted that, the mean free path available for particulate motion would have been augmented atlower volume concentrations of nanofluids. At higher volume proportions of nanofluids, due to the constricted diffusion of particles in the fluid medium, the rate of heat transfer is reduced [19].
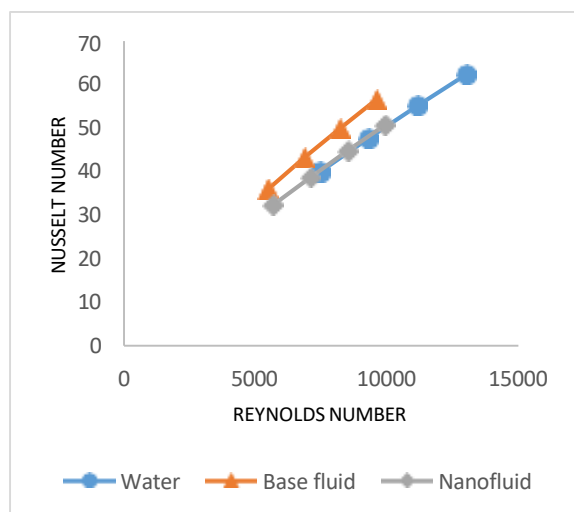

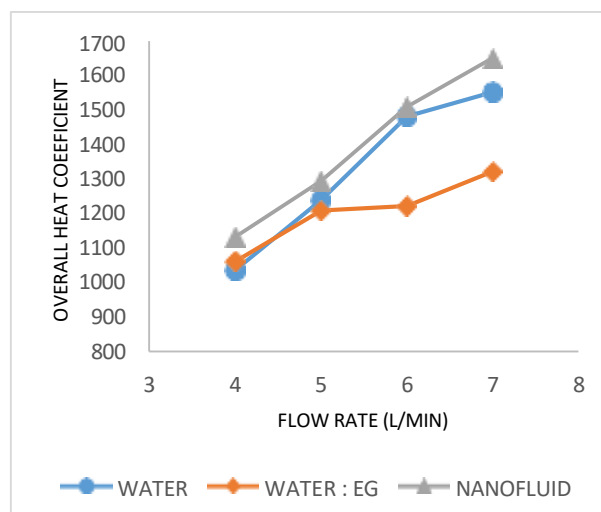Figure 4 Nusselt number Vs Reynolds Number

Figure 5 Overall Heat transfer co-efficient Vs flow rate

4. Conclusion

The forced convective heat transfer was conducted in the test section using a car radiator with distilled water, water ethylene glycol solution and nanofluid respectively as coolants at the flow rates of 4, 5, 6 and 7 L/min and the following conclusions can be drawn from this:

- The rate of heat transfer was found to increase by about 24.5% for the nanofluids when compared to base fluid (water: EG solution).
- The results shows that the Nusselt number increases with the increase in the coolant flow rate following a trend similar to Reynolds number.
- Finally, the experiment proves that nanofluids have high heat transfer rates to remove the excessive heat at high temperature and flow rates and have proved to be a better coolant thandistilled water and water ethylene glycol solution.

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