Experimental Study of Heat Transfer Enhancement by using ZnO and Al_2O_3 Water Based Nano Fluids in Car Radiator

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Abstract - *This study demonstrates the enhancement of convective heat transfer capacity of coolants being used in car radiator i.e. Water based Nano-fluids of ZnO and Al_2O_3. The experimental system was developed, quite similar to cars cooling system. Different concentrations (0.1%, 0.2%, 0.3%, and 0.4%) of nano particles in the base fluid (water) were used in experimentations. Flow rate of Nano fluids were given the range from 4 to 12 l/min which ultimately gave the rise to Reynolds number and Nusselt number from 25000 to 80000 and 65 to 300 respectively. The difference between temperature of coolant at radiator inlet and outlet was measured while the temperature of coolant leaving heat source was kept constant i-e 80°C. It was found that temperature gradient of the nano fluid increases with the increase of volume concentrations. However, the thermal conductivity of nano fluids increases directly with the rise in flow rate of fluid. Moreover, the maximum temperature gradient with water was found to be 10°C and better results were found with the ZnO. The results it was observed that the increment in heat transfer is about 56% by using ZnO and 48% by using Al_2O_3 as nano fluid in the water at the volumetric concentration of 0.2%.*

Key Words: Nano Fluid, Volume Concentration, Heat Transfer Capacity, Thermal Conductivity.

1. INTRODUCTION

Growing petroleum prices and energy-saving awareness have focused attention on the issue of improving vehicle energy efficiency. Numerous mechanical experts are focused on developing a new type of engine or vehicle to improve the performance of automobiles heat dissipation system in order to reduce the weight of the cooling equipment to save fuel for vehicles [1]. Circumstances coolant with a high heat dissipation performance to enhance the cooling efficiency is the best method for improving the heat diffusion performance. Numerous researchers have added Nano particles to the working fluid to form a stable suspension of the particles and called this steady suspension as "Nano fluids" [2]. The actual reason to add the solid particles having diameter in nano-meters to a liquid is the betterment of its thermal properties; and this new fluid formed is called Nano fluid. Addition of particles of metallic and non-metallic oxides to base fluids like water and Ethylene Glycol have gained a lot of attention of researchers in few past years [3] – [9]. The goal of which is to obtain good thermal conductivity and heat transfer performance. Consequently, using Nano fluids with a high thermal performance in automobile cooling system is worthy of research. The thermal conductivity of Nano fluids increases as the volume concentrations increases up to an optimum level and then further increase in concentration starts to decline the heat transfer [10]. The heat transfer capacity of the fluid increases with Nano particles than that of simple liquid [11]. Heat dissipation from Zinc oxide and Aluminum Oxide nano particles in pure water alternatives has been analyzed. The results depicts that by utilizing the dispersion of Nano particles in the water enhance the heat transfer area in compare with that of water [12] The entire heat transfer coefficient boosts with the advancement in the Nano fluid amount from 0.1% to 0.4 vol. %. Conversely, the entire heat transfer coefficient lessens with increasing the Nano fluid inlet temperatures 80ºC. The execution of Nano fluid escalates the overall heat transfer coefficient up to 12% at nano fluid awareness of 0.4 vol. % in comparison to the bottom fluid [13]. By utilizing the efficiency factor (EF), the pumping power was correlated with heat exchange capacity in the study. Experimentation had shown that the both heat transfer capacity and the efficiency of Nano fluids as a coolant are higher than the conventional coolants (water and EG), and zinc oxide is higher than the Aluminum oxide Nano fluids according to most experimental data [14]. The fluctuations in Thermal conductivity, specific heat of nano fluids have been experimentally studied by varying the temperature and nano particle concentrations. On the basis of these results increase in heat transfer had been achieved of 56% in average by using these Nano fluids.

1.1 Preparation method of nano fluids

1.1.1 Two-step method

Two step methods is most widely used method for the preparation of nano fluids. Nano particles used in this method are first produced as nano powders obtained as a result of mechanical grinding. Then, the ultrasonic vibrator device is used to stir nano powders with host fluid. Frequent use of ultrasonic tionor stirring is required to reduce particle agglomeration. Due to high surface area nano particles have tendency to aggregate. To enhance the stability of nano particles in fluids is use of bio surfactants i.e. Sodium Hexameta phosphate.

2. EXPERIMENTAL SETUP

To study the increment in heat transfer with the Nano fluids, an experimental apparatus has been designed, as Shown in Figure no 1.

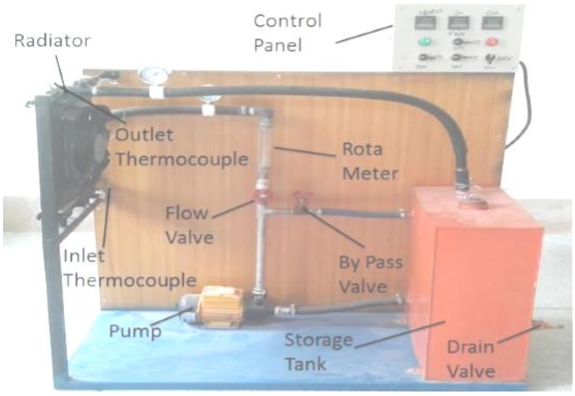

Fig -1: Experimental setup of car radiator

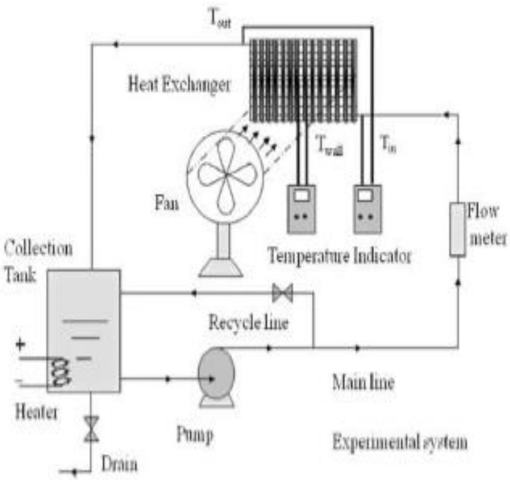

Fig -2: Schematic Diagram

In the setup a heat source has been made in which the temperature of Nano fluid was raised using an electric heater of 3 kW. The temperature of fluid was controlled (80°C) using a thermostat. The circulation of the fluid throughout the cycle was done by a centrifugal pump. The flow rate of the fluid was varied by using variable flow meter „Rota meter" having a range from 4 to 20 l/min. The heat was transferred in car radiator, in which a radial flow fan was used to transfer the heat of fluid with air. The specifications of car radiator have been shown in Table 1.

Table -1: Dimensions of radiators used in experimental setup

L× W × H (mm³)	23.98 × 1.56 × 375
Area of tube periphery (mm²)	18890.4
Hydraulic diameter (mm)	4.3
Perimeter (mm)	26.9
Total area of tube	374.6

A by-pass valve was given for accommodating the over flow of the fluid. K type thermocouples were installed at different points for the measurement of temperature. A control panel has been setup in which different input parameters were controlled from a single compact unit. The size of nano particles used for the preparation of Nano fluids was 140 nm as shown in Figure no 3.

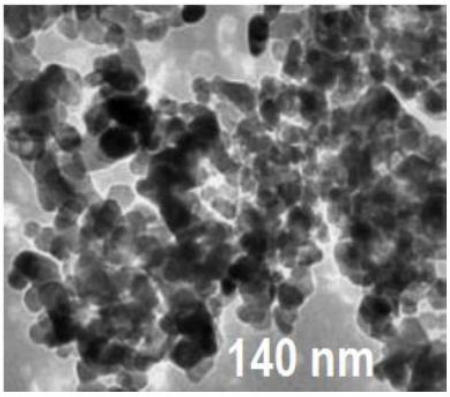

Fig -3: ZETA-SIZER analysis of nano particles

3. DATA REDUCTION

The validity of the results was made by calculating the Reynolds's number from equation 1.

$$Re = \frac{\rho . V . Dh}{\mu} \tag{1}$$

Where Re, ρ, V, Dh and μ is representing Reynolds number, density, velocity, hydraulic diameter and the dynamic viscosity respectively and Dh is found by the mathematical relation

$$Dh = \frac{4\acute{A}}{P} \tag{2}$$

Where the peripheral area of tube and P is is for the perimeter of cylindrical radiator tubes and calculated by the relations.

$$\acute{A} = \frac{\pi}{4} d2 + (D - d)d \tag{3}$$

$$P = \pi d + 2(D - d) \tag{4}$$

Where D is the major diameter and d is the minor diameter.

$$\rho\,(n.f) = \phi * \rho P + (1 - \phi)\,\rho(b.f) \tag{5}$$

$$\mu n.f = \mu\,(b.f)(1 + 7.3\phi + 123\phi 2) \quad (6)$$

Where φ is the volumetric concentration of nano-particle and the n.f, p and the b.f are used for nano fluid, nano particle and base fluid respectively.

$$Q = \dot{m}C_p\,(Tin - Tout) \quad (7)$$

$$Nu = \frac{h\,Dh}{k} \quad (8)$$

$$k(n.f) = \frac{kp + (w-1)k(b.f) - \phi(w-1)(k(b.f) - kp)}{kp + (w-1)k(b.f) - \phi(k(b.f) - kp)}\,k(b.f) \quad (9)$$

h is the convection heat transfer coefficient, K is the thermal conductivity, w is the empirical shape factor and its value is taken as 3 for spherical shaped particle

$$h = \frac{\dot{m}Cp\,(Tin - Tout)}{\acute{A}(Tb - Tw)} \quad (10)$$

Where Tb is the average bulk temperature, Tw is the wall temperature and Á is peripheral area of radiator tubes.

$$C_p\,(n.f) = \varphi * Cpp + (1-\phi) * Cp(b.f) \quad (11)$$

And the overall heat transfer coefficient was calculated by the equation.

$$U = \frac{Q}{A * LMTD} \quad (12)$$

Where A is the radiator area and LMTD is the log mean temperature difference.

$$A = L * W \quad (13)$$

$$LMTD = \frac{(Tin - Tout)}{\ln(\frac{Tin}{Tout})} \quad (14)$$

Where L is the length and W is the width of radiator respectively.

4. RESULTS AND DISCUSSIONS

In order to validate the results of the experimentation, Nusselt number for pure water, Al_2O_3 and ZnO were determined experimentally and were compared with that of Dittus-Boelter [15] as shown in chart-1. From the chart-1 it is evident that the Experimental results are showing a very small gap with the theoretical Nusselt number over the range of Reynolds number. Theoretical Nusselt number was determined by the following correlation [15].

$$Nu = 0.0236\ Re^{0.8}\ Pr^{0.3} \quad (15)$$

Where "Pr" is the Prandtl number, determined from the following relation:

$$P_r = \frac{\mu Cp}{k} \quad (16)$$

Results from the chart-1 shows that the pure water gives higher Nusselt number than that of Al_2O_3 (0.2%) and ZnO (0.2%) Nano fluids. As Nusselt number is the ratio of convective to conductive heat transfer and conduction only exist in solid particles i.e. in nano fluids, so water gives the higher Nusselt number than that of nano fluids.

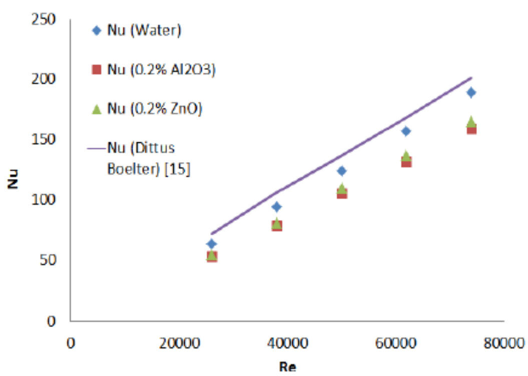

Chart -1: Validity of experimental data with that of dittusboelter [15]

4.1 Heat transfer of nano fluids (Q)

Heat transfer between air and Nano fluids were determined experimentally using different concentrations of Nano fluids (i.e. 0.1%, 0.2%, 0.3% and 0.4%) for both Al_2O_3 and ZnO, as shown in Fig. 5-6 respectively. Heat transfer for both Nano fluids was determined with the variation in flow rate of the Nano fluid. Heat transfer varies directly as the flow rate as shown in Figure. 5.and Figure.6. From the both figures it can also be clearly seen that 0.2% volumetric concentration gives the higher heat transfer for both Al_2O_3 and ZnO.

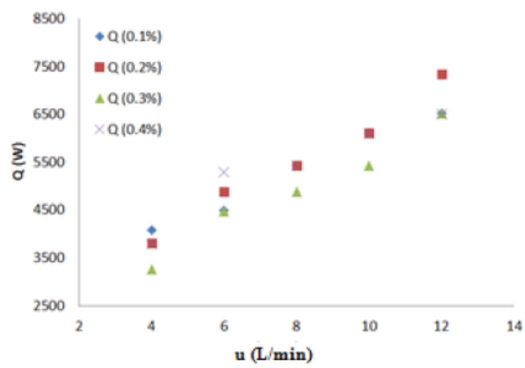

Chart -2: Effect of volumetric concentration on heat transfer of AL_2O_3 nano fluid

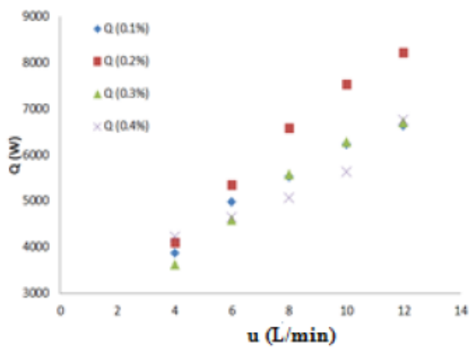

Chart -3: Effect of volumetric concentration on heat transfer of ZNO nano fluid

The comparative results of heat transfer for water, ZnO and Al_2O_3 is shown in chart-4. Heat transfer for ZnO and Al_2O_3 were compared at 0.2% volumetric concentration due to higher heat transfer rate at this concentration as shown in chart 2-3. Chart-4 shows the higher heat transfer for ZnO than water and Al_2O_3 that's why ZnO comes out to be more thermally efficient than pure water and Al_2O_3.

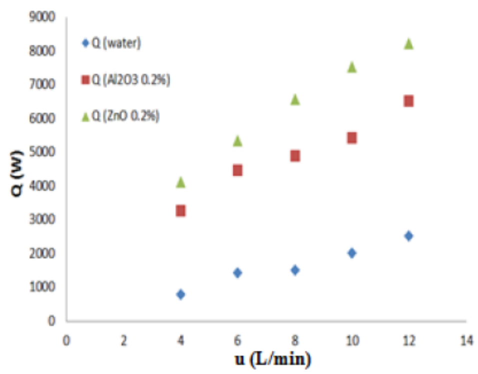

Chart -4: Comparison of heat transfer between the fluids used in the study.

4.2. Heat transfer ratio

Chart -4 shows the heat transfer ratio between ZnO as Nano fluid to pure water as base fluid. From the chart -5 it is shown that the heat transfer is increased from 40% to 70% by using ZnO as nano fluid in the water at the volumetric concentration of 0.2%, at higher concentrations i.e. 0.3% & 0.4%, the friction factor becomes significant due to which there is not as much heat transfer as it was at 0.2%. From the chart -5 it can also be seen that the optimum flow rate of 8 lpm shows the highest heat transfer at every concentration. After 8 l/min the heat transfer is decreased significantly because at higher flow rates the fluid behavior becomes turbulent. So both the volumetric concentration and flow rate affects the heat transfer of the Nano fluid inside the car radiator.

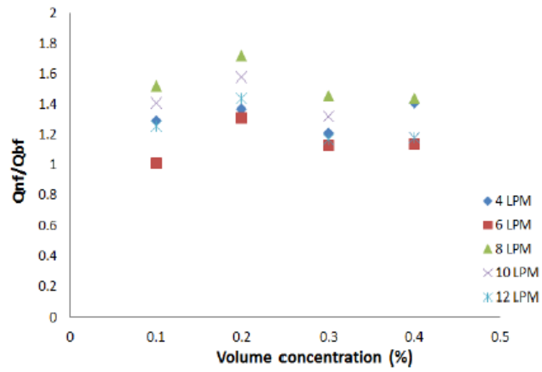

Chart -5: Heat transfer ratio for ZNO with pure water as base fluid at different concentrations

4.3. Overall heat transfer coefficient (U)

Overall heat transfer coefficient (U) for the fluids used in the experimentations has been shown in chat -6. Due to higher heat transfer at 0.2% volumetric concentration of ZnO and Al_2O_3, U was compared at this concentration of 0.2%. From the chat -6. It is evident that ZnO hold more overall heat transfer coefficient than pure water and Al_2O_3 due to higher Log Mean Temperature Difference (LMTD) across the inlet and outlet of radiator. As seen from the figure 8 the optimum flow rate for highest U of ZnO comes out to be 8 LPM. At this flow rate U increases about 35 to 37% than the pure water.

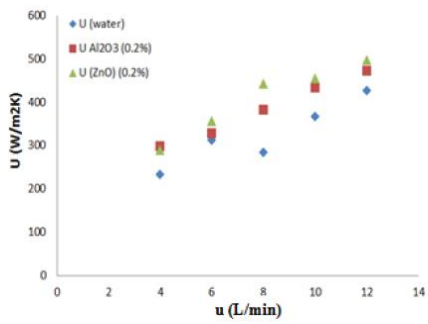

Chart -6: Comparison of overall heat transfer coefficient for the fluids used in study

5. CONCLUSIONS

The experimental system was developed, quite similar to car‟s cooling system, to determine the increase in above mentioned parameters of nano fluids (ZnO and Al_2O_3) in comparison with conventional coolant in the radiator i.e. water. In this study different concentrations (0.1%, 0.2%, 0.3%, and 0.4%) of nanoparticles were added to base fluid water to study the mentioned parameters. From the study it was concluded that:

1. Experimental results are showing a very small gap with the theoretical nusselt number over the range of Reynolds number.

2. Pure water gives higher nusselt number than that of Al_2O_3 (0.2%) and ZnO (0.2%) Nano fluids.

3. 0.2% volumetric concentration gives the higher heat transfer for both Al_2O_3 and ZnO.

4. ZnO gives higher heat transfer than water and Al_2O_3 that's why ZnO comes out to be more thermally efficient than pure water and Al_2O_3.

5. The heat transfer is increased from 40% to 70% by using ZnO as nano fluid in the water at the volumetric concentration of 0.2%.

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