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Experimental study on enhancement of heat transfer coefficient in an automobile radiator using Al_2O_3nanofluid as a coolant

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Cooling system plays an important role in an automobile engine. An efficient cooling system can prevent engine from overheating and assists the vehicle running at its optimal performance. Nanofluids are expected to have a better thermal performance than conventional heat transfer fluids due to higher thermal conductivity. In the present study, experimental setup of radiator is fabricated and experiments were conducted with Al_2O_3 nanofluid at 0.03 and 0.06 particle concentrations. For all the experiments water and ethylene glycol was taken as base fluid. The experimentswereconducted at different flow rates i.e, 6 lpm, 9 lpm & 12 lpm and all the results are compared with conventional fluids. The heat transfer rate of nanofluid based automobile radiator was enhanced compared to the conventional fluids. The mass flow rate also effects the heat transfer rate and heat transfer coefficient.

***Keywords*:** heat transfer coefficient, nanofluids, thermal conductivity, volume concentration.

1. Introduction

There are a lot of systems which influence the engine performance like fuel ignition system, emission system & cooling system etc., In an automobile, due to the combustion a lot of heat is produced, only a portion of heat is can be useful to produce the power rest of heat is wasted as the exhaust heat. If excess heat is placed in it, the engine temperature become too high which results overheat and viscosity breakdown of the lubricating oil, wear of the engine parts and due to the thermal stress, the engine components may failure. Therefore, it was very much important that better cooling system i.e. radiator should be used to cool the engine. Constrain to the design aspects, the heat transfer rate can be improved by replace nanofluid with conventional fluid without change of radiator design.

In development of coolants it is found that mixture of water and ethylene glycol improves heat transfer better than water. Salmon et. al [1] discussed on the TiO_2 – water/propylene glycol (70:30) nanofluid as coolant and used in automobile radiator. They concluded that,the heat transfer rate of TiO_2nanofluid at 0.3%volume concentrationis 8.5% more than conventional fluid. S.M.Peyghambarzadesh et. al [2] conducted experimental test on automobile radiator by using Al_2O_3-water nanofluid as coolant at different concentrations and at different flow rates.They concluded that nanofluid based radiator has 45% more heat transfer than water with in the temperature range of 37-49 °C.

2. Experimental details

The line diagram of the experimental set up and image of the experimental setup are presented in fig. 1 and fig. 2.

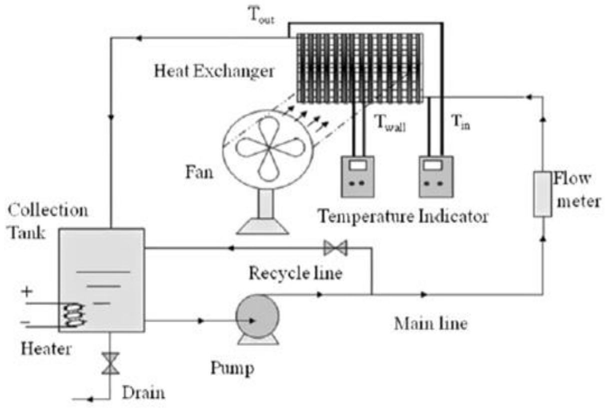

Fig 1. Line diagram of the experimental setup

Fig 2. Experimental setup

2. 1. Nanofluid Preparation

In this present work two step method is used to prepare all the nanofluids. Al_2O_3 nanoparticles were purchased from the Nano Research Lab, Mumbai, India with an average size of 30 to 50 nm. The photographic view of the nano particles is as shown fig. 4. The weight of nanoparticles for a particular volume concentration can be measured by using eq. (1). Thermophysical properties of the nanofluid were estimated using the equations given in table 2.

$$\% \text{ volume concentration} = \frac{\left[\dfrac{w_{Al_2O_3}}{\rho_{Al_2O_3}}\right]}{\left[\dfrac{w_{Al_2O_3}}{\rho_{Al_2O_3}} + \dfrac{w_{bf}}{\rho_{bf}}\right]} \text{ x } 100 \qquad (1)$$

$w_{Al_2O_3}$ = weight of Al_2O_3 nano particles

$\rho_{Al_2O_3}$ = density of Al_2O_3 nano particles.

w_{bf} = weight of base fluid

ρ_{bf} = density of base fluid

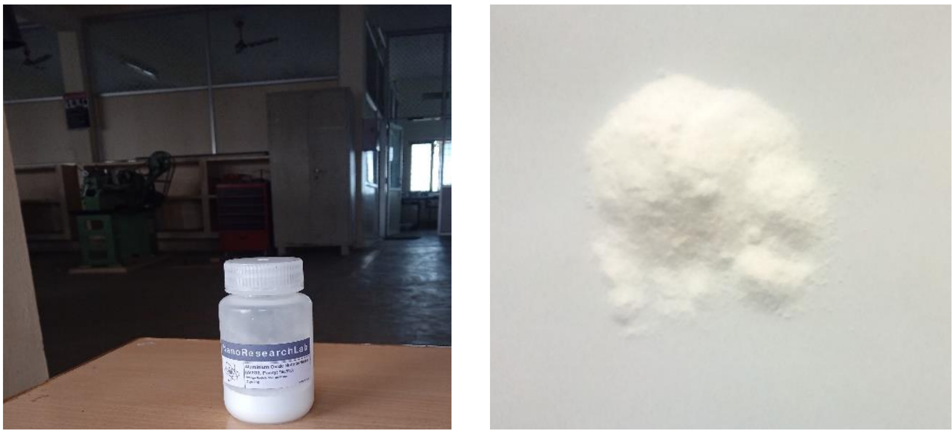

Fig. Photographic view of Al_2O_3 Nano particles

3. Data reduction

The heat transfer coefficient can be obtained by using the following formula.

$Q = h\times A\times \Delta T = h\times A\times(T_b - T_w)$ (2)

Heat transfer rate can be calculated as follows:

$Q = m\times Cp\times \Delta T = m\times Cp\times(T_{in}-T_{out})$ (3)

Where,

m = flow rate of Mass (Density ×Volume flow rate)

Cp = Specific heat capacity

A = Peripheral area of radiator tubes

T_{in} = inlet temperature

T_{out} = outlet temperature

T_b = Average value of inlet and outlet temperatures

T_w = Tube wall temperature which is the mean value of surface thermocouples

Table.1: Relations to find thermophysical properties of the nanofluid

S. No.	Thermo-physical property	Formulae
1	Density	$\rho_{nf} = (1-\phi)\rho_f + \phi\rho_p$
2	Heat capacity	$C_{nf} = \frac{(1-\phi)\rho_f C_f + \phi\rho_p}{\rho_{nf}}$
3	Viscosity	$\mu_{nf} = -0.4491 + \frac{28.837}{T} + 0.574\phi - 0.1634\phi^2 + 23.053\frac{\phi^2}{T^2}$ $+0.0132\phi^3 - 2354.735\frac{\phi}{T^3} + 23.498\frac{\phi^2}{d_p^{\;2}} - 3.0185\frac{\phi 3}{d_p^{\;2}}$ $0.01 \le \phi \le 0.09, 20 \le T(^0C) \le 70, 13nm \le d_p \le 131nm$
4	Thermal conductivity	$\frac{k_{nf}}{k_f} = 0.9843 + 0.398\phi^{0.7383}\left(\frac{1}{d_p(nm)}\right)^{0.2246}\left(\frac{\mu_{nf}}{\mu_f}\right)^{0.0235}$ $-3.9517\frac{\phi}{T} + 34.043\frac{\phi^2}{T^3} + 32.509\frac{\phi}{T^2} --------(20)$ $11nm \le d_p \le 150nm,$

4. Results and Discussion

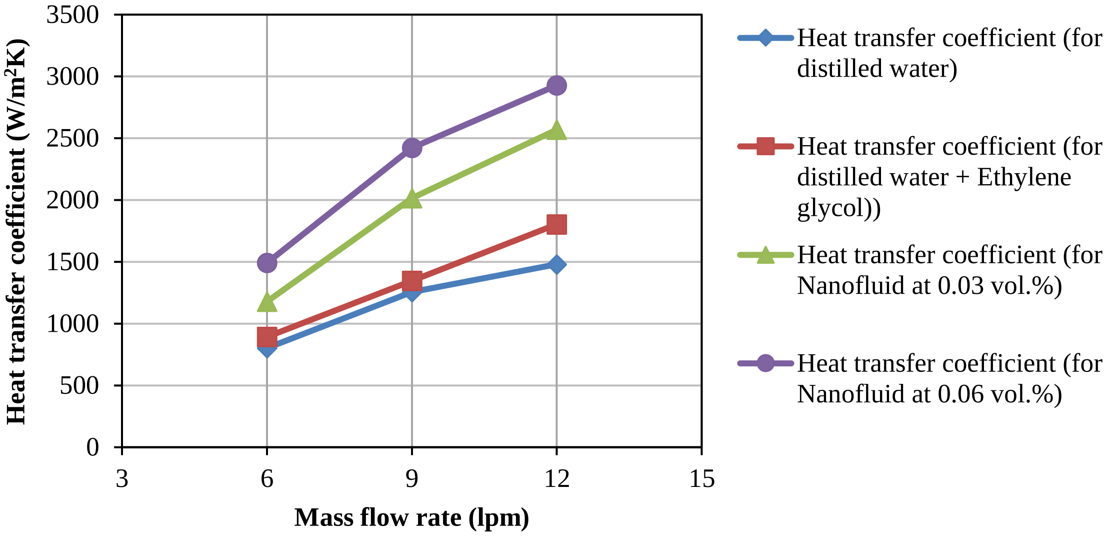

Fig. 3 Experimental results of pure water in comparison with water+ Ethylene glycol and nanofluid

It can be shown in figure 3 that whenever the concentration becomes greater, heat transfer coefficient becomes larger. By the addition of only 0.03 vol. % of Al_2O_3 nanoparticle into the pure water + Ethylene glycol, an increase of about 46% to 73% in comparison with the pure water heat transfer coefficient and when compared to Ethylene glycol + pure water coolant the increasing rate is about 31.98% to 42%. When the volume concentration increasing to 0.06% the heat transfer rate increases but is in the range of 85% to 97% when compare with pure water and when compared to pure water + Ethylene glycol the increasing rate about 62% to 76%. The cost of the working fluid is increases but increasing of heat transfer rate is more. The average heat transfer coefficient of nanofluids as a function of volume flow rate for different nanoparticle concentrations is presented in figure 3. It is observed that the heat transfer coefficient of all nanofluids is significantly higher than that of the base fluid.

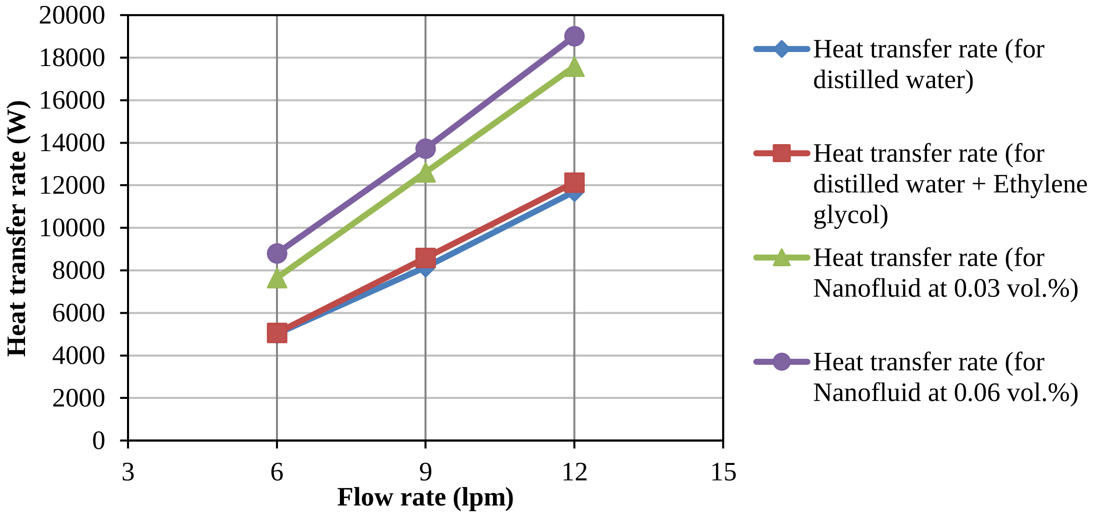

Fig. 4 Heat transfer comparison of pure water with water + Ethylene glycol and nanofluid

From the figure 4 it can be observed that whenever the concentration becomes greater, heat transfer rate becomes larger. By the addition of only 0.03 vol. % of Al_2O_3 nanoparticle into the pure water + Ethylene glycol, an increase of about 35% to 64% in comparison with the pure water heat transfer coefficient and when compared to Ethylene glycol + pure water coolant the increasing rate is about 28.7% to 37.4%. When the volume concentration increasing to 0.06% the heat transfer rate increases but is in the range of 81% to 95% when compare with pure water and when compared to pure water + Ethylene glycol the increasing rate about 58% to 71%. The cost of the working fluid is increases but increasing of heat transfer rate is more. The average heat transfer coefficient of nanofluids as a function of volume flow rate for different nanoparticle concentrations is presented in figure 4. It is observed that the heat transfer coefficient of all nanofluids is significantly higher than that of the base fluid.

5. Conclusions

- The heat transfer rate and heat transfer coefficients are enhanced by using nanofluid as coolant in the automobile engine radiator when compared with conventional fluids.
- The heat transfer coefficient was increasing with the particle concentration and mass flow rates.

References

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