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

M. Vinod Kumar[a,*], R. Srinath[a], K. Naga Suresh[a], S. V. Rambabu[a]
[a]*Department of mechanical engineering, Sasi Institute of Technology & Engineering, Tadepalligudem, 534101, Andhra Pradesh, India*

*Corresponding author Email: mvinodkumar04@gmail.com

Cooling system plays an important role in an automobile engine. To prevent engine from overheating the effective cooling system is needed. 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 experiments were conducted 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 coefficient.

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

1. Introduction

There are a lot of systems which influence the engine performance like cooling system, emission system, fuel ignition system etc. In an automobile, due to the combustion a lot of heat is produced, out of this some amount of is utilised and remaining heat is wastage. 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.

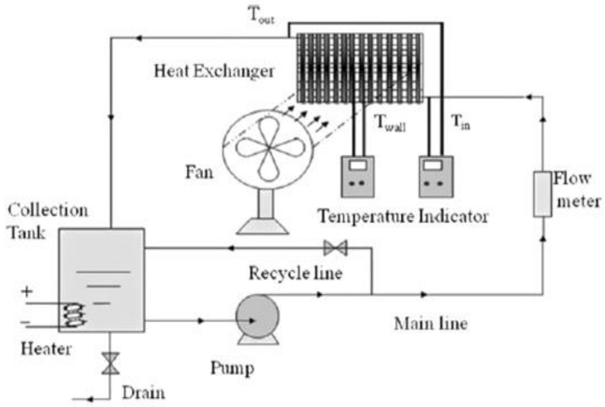

Fig 1. Line diagram of the experimental setup

Fig 2. Experimental setup

2. 1. Preparation of nanofluid

In 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.

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

$w_{Al_2O_3}$ = 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

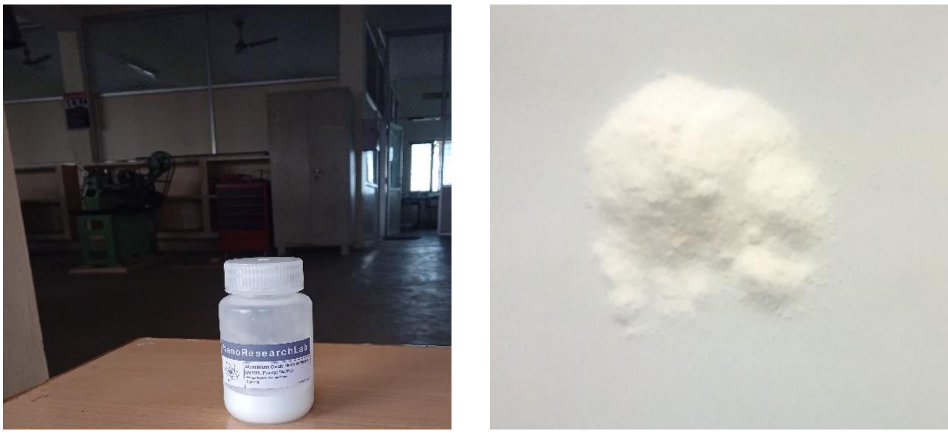

Fig. Photographic view of Alumina Nano particles

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)

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

Where,

m = mass flow rate

Cp = Specific heat capacity

A = Peripheral area of radiator tubes

T_{in} = Temperature of the fluid at inlet

T_{out} = Temperature of the fluid at outlet

T_b = Average temperature

T_w = Tube wall temperature

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

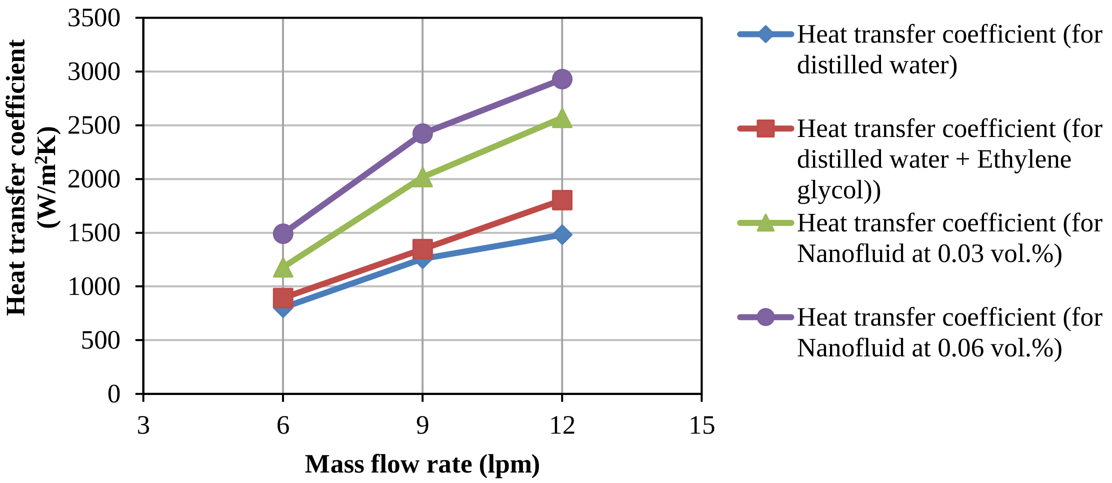

Fig. 3 Comparison of pure water with water+ Ethylene glycol and nanofluid

Fig 3 shows that the heat transfer coefficient increases with particle concentration. The heat transfer coefficient of nanofluid increases from 46% to 73% and 31.98% to 42% when compared with the pure water and when compared to Ethylene glycol + pure water respectively at 0.03% concentration. But further increase in concentration the heat transfer coefficient values are not much changed. The cost of the working fluid is increases but increasing of heat transfer rate is more. Also fig 3 shows that the influence of mass flow rate on heat transfer coefficient.

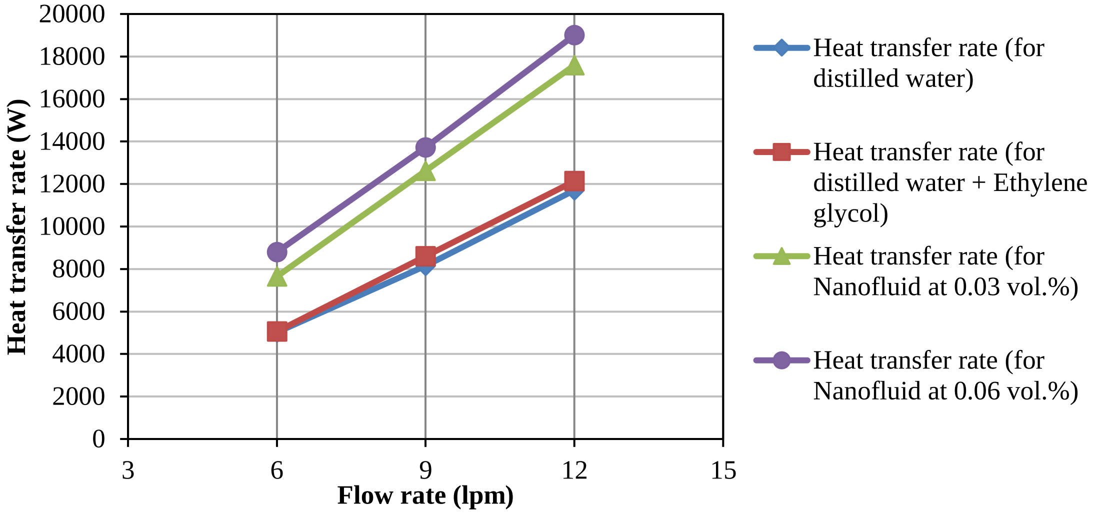

Fig. 4 Heat transfer comparison of pure water with water + Ethylene glycol and nanofluid

Fig 3 shows that the heat transfer coefficient increases with particle concentration. The heat transfer coefficient of nanofluid increases from 35% to 64% and 28.7% to 37.4% when compared with the pure water and when compared to Ethylene glycol + pure water respectively at 0.03% concentration. But further increase in concentration upto 0.06% the heat transfer coefficient values are not much changed. The cost of the working fluid is increases but increasing of heat transfer rate is more. Also fig 3 shows that the influence of mass flow rate on heat transfer coefficient. 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%.

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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