Heat Transfer Rate Improvement on Radiator (IC Engine) Using Nanofluids

J.D.Andrew Pon Abraham [1], J.Sai Ganesh[2]
[1,2]*Department of Automobile Engineering Kumaraguru College of Technology, Coimbatore, Tamilnadu State, India*

***Abstract*- Invention of motor vehicle has advanced the life style of human being. Motor vehicle made a contribution in place to place mobility and is also helpful in small scale transportation of essential commodities. But the heat transfer rate of radiator place a vital role in the efficiency of engine. Many methods were implemented to increase the heat transfer rate. But still the efficiency of engine is limited only to a certain extent. In this system the heat transfer rate can be increased to a greater level by using nanofluids as coolant in radiator.**

***Key words*- Nanofluid, Forced Convection, Radiator, Heat Transfer enhancement**

I. INTRODUCTION

The automobile industry continuously faces challenges to obtained best automobile design in aspects of performance, fuel consumption, safety etc. The thermal performance of an automobile radiator plays an important role in the performance of automobiles cooling systems and all other associated systems. The air cooled heat exchangers found in radiators, AC condenser and evaporator have an important role in the weight and also in the design of its front end module, which also has a strong impact on the car aerodynamic behavior. In recent years a growing and intense attention has been turned to the study of new concept heat exchangers, as they represent a good solution in terms of dimensions and efficiency for industrial applications compared to traditional ones.

Radiators, which are vital component in the control of the engine temperature in automobiles uses a liquid (commonly water, glycol-mixture) to be cooled by air .The liquid flows in flat tubes while the air flows in channels setup by fin surfaces. With recent developments, nanotechnology has been widely used in traditional industries because materials with grain size of nanometers posses unique optical, electrical and thermal properties. Nanofluids are suspensions of metallic or non-metallic nanopowders in base liquid and can be employed to increase heat transfer rate in various applications. The recent advance in materials technology has made it possible to produce nanometers-sizes particles that can overcome these problems. Innovative heat transfer fluids-suspended by nanometer-sized solid particles are called 'nanofluids'. These suspended nanoparticles can change the transport and thermal properties of the base fluid [3]. In this work laminar flow forced convection heat transfer of Al_2O_3/water nanofluid inside a radiator with constant inlet temperature was investigated experimentally

Table 1 Nomenclature

Nomenclature	**Expansion**
k_S	Thermal conductivity of nanoparticle (W/m.K)
k_w	Thermal conductivity of water (W/m.K)
k_{nf}	Thermal Conductivity of nanofluid (W/m.K)
ρ_s	Nanoparticle density (kg/m^3)
ρ_w	Water density (kg/m^3)
ρ_{nf}	Density of nanofluid (kg/m^3)
Cp_s	Specific heat of nanoparticle (J/kg.K)
Cp_w	Specific heat of water (J/kg.K)
Cp_{nf}	Specific heat of nanofluid (J/kg.K)
μ_w	Viscosity of water (kg/m.s)
μ_{nf}	Viscosity of nanofluid (kg/m.s)
Pr_{nf}	Prandtl Number for nanofluid
m_s	Mass of nanoparticle (kg)
υ	Nanoparticle volume fraction

II. NANOFLUID PREPARATION

Preparation of nanoparticles suspension is the first step in applying nanofluid for heat transfer enhancement. In the present study c-Al2O3/water nanofluid was employed. Al2O3 nanoparticles with an average diameter of 13 nm were dispersed in water. In our study no dispersant or stabilizer was used. This is because of the fact that addition of any agent may change the fluid properties [5].

The nanofluids with six different Al2O3 nanoparticles concentrations (0.2%, 0.5%, and 1.0% volume fraction) were prepared and used to study enhanced heat transfer. The volume fraction and the density of the nanoparticles in suspension are defined as follows:

$$\upsilon = \frac{V_s}{V_t} \text{--------------------(1)}$$

$$\rho_s = \frac{m_s}{V_s} \text{------------------(2)}$$

Then the required mass of nanoparticles for nanofluidsuspension determined as follows:

$$\boldsymbol{m_s = 1 \times 10^{-3} \times \upsilon \times \rho_s}$$

--------------------(3)

III. THERMAL PROPERTIES FOR NANOFLUID

The physical properties used for nanofluid were calculated [5,1] from water and nanoparticle properties at average bulk temperature using following correlations for density, viscosity, specific heat and thermal conductivity are defined as follows:

a) Density of nanofluid (ρ_{nf}):

$$\rho_{nf} = (\upsilon \times \rho_s) + ((1-\upsilon) \times \rho_w)$$

---------------------------(4)

b) Viscosity of nanofluid (μ_{nf}):`

$$\mu_{nf} = \mu_w (1 + 2.5\upsilon)$$

--------------------------(5)

c) Specific heat of nanofluid (Cp_{nf}):

$$\mathbf{Cp_{nf}} = \frac{(\upsilon \times \rho_s \times Cp_s) + ((1-\upsilon)\rho_w \times Cp_w)}{\rho_{nf}}$$

-----------------------------(6)

d) Thermal Conductivity of nanofluid (k_{nf}):

$$k_{nf} = \left[\frac{(k_s + 2k_w + 2(k_s - k_w)(1+\beta)^3\upsilon}{(k_s + 2k_w + (k_s - k_w)(1+\beta)^3\upsilon}\right] \times k_w$$

------------------------(7)

In above equation is the ratio of the nanolayer thickness to the original particle radius and β = 0.1 were used to calculate the nanofluid effective thermal conductivity .The rheological and physical properties of the nanofluid were calculated at the mean temperature.

Table 2: Al_2o_3 Nanoparticle Suspension Fluid Properties At 20^oc And 100kpa

Properties	**0.2%Al_2O_3**	**0.5%Al_2O_3**	**1%Al_2O_3**
m_{nf} (kg)	7.2×10^{-3}	0.018	0.036
ρ_{nf} (kg/m^3)	1005.2	1013	1026
μ_{nf} (kg/m-s)	1.0115×10^{-3}	1.0191×10^{-3}	1.0316×10^{-3}
Cp_{nf} (J/ kg.k)	4162.546	4126.33	4067.21
k_{nf} (W/m.k)	0.601517	0.6084	0.61993

IV. EXPERIMENTAL PROCEDURE AND DATA PROCESSING

A several years ago, the nanofluid has been found to be an attractive heat transport fluids. It has exhibited a significant potential for heat transfer augmentation relative to the conventional pure fluids. It has been expected to be suitable for the engineering application without severe problems in pipeline and with little or no penalty in pressure drop. However, the earlier researches revealed that most studies of the transport properties of the nanofluid were focused on the thermal conductivity. The convective heat transfer of nanofluids has received comparatively little attention in literature. There are few publications dealing with the convective heat transfer of nanofluids. The most productive studies have been continuously carried out by the following researchers. Li and Xuan [2], and Yang Y, Zhang ZG, Grulke EA, Anderson WB, Wu G [4] presented an experimental system to investigate the convective heat transfer coefficient and friction factor of nanofluids for laminar and turbulent flow in a tube.

In order to study convective heat transfer under constant inlet temperature boundary condition an experimental setup was designed and constructed (Fig. 1). The experimental set-up consisted of a flow loop containing several sections such as thermocouple, flow rate measuring units, heating and cooling sections, flow controlling system and radiator. The radiator is placed in front of the fan. In order to control the fluid flow rate, a reflux line with a valve was used. The fan is used for cooling the fluid. Flow measuring section consists of 3 litre glass vessel. Flow rate was measured directly by using the time taken to fill the glass vessel. After being carefully assembled, the experimental setup was first thoroughly checked for possible leaks from various connections in piping system; some corrections were then performed accordingly.

After the injection of nanofluid with specified concentration in reservoir tank, the pump, cooling system (fan), and heating started. After 5-7 min, the nanofluid reached the desire temperature. The flow rate was regulated by using the valve on the reflux line and the tests were repeated at least for three flow rates for each concentration. During experimental runs, inlet and outlet temperature of nanofluid, inlet and outlet Air temperature and flow rate was measured. The thermocouples used have a maximum precision of 0.1^0C and were calibrated.

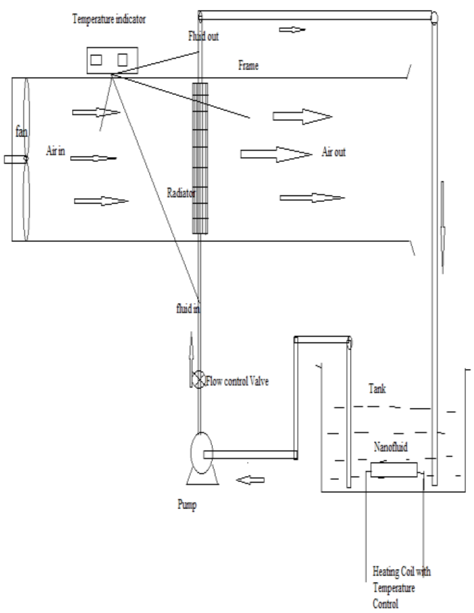

Fig.1 Schematic of experimental set-up

Using this system nearly fifty tests were performed using water and Al_2O_3/water nanofluid with three different particle volume concentrations, namely 0.2%, 0.5% and 1%. It is interesting to mention that the Al_2O_3–water nanofluid, with particle mean-diameter of 13 nm, has been purchased readily prepared and mixed from a commercial source.

From the collected data of temperatures and mass flow rates, the heat transfer rate at the water side and air side of the radiator can easily be determined for the following equations.

$$Q_{nf} = m_{nf} \times C_{nf} \times \Delta T$$

----------------------------(8)

Where, Q_{nf} = heat transfer rate of nanofluid in kJ/s , m_{nf} = Mass flow rate of nanofluid in kg/s, C_{nf}=Specific heat of nanofluid in KJ/kg.K and ΔT = difference between the inlet and outlet nanofluid temperature in K.

V. RESULTS AND DISCUSSION

The experiments were performed by varying the nanofluid flow rate at a given concentration.

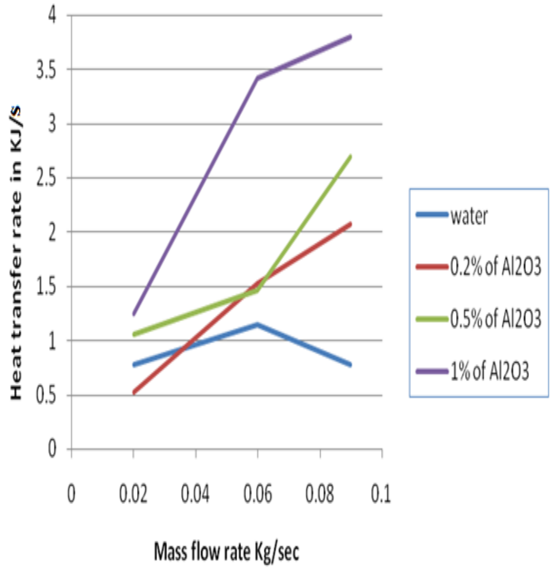

Fig.2 Heat transfer rate of water, 0.2%, 0.5%, 1% of Al_2O_3 Vs. Mass flow rate at Temperature 50°C

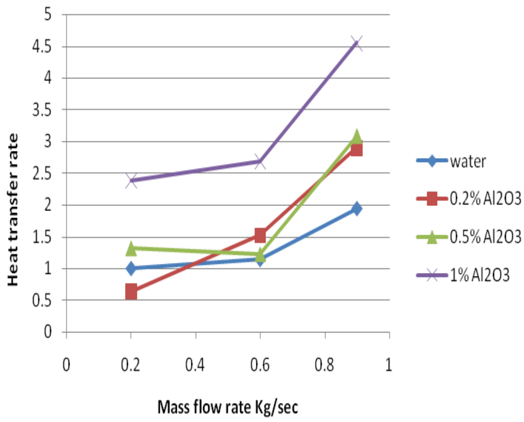

Fig.3 Heat transfer rate of water, 0.2%, 0.5%, 1% of Al_2O_3 Vs. Mass flow rate at temperature 60°C

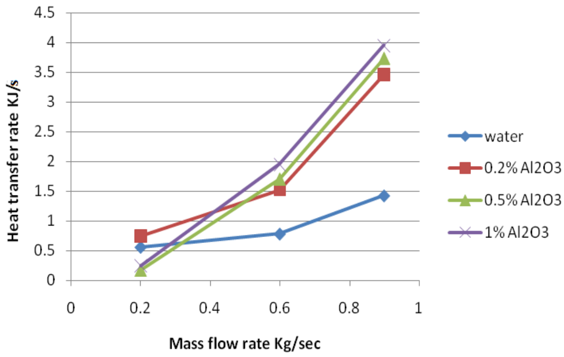

Fig.4 Heat transfer rate of water, 0.2%, 0.5%, 1% of Al_2O_3 Vs. mass flow rate at temperature 70°C

The varying mass flow rate (kg/s) of the nanofluid flowing with different concentration (Water, 0.2%, 0.5% and 1%) inside the radiator with constant temperatures 50 ^{o} C, 60°C and 70°C.

Fig.2, 3&4 shows heat transfer rate versus mass flow rate at different concentration. In all the above figures, as the mass flow rate increases heat transfer rate also increases. With increase in the concentration of Al_2O_3, the heat transfer rate also increased when compared with water.

CONCLUSION

Convective heat transfer of Al_2O_3/water nanofluid through radiator with constant inlet temperature condition was investigated experimentally. The experimental result indicates that the heat transfer rate increases with mass flow rate as well as nanoparticle concentration. The increase in heat transfer rate due to presence of nanoparticle is much higher than the heat transfer rate of water. It is concluded that, with the increase in the thermal conductivity heat transfer also increases. With the results obtained, we can conclude that the size of the radiator can be reduced with the use of nanofluids.

REFERENCES

[1] **Jaeseon Lee, Issam mudawar.** Assessment of the effectiveness of nanofluids for single-phase and two-phase heat transfer in micro-channels. ELSEVIER, International Journal of Heat and Mass Transfer 50 (2007) 452-463.

[2] **Li Q, Xuan Y.** Convective Heat Transfer and Flow Characteristics of Cu-Water Nanofluid. Science in China (Series E) 2002; 45(4):408–16.

[3] **Visinee trisaksri,Somchai Wongwises.** Critical review of heat transfer characteristics of nanofluids. ELSEVIER, Renewable and Sustainable Energy Reviews 11(2007)512-523.

[4] **Yang Y, Zhang ZG, Grulke EA, Anderson WB, Wu** G. Heat Transfer Properties of Nanoparticle-in-Fluid Dispersions (Nanofluids) in Laminar Flow. Int J Heat Mass Transfer 2005;48(6):1107–16.

[5] **Zeinali Heris.s, M.Nasr Esfahany,S.Gh.Etemad**. Experimental investigation of convective heat transfer of Al2O3/water nanofluid in circular tube. ELSEVIER, International Journal of Heat and Fluid Flow xxx (2006) xxx-xxx.