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# Experimental Analysis of Heat Transfer From Car Radiator Using Nanofluids

[1]Datta N. Mehtre, [2]Sandeep S. Kore
[1]M.E. Student (Heat Power) G.S.Moze COE,Pune,(MS) India. delta1_mehtre@yahoo.com
[2]Associate Professor at Department of Mechanical Engineering, Sinhgad Academy of Engineering, Kondhawa, Pune, (MS) India. sskore.sae@sinhgad.edu

**Abstract-- The objective of this experimental study is to discuss the thermal performance of car radiator using $Al_2O_3$–nanofluid in temperature ranges from (40-75°C) under different fractions of nanoparticles from 0.5, 1, 1.5% by volume. In this study, the heat transfer with water based nano-fluids was experimentally compared to that of pure water as coolant in an automobile radiator. By varying the amount of $Al_2O_3$ nano particles blended with base fluid water, three different concentrations of nano-fluid 0.5%, 1%, 1.5% (by vol.) were obtained. The size of nanoparticle used was 100 nm. Liquid flow rate has been changed in the range of 50 lph to 200 lph and air velocity in the range of 3.8 m/s to 6.2 m/s. The fluid inlet temperature was varying from 40°C to 75°C to find the optimum inlet condition. Results demonstrate that increasing coolant flow rate can improve the heat transfer performance. Also increasing the air flow rate improves the heat transfer rate. The rate of heat transfer enhancement was found 19% to 42% in comparison with pure water.**

**Key Words - NanoFluid, Radiator, Flow Rate, Cooling Performance, Heat Transfer enhancemnt.**

## I. INTRODUCTION

Modern automotive internal combustion engines generate a huge amount of heat. This heat is created when the gasoline and air mixture is ignited in the combustion chamber. This explosion causes the piston to be forced down inside the engine, levering the connecting rods, and turning the crankshaft, creating power. Metal temperatures around the combustion chamber can exceed 538°C. In order to prevent the overheating of the engine oil, cylinder walls, pistons, valves, and other components by these extreme temperatures, it is necessary to effectively dispose of the heat. Approximately 1/3 of the heat in combustion is converted into power to drive the vehicle and its accessories. Another 1/3 of the heat is carried off into the atmosphere through the exhaust system. The remaining 1/3 must be removed from the engine by the cooling system

The use of nanofluids has the potential to improve the engine cooling rates. These improvements can be used to remove engine heat with a reduced size cooling system. Smaller cooling system leads to use of smaller and lighter radiators which in turn will lead to better performance and increased efficiency. Alternatively, improved cooling rates can be used to remove more heat from higher horsepower engines with same size of cooling system.

V.L.Bhimani et.al. [1] experimentally investigated forced convective heat transfer in a water based nanofluid. Five different concentrations of nanofluids in the range of 0.1-1 vol. % have been used with flow rate in the range of 90-120 lit./min. The result shows that heat transfer enhancement of 40-45% compared to pure water at the concentration of 1% vol.

Gaurav Sharma et al. [2] Experimentally investigated the thermal conductivity and viscosity of $Al_2O_3$-engine nano-coolant. For 0.5% vol. concentration of $Al_2O_3$ nanofluid at 40ºC The maximum improved thermal conductivity is 5.7% and the enhancement in viscosity is 124%.

Adnan M. Hussein et al. [3] experimentally investigated the friction factor and forced convection heat transfer enhancement using $SiO_2$ nanoparticles suspended into water. Four different concentrations of nanofluids in the range of 1 to 4 % (Vol.) with changed flow rate from 1 to 5 lpm have been used. The maximum value of friction factor was increased to 22% and a highest value of the heat transfer coefficient enhances upto 40% for $SiO_2$ nanoparticles with 4% volume concentration.

Rahul A.Bhogare et.al. [4] illustrated a review on application and challenges of nano-fluids as coolant in automobile radiator. Nanofluids have great potential to improve automotive and heavy – duty engine cooling rates by increasing the efficiency, lowering the weight and reducing the complexity of thermal management

Chavan D.K. et.al. [5] illustrated the study, analysis and design of automobile radiator proposed with CAD drawing and geometrical model of the fan. He investigated that velocity increases with the increase in rpm of radiator fan. So he concluded that for optimum efficiency eliminates corners and develop radiator of circular shape.

Deepak Chintakayalaet. al. [6] studied the cooling effect by using a nanofluid as a coolant in a radiator and is analyzed for evaluating the fluid flow and heat transfer characteristics. This study is analyzed by using a CFD software FLUENT. It is clearly observed that loss in temperature for conventional coolant is 17°C and for nanofluid as coolant it is 20ºC. From his study he concluded that the rate of heat transfer is better when nanofluid ($Al_2O_3$ + water ) is used as coolant than conventional coolant.

Navid Bozorgan et.al.[7] numerically investigated the use of CuO - water nanofluid as a coolant in a radiator at Chevrolet suburban diesel engine with a given heat exchanger capacity. The results showed that for CuO-water nanofluid at 2 % volume concentration circulating through the flat tubes with Re -6000 while the automotive speed is 70 km/hr , the overall heat transfer coefficient and pumping power are approximately 10 % and 23.8 % more than that of base fluid for given conditions.

Paresh Machhar et.al. [8] experimentally analyzed the heat transfer enhancement of automobile radiator with TiO2 /water nanofluid. Five different concentrations of nanofluids in the range of 0.1-1 volume % will be prepared by the addition of $TiO_2$ nanoparticles into the water. He observed from investigation that the application of nanofluid with low concentration can enhance heat transfer efficiency up to 45 % in comparison with pure water.

Ravikanth S.Vajjha et.al.[9] investigated a three dimensional laminar flow and heat transfer with two different nanofluids $Al_2O_3$ and CuO nanoparticle in an ethylene glycol and water mixture circulating through the flat tubes of an automobile radiator. The numerical results showed at a Reynolds number of 2000, the percentage increase in the average heat transfer coefficient over the base fluid for a 10% $Al_2O_3$ nanofluid was 94 % and that for a 6 % CuO nanofluid was 89 %.The average skin friction coefficient for a 6% CuO nanofluid in the fully developed region is about 2.75 times in comparison to that of the base fluid at a constant inlet velocity of 0.3952 m/s.

## II. NANOFLUID PREPRATION

In this experimentation a two-step procedure was used for preparing the nanofluid. A measured quantity of nanoparticle was taken and mixed thoroughly in the water. Mechanical stirrer was used to mix it uniformly. It was kept in the sonicator and subjected to vibrations so as to reduce to problem of agglomeration. Nanofluid was kept still for two days to check for sedimentation. Even after two days there was no appreciable sedimentation and the important fact is that the moment it was stirred again it turned into a uniform fluid with evenly suspended nanoparticles in it.

## III. ESTIMATION OF NANOFLUID PROPERTIES

By assuming that the nanoparticles are well dispersed within the base fluid, i.e. the particle concentration can be considered uniform throughout the system; the effective physical properties of the studied mixtures can be evaluated using some classical formulas as usually used for two phase fluids. These relations have been used to predict nanofluid physical properties like density, specific heat, viscosity and thermal conductivity at different temperatures and concentrations. In this paper, the following correlations were used to calculate the physical properties of nanofluid.

$$\rho_{nf} = (1-\phi)\rho_f + \phi\,\rho_p \quad (1)$$

$$C_{pnf} = \frac{(1-\phi)(\rho\, c_p)_f + \phi\,(\rho\, c_p)_p}{\rho_{nf}} \quad (2)$$

$$\mu_{nf} = \mu_f\,(1 + 2.5\,\phi) \quad (3)$$

$$\frac{k_{nf}}{k_f} = \frac{k_p + 2k_f + 2(k_p - k_f)\phi_{eff}}{k_p + 2k_f - 2(k_p - k_f)\phi_{eff}} \quad (4)$$

In the above equations, the subscripts “p”, “f” and “nf” refer to the particles, water and nanofluid respectively. The characteristics of water and $Al_2O_3$ nanoparticles at room temperature are summarized in Table 1.

Table 1: Comparison between properties of pure water as a base fluid and $Al_2O_3$ at room temperature

| Property | Base fluid (water) | Nanoparticles ($Al_2O_3$) |
|---|---|---|
| Specific heat, $C_p$ ,(kJ/kg ºC) | 4182 | 765 |
| Density, ρ (kg/m$^3$) | 997.1 | 3880 |
| Thermal conductivity,k ,(W/m K) | 0.6 | 36 |
| Thermal diffusivity, α , m$^2$/s | 1.465 | 1.19*10$^{-9}$ |

Both the resulting nanofluids' specific heat and density have been calculated considering different nanoparticles volumetric fraction (0 - 1.5) %. Using those models, the augmentation of nanofluid density and decrease in the specific heat are listed Table 2.

Table 2: $Al_2O_3$-Water nanofluid properties with different nanoparticles volumetric concentration

| Nanoparticle volume concentration % (ϕ) | Density, ρ ($kg/m^3$) | Specific heat, Cp (kJ/kg ºC) |
|---|---|---|
| 0 | 997.1 | 4197 |
| 0.5 | 1012 | 4129 |
| 1 | 1028 | 4059 |
| 1.5 | 1040 | 4006 |

## IV. EXPERIMENTAL SETUP AND PROCEDURE

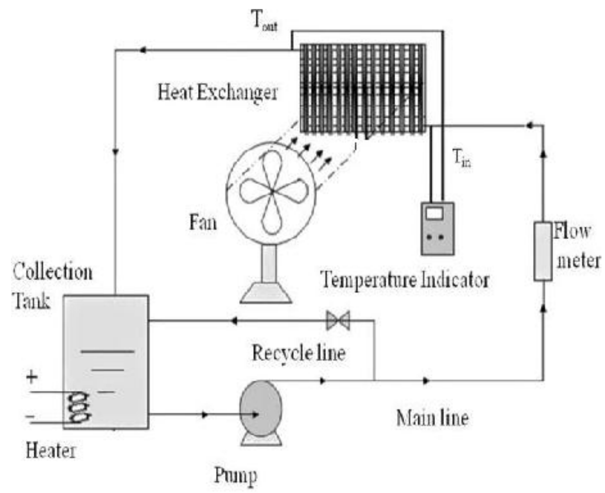


Fig. 1 Experimental test rig.

This experimental setup includes a reservoir in the form of plastic tank, electrical heater, a centrifugal pump, a flow meter, flow control valves, fan, D.C power supply; ten thermocouples type T for temperature measurement, and heat exchanger (automobile radiator). The fluid flows through plastic tubes (0.5 inch) by a centrifugal pump (1800 rpm) from the tank to the radiator. The total volume of the circulating fluid is (5 liters) and constant in all the experimental steps. An electrical heater (2000W) is placed inside a plastic storage tank (20 cm height and 18 cm diameter) which represent the engine. The heater is used to heat the working fluid. A voltage regular (0-220 V) is provided to maintain inlet fluid temperature from 40 ºC to 75ºC. A rotameter (0- 500 lph) and two valves used to measure and control the flow rate of the fluid. Two thermocouples (copper – constantan) types T have been fixed on the flow line for recording the inlet and outlet fluid temperatures. Eight thermocouples type T have been fixed to the radiator surface to ensure more of surface area temperature measurement. Very small thickness and high thermal conductivity of the copper flat tubes caused to make the inside temperature of the tube with the outside one are equated. A handheld (-40ºC to 1000ºC ) digital temperature indicator with the accuracy of ± (0.1 ºC ) used to read all the temperatures from thermocouples. The calibration of thermocouples carried out by using a constant temperature water bath and their accuracy estimated to be 0.15ºC. The car radiator has louvered fin and 32 flat vertical copper tubes with flat cross sectional area. The distances among the tube rows filled with thin perpendicular copper fins. For the air side, an axial force fan with three stage velocities (3.8 m/s, 4.9 m/s and 6.2 m/s) was installed close and face to face to the radiator. The D.C power supply used to turn the axial fan instead of a car battery.

Fig.2 Photographic view of total setup

The experimental set up is shown in Fig. 1 used to measure heat transfer rate and heat transfer coefficient in the automotive engine radiator. The specifications of radiator used in this experiment are shown in Table 3.

Table 3: Radiator Specifications

| **Specifications** | Radiator of 4-strock, 4-cylinder petrol engine | Volume of coolant | 5 liters |
|---|---|---|---|
| Make | Maruti 800 | Nanoparticles | $Al_2O_3$ nanopowder dispersible in water |
| Radiator size | 335mm x 300mm x 17mm | Purity | 80 % |
| Tube side area | 330905.3 $mm^2$ | Blower | Axial fan with 3 speeds |
| Fin side area | 2310000 $mm^2$ | Water dispersibility | more than 95 % |

## V. EXPERIMENTAL DATA ANALYSIS

According to Newton's cooling law the following procedure followed to obtain heat transfer coefficient.

$$Q = hA\Delta T = hA\left(T_b - T_W\right) \quad (5)$$

A: is surface area of tube, $T_b$ is the bulk temperature

$$T_b = \frac{T_{in} + T_{out}}{2} \quad (6)$$

($T_{in}$, $T_{out}$) are inlet and outlet temperatures and $T_w$ is the tube wall temperature which is the mean value by two surface thermocouple as

$$T_w = \frac{1}{a}\sum_{i=1}^{a} T_i \quad (7)$$

And heat transfer rate calculated by

$$Q = m*c*(T_{in} - T_{out}) \quad (8)$$

$$m = density*v$$

$$V = LPH*0.001/3600$$

m-mass flow rate of coolant Kg/s, v-volume flow rate( $m^3$/s).

The heat transfer coefficient can be evaluated by collecting eq. (5) and (8)

$$h = \frac{\mathbf{m*c*}(T_{in} - T_{out})}{hA(T_b - T_w)} \quad (9)$$

## VI. RESULTS AND DISCUSSION

The heat transfer enhancement in car radiator is experimentally investigated by using $Al_2O_3$ nanofluid mixed with water. The concentrations of nanofluids 0.5%, 1% and 1.5%.of $Al_2O_3$ were used in this experiment. While the flow rate was varied from 50 lph to 200 lph and the air flow rate from 3.8 m/s to 6.2 m/s. The results obtained from this experimentation were discussed below.

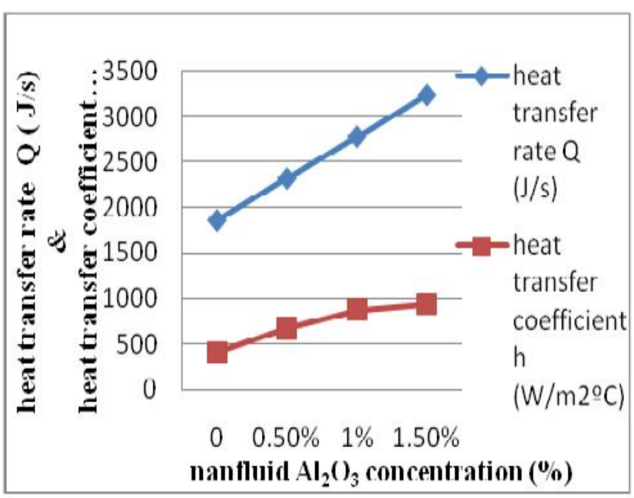


Fig. 3: Experimental heat transfer coefficient and heat transfer rate with varying concentration of $Al_2O_3$

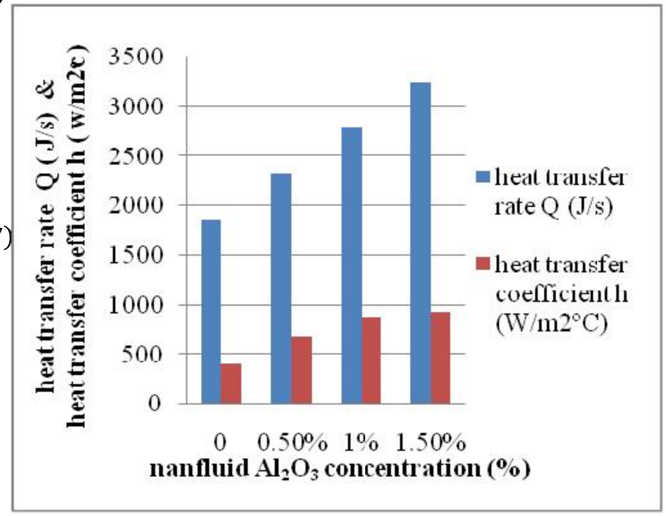


Fig. 4 Effect of nanofluid concentration on heat transfer coefficient and heat transfer rate

The effect of nanofluid concentration on amount of heat transfered from car radiator at constant coolant flow rate and constsant air flow rate is shown in Fig.3 and Fig.4. From Fig.3 and Fig.4, it is evident that addition of nanofluid concentration from 0.5% to 1.5% enhances the rate of heat transfer. This may be due to the fact that increased thermal conductivity due to the addition of nano particles in the base fluid water. It is obserevd that 19% to 42 % heat transfer enhancemnt is abtained with the addition of nanofluid.

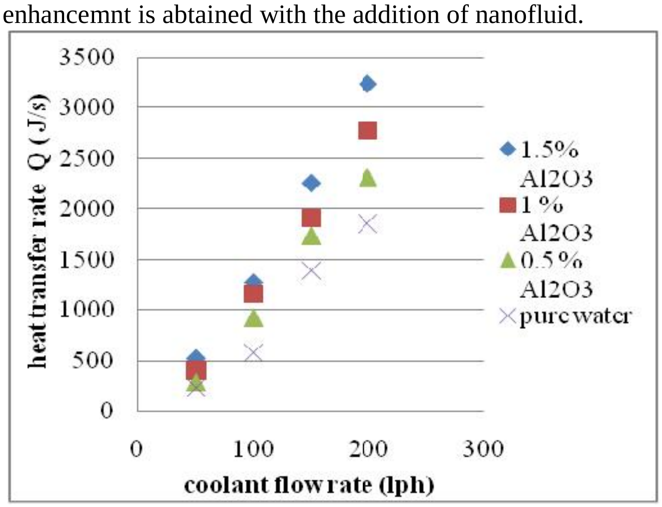


Fig.5: Experimental results for rate of change of heat transfer rate for variety of coolants

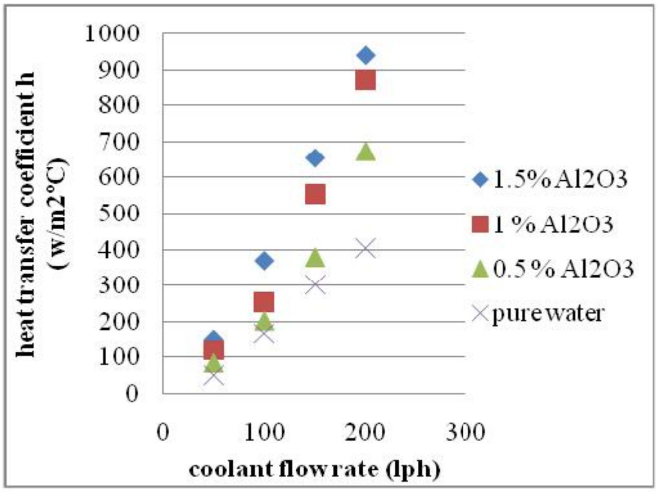


Fig.6:Experimental results for heat transfer coefficient for variety of coolants

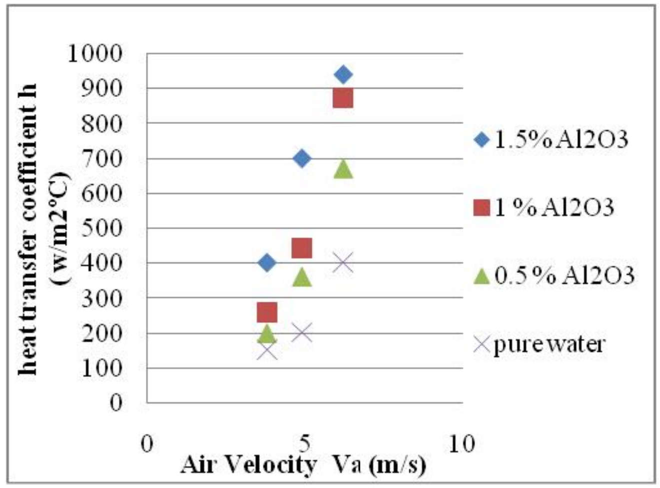


Fig.7:Experimental results for overall heat transfer coefficient for different air flow rate.

The effect nano fluid concentration on the amount of heat transferred from the car radiator for varying coolant flow rate with constant air flow rate was shown in Fig.5 and Fig.6. An increase in heat transfer is found for increase in cooloant flow rate. Also as the nanofluid concentration increases the rate of heat transfer is also found to be increased.

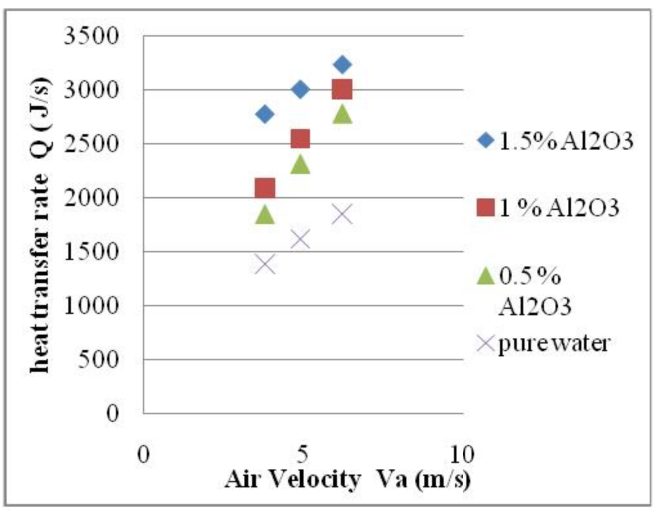


Fig.8 experimental results for rate of change of heat transfer for different air flow rate

The effect nano fluid concentration on the amount of heat transferred from the car radiator for varying air flow rate with constant cooclant flow rate was shown in Fig.7 and Fig.8. An increase in heat transfer rate was found for increase in air flow rate. Also as the nanofluid concentration increases the rate of heat transfer is also found to be increased. Heat transfer coefficient increases as the cooling air flow increases at constant coolant flow rate.

## CONCLUSION

In this experimental research work, the total heat transfer rate from an automotive radiator is determined using two working fluids: water and water based nanofluid ($Al_2O_3$) at three different concentrations 0.5%, 1% and 1.5% on volume basis. From the experimental work, the following conclusions were made.

1)19% rate of heat transfer is increased in car radiator by addition of 0.5% $Al_2O_3$ nano powder of 100nm size in pure water at constant coolant flow rate of 200 lph and constant air flow rate of 6.2 m/s.

2) 33% rate of heat transfer is increased in car radiator by addition of 1% $Al_2O_3$ nano powder of 100nm size in pure water at constant coolant flow rate of 200 lph and constant air flow rate of 6.2 m/s.

3)42% rate of heat transfer is increased in car radiator by addition of 1.5% $Al_2O_3$ nano powder of 100nm size in pure water at constant coolant flow rate of 200 lph and constant air flow rate of 6.2 m/s.

4) Additon of 0.5% to 1.5% $Al_2O_3$ nanopowder in pure water gives 14% to 42 % heat transfer enhancement than pure water.

5) Additon of 0.5% to 1.5% $Al_2O_3$ nanopowder in pure water gives 15% to 47% enhancement in heat transfer coefficient than pure water.

6) Rate of heat transfer increase as the coolant flow rate increases at constant air flow rate
7) Rate of heat transfer increase as the cooling air flow increases at constant coolant flow rate

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