

Research Article

Heat Enhancement using TiO₂-Nano fluid in Automotive Cooling System

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Abstract

In today's world of increasing demands of energy, heat management plays a crucial role for humans. As we look into automobile sector management of heat is now really important. Nano fluids are latest introduced cooling fluids containing ultrafine nano particles (1-100nm), which could increase thermal conductivity and heat transfer rate as compared to base fluid. These are suspended in base fluid which gets dispersed into base fluid. Nano fluid TiO₂ has been investigated experimentally in this report to evaluate heat transfer in automotive radiator. Its size ranges from 10-100nm. A significant volume reduction of radiator has been observed and in contrary pumping power of pump is increased simultaneously.

Keywords: Nanofluids, TiO₂, Heat, Thermal conductivity, Nanoparticles.

1. Introduction

The main reason solid particles less than 100 nm are added to a liquid is to improve its thermal properties. This new fluid is then defined as a nanofluid. Solid metallic or nonmetallic materials dispersed in base fluids such as water, ethylene glycol and glycerol have become a topic of interest in recent years. Thermo fluid has numerous applications and one of them is automotive cooling systems. Base fluids (water, ethylene glycol and glycerol) have been used as conventional coolants in an automobile radiator for many years, however these offered low thermal conductivity, which has prompted researchers to find fluids that offer higher thermal conductivity compared to that of conventional coolants. This resulted in nanofluids being used instead of these base fluids. Forced convection heat transfer to cool circulating water from an automobile radiator was carried out by (Peyghambarzadeh *et al.*, 2011). A high efficiency engine is not only based on its performance but also for increasing fuel economy and reducing emission. Vehicle weight can be reduced for optimizing design and size of a radiator which is necessary for making the world green.

Addition of fins is one of the approaches to increase the cooling rate of the radiator. It increases heat transfer area and enhances the air convective heat transfer coefficient (Eastman JA *et al.*, 1996). Traditional approach of increasing the cooling rate by using fins and micro-channel has already reached to

their limit. Also heat transfer fluids at air and fluid side, such as water and ethylene glycol exhibit lower thermal conductivity. As a result it become necessary for new and innovative heat transfer fluids for improving heat transfer rate in an automotive car radiator. Nanofluids seem to be potential replacement of conventional coolants in engine cooling system. Yu *et al.* reported that about 15-40% of heat transfer enhancement can be achieved by using various types of nanofluids. Having these superior characteristics, the size and weight of an automotive car radiator can be reduced without affecting its heat transfer performance which results into a better aerodynamic feature for design of an automotive car frontal area. Coefficient of drag can be minimized and fuel consumption efficiency can be improved.

2. Literature Review

Eastman *et al.* (1996) observed that a nanofluid consisting of Cu nanometer sized particles dispersed in ethylene glycol which has much higher thermal conductivity than pure ethylene glycol. Thermal conductivity can be increased by 40 % for nanofluid consisting approx 0.3 vol % Cu nano particles of mean diameter <10nm.

Pak and Cho (1998) used 10 % vol Al₂O₃ which increased viscosity and power of pumping of fluid. The thermal conductivity of pure nano metallic particles is more than 100 times higher than that of oxide nano particles.

Duangthongsuk and Wong Wises (2009) reported that heat transfer coefficient of TiO₂ nanofluid had

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higher than base fluid. M.Naraki (2013) found that thermal conductivity of CuO/H₂O nanofluid has much higher than of base fluid. The overall heat transfer coefficient increases the enhancement of nanofluid from 0 to 0.04 vol %. Nguyen *et al.* (2007) performed experiments in the radiator type heat exchanger and at 6.8 % vol (Al₂O₃) in water obtained 40 % increase in heat transfer coefficient.

Zamzamian *et al.* (2011) investigated the effects of forced convective heat transfer coefficient with (Al₂O₃)/EG and CuO/EG nanofluid in double pipe and plate heat exchangers. Their results showed that heat transfer coefficient of nanofluid enhanced to a 2-50 % in convective heat transfer coefficient of nanofluid. M. Ebrahimi *et al.* (2014) experimentally studied the effect of the adding of SiO₂ nano particles to the base fluid water in the automobile car radiator. The volume fraction of the nano particles as 0.1 %, 0.2 %, 0.4 %, and Reynold number from 8000-24000. They observed that there were improvement in the heat transfer when $\phi=0.04$ and water considered as based fluid was about 3.8 %, and this value is about 4 % for water propelen glycol. They concluded that with increasing the fluid inlet temperature, nano particles concentration, and Reynolds number the Nusselt number would be increased. S. M. Peyghambarzadeh (2013) found that nano fluid consisting of CuO and Fe₂O₃ nanoparticle dispersed in water has much heat transfer than pure H₂O. Ollivier *et al.* used nanofluid to increase thermal signal variation by around 15% over that predicted using water alone.

3. Methodology

The test rig shown in Fig.1 was used to measure the heat transfer coefficient in the automotive radiator.

This experimental setup includes:

- 1) A plastic storage tank: 40 cm height and 30 cm diameter
- 2) An electric heater: 1500W
- 3) A centrifugal pump: 0.5 hp and 3 m head
- 4) Plastic tubes: 0.5 in
- 5) A fan: 1500 rpm
- 6) An AC power supply: 10-12V
- 7) Lugs type thermocouples
- 8) Automobile radiator: The car radiator has lowered fins and 32 flat vertical aluminum tubes with a flat c/s area. The distance between the tube rods was filled with thin perpendicular Cu fins.
- 9) A voltage regulator: 0-220V

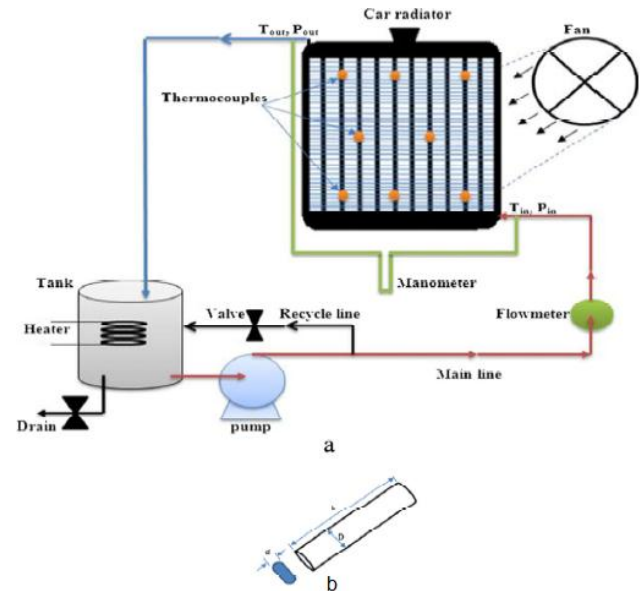


Fig.1 Experimental Setup

4. Theoretical data analysis

4.1 Base Fluid's Physical Properties

The base fluid (water) properties are estimated depending on the base temperature as regression equations (Adnan M. Hussein 1, 4, R.A. Bakar1, 2, K. Kadirgama1, 2 and K.V. Sharma3, January-June 2013)

1. Density of base fluid

$$\rho_f = 1000 \times \frac{[1 - (T_f - 4)^2]}{[119000 + 1365T_f - 4(T_f)^2]} \quad (1)$$

2. Specific heat of base fluid:

$$C_f = 4217.62 - 3.2088T_f + 0.0950(T_f)^2 - 0.0013(T_f)^3 \quad (2)$$

3. Thermal Conductivity:

$$K_f = 0.5611 + 0.00193T_f - 2.6015e^{-6T_f} - 6.088e^{-8T_f} \quad (3)$$

5. Experimental data analysis

5.1 Numerical Design

According to Newton's cooling law the following procedure was followed to obtain the heat transfer coefficient and corresponding Nusselt number as:

$$Q = hA\Delta T = hA(T_b - T_s) \quad (4)$$

A_s is surface area of tube, T_b is the bulk temperature:

$$T_b = \frac{[T_{in} - T_{out}]}{2} \quad (5)$$

(T_{in}, T_{out}) are inlet and outlet temperatures and T_s is the tube wall temperature which is the mean value measured by the two surface thermocouples as:

$$T_s = [T_1 + \dots + T_8] / 8$$

Heat transfer rate is calculated by:

$$Q = m \cdot C \Delta T = m \cdot C (T_{in} - T_{out}) \tag{6}$$

m* is the mass flow rate, which is determined as:

$$m^* = \rho \cdot V^*$$

The heat transfer coefficient can be evaluated by collecting Eqs. (1) and (4):

$$h_{exp} = m \cdot C (T_{in} - T_{out}) / n A_s (T_b - T_s) \tag{7}$$

The Nusselt number can be calculated as:

$$Nu = [h_{exp} \times D_h] / k \tag{8}$$

6. Results and Discussion

- 1) A number of experimental runs with pure water were conducted with the cooling system to verify the experimental results. Theoretically as Re no. increases Nu no. also increases for pure water and TiO₂. Fig 2 (a) and (b)
- 2) Theoretical values for Pr no. and Nu no. are calculated for different temperatures and volume flow rate. It shows that as temperature increases Pr no. decreases and Nu no. increases. Fig 3 (a) and (c). Re also increases with increases in temperature. Fig 3 (b) and (d)

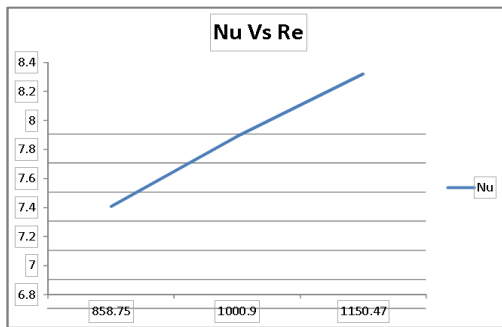


Fig.2 (a) Nu v/s Re for pure water

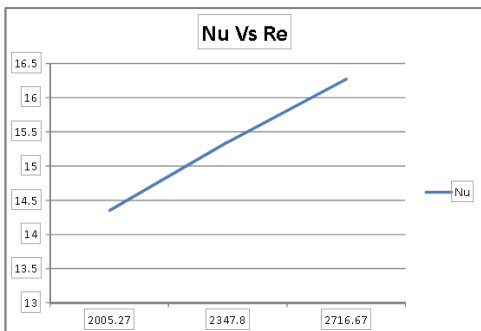


Fig.2 (b) Nu v/s Re for TiO₂

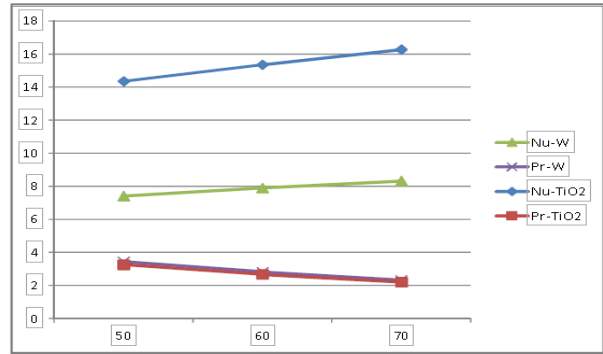


Fig.3 (a) Nu and Pr no. v/s T

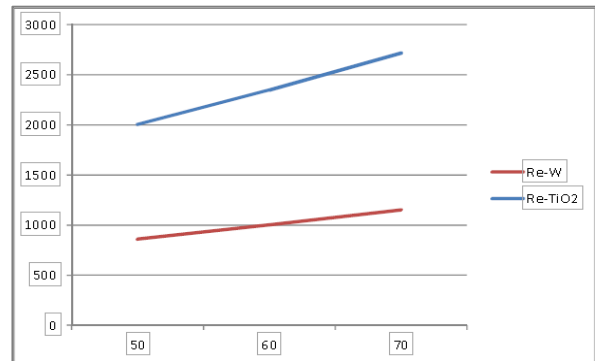


Fig.3 (b) Re v/s T

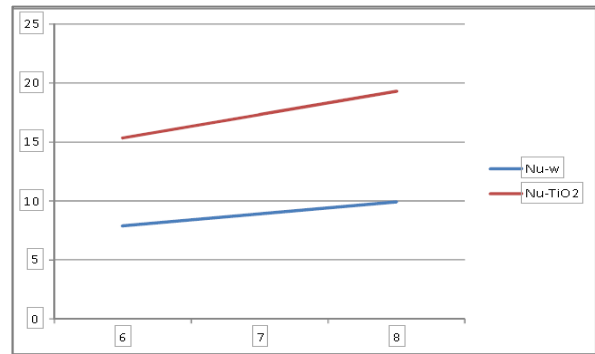


Fig.3 (c) Nu v/s Flow rate

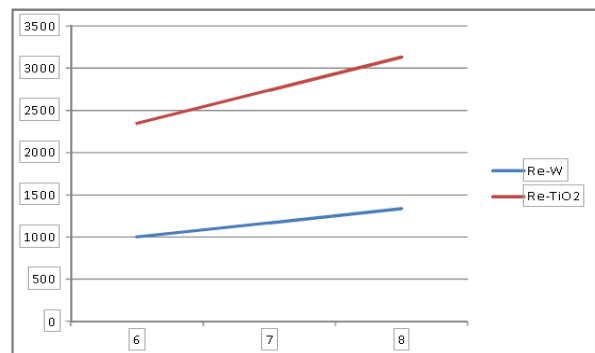


Fig.3 (d) Re v/s Flow rate

- 3) It is analyzed with experimental data Fig 4 (a) and (b) which shows that Nu no. increases with increases in temperature and volume flow rate

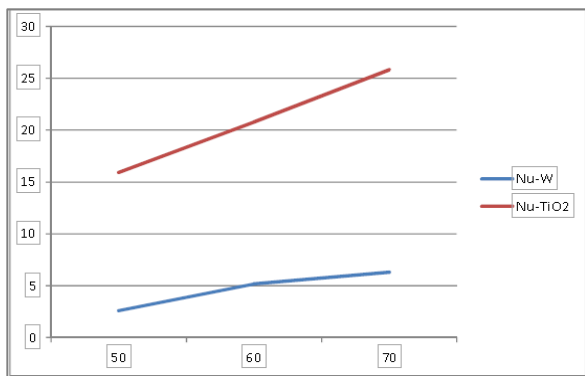


Fig.4 (a) Nu v/s T

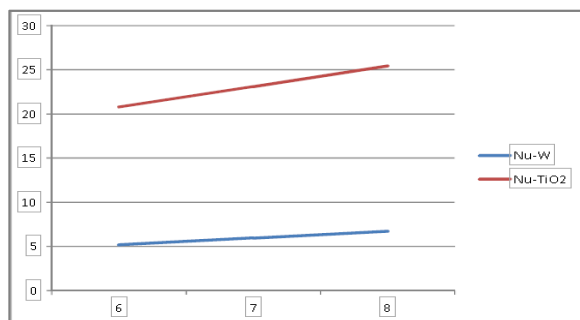


Fig.4 (b) Nu v/s Flow rate

4) Fig 5(a) and (b) shows that heat transfer coefficient also increases with increase in temp. and volume flow rate.

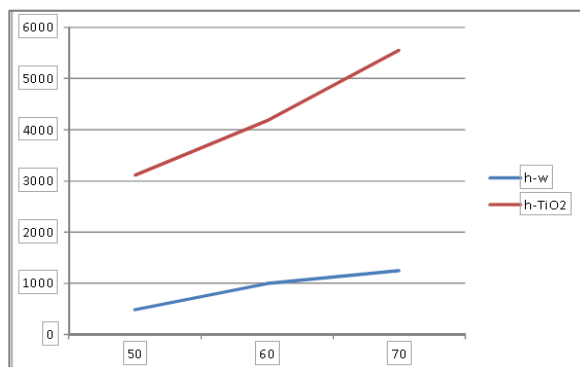


Fig.5 (a) h_{exp} v/s T

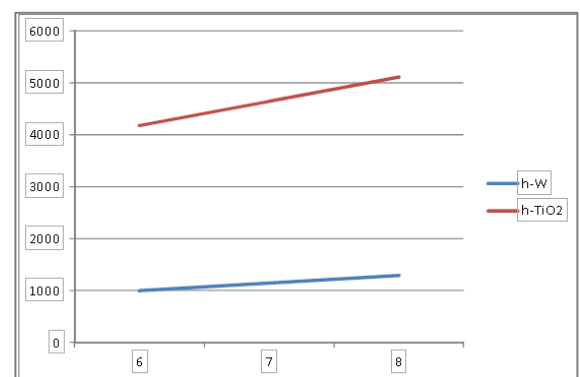


Fig.5 (b) h_{exp} v/s Flow rate

Conclusions

- 1) Overall heat transfer coefficient enhances with increasing the liquid flow rate.
- 2) Increasing the concentration of nano particles enhances the overall heat transfer coefficient especially for TiO₂-water nanofluids.
- 3) The nanofluids has a high boiling point, and it can be used to increase the normal coolant operating temperature and then reject more heat through the existing coolant system.
- 4) The use of high-thermal conductive nanofluids in radiators can lead to a reduction in the frontal area of the radiator up to 10%. The fuel saving is up to 5% due to the reduction in aerodynamic drag.
- 5) New working fluid with higher heat transfer performance would promote the car engine performance and would reduce fuel consumption. Therefore, it can be followed by other investigators to eliminate the deficiencies for industrialization in the car industries.
- 6) Increasing the flow rate of working fluid (or equally Re) enhances the heat transfer coefficient for both pure water and nanofluid considerably while the variation of fluid inlet temperature to the radiator (in the range tested) slightly changes the heat transfer performance.

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