International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in; editorijoer@gmail.com

Vol.4., Issue.6., 2016
Nov-Dec.

RESEARCH ARTICLE

ISSN: 2321-7758

STUDY AND INVESTIGATION ON CAR RADIATOR BY USING NANOPARTICLE VOLUME (TiO_2, Al_2O_3) FRACTION WITH WATER AND ETHYLENE GLYCOL AS A BASE FLUID

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ABSTRACT

The effect of Nanoparticle TiO_2 and Al_2O_3 suspended in water and ethylene glycol (3:1) mixture as base fluid used as coolant in radiator and the performance car radiator of engine cooling systems is studied and investigated using this project. The experimental setup includes a car radiator, and the effects on heat transfer performance under the different operating conditions are analyzed under constant air velocity conditions. The volume flow rate, inlet temperature and nanofluid volume concentration are in the range of 4–8 LPM, 60–70 °C and 0.1, 0.15, 0.2 respectively. The results showed that the Nusselt number and Heat transfer coefficient increased with volume flow rate and slightly increased with inlet temperature and nanofluid volume concentration. The maximum heat transfer coefficient is 2131.31 W/m2 K obtained at 8 LPM, 0.2 Volume fraction of Al_2O_3 at 70 ^{0}C. The maximum Nusselt number is 16.68 obtained at 8 LPM, 0.2 Volume fraction of TiO_2 at 70 ^{0}C.

The correlation equation by Shah-London and Dehghandokht et al. used for input volume flow rate, inlet temperature and nanofluid volume concentration and response Nusselt number was found. These experimental results were found to be in good agreement with other researchers' data, with a deviation of approximately 2 -10 %.

I. INTRODUCTION

Nanoparticle-fluid suspensions are termed nanofluids, obtained by dispersing nanometre sized particles in a conventional base fluid like water, oil, ethylene glycol etc. Nanoparticles of materials such as metallic oxides (Al_2O_3, CuO), nitride ceramics (AlN, SiN), carbide ceramics (SiC, TiC), metals (Cu, Ag, Au), semiconductors (TiO_2, SiC), single, double or multi walled carbon nanotubes (SWCNT, DWCNT, and MWCNT), alloyed nanoparticles etc. have been used for the preparation of nanofluids. These nanofluids have been found to possess an enhanced thermal conductivity as well as improved heat transfer performance. [5]

Nanofluids are the new window which is open recently and it is confirmed by several authors that this working fluid can enhance heat transfer performance in an automotive car radiator. As a result, there is a need for new and novel heat transfer fluids for improving heat transfer rate in an automotive car radiator. [3]

A recent advance in nanotechnology is development of a new category of fluids term nanofluids. Such fluids are liquid suspensions containing particles that are significantly smaller than 100 nm, and have a bulk solids thermal conductivity higher than the base liquids nanofluids seem to be potential replacement of conventional coolants in engine cooling system. [8]

II. LITERATURE REVIEW

Lots of researches have done on nano fluid technology and its application in heat transfer device. This chapter shows previously published researcher reviews in the area of nano fluid, which is foundation for further investigation and better understanding of the topic and also act as guideline for present work

Peyghambarzadeh et al. [1] added Al_2O_3 nanoparticles with different concentrations (0.1, 0.3, 0.5, 0.7, and 1 vol. %) into pure water, EG, and EG/water mixtures (5, 10, and 20 vol. % EG) to form the Al_2O_3 nanofluid, and adopted these nanofluids in a car radiator to evaluate the nanofluid heat transfer performance. The liquid flow rate changed from 2 to 6 L/min, and the fluid inlet temperature (water: 35-50 ^{0}C; EG: 45-60 ^{0}C) changed for all the experiments. The heat transfer improved by approximately 40%, compared to the base fluids in the best conditions.

Peyghambarzadeh et al. [2] evaluated the heat transfer performance of an automobile radiator with CuO and Fe_2O_3/water nanofluids by calculating the overall heat transfer coefficient by using the conventional Ɛ-NTU technique. The concentrations were 0.15, 0.4, and 0.65 vol. % after considering the best pH for longer stability. The liquid-side Reynolds number varied in the range of 50-1000, and the inlet liquid changed at 50, 65, and 80 ^{0}C. The results indicated that the overall heat transfer coefficient of nanofluids increased to 9% compared with the water. Increasing the nanoparticle concentration, air velocity, and nanofluid velocity enhanced the overall heat transfer coefficient. In contrast, increasing the nanofluid inlet temperature reduced the overall heat transfer coefficient.

Duangthongsuk and Wongwises [3] reported an experimental study on forced convective heat transfer of a nanofluid consisting of water and 0.2 vol. % TiO_2 nanoparticles in a horizontal double-tube counter flow heat exchanger under turbulent flow condition. Their results show that the heat transfer coefficient of the nanofluid increases with an increase in the mass flow rate of the hot water and nanofluid and increases with a decrease in the nanofluid temperature. It was found that convective heat transfer coefficient of nanofluid is slightly higher than that of the base liquid by about 6-11%.

Leong et al. [4] applied Cu/ethylene glycol (EG) nanofluids with different concentrations at 0-2 vol. % and an inlet temperature of 70-95 ^{0}C in an automotive cooling system. The results showed that approximately a 3.8% heat transfer enhancement and 18.7% reduction of the air frontal area were achieved with 2 vol. % Cu/EG nanofluid at the 6000 and 5000 Reynolds number for the air and coolant, respectively, and an additional 12.13% pumping power was needed for a radiator at a 0.2 m3/s coolant volumetric flow rate compared to the pure EG coolant.

Naraki et al. [5] used CuO/water nanofluids (0-0.4 vol.%) in a car radiator to investigate the overall heat transfer coefficient under the laminar flow regime ($100 < Re < 1000$). The nanofluids had been stabilized with a variation in pH and the use of sodium dodecyl sulfonate (SDS) as a surfactant. The results demonstrated that the overall heat transfer coefficient decreased with an increase in the nanofluid inlet temperature from 50 to 80 ^{0}C. The overall heat transfer coefficient increased to 8% at a nanofluid concentration of 0.4 vol. %, compared with the base fluid.

Namburu et al. [6] numerically analyzed turbulent flow and heat transfer to three types of nanofluids namely copper oxide (CuO), alumina (Al_2O_3) and silicon dioxide (SiO_2) in ethylene glycol and water, flowing through a circular tube under constant heat flux. Results revealed that nanofluids containing smaller diameter of nanoparticles produce higher viscosity and Nusselt number. Nusselt numbers are also increased at higher volume fraction of particles. It is observed that at a constant heat flux (50 W/cm2) with a constant Reynolds number (20,000), heat transfer coefficient of 6% CuO nanofluid has increased 1.35 times than that of the base fluid. At the same particle volume fraction, CuO nanofluid produced higher heat transfer coefficient compared to that of other types of nanofluids.

Xie et al. [7] reported the convective heat transfer enhancement of nanofluids as coolants in laminar flows inside a circular copper tube with constant wall temperature. Different nanofluids consisting of Al_2O_3, ZnO, TiO_2, and MgO nanoparticles were prepared with a mixture of 55 vol. % distilled water and 45 vol.% EG as base fluid. MgO, Al_2O_3, and ZnO nanofluids exhibited superior enhancements of heat transfer coefficient, with the highest enhancement up to 252% at a Reynolds number of 1000 for MgO nanofluid. The performance of finned tube heating units with nanofluids has been compared mathematically with a conventional heat transfer fluid which comprised of 60% EG and 40% water

Jung et al. [8] conducted convective heat transfer experiments for a nanofluid (Al_2O_3-water) in a rectangular micro channel under laminar flow conditions. The convective heat transfer coefficient increased by more than 32% for 1.8 vol. % nanoparticle in the base fluids. The Nusselt number increased with an increasing Reynolds number in the laminar flow regime ($5< Re< 300$).

Zeinali et al. [9] experimentally investigated convective heat transfer to alumina water (Al_2O_3/water) nanofluids in laminar flow inside a circular tube with constant wall temperature under different concentrations of nanoparticles. They obtained augmentation of heat transfer coefficient of nanofluid with increase of nanoparticle concentration. They also obtained greater heat transfer coefficient of nanofluid in comparison to that of distilled water base fluid at a constant Peclet number. Authors have reported that the heat transfer augmentation results are much higher in experimental observation than that of predicted results.

Rahul A. Bhogare, B. S. Kothawale [18] reported that effect of adding Al_2O_3 nanoparticle to base fluid (mixture of EG and Water) in Automobile radiator is investigated experimentally. Radiators are compact heat exchangers optimized and evaluated by considering different working conditions. The cooling system of a Automobile plays an important role in its performance, consists of two main parts, known as radiator and fan. Improving thermal efficiency of engine leads to increase the engine's performance, decline the fuel consumption and decrease the pollution emissions. For this purpose, an experimental setup was designed. Effects of fluid inlet temperature, the flow rate and nano particle volume fraction on heat transfer are considered. Results show that Nusselt number, total heat transfer, effectiveness and overall heat transfer coefficient increases with increase , nano particle volume fraction air Reynolds number and mass flow rate of coolant flowing through radiator.

A. Concluding Remark From Literature Review

The above review shows that many researchers used nanoparticle (γ-Al_2O_3, Al_2O_3, MgO, SiO_2, CNT's, ZnO, Fe_2O_3, CuO, TiO_2) with base fluid as coolant in radiator and heat exchanger at different flow rate, volume fraction of nanoparticle and inlet temperature. They found that it is very good technology available for the development and use of radiator in engine cooling system with nanoparticle. It enhances the thermal properties of base fluid and ultimately the thermal performance of engine cooling system increases.

But there is still very large scope available for development of engine cooling system with nanoparticle at different volume concentration, inlet temperature and flow rate of fluid.

Therefore, this study attempts to study the thermal performance of an automobile radiator using mixture of ethylene glycol and water (1:3) combination base fluid with nanoparticle as coolants. The effect of volume fraction, coolant flow rate, type of nanoparticles with base fluids is studied and thermal performance of a radiator is also calculated and compared with pure water, water and ethylene glycol.

III. PROBLEM DEFINITION

Continuous technological development in automotive industries has increased the demand for high efficiency engines. A high efficiency engine is not only based on its performance but also for better fuel economy and less emission. Reducing a vehicle weight by optimizing design and size of a radiator is a necessity for making the world green. Addition of fins is one of the approaches to increase the cooling rate of the radiator. It provides greater heat transfer area and enhances the air convective heat transfer coefficient. However, traditional approach of increasing the cooling rate by using fins and micro-channel has already reached to their limit.

In addition, heat transfer fluids at air and fluid side such as water, ethylene glycol and mixture of ethylene glycol and water (50:50) combination exhibit very low thermal conductivity. As a result there is a need for new and innovative heat transfer fluids for improving heat transfer rate in an automobile radiator

Therefore to improve the radiator performance nanofluid have attractive attention as a new generation of heat transfer fluids in developing in automotive cooling applications, because of their excellent thermal performance. Recently, there have been considerable research findings highlighting superior heat transfer performances of nanofluids

A. Objective of the Project

1. Evaluation thermal performance of car radiator by using (AL_2O_3 and TiO_2) nano material.
2. Find the effect of 0.1%, 0.15% and 0.2% volume fraction of Nano particle on Thermal conductivity, Nusselt number, Heat transfer coefficient and Reynolds number is considered.
3. To investigate the effect of 4LPM, 6LPM and 8LPM flow rate of coolant on Thermal conductivity, Nusselt number, Heat transfer coefficient and Reynolds number is considered.

IV. EXPERIMENTAL SETUP

The Experimental setup shown in Fig. I includes Storage tank, Pump, Flow meter, Induced fan, Finned tube radiator, Temperature controller, Temperature indicator 12 point, Thermocouples K type Alumel Chromel, On-Off switches, Manometer, Valve, Heater and Flow lines.

This experimental setup includes Reservoir tank (capacity 25 lit), Two electrical heater (Capacity 1000 watt each), Centrifugal pump (0.5 HP), Flow meter (capacity 11 LPM), Valve, Induced draft fan (capacity 1500 rpm), AC power supply, 12 resistance temperature detector for temperature detection in heat exchanger (automobile radiator).An electrical heater inside a storage is use to heat the fluid and maintain the temperature of fluid at 60ºC, 65ºC and 70ºC by using controller. Flow meters used to measure and control the flow rates at 4LPM, 6LPM, and 8LPM. A flow meter is installed on inlet line of radiator. A fluid flows through a plastic tube by centrifugal pump. All thermocouple temperatures are displayed by respective digital controller which is used to set and control the temperature. Radiator has louvered fins and 29 flat vertical tubes with flat cross sectional area. The distance among the tubes rows filled with thin perpendicular fins. For the airside, an axial induced fan installed closed on the axis line of radiator. The AC power supply use to run the axial fan. From the tank to radiator flow meter range 11 LPM installed. The total volume of circulating fluid is 10 liters and constant in all the experimental setup. 2 thermocouples are set at Inlet and Outlet of fluid lines in order to record the inlet and outlet fluid temperatures respectively. 5 thermocouples are fixed in radiator to measure the radiator surface temperature and one thermocouple is deep in reservoir to control inlet fluid temperature at 60ºC, 65ºC and 70ºC. 2 thermocouples are set at radiator inlet and outlet to record air inlet and outlet temperature.

On experimental setup four tests at different inlet temperature of coolant 60^0C, 65^0C and 70 ^{0}C and flow rate of 4 LPM, 6 LPM, and 8 LPM, Following test carryout

Fig. 1 Experimental Setup

On experimental setup four tests at different inlet temperature of coolant 60^{0}C, 65^{0}C and 70 ^{0}C and flow rate of 4 LPM, 6 LPM, and 8 LPM, Following test carryout

1. Test by using water,
2. Test by using mixture of water and ethylene glycol at 3:1 ratio respectively,
3. Test by using mixture of water and ethylene glycol at 3:1 ratio respectively and Nanopowder of TiO_2 at 0.1%, 0.15% and 0.2% volume fraction,
4. Test by using mixture of water and ethylene glycol at 3:1 ratio respectively and Nanopowder of Al_2O_3 at 0.1%, 0.15% and 0.2% volume fraction.

A. *Radiator*

Radiators are heat exchangers used to transfer thermal energy from one medium to another for the purpose of cooling and heating. The majority of radiators are constructed to function in automobiles, buildings, and electronics. The radiator is always a source of heat to its environment, although this may be for either the purpose of heating this environment, or for cooling the fluid or coolant supplied to it, as for engine cooling.

Radiator consist of small elliptical shape tube, Dimension of elliptical tube

- Length (L)=40 cm =40X10-2 m
- Diameter of elliptical tube(D) =25 mm=25X10-3m
- No. of tubes =29

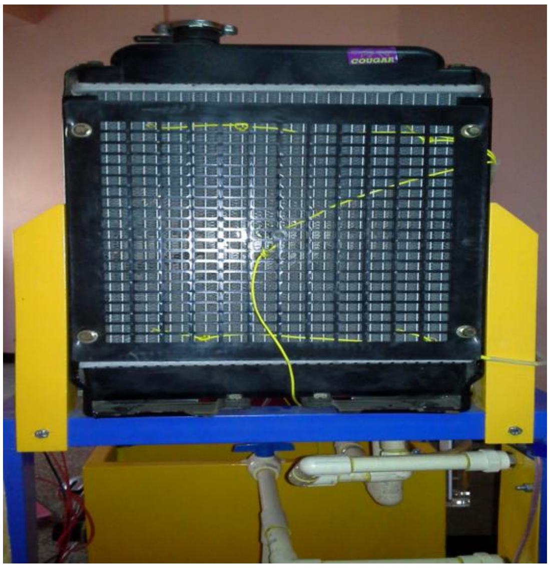

Fig. 2 Radiator

TABLE I: SPECIFICATIONS AND MEASUREMENT PARAMETERS OF RADIATOR

Sr.No.	**Parameter**	**Calculated**
1	Total no of tubes in	29
2	Length of tube (L)	40x10-2 m
3	Major diameter of	25x10-3 m
5	Parameter of tube(P)	0.05342
6	Cross section area of	0.00049
7	Surface area of	0.00314
8	Hydraulic diameter of radiator (Dhyd.)	0.00547

B. *Nanofluid Preparation Using Nanoparticles*

The Al_2O_3 and TiO_2 nano particles having an average size of 30-50 nm and 10-20 nm the photographic view of the nanoparticles as seen by the transmission electron microscope shown in the figure.3 and 4 TiO_2 and Al_2O_3 nanoparticles, respectively.

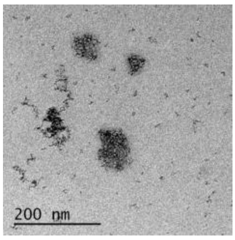

Fig. 3 TEM images of TiO_2

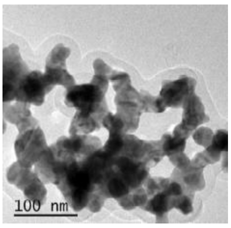

Fig 4 TEM images of Al_2O_3

Preparation of nanofluids is an important stage and nanofluids are prepared in a systematic and careful manner. A stable nanofluid with uniform particle dispersion is required and the same is used for measuring the thermo physical properties of nanofluids. In the present work, Water-Ethylene glycol mixture (70:30 by volume) is taken as the base fluid for preparation Al_2O_3 and TiO_2 nanofluids. Basically three different methods are available for preparation of stable nanofluids and are listed below.

C. *Thermo Physical Properties of Nanofluid*

Heat transfer coefficient of nano particle depend on thermal conductivity of nano fluid, heat capacity of base fluid and nano fluid, Inlet temperature, Inlet flow rate, Flow pattern, Prandtl number, Reynolds number, Shape and size of nano particle so some important thermo physical properties. [18]

Following correlation used to calculate thermo physical properties [18]

Thermal conductivity of nano fluid is calculated by using following correlation Maxwell,

$$K_{nf} = K_f \left(\frac{(K_s + 2K_f) - 2\emptyset(K_f - K_s)}{(K_s + 2K_f) + \emptyset(K_f - K_s)} \right)$$

Thermal conductivity of nanofluids is found to be an attracting characteristic for many applications. It represents the ability of material to conduct or transmit heat.

.It has been noticed that most authors agreed that nanofluids provide higher thermal conductivity compared to base fluids. Its value increases with particles concentration. Temperature, particles size, dispersion and stability do play important role in determining thermal conductivity of nanofluids [1].

Specific heat of nano fluid is calculated by using following correlation [19],

$$C_{pnf} = \left(\frac{\emptyset \rho_p C_{pp} + (1 - \emptyset)\rho_{bf} C_{pbf}}{\rho_{bf}} \right)$$

Density of nano fluid is calculated by using following correlation [19],

$$\rho_{nf} = \emptyset \rho_p + (1 - \emptyset)\rho_{bf}$$

Viscosity of nano fluid is calculated by using following correlation [18],

$$\mu_{nf} = \mu_{bf} \left(\frac{1}{(1 - \emptyset^2)} \right)$$

TABLE II: PROPERTIES OF THE NANO FLUID AND BASE FLUID AT 30^0C [20]

Material	Density (kg/m3)	Viscosity	Specific heat (kJ/kg K)	Thermal Conductivity (W/m K)
Water	1000	0.0008	4.184	0.613
Air	1.1839	0.000018	1.005	0.024
EG 30% Water 70%	1055	0.00226	3.502	0.412
Titanium oxide TiO2	4230	0.000565	0.692	8.4
EG 30% Water 70% and TiO2 0.1%	1372.5	0.001867	0.6482	0.5291
EG 30% Water 70% and TiO2 0.15%	1584	0.001708	0.7663	0.596
EG 30% Water 70% and TiO2 0.2%	1690	0.001569	0.8844	0.671
Alumina (Al2O3)	3960	0.000565	0.773	40
EG 30% Water 70% and Al2O3 0.1%	1345.5	0.001867	0.6606	0.5445
EG 30% Water 70% and Al2O3 0.15%	1490.75	0.001708	0.7850	0.6224
EG 30% Water 70% and Al2O3 0.2%	1636	0.001569	0.9093	0.7094

V. HEAT TRANSFER COEFFICIENT CALCULATIONS

According to Newton's low of cooling Nu and Re number can calculated as [1-2, 5]

- Heat transfer coefficient

  $Q= h A\Delta T=h A_s (T_b-T_s)$ (1)

- Bulk temperature (Tb)

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

- Tube wall temperature

  $$T_s = \left(\frac{T_1+\cdots.T_n}{n} \right) \quad (3)$$

- Heat transfer rate

  $Q=m^* C\Delta T=m^* C\Delta(T_{in}\text{-Tout})$ (4)

- Mass flow rate

  $m= \rho V$ (5)

By comparing (1) and (4)

- Heat Transfer Coefficient

$$\text{hexp} = \left(\frac{\text{m} * \text{C}(\text{Tin} - \text{Tout})}{\text{As}(\text{Tb} - \text{Ts})}\right) \qquad (6)$$

- Nusselt number

$$\text{Nu} = \left(\frac{\text{h exp Dh}}{\text{k}}\right) \qquad (7)$$

- Hydraulic diameter

$$\text{Dh} = \frac{4*[\frac{\pi}{4}\text{d}^2+(\text{D}-\text{d})\text{d}]}{\pi\text{d}+2(\text{D}-\text{d})} \qquad (8)$$

- Reynolds number

$$\text{Re} = \left(\frac{\rho_{\text{nf}}\ \text{Dh u}}{\mu_{\text{nf}}}\right) \qquad (9)$$

VI. RESULTS AND DISCUSSIONS

Comparison was made between the experimental data and two well-known empirical correlations by Dehghandokht et al. [21] and Shah London equation [22]. The following relationship for the flow through the compact heat exchanger

1) Nu by Dehghandokht et al

$$(\text{Nu}) = 0.28\ \text{Re}^{0.35}\text{Pr}^{0.36}$$

2) Nu by shah – London equation

$$(Nu) = 1.953\left(RePr\ {}^{D_h}/_{K}\right)^{1/3}$$

TABLE III: NUSSELT NUMBER AT DIFFERENT CONCENTRATION AND FLOW RATE BY USING DEHGHANDOKHT ET AL.CORRELATION AND SHAH-LONDON EQUATION.

Working Fluid	Flow Rate in LPM	Re	Pr	Nu by Dehghandokht	Nu by Shah London
EG 30% Water 70% and TiO_2 0.1%	4	8303.58	2.29	8.88	11.35
	6	12467.8	2.29	10.24	13
	8	16619.6	2.29	11.32	14.31
EG 30% Water 70% and TiO_2	4	9076.57	2.20	9.02	10.19
	6	13628.5	2.20	10.41	11.68
	8	18166.8	2.20	11.51	12.85
EG 30% Water 70% and TiO_2 0.2%	4	9880.68	2.07	9.1	9.8
	6	14835.9	2.07	10.49	11.22
	8	19776.2	2.07	11.6	12.35
EG 30% Water 70% and Al_2O_3 0.1%	4	8303.58	2.27	8.85	10.51
	6	12467.8	2.27	10.21	12.04
	8	16619.6	2.27	11.29	13.25
EG 30% Water 70% and Al_2O_3 0.15%	4	9076.57	2.15	8.96	10.05
	6	13628.5	2.15	10.33	11.5
	8	18166.8	2.15	11.42	12.65
EG 30% Water 70% and Al_2O_3 0.2%	4	9880.68	2.01	9.01	9.62
	6	14835.9	2.01	10.38	11.01
	8	19776.2	2.01	11.48	12.12

The correlation equation by Shah-London and Dehghandokht et al. use for input (volume flow rate, inlet temperature and nanofluid volume concentration) and response (Nusselt number) was found. The results of the analysis indicated that significant input parameters to enhance heat transfer with car radiator. These experimental results were found to be in good agreement with other researchers' data.

The experimental data obtained from three input temperature condition, three flow rates in LPM and three different volume fraction of Nanoparticle are presented in this chapter. To compare the Nusselt number at different inlet temperature, flow rate and different volume fraction of Nanoparticle various graphs are plotted. The graphs are obtained from observation and result table shown in chapter 4 and validation by using correlations by Dehghandokht et al. [21] and Shah London equation [22].

A. *Effect of Flow rate and Volume fraction of TiO_2 and Al_2O_3 on Nusselt Number at 60 ^{0}C*

Figure 3 and 4 shows the effect of flow rate and volume fraction of Nanoparticle TiO_2 and Al_2O_3 on Nusselt number at 60^{0}C respectively. The maximum value of Nu obtained is 16.22 at 8 LPM and 0.2% volume concentration of Al_2O_3. Higher Nusselt number obtained by using nanofluid instead of water in the automobile radiator. The addition of nanoparticles to the water has the potential to improve automotive radiator.

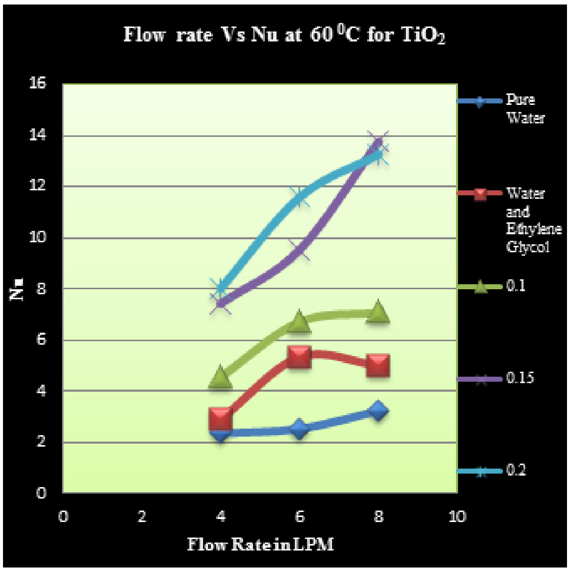

Fig. 3 Effect of Flow rate and Volume fraction TiO_2 on Nusselt number at 60^0C

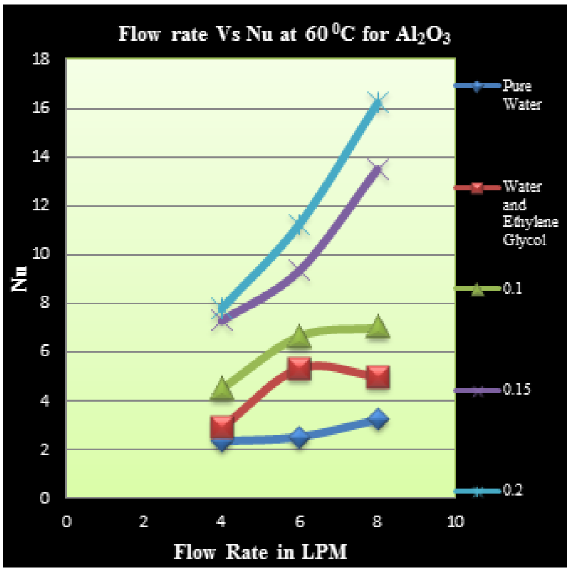

Fig.4 Effect of Flow rate and Volume fraction Al_2O_3 on Nusselt number at 60^0C

B. *Effect of Flow Rate and Volume fraction of TiO_2 and Al_2O_3 on Nusselt Number at 65 ^0C*

Figure 5 and 6 shows the effect of flow rate and volume fraction of Nanoparticle TiO2 and Al_2O_3 on Nusselt number at 65^0C respectively. The maximum value of Nu obtained is 16.15 at 8 LPM and 0.2% volume concentration of TiO_2. Nusselt number increased with increasing the inlet temperature and by increasing the volume concentration of nano particles in to the base fluid. Inlet temperature affects the Nusselt number as inlet temperature increases nusselt number is also increases.

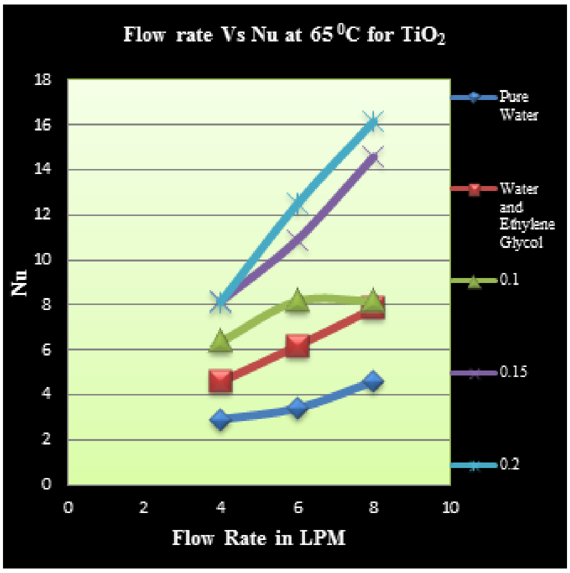

Fig 5 Effect of Flow rate and Volume fraction TiO_2 on Nusselt number at 65^0C

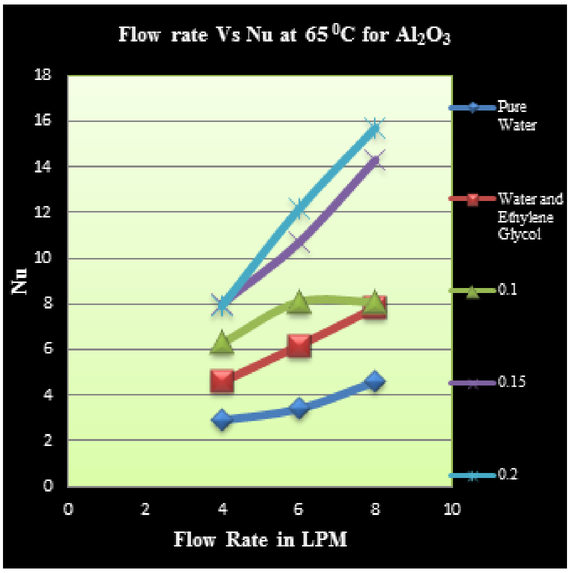

Fig. 6 Effect of Flow rate and Volume fraction Al_2O_3 on Nusselt number at 65^0C

C. *Effect of Flow Rate and Volume fraction of TiO_2 and Al_2O_3 on Nusselt Number at 70^0C*

Fig 7 and 8 shows the effect of flow rate and volume fraction of Nanoparticle TiO_2 and Al_2O_3 on Nusselt number at 65^0C and maximum value of Nu obtained as 16.68 at 8 LPM and 0.2% volume concentration of $TiO_{2.}$ Nusselt number increased with increasing the inlet temperature and by increasing the volume concentration of nano particles in to the base fluid. Inlet temperature affects the Nusselt number as inlet temperature increases nusselt number is also increases.

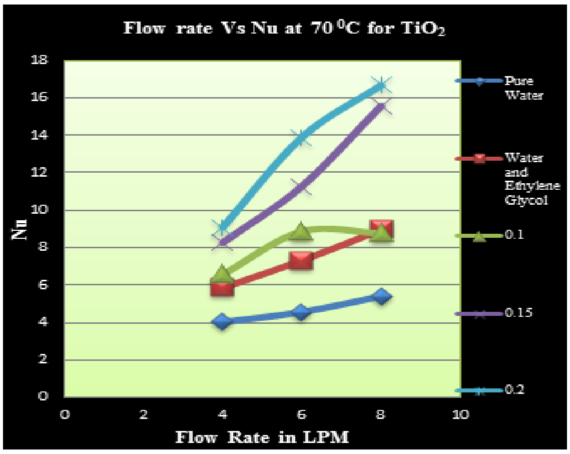

Fig.7Effect of Flow rate and Volume fraction TiO_2 on Nusselt number at 70^0C

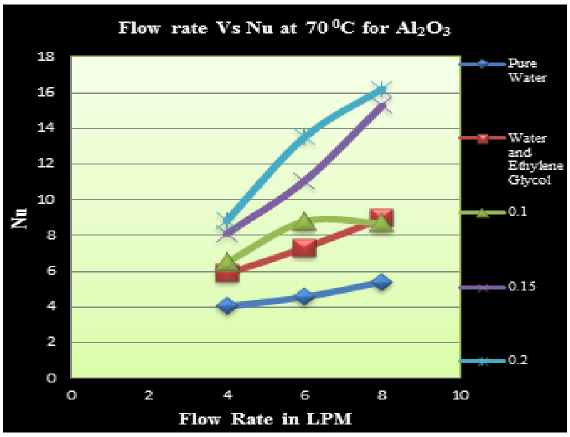

Fig.8: Effect of Flow rate and Volume fraction Al_2O_3 on Nusselt number at 70^0C

D. *Effect of Flow Rate and Volume fraction of TiO_2 on Heat transfer Coefficient at Inlet temperature 60^0C, 65^0C, 70^0C*

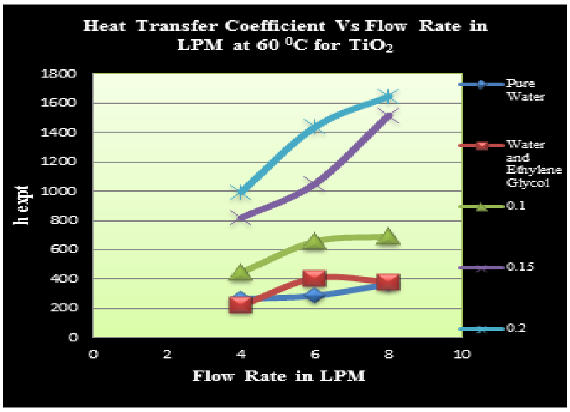

Fig. 9 Effect of Flow rate and Volume fraction of TiO_2 on Heat Transfer Coefficient at 60^0C

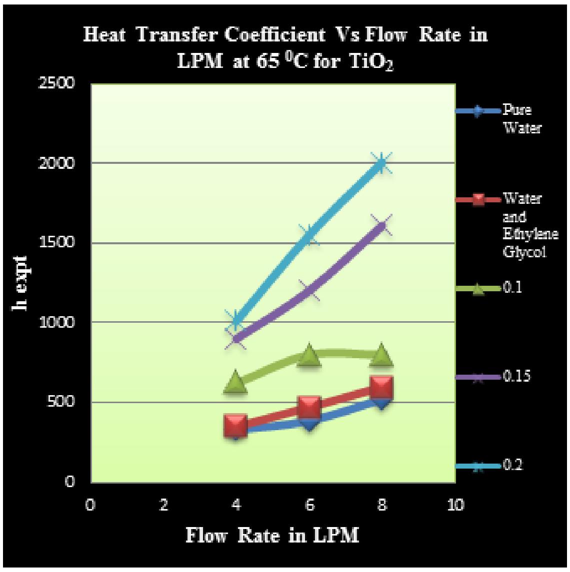

Fig. 10 Effect of Flow rate and Volume fraction of TiO_2 on Heat Transfer Coefficient at 65^0C

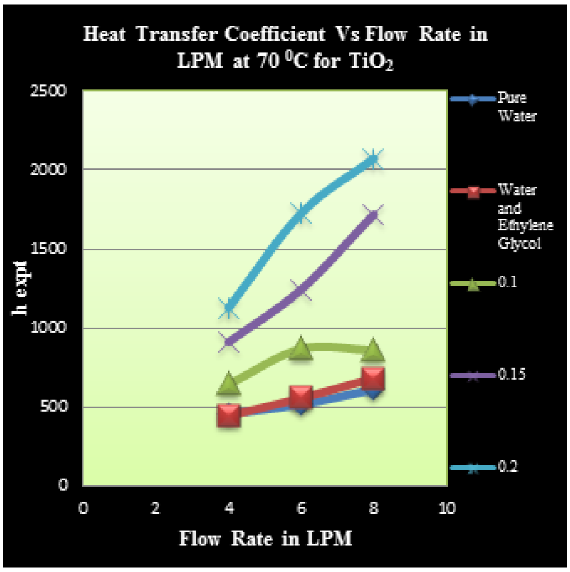

Fig. 11 Effect of Flow rate and Volume fraction of TiO_2 on Heat Transfer Coefficient at 70^0C

Figure 9, 10, 11 shows the effect of flow rate and volume fraction of Nanoparticle TiO_2 on heat transfer coefficient at 60^0C, 65^0C, 70^0C as the volume fraction of nanoparticle and inlet temperature increases heat transfer coefficient is increases and maximum value of heat transfer coefficient obtained as 2072.94 W/m2 K at 8 LPM and 0.2% volume concentration of TiO_2 at 70^0C.

Higher heat transfer coefficients obtained by using nanofluid instead of water allow the working fluid in the automobile radiator. The addition of nanoparticles to the water has the potential to improve automotive and heavy-duty engine cooling rates or equally causes to remove the engine heat with a reduced-size coolant system. Smaller coolant systems result in smaller and lighter radiators, which in turn benefit almost every aspect of car and truck performance and lead to increased fuel economy.

E. *Effect of Flow Rate and Volume fraction of Al_2O_3 on Heat Transfer Coefficient at Inlet temperature 60^0C, 65^0C, 70^0C.*

Figure 12, 13,14 shows the effect of flow rate and volume fraction of Nanoparticle Al_2O_3 on Heat transfer coefficient at 60^0C, 65^0C, 70^0C and maximum value of heat transfer coefficient obtained as 2131.31 W/m2 K maximum at 8 LPM and 0.2% volume concentration of Al_2O_3 at 70^0C. As the volume fraction of nanoparticle increases heat transfer coefficient is also increases. Al_2O_3 Nanofluid produces a higher heat transfer enhancement than the TiO_2 nanofluid; likewise, TiO_2 nanofluid enhanced heat transfer more than pure water and Water ethylene glycol.

Higher heat transfer coefficients obtained by using nanofluid instead of water allow the working fluid in the automobile radiator. The addition of nanoparticles to the water has the potential to improve automotive and heavy-duty engine cooling rates or equally causes to remove the engine heat with a reduced-size coolant system. Smaller coolant systems result in smaller and lighter radiators, which in turn benefit almost every aspect of car and truck performance and lead to increased fuel economy.

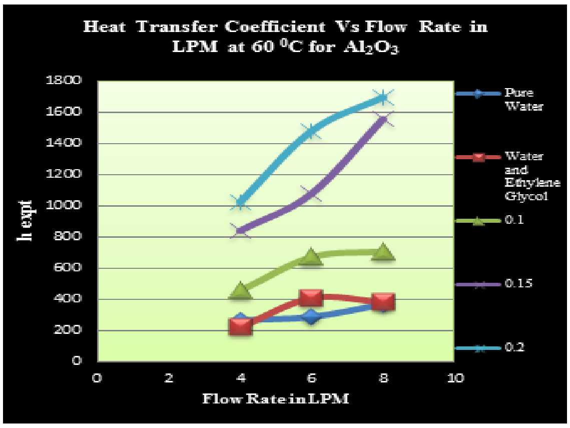

Fig. 12 Effect of Flow rate and Volume fraction of Al_2O_3 on Heat Transfer Coefficient at 60^0C

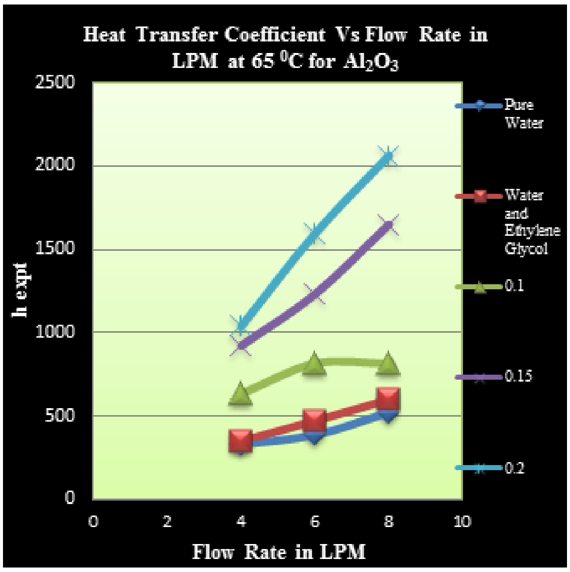

Fig. 13 Effect of Flow rate and Volume fraction of Al_2O_3 on Heat Transfer Coefficient at 65^0C

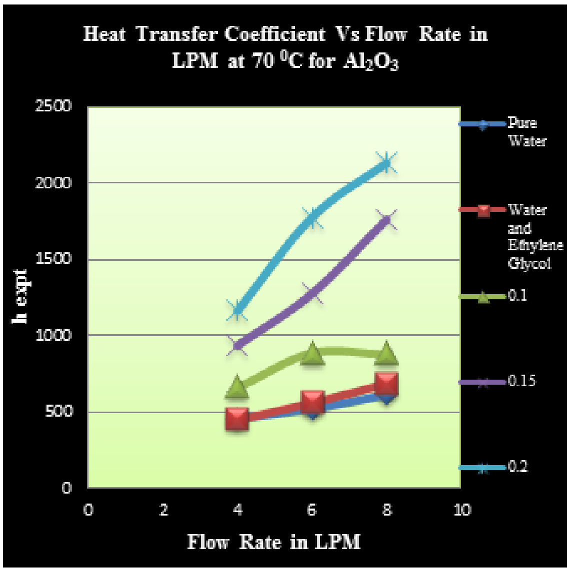

Fig. 14 Effect of Flow rate and Volume fraction of Al_2O_3 on Heat Transfer Coefficient at 70^0C

F. *Validation using Dehghandokht and Shah-London Correlation*

The comparison of experimental results was carried with the results of correlation developed by Dehghandokht and Shah-London. Theoretical Nusselt number calculated by using correlations developed by Dehghandokht and Shah-London equation. From figure 15 and 16, it is observed that Experimental results are in good agreement with the correlation results.

With increase in the mass flow rate of the coolant flowing through automobile radiator, it increases coolant Nusselt number. Average deviation by using Dehghandokht et al. equation are 20-35% calculated for 0.1, 0.15, 0.2 volume fraction of TiO_2 and Al_2O_3 nanoparticle respectively for all flow rate. Similarly by using Shah-London equation it 15.19%, 22.3926%, 25% calculated for 0.1, 0.15, 0.2 volume fraction of TiO_2 and Al_2O_3 Nanoparticle respectively and for all flow rate. Figure 6.13, 6.14 shows Shah-London equation gives close agreement than Dehghandokht et al. equation

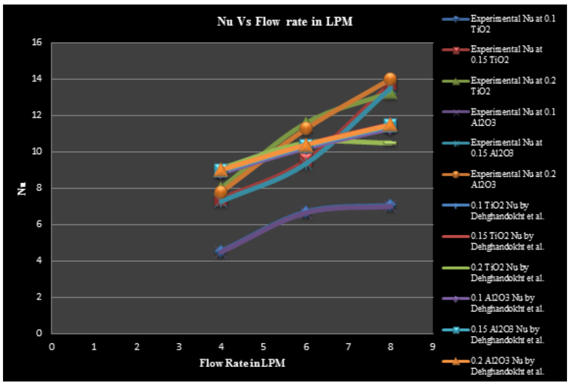

Fig. 15 Experimental Results for TiO_2 and Al_2O_3 in Comparison with Dehghandokht Correlations

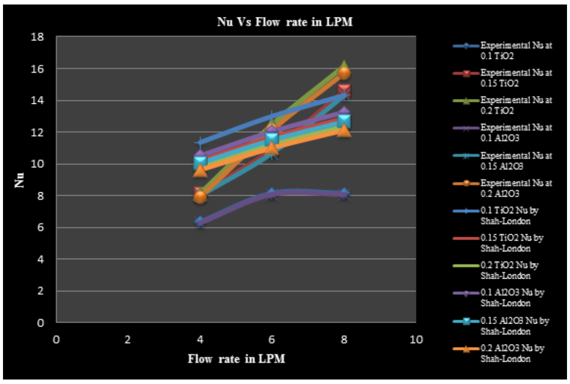

Fig. 16 Experimental results for TiO_2 and Al_2O_3 in comparison with Shah London correlations

VII. CONCLUSION

In this investigation, Experimental heat transfer coefficient, Nusselt number in the car radiator have been measured with two different water ethylene glycol based nanoparticles (TiO2 and Al2O3) at different volume fraction, coolant flow rate and inlet temperatures, air velocity kept as constant.

The major conclusions are as follows:

1) Heat transfer coefficient and Nusselt number increases while the liquid inlet temperature increases.
2) Heat transfer coefficient enhances with increasing the coolant flow rate.
3) Nusselt number increases with increasing the coolant flow rate.
4) Increasing the volume fraction of nanoparticles enhances the heat transfer coefficient. The maximum heat transfer coefficient is 2131.31 W/m^2 K obtained at 8 LPM, 0.2 Volume fraction of Al_2O_3 and at 70 0C.
5) Increasing the volume fraction of nanoparticles increases the Nusselt number. The maximum Nusselt number is 16.68 obtained at 8 LPM, 0.2 Volume fraction of TiO_2 and at 70 0C.
6) The correlation developed by Shah-London predicts good agreement the experimental data.
7) This new working fluid with higher heat transfer performance would advance the car engine thermal performance and would reduce fuel consumption.
8) These experimental results were found to be in good agreement with other researchers' data.

Nomenclature

k: thermal conductivity, W/m 0C
Nu: Nusselt number
Pr: Prandtl number
Re: Reynolds number
T: Temperature, 0C
A: peripheral area (m2)
Cp: specific heat (J/kg 0C)
P: tube periphery (m)
Dhy: hydraulic diameter (m)
h: heat transfer coefficient (W/m20C)
m: mass flow rate (kg/s)
Q: heat transfer rate (W)

Greek letters

ρ: density (kg/m3)
μ: viscosity (kg/m s)
Φ: volume fraction

Subscripts

b: bulk
exp.: experimental
in: input
nf: nanofluid
out: output
p: particle

w: wall
s: surface

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