IMPROVING THE COOLING PERFORMANCE OF AUTOMOBILE RADIATOR WITH ETHYLENE GLYCOL WATER BASED ZrO_2 NANOFLUID AND COMPARE WITH AL_2O_3 NANOFLUID

Nikhil S. Nagulkar[1], Dr. S. M. Lawankar[2]

[1]*P.G. Student, Dept. of Mechanical Engineering Govt. Engineering College, Amravati, Maharashtra, India*
[2]*Assistant Professor, Dept. of Mechanical Engineering Govt. Engineering College, Amravati, Maharashtra, India*

---***---

Abstract - *Enhancement of heat transfer coefficient to be an important research areas in various field of engineering. Heat transfer coefficient can be increases by using nanofluids in heat exchanger like Radiator. In this paper more focused on the heat transfer enhancement of Car radiator by using Nanofluid. Many researchers have done a lot of research on nanofluid technology and its applications in the heat transfer devices. This paper reviews the previously published literatures in this area. Nanofluid is the new generation fluid, it improves properties such as density, thermal conductivity, viscosity, specific heat of basic fluid in which nanoparticles added. The Prandtl number, Reynolds number and Nusselt number are functions of thermophysical properties of nanofluids and these numbers strongly influence the convective heat transfer coefficient. The thermophysical properties vary with temperature and volumetric concentration of nanofluids. Such as Density, specific heat, thermal conductivity and viscosity. Effect on prandlt number, Reynolds Number, heat transfer coefficient of different particle volumetric concentrations solutions are discussed in this paper.*

Key Words: *Nanofluid, thermal conductivity viscosity, convective heat transfer, heat exchanger, radiator*

1. INTRODUCTION

Conventional coolants have been widely employed to dissipate heat in majority of the engineering applications. Typical coolants include matter in all three states namely solid, liquid and gas based on the requirements of application and possible mode of heat transfer. However, with the latest technological advancements, an emerging class of new coolants namely nano-coolants (coolants with dispersed nano-particles) find their applications in a variety of engineering application and are expected to replace conventional coolants in the near future. A typical Nano fluid is prepared by dispersing certain types of select nano-particles in a suitable base fluid (water, ethylene glycol and coolant) with different volume concentrations; some of the specific advantage of Nano fluids includes enhanced thermal properties when compared to the base fluid. Mixing of additives in coolants has been in use from decades to enhance the heat transfer and reduce the pressure drop along the flow. There has been more attention toward to increase convective heat transfer rate of nanofluid [1]particle having size less than 100nm added to base fluid to increase thermal conductivity define as a nanofluid in conventional method water, ethylene glycol ,used as coolant in car radiator in these case nanofluid added to base fluid to increase the heat transfer rate in case study of nanofluid in car radiator pump for force convection used and the heat transfer rate calculated at different input flow rate [1-4]this rate was compare with nanofluid used in base fluid. Effect of different nanofluid with different concentration calculated and compare with base fluid with actually performed experimental setup readings .different models by using different software are created and compare and verified with actual perform values different correlation of thermal conductivity ,viscosity as a function of particle temperature and concentration are used in the different papers Viscosity is also important parameter for performance enhancement and pressure drop is related with the pumping power and viscosity is related with viscosity .as increase the viscosity it increase the pumping power so that the minimization of viscosity is also the critical facture. It is observe that viscosity increases when concentration of nanofluid is increases. Density is also one of the important properties it is also having direct effect of pumping power and pressure drop. It is not affected by size, shape and additive it is only affected by the concentration of nanofluid.

Xuan et al. [1] measured the thermal conductivity of Cu/water nanofluids with hot wire method. They studied the effect of various parameters such as particle volume fraction, size and properties of nanoparticles on the thermal conductivity and revealed that thermal conductivity was highly dependent on these parameters. They concluded that for 2.5 % to 7.5 % nanoparticle volume fraction, the thermal conductivity was increased by factor of 1.24 to 1.78.

Kakaç et al. [2] reviewed that heat transfer capabilities of ordinary fluids such as water, oils and ethylene glycol can be increased significantly by addition of nanoparticles. They marked the importance of heat transfer fundamentals for a diverse advancement in the field of nanotechnology. Theoretical and experimental understanding of microscopic particle mechanism is vital.

Vajjha et al. [3] studied the effect of Al2O3 and CuO based nanofluids on the performance of an automobile radiator. Base fluid used was the mixture of water and ethylene glycol. Radiator under consideration was employed with flat tubes. Experiments were carried out in the laminar flow region. They concluded that the average heat transfer coefficient was increased considerably with particle volume concentrations. They showed that for 10 % Al2O3 nanofluid, the average heat transfer coefficient was improved by 94 %, while for 6 % CuO nanofluid, it was increased by 89 %. Also, for a fixed inlet velocity, average skin friction coefficient was increased by increasing the particle volume concentration. But, for the same amount of heat transfer, pumping power requirement with respect to base fluid was reduced by 82 % and 77 % for Al2O3 and CuO nanofluid, respectively.

Peyghambarzadeh et al. [4] studied the effect of Al2O3/water nanofluid on the cooling performance of an automobile radiator. Five different concentrations varying from 0.1 to 1 % (vol.) of Al2O3/water nanofluids were taken. Flow rate of fluid inside the tubes were changed from 2 to 5 litre per minute. Experiments were carried out in fully developed turbulent region. Inlet temperature of fluid through the tubes was varied from 37 °C to 49 °C. They concluded that the heat transfer performance of the heat exchanger was improved by increasing the flow rate of fluid flowing through the tubes. With respect to pure water, heat transfer was enhanced by 45 % by adding Al2O3 nanoparticles. By increasing the Reynolds number of working fluid, effective thermal conductivity was increased by 3%.

Preparation And Estimation Of Nanofluid Properties

The idea behind development of nanofluids is to use them as thermo fluids in heat exchangers for enhancement of heat transfer coefficient and thus to minimize the size of heat transfer equipment's. Nanofluids help in conserving heat energy and heat exchanger material. The important parameters which influence the heat transfer characteristics of nanofluids are its properties which include thermal conductivity, viscosity, specific heat and density. The thermo physical properties of nanofluids also depend on operating temperature of nanofluids. Hence, the accurate measurement of temperature dependent properties of nanofluids is essential. Thermo physical properties of nanofluids are pre requisites for estimation of heat transfer coefficient and the Nusselt number

Estimation Of Nanoparticle Volume Concentration

The amount of Al_2o_3 and ZrO_2 nanoparticles required for preparation of nanofluids is calculated using the law of mixture formula. A sensitive weighing balance with a 0.001mg resolution is used to weigh the Al_2o_3 and ZrO_2 nanoparticles very accurately. The weight of the nanoparticles required for preparation of 100 ml Al_2o_3 and ZrO_2 nanofluid of a particular volume concentration, using water-ethylene glycol base fluid is calculated by using the following relation

$$\text{Volume concentration } \varphi = \frac{\frac{\text{WParticle}}{\rho\text{Particle}}}{\frac{\text{WParticle}}{\rho\text{Particle}}+\frac{\text{WFluid}}{\rho\text{Fluid}}} \times 100$$

Correlation for thermophysical properties

Heat transfer coefficient of Nano particle depend on thermal conductivity of nanofluid, heat capacity of base fluid and nanofluid ,Inlet temperature ,inlet flow rate ,flow pattern, prantal number, Reynolds number, shape and size of Nano particle so some important thermo physical properties with their correlation are discussed below.
The nanofluid presented equation are calculated by using of the Pak and Choi [10] correlations, which are defined as follows:

$$\rho_{nf} = (1-\varphi)\rho_f + \varphi\rho_p \tag{8}$$

Where ρ_{nf} is the density of nanofluid, φ is the particles volume concentration, ρ_f is the density of the base fluid and ρ_p is the density of the nanoparticles.
The specific heat is calculated from Xuan and Roetzel [1] as following:

$$(\rho cp)_{nf} = (1-\varphi)(\rho cp)_f + \varphi(\rho cp)_p \tag{9}$$

An alternative formula for calculating the thermal conductivity was introduced by Yu and Choi [10], which is expressed in the following form

$$K_{nf} = K_f \frac{K_p + 2K_f - 2\varphi(K_f - K_p)}{K_p + 2K_f + 2\varphi(K_f - K_p)} \tag{10}$$

where K_{nf} is thermal conductivity of the nanofluid, K_p is thermal conductivity of the nanoparticle and K_f is the base fluid thermal conductivity.
The viscosity of the nanofluid as per the well-known Einstein equation for calculating viscosity, is defined as follows

$$\mu_{nf} = (1+2.5\varphi)\mu_f \tag{11}$$

Where μ_{nf} f is the Nano fluid viscosity and μ_f is the base fluid viscosity.

3. SYSTEM DEVELOPMENT

3.1 Experimental Model

Calculation of heat transfer coefficient

To obtain heat transfer coefficient and corresponding Nusseltnumber, the following procedure has been performed. According to Newton's cooling law

$$q = m_{air}c_{pair}(T_{air,out} - T_{air,in}) = m_{nf}c_{pnf}($$

$$T_{nf,in} - T_{nf,out})$$

Heat transfer rate can be calculated as follows:

$$Q = hA\Delta T = hA(T_b - T_w)$$

Heat transfer rate can be calculated as follows:

$$Q = mc_p\Delta T = mc_p(T_{in} - T_{out})$$

Regarding the equality of Q in the above equations

$$Nu_{exp} = \frac{h_{exp} \times D_h}{k_{nf}} = \frac{mc_p(T_{in} - T_{out})D}{A(T_b - T_w)k_{nf}}$$

Nu is average Nusselt number for the whole radiator, m is mass flowrate which is the product of density and volume flow rate of fluid, Cp is fluid specific heat capacity, A is peripheral area of radiator tubes, Tin and Tout are inlet and outlet temperatures, Tb is bulk temperature which was assumed to be the average values of inlet and outlet temperature of the fluid moving through the radiator, and Tw is tube wall temperature which is the mean value by two surface thermocouples. In this equation, k is fluid thermal conductivity and day is hydraulic diameter of the tube. It should also be mentioned that all the physical properties were calculated at fluid bulk temperature

Correlations for Nusselt number estimation for single phase fluids

DittuseBoelter Correlations

$$Nu = 0.023\mathrm{Re}^{0.8}\mathrm{Pr}^{0.3}$$

Gnielinski correlation for single phase fluid

$$Nu = \frac{\left(\frac{f}{2}\right)(Re - 1000)Pr}{1 + 12.7\left(\frac{f}{2}\right)^{0.5}\left(Pr^{\frac{2}{3}} - 1\right)}$$

$$f = (0.79 lnRe - 1.69)^{-2}$$

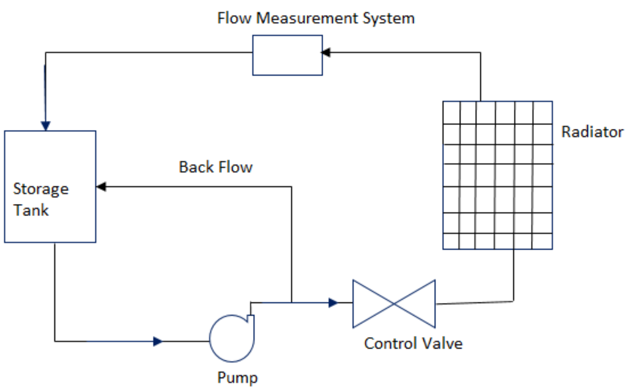


Figure.1 schematic diagram of experimental set-up

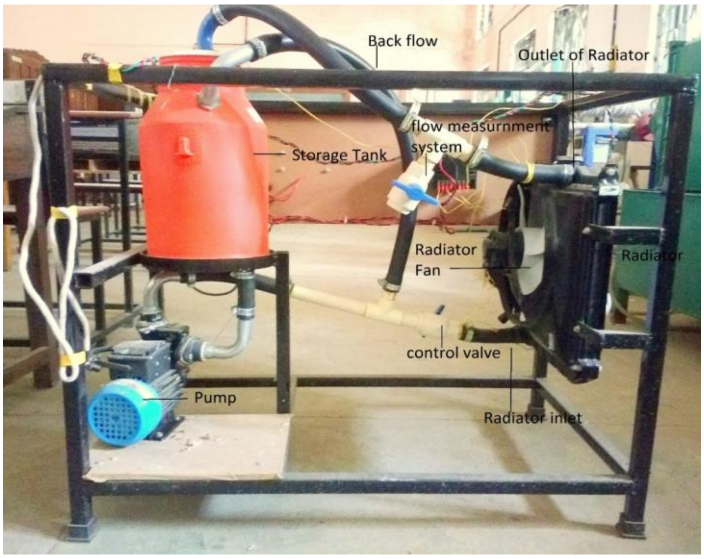


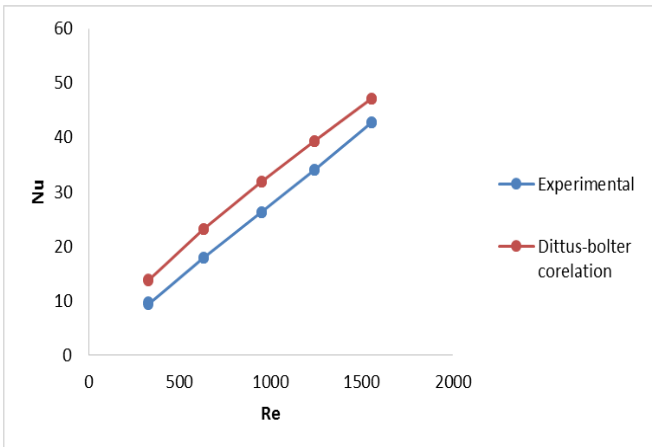
Figure.2 Actual setup

RESULTS AND DISCUSSION:

4.1 Data Validation

A thorough check of the instruments and the test set-up was followed by experimentation on Radiator. The average values of Nusselt number was determined. These values are compared with the values obtained from the standard correlation with Dittus-Boelter equation for Nusselt number in case of Radiator. The standard equations for Nusselt number is given as:

$$Nu = 0.023\mathrm{Re}^{0.8}\mathrm{Pr}^{0.3}$$

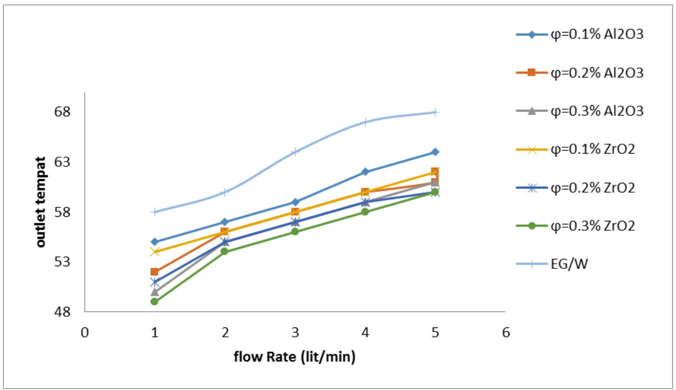


Graph:1 Nusselt number Vs Reynolds Number

Experimental calculated value, Fig. 4.1.1 shows the validation of Nusselt number over the radiator equation. Deviation of ±11 % is seen in the case of Nusselt number. This small deviation in experimental result allows proceeding with the experimentation

Effect on Radiator output temperature

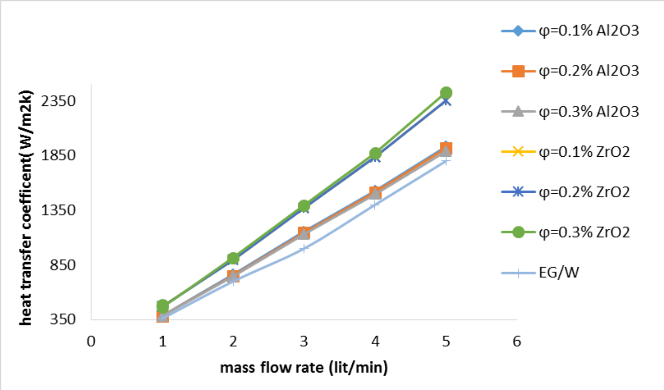
In order to check In order to check the effect of nanofluid on the outlet temperature of the radiator, the figure of radiator outlet temperatures, Tout, as a function of fluid volume flow rate circulating in the radiator, is given shown in Figure 4. As can be seen, adding nanoparticles to base fluid decreased radiator outlet temperature. It should be said that, for every cooling system, in an equal mass flow rate, the more reduction in working fluid temperature indicated better the thermal performance of the cooling system. Moreover, Figure 4 shows the decrease in cooling rate to increase in the volume flow rate circulating in the radiator. It may be because, increase in volume flow rate caused increase in velocity of the fluid. Therefore, the fluid had less time for connecting with air which comes from the fan and so the outlet temperature increased. It should be noted that all the data in Figure were obtained when the fluid inlet temperature of the radiator was 90 °C



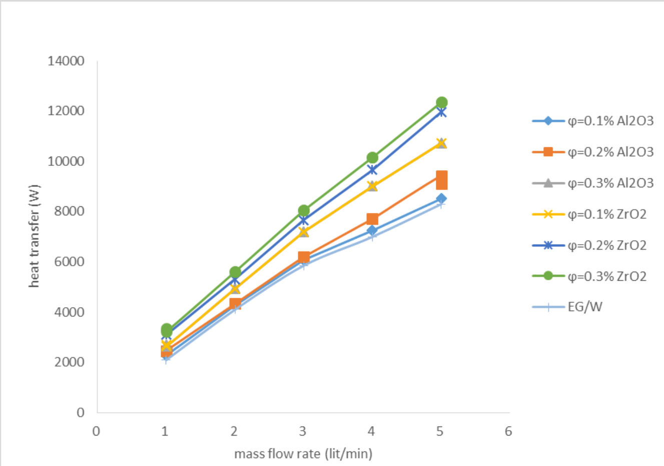
Graph.2 Flow rate Vs. Radiator outlet

Effect on heat transfer coefficient

In this study, the nanofluid was used at different Al_2O_3 and ZrO_2concentrations, that is, 0.1, 0.2, 0.3, vol% and in different flow rates of 1, 2, 3, 4, and 5 lit/min wereimplemented as the working fluids. , the experiment was done at constant inlet temperatures in order to study the effect of temperature on thermal performance of the radiator. Figure 3 shows the Nu(exp) numbers as a function of Re number at different concentrations of nanofluid. As can be seen in Figure 3, Nu number increased with the increase in Re number and nanoparticle concentrations. In high flow rates the dispersion effect and chaotic movement of the nanoparticles intensified the mixing fluctuations and increased heat transfer coefficient. Also, increasing the concentration nanoparticles intensified the mechanisms responsible for the enhanced heat transfer. If we compare two nanofluid for same concentration of Al_2O_3 and ZrO_2. ZrO_2have greater nussult and reynold number so have greater heat transfer coefficient and heat transfer.



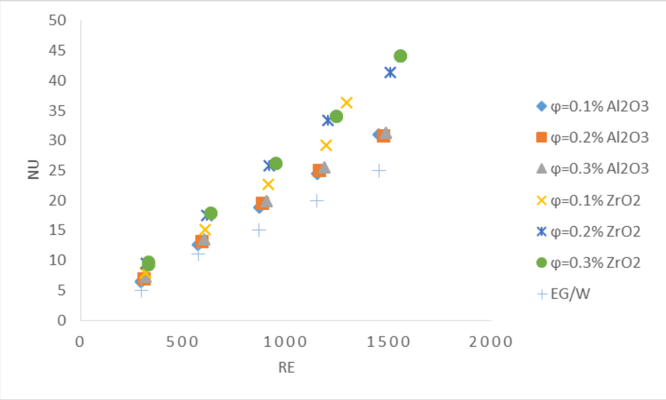
Graph 3 Mass flow rate Vs. Heat transfer coefficient



Graph 4 Mass flow rate Vs. Total Heat transfer

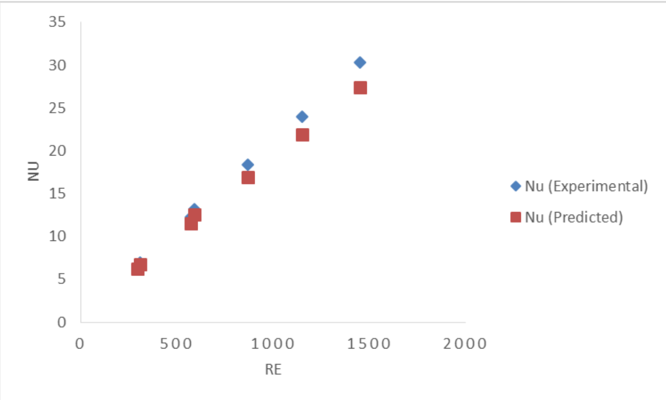
Nusselt number Vs Reynolds Number

Fig. compares the variation of Nusselt number for nanofluids with various volume concentrations as a function of Reynolds number at radiator inlet temperature of 90 °C. It is clearly observed from the figure, that the Nusselt number increases with increase of particle concentration and Reynolds number. The enhancement of 20% was obtained for 0.3% volume concentration of Al_2O_3nanofluid compared with the 0.1% volume concentration of Al_2O_3 nanofluid. The enhancement of 31.25% was obtained for 0.3% volume concentration of ZrO_2 nanofluid compared with the 0.1% volume concentration of ZrO_2 nanofluid. If we compare these two nanofluid we get enhancement 16.2% of heat transfer. These higher heat transfer coefficients obtained by using nanofluid instead of base fluid allow the working fluid in the automobile radiator to be cooler.



Graph 5 : Nusselt number Vs Reynolds Number

The calculated values of Nusselt number from developed correlation have been compared with the experimental values as shown in Graph . It has been found that these values are reasonably good as maximum deviation found within ±10%.



Graph 6: Nusselt number Vs Reynolds Number

5. CONCLUSIONS

Experimental heat transfer coefficients in the automobile radiator have been measured with two distinct working liquids: Al_2O_3 EG/W based nanofluid and ZrO_2 EG/W based nanofluid and at different concentrations and the following conclusions were made. enhance the heat transfer rate of the automobile radiator. The degree of the heat transfer enhancement depends on the amount of nanoparticle added to base fluid the enhancement of 20% was obtained for 0.3% volume concentration of Al_2O_3nanofluid compared with the 0.1% volume concentration of Al_2O_3 nanofluid. The presence of ZrO_2 nanoparticle in EG/W can enhance the heat transfer rate of the automobile radiator. The degree of the heat transfer enhancement depends on the amount of nanoparticle added to base fluid the enhancement of 31.25% was obtained for 0.3% volume concentration of ZrO_2 nanofluid compared with the 0.1% volume concentration of ZrO_2 nanofluid.

If we compare these two nanofluid we get enhancement 16.2% of heat transfer. These higher heat transfer coefficients obtained by using nanofluid instead of base fluid allow the working fluid in the automobile radiator to be.
Increasing the flow rate of working fluid (or equally Re) enhances the heat transfer coefficient for both Al_2O_3 ZrO_2 nanoparticle EG/W based nanofluids

Nusselt number of nanofluid was increased with Reynolds number of nanofluid and nanoparticles volume concentration. For 90°C inlet fluid temperature, Nusselt number was higher than that of nanofluid by 33 % of ZrO_2 than Al_2O_3 for 0.1% and 18% for 0.2% 14% for 0.3% concentration of nanofluid, respectively

Thermal conductivity of base fluid was enhanced significantly with addition of nanoparticles. Also thermal conductivity observed to be a strong function of temperature. Enhancement of 7% in thermal conductivity was seen at 70°C while it was 5% at 80°C for Al_2O_3. From 0.1% to 0.3% of volumetric concentration Enhancement of 7% in thermal conductivity was seen at 70°C while it was 5% at 80°C. For ZrO_2 From 0.1% to 0.3% of volumetric concentration Density of nanofluid was slightly higher than the base fluid. With increasing temperature density was decreased. Density was decreased by 0.2% as temperature increased from 70°C to 80°C.for Al_2O_3. 0.1% with increasing temperature density was decreased. Density was decreased by 0.2% as temperature increased from 70°C to 80°C.for ZrO_2 0.1% Viscosity of nanofluid was slightly higher than that of base fluid, but it was decreased significantly with temperature. Viscosity of nanofluid was decreased up to 17% as temperature rises from 70°C to 80°C For Al_2O_3. ZrO_2 nanofluids. The specific heat of Al_2O_3 and ZrO_2 nanofluids decreases with increase in the volume concentration of nanofluids. Specific heat of nanofluids also increases with increase in the nanofluid temperature and the same can be observed.

REFERENCES

[1] Xuan, Y., & Li, Q. (2000). Heat transfer enhancement of nanofluids. International Journal of heat and fluid flow, 21(1), 58-64.

[2] Kakac, S., & Pramuanjaroenkij, A. (2009). Review of convective heat transfer enhancement with nanofluids. International Journal of Heat and Mass Transfer, 52(13), 3187-3196.

[3] Vajjha, R. S., Das, D. K., & Namburu, P. K. (2010). Numerical study of fluid dynamic and heat transfer performance of Al 2 O 3 and CuO nanofluids in the flat tubes of a radiator. International Journal of Heat and fluid flow, 31(4), 613-621.

[4] Peyghambarzadeh, S. M., Hashemabadi, S. H., Jamnani, M. S., & Hoseini, S. M.(2011). Improving the cooling performance of automobile radiator with Al 2 O 3/water

nanofluid. Applied thermal engineering, 31(10), 1833-1838.

[5] Naraki, M., Peyghambarzadeh, S. M., Hashemabadi, S. H., & Vermahmoudi, Y.(2013). Parametric study of overall heat transfer coefficient of CuO/water nanofluids in a car radiator. International Journal of Thermal Sciences, 66, 82-90.

[6] Leong, K. Y., Saidur, R., Kazi, S. N., & Mamun, A. H. (2010). Performance investigation of an automotive car radiator operated with nanofluid-based coolants (nanofluid as a coolant in a radiator). Applied Thermal Engineering, 30(17), 2685-2692.

[7] Ali, F. M., & Yunus, W. M. M. (2011). Study of the effect of volume fraction concentration and particle materials on thermal conductivity and thermal diffusivity of nanofluids. Japanese Journal of Applied Physics, 50(8R), 085201.

[8] Nieh, H. M., Teng, T. P., & Yu, C. C. (2014). Enhanced heat dissipation of a radiator using oxide nano-coolant. International Journal of Thermal Sciences, 77, 252-261.

[9] Das, S. K., Putra, N., Thiesen, P., & Roetzel, W. (2003). Temperature dependence of thermal conductivity enhancement for nanofluids. Journal of Heat Transfer, 125(4), 567-574.

[10] Eastman, J. A., Choi, S. U. S., Li, S., Yu, W., & Thompson, L. J. (2001). Anomalously increased effective thermal conductivities of ethylene glycol-based nanofluids containing copper nanoparticles. Applied physics letters, 78(6), 718-720.

[11] Nassan, T. H., Heris, S. Z., & Noie, S. H. (2010). A comparison of experimental heat
Transfer characteristics for Al 2 O 3/water and CuO/water nanofluids in square crosssection
Duct. International Communications in Heat and Mass Transfer, 37(7), 924-928.

[12] Heris, S. Z., Esfahany, M. N., & Etemad, S. G. (2007). Experimental investigation of heat transfer of Al 2 O 3/water nanofluid in circular tube. International Journal of Heat and Fluid Flow, 28(2), 203-210.

[13] Huminic, G., & Huminic, A. (2012). The cooling performances evaluation of nanofluids in a compact heat exchanger (No. 2012-01-1045). SAE Technical Paper

[14] Chavan, D., & Pies, A. T. (2014). Performance investigation of an automotive car radiator operated with nanofluid as a coolant. Journal of Thermal Science and Engineering Applications, 6(2), 021010.

[15] Arani, A. A., & Amani, J. (2012). Experimental study on the effect of TiO 2–water nanofluid on heat transfer and pressure drop. Experimental Thermal and Fluid Science, 42, 107-115.

[16] Davarnejad, R., & Ardehali, R. M. (2013). Modeling of TiO2-water Nanofluid Effect on Heat Transfer and Pressure Drop. International Journal of Engineering-Transactions B: Applications, 27(2), 195.

[17] Vermahmoudi, Y., Peyghambarzadeh, S. M., Hashemabadi, S. H., & Naraki, M. (2014). Experimental investigation on heat transfer performance of/water nanofluid in an air-finned heat exchanger. European Journal of Mechanics-B/Fluids, 44, 32-41.

[18] Heris, S. Z., Shokrgozar, M., Poorpharhang, S., Shanbedi, M., & Noie, S. H. (2014).Experimental study of heat transfer of a car radiator with CuO/ethylene glycol-water as avcoolant. Journal of Dispersion Science and Technology, 35(5), 677-684.

[19] Ghanbarali S., Mohammadhadi H. & Hamed J. (2014). Analysis of Thermal Performance of a Car Radiator Employing Nanofluid. International Journal of Mechanical Engineering