# Enhancement of Heat Transfer Coefficient in an Automobile Radiator Using Ethylene Glycol Water Based ZnoNanofluids-An Experimental Investigation

**M. Chandra Sekhara Reddy**

***Abstract*: A novel enhancement scheme of heat transfer coefficient is demonstrated experimentally using ZnO nanofluid flowing in a commercially available car radiator under turbulent flow conditions. In the present investigation ZnO nanofluidis prepared by mixing ethylene glycol and distilled water in the ratio of 40: 80 percent by volume. The heat transfer experiments were conducted in the range of volume concentrations from 0.01% to 0.035 % (by volume) and in the range of Reynolds number from 3000 to 10000. Experimental studies were conducted with base fluid (40:80% ethylene glycol and water mixture) followed by nanofluids. The experimental results express the increased fluid-circulated rate which can be enhanced based on performance of heat transfer while the temperature ranges of inlet fluid to radiator as trivial affects. Moreover, the usage of nano-fluids with very low concentrations can improves the efficiency of heat transfer up to 40% over the base fluids. Results are illustrated based on several factor such as Nusselt number, non-dimensional heat transfer coefficient, as a function of Reynolds number for several concentrations of nano-fluids.***

***Index Terms*: Automotive cooling system, Heat Transfer Enhancement, Nanofluids, Car radiator**

## I. INTRODUCTION

In most of the industries, fluids such as engine-oil, water, propylene glycol, ethylene glycol, and transformer oil etc. are widely used in heat transfer equipment. The effectiveness of these equipments largely dependence based on thermal-conductivity of working fluid. The thermal conductivity of these fluids may be enhanced by dispersing nanosize solid particles. Choi [1] successfully prepared a fluid (called as nanofluid) by dispersing nano-meter sized particles and achieved better thermal conductivity. In order to use such nanofluids in thermal devices, its heat transfer characteristics are to be investigated. Researcher have observed heat transfer enhancement while using nanofluids compared to its base fluid. Hwang et al. [2] observed 8% heat transfer enhancement for 0.03% volume concentration of $Al_2O_3$-water nanofluid flow in tube under laminar flow conditions. Fotukian and Esfahany [3] observed heat transfer enhancement for $Al_2O_3$-water nanofluid in turbulent flow compared to its base fluid. Yu et al. [4] obtained 57% and 106% heat transfer enhancement for 1.0% and 2.0% volume concentration of $Al_2O_3$-ethylene glycol (45%) and water (55%) nanofluid at a Reynolds number of 2000, respectively. Pak and Cho [5] achieved 75% heat transfer enhancement for a 2.78% volume concentration of $Al_2O_3$-water nanofluid in turbulent flow. Hojjat et al. [6] observed heat transfer enhancements of 68%, 67%, and 71% for $Al_2O_3$, $TiO_2$ and CuO nanofluids at 1.5% volume concentration, respectively. Nguyen et al. [7] found heat transfer enhancement of 40% for 6.8% volume concentration of $Al_2O_3$-water nanofluid in radiator type heat exchanger. Peyghambarzadeh et al. [8] obtained 45% heat transfer enhancement for $Al_2O_3$-water nanofluid in an automobile radiator compared to pure water. Jung et al. [9] observed convective heat transfer enhancement of 32% for 1.8% volume concentration of $Al_2O_3$nanofluid. Ho et al. [10] obtained heat transfer enhancement of 51% for 2.0% volume concentration of $Al_2O_3$nanofluid. Lai et al. [11] observed Nusselt number enhancement of 8% at 1.0% volume concentration of $Al_2O_3$-water nanofluid.The present work deals with the estimation of CuO nanofluid flow in a car radiator under turbulent flow conditions. CuO nanofluids were prepared using ethylene glycol and water mixture. Commercially available car radiator was used for the study. The volume concentrations of 0.02%, 0.04% and 0.06% were used in this study in the range of 3000 to 10000 as numbers of Reynolds series.

## II. PREPARATION OF ZNO NANOFLUID

The preparation of nano-fluid in proposed work depends on 60% of water and 40% of ethylene glycol with several concentrations of ZnO nano-particles. These particles are attained from [12] In USA, the chemicals industry named as Sigma-Aldrich, with average particle diameters of 21 nm. The concentration of these nano-particles is pre-requisite for known percentage of estimated volumetric specifications from Eqn. (1).

$$\varphi = \left[\frac{\frac{w_{Particle}}{\rho_{Particle}}}{\frac{w_{Particle}}{\rho_{Particle}}+\frac{w_{Fluid}}{\rho_{Fluid}}}\right] \times 100 \qquad (1)$$

Nanofluids were prepared by taking 12 liters of ethylene glycol and water mixture by dispersing required quantity of ZnO nanoparticles. A Cetyl-Trimethyl Ammonium Bromide (C-TAB) and surfactant oleic acid was employed for stable operation of respective particles. The basic properties of ZnO nano-particles and base fluids at a temperature range of 30ºC are illustrated in Table.1. The several physical properties of thermo nano-fluids are acquired based on variant mixture of solid-fluids. Cho & Pak [5] mathematical formations are generally used for approximation of specific heat as well as viscosity density; and conductivity is illustrated as below.

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**M. Chandra Sekhara Reddy**, Department of Mechanical Engineering, SV College of Engineering, Karkamadi Road, Tirupati, Andhra Pradesh, INDIA


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**Table 1: Base fluid, ZnO nanoparticles properties at 30°C**

| Material | Density, kg/m³ | Viscosity, mPa sec | Specific heat, J/kg K | Thermal conductivity, W/m K |
|---|---|---|---|---|
| **ZnO** | 993.1 | ------ | 4177.9 | 0.6281 |
| **Water** | 1000 | 0.000894 | 4184 | 0.6130 |
| **Air** | 1.1839 | 0.000018 | 1005 | 0.024 |
| **20:80% EG/W** | 1055.39 | 0.002260 | 3502 | 0.4120 |

$$\rho_{nf} = \varphi\rho_{p} + (1-\varphi)\rho_{bf} \quad (2)$$

$$C_{p_{nf}} = (1-\varphi)\left(\frac{\rho_{bf}}{\rho_{nf}}\right)C_{p_{bf}} + \varphi\left(\frac{\rho_{p}}{\rho_{nf}}\right)C_{p_{p}} \quad (3)$$

$$k_{nf} = \frac{k_p+(n-1)k_{bf}-\varphi(n-1)(k_{bf}-k_p)}{k_p+(n-1)k_{bf}+\varphi(n-1)(k_{bf}-k_p)} \quad (4)$$

$$\mu_{nf} = \mu_{bf}(1+2.5\varphi) \quad (5)$$

## III. EXPERIMENTAL SET-UP & PROCEDURE

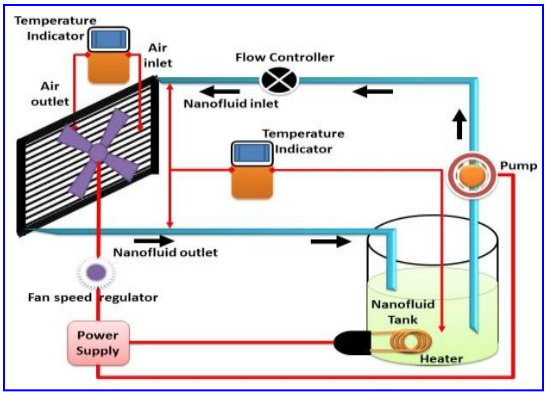


**Fig. 1 Schematic representation of experimental setup**

**Fig. 2 Experimental setup**

The experimental test-rig was implemented by utilizing commercial accessible car radiator. It comprises of coolant storage tank, an industrial heater with a high range temperature pump, a fan, radiator, anemometer, thermocouples, and temperature indicator for measuring the temperature ranges. The experimental prototype set-up was illustrated in Fig.1 as well as implemented is illustrated in Fig.2. The front side and back side of an experimental setup are shown in Fig. 3 and Fig. 4.

**Fig. 3 Front view of test rig**

**Fig. 4 Rear view of test rig**

## IV. DATA ABSTRACTION

### A. Co-efficient Approximation of heat-transfer

The coefficient of approximated heat- transfer in radiator is described for the coolant with an air-flowed over the radiator fins. The heat transfer ranges for coolant and the air is approximated as;

$$Q = hA\Delta T = hA(T_b - T_w) \quad (6)$$

Heat transfer rate can be calculated as follows

$$Q = mC_p\Delta T = mC_p(T_{in} - T_{out}) \quad (7)$$

Regarding the equality of Q in above equations

$$Nu_{Exp} = \frac{h_{Exp}\times D_h}{k} = \frac{mC_p(T_{in}-T_{out})}{C_p(T_{in}-T_{out})} \quad (8)$$

Where, Nu represents the average value of Nusselt number for complete radiator, m represent the rate of mass-flow range which is the product of volume & density flow rate of fluid $C_p$ based on specific heat range. A is peripheral area of radiator tubes, $T_{in}$ represented as inlet temperature and $T_{out}$ represented as outlet temperatures, $T_b$ is the bulk temperatures which is assumed based on inlet & outlet temperatures of moving fluid through radiator and $T_w$ is the tube-wall temperatures which should be mean-value of two thermo-couple surfaces, k represents the conductivity of fluid thermals and $D_h$ is hydraulic diameter of tube. It should be validated based on physical parameters at bulk fluid temperatures.

### B. Nusselt number for single-phase fluids

Gnielinski [13] correlation:

$$Nu = \frac{\left(\frac{f}{2}\right)(Re-1000)Pr}{1+12.7\left(\frac{f}{2}\right)^{0.5}\left(Pr^{\frac{2}{3}}-1\right)} \qquad (9)$$

$$f = (1.58\, ln(Re) - 3.82)^{-2};\ 2300 < Re < 5\times10^{6};\ 0.5 < Pr < 2000$$

Tam and Ghajar [14] correlation:

$$Nu = 0.023\, Re^{0.8} Pr^{0.385}\left(\frac{L}{D}\right)^{-0.0054}\left(\frac{\mu_b}{\mu_w}\right)^{0.14} \qquad (10)$$

$$3 \le \frac{L}{D} \le 192;\ 7000 \le Re \le 49000;\ 4 \le Pr \le 34;\ 1.1 \le \frac{\mu_b}{\mu_w} \le 1.7$$

## V. RESULTS & DISCUSSION

### A. Base fluid in radiator

The analysis is conducted when the use of nano-fluids in radiator, some experimental system verifies with a base fluid (40:80% EG/W) so as to validate the reliability and accuracy of experimental modules. Fig.5 represents the experimental desired results with a measurement of constant inlet-temperature ranges as 35ºC, as apprehend the increment of Nusselt number results the significant function of Reynolds series too. As well as, the comparative analysis is carried based on data furnishing and two-reputed empirical standard values of Gnielinski in [13] & Ghajar & Tam [14]. In verified Reynolds number range, increased 25% deviation is observed over the current experimental data and mathematical values considered from various literature reviews. Fig. 6 shows results of experiment for different t inlet temperature of water. As expected as volume flow rate and temperature of water increases Nusselt number also increases. Fig. 7 shows results of experimental for different inlet temperature of EG. /Water. As expected as volume flow rate and temperature of EG/Water increases Nussle number also increases.

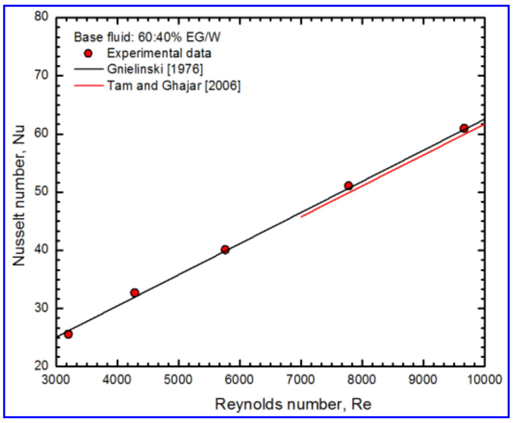


**Fig. 5 Comaprsion of Nusselt series of base fluid with published literature**

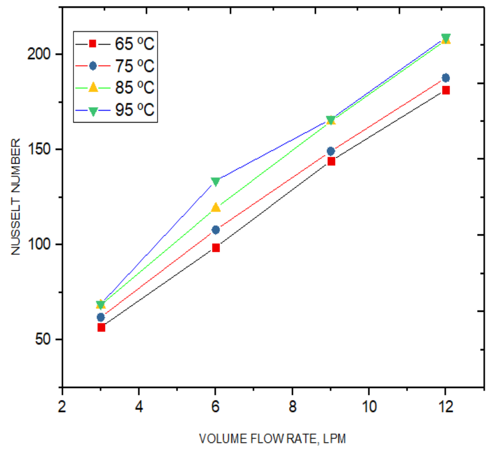


**Fig. 6 Variation of experimental Nusselt series as the basis of flow rate at several temperature of water**

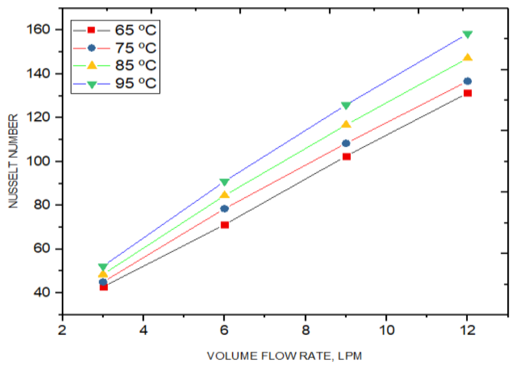


**Fig. 7 Variation of experimental Nusselt series as the basis of flow rate at several temperature for various temperatures of 40:60 % EG/W fluid**

### B. Nanofluid in radiator

The nano-fluids of several concentrations of ZnO nano-fluid with flow ranges of 3; 6; 9 and 12 1/min were employed in a car radiator for estimation of coefficient of heat transfer. It is very prominent to describe the forms of implementation view for each cooling system at same mass flow rates, greater minimization in working-fluid temperatures which specifies a good thermal characterization of cooling scheme. Fig.8 depicts the improvements in heat transfer due to replacement of base fluids with a non-fluid in any automobile radiators at several flow-rates. From Fig.8, Nusselt number for all concentrations is increased for associated increments in flow rate of fluids and its consequent Reynolds number. As well as, the concentration of nano-particles plays a key role in heat transfer efficiency. It can be seen as improvements in coefficients of heat transfer which is linear to concentration of nano-particles in respective field. The addition of 0.035% ZnO nano-particles by volume into base fluids at a temperature ranges of 70ºC, with the increase of 10.42% as measured compared to the base fluid.


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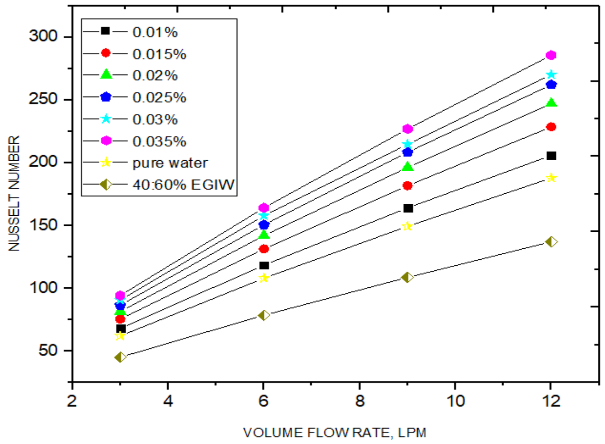


**Fig.8 Variation of experimental Nusselt number as a function of volume flow rate for different volume concentration of EG/ W based ZnO Nanofluid at 70$^0$C**

The thermo-physical properties of nano-fluids are estimated based on respective equations which are slightly different over the base fluids. The thermal & density conductivity is increased with a specific heat which is slightly decreased over the base fluids. When the viscosity is increased more, this is unfavourable in the enhancements of heat transfer. Moreover, these variations are too small (4%) to describe the heat transfer enhancements up to 10.42% as per study. Several researchers has been explored in fact of Brownian motion as one of the significant factor for enhancing heat transfer. The influence of nano-particles and their respective random motion within the base fluids may causes the thickness of thermal boundary layer to minimize the various contributions to such heat transfer enhancements. These random movements of ultra-fine particles are created with a slip-velocity in between the solid particles as a fluid medium.

From figure, Nussle number maximizes when the increment in particle concentration and Reynolds number. The enhancements of 10.42% were attained for 0.06% volume concentrations of ZnO nano-fluids compared to the base fluids. At very low volume concentrations of 0.01%, the improvement is 1.63%. These small variations in Nu may be attributed based on effect of temperatures on physical properties. These coefficients of high-range heat values are attained by using nano-fluids in the place of base fluids which allows the working fluid in radiator to be dominantly cooler. The addition of nano-particles to respective coolant base fluids has high potential to enhance heavy-duty automobile engine cooling ranges to a fewer size of cooling schemes. Smaller cooling schemes results in very lighter and smaller radiators, which interns benefits almost every aspect of vehicle performance and leads to increased fuel economy.

## VI. CONCLUSION

In this paper, experimental prototype heat transfer coefficients in a commercial automobile radiators has been validated for 40:60% EG/W based ZnO nano-fluids at several concentrations and temperatures. The presence of ZnO nano-particles in the range of 0.01% to 0.035% based on volume in 40:60% can improve the rate of heat transfer of automobile radiator. The range of heat transfer enhancement totally depends on amount of nano-particles which is added to base fluids. At the concentration levels of 0.035%, the improvements in heat transfer were measured to be 10.02% over the base fluids. By increasing the flow-rate of working fluids ($3000 \leq Re \leq 10000$) improves the coefficient of heat transfer for considerably nano-fluids. The variations of fluid inlet temperatures didn't represent the important effect on thermal performance of radiator in the range of observation.

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