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Influence of Ethylene Glycol- Water Mixture Ratio on Al_2o_3 Nanofluid for Turbulent Flow Heat Transfer Characteristics

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Abstract: *In this present study, a numerical analysis is developed to evaluate the base fluid and mixture ratios influencing on the heat transfer coefficient and flow characteristics of nanofluids in the turbulent range of Reynolds number employing in the investigation. This analysis formulated with the help of Eddy diffusivity equation of Van Driest. The properties of Aluminum dioxide (Al_2O_3) nanofluid with a low fluid Ethylene Glycol (EG) -Water (W) mixture of 60:40 ratio is employed in a wide range of concentrations of 0.5% to 2% on a bulk temperature range of 20^{oC} to 90^{oC}.The influences of density and temperature effect on heat transfer coefficients are determined. The maximum concentrations for which the heat transfer enhancement can attain are estimated to be 1.5% and 2.0% at 30^{oC} and 80^{oC} respectively under turbulent range. The temperature effect and concentration ratios are influencing on a heat transfer coefficient of nanofluids were analyzed and observed that the heat transfer coefficients enhances with concentration and decreases with temperature.*

Keywords: Aluminum dioxide, ethylene glycol, Nanofluids, properties of nanofluids and turbulent region.

I. INTRODUCTION

In any automobile device, the cooling system is considered a crucial role to act as an efficient condition. Based on the above context to cool the engine continuously, then the engine parts are with the help of base fluid and cooling agents. In an automotive engine component’s heat must be removed from the elements to the cooling medium. However, conventional fluids are very poor to extract the heat from ingredients. This is a limitation for a traditional liquid to improve the heat transfer is the aim of the present investigation. To overcome the above problem, the nanofluids are used in a base fluid to increase the heat transfer coefficients.

Nanofluids are nothing but the dispersions of nanoparticles in liquids uniformly with metal or metal oxide nanometer-sized spherical particles. Nano particles studied (Ahuja, 1975; and A. E. Bergles, 1985) based on his studies to improve the higher heat transfer rates, the application of nanotechnology have been employed successfully. Recent trends suggest that using nanofluids dispersed in EG and water mixture as the base liquid has proved to be beneficial for low-temperature applications (Vajjha et al., 2009; Vajjha and Das 2009; Vajjha and Das 2009) have presented various experiments to find the properties of Al_2O_3 CuO, SiO_2 and ZnO nanofluids. Namburu et al. (2007) have determined the properties of CuO nanofluids. Sundar et al. (2014) have investigated the improvement of thermal properties of Nanodiamondfluids with base fluids. Sahoo et al. (2009, 2012) carried out experiments with SiO_2 and Al_2O_3 nanofluids to find the properties of nanofluids. Kulkarni et al. (2008) performed experiments for the estimation of viscosity with SiO_2nanofluid. Vajjha et al. (2010) calculated the nanofluids characteristic with forced convection heat transfer coefficients in the turbulent region as a condition and with Al_2O_3 (45nm), CuO (29nm), and SiO_2 (20, 50, 100nm) for a maximum concentration of 10.0% for temperature varying from 20 to 90^{oC} in base liquid EG-water mixture in 60:40 ratio. They have reported the enhancement of 81.74% in heat transfer for Al_2O_3 nanofluid at a concentration of 10%.

To define the nanofluid heat transfer constant for a combination of base liquid and EG-water mixture of 60:40 ratios are used for experiments. The heat transfer enhancement reported by Vajjha et al. (2010) is 82% with Al_2O_3 nanofluid while Kulkarni et al. (2008) said only 16% with SiO_2 nanofluid at the same volume concentration of 10%. Any author has not presented the heat transfer enhancement for Al_2O_3 nanofluids in the turbulent region and hence numerical analysis is used as a reference for determining the properties of nanofluids. Usri et al. (2015a, 2015b) experiments conducted under the turbulent region for the estimation of properties of nanofluids such as Al_2O_3 (13nm) and TiO_2 (50nm) for a maximum concentration of 1.5% for temperature varying between 50-70^{oC}. They reported the enhancement of 14.6% in heat transfer for Al_2O_3 nanofluid at a level of 0.6%, whereas the enhancement for TiO_2 was observed to be 33.9% with nanofluid at 1.5% volume concentration.

II. PROPERTIES OF EG-WATER 60:40 RATIO

The properties of nanofluids are EG-W mixture in 60:40 ratios such as density, specific heat, viscosity and thermal conductivity of mixture were established through regression equations from the literature (Ashrae 2005). EG-W base fluid properties were obtained from regression equations

$$\rho = 1066.79734 - 0.3071T - 0.00243T_{nf}^{2} \quad (1)$$

$$Cp_{bf} = 3401.21248 + 3.3443T_{nf} + 9.04977 \times 10^{-5}\, T_{nf}^{2} \quad (2)$$

$$K_{bf} = 0.39441 + 0.00112T_{nf} - 5.00323 \times 10^{-6}\, T_{nf}^{2} \quad (3)$$

$$M_{bf} = 0.00492 - 1.24056 \times 10^{-4}\, T + 1.35632 \times \times 10^{-6}\, T^{2} - 5.56393 \times 10^{-9}\, T_{nf}^{2} \quad (4)$$

III. NANOFLUID PROPERTIES

The nanofluid properties such as thermal conductivity, specific heat and density of fluids are calculated for mixtures as follows:

$$\rho_{nf} = (\phi p/100)\rho p + (1 - \phi/100)\rho_{bf} \quad (5)$$

A correlation was established based on thermal conductivity and it is assumed that the nanofluid thermal conductivity growths linearly with a particle concentrations increase. Sundar et al. (2014) given by,

$$k_{nf} = k_{bf}(A + B\phi) \quad (6)$$

Where, A = 1.0806 and B = 10.164. Similarly, viscosity correlation was developed considering the nanofluid viscosity to increase exponentially with the volume concentration Sundar et al. (2014) given by,

$$M_{nf} = M_{bf}\, Ae^{B\varphi} \quad (7)$$

Where A = 0.9299 and B = 67.43.

The experimental values of forced convection nanofluid Nusselt number in base liquid EG-water mixture in 60:40 ratios used for regression given by Eqs. (8). Employing the data of Usri et al. (2015).

$$Nu = 0.0257\, Re^{0.8}\, Pr_{bf}^{0.4}\, (1 + Pr_{nf})^{-0.04297}\, (1 + \phi/100)^{5.205} \quad (8)$$

IV. RESULTS AND DISCUSSION

The base fluid and nanofluid properties are found concerning heat transfer coefficients are validated with the experimental data. The experimental data of base liquid and-W base fluid of thermal conductivities compared based on Eqs. (3). The EG-W base liquid determined using the regression investigation is kept in comparison with the Ashrae data (2005) and is observed that to be an agreement with a deviation of less than 1%.

4.1Thermal conductivity

The thermal conductivity of EG-W based nanofluids and water-based nanofluids are predicted using equations given by Sharma et al. (2016). Comparisons are made for the thermal conductivity of Al_2O_3 nanoparticles distributed in a base fluid and EG-W 60:40 as shown in Fig.1. As the temperature (T_{nf}) increases, then the thermal conductivity (K_{nf}) of nanofluids increased for all values of ϕ. While increasing in the volumefraction (ϕ) of nanofluids then the thermal conductivity (K_{nf}) also increases simultationly. It is clearly indicated that the density of nanofluid increases thermal conductivity also increased. It is quite evident that nanofluid concentration increases the thermal conductivity also increases. It is finding out that, the thermal conductivity of nanofluid increases with respect temperature also.

4.2 Nusselt Number

Heat transfer coefficients predicted from the formulated Nusselt equations of Sharma et al. (2010,2016). In Fig. 2, Reynolds number (Re) increases, then the Nusselt number (Ns) also increased for all values of ϕ. The increasing the volumefraction (ϕ) then decreases the Nusselt number (Ns). It is clearly indicated that the density of nano particles increases, then the Ns

decreased. The nanoparticle concentration increases in a base fluid and finds the Nusselt number concerning Reynolds number increases, then the Nusselt number decreases while increase concentration. This effect, as shown in Fig. 2.

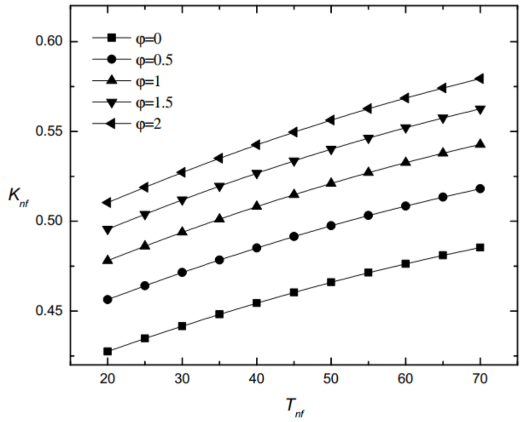

Figure 1: Comparison of nanofluid concentration and temperature of the fluid.

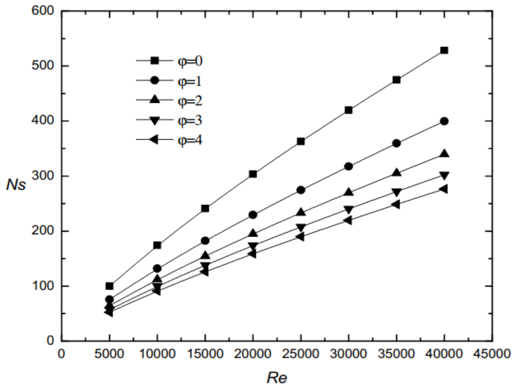

Figure 2: Comparison of Nusselt Number for Al_2O3 Nanofluids

4.3 Viscosity

The viscosity of Al_2O_3 nanoparticles comparisons was made between the base fluid and EG-Wnanofluids as shown in Fig. 3. As the temperature (T_{nf}) increases, then the viscosity (M_{nf}) also decreased for all values of ϕ. But, the increasing in the volume fraction (ϕ) also increases the viscosity (M_{nf})). It is clearly indicated that the density of nanofluid increases thermal viscosity also increased. It is quite evident that the viscosity of EG is quite higher than the water. Hence water-based nanofluids predict lower viscosity values than EG-W based nanofluids.

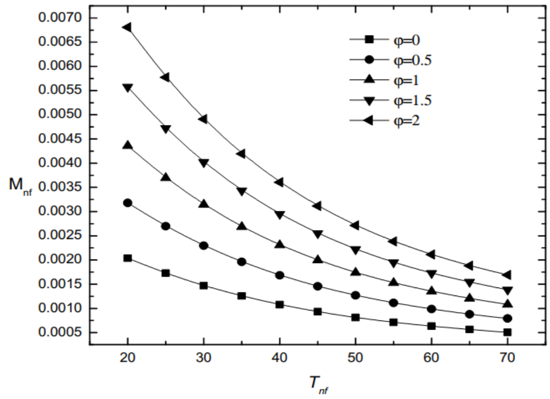

Figure 3: Viscosity Values of Water-based and EG-W based Nanofluids

4.4 Enhancement Ratio

The enhancement ratio depends on the concentration and temperature of the particle size of fluids as shown in Fig.4. *Er* can rely on the frequency and a given temperature and particle size. The variation of ER in Al_2O_3 nanofluid concentrations for 20^{oC} to$100^{oC}$are shown plotted in Fig.4 applicable for turbulent flow condition. As the temperature (T_{nf}) increases, then the enhancement (*Er*) also decreased for non zero value as of ϕ. But, at the ϕ =0 the enhancement (*Er*) also increased. It is clearly indicated that the density of nanofluid increases enhancement (*Er*) values increased. It implies that if experiments be undertaken with frequencies higher than the maximum values determined, enhancement in heat transfer with strength is not feasible.

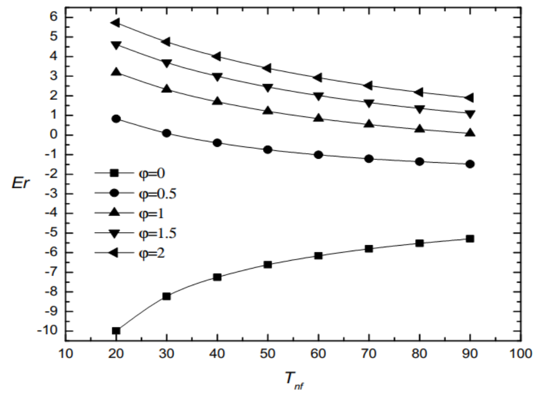

Figure 4: Variation of ER with temperatures and different concentration of Al_2O_3

V. CONCLUSION

Though water-based nanofluids predict higher thermal conductivities, the comparisons among the base fluid suggest that EG-W based nanofluids show a higher heat transfer coefficient with a higher Nusselt number.

Heat transfer coefficients are increasing when decreasing the temperature of the surroundings. It indicates that low-temperature regions are good enough to attain higher heat transfer coefficients. The volume of concentration also has a good impact on the viscosity of nanofluid as shown in Fig. 3. The strength of nanoparticle increases to attain maximum heat transfer coefficients. The enhancement ratio depends on the temperature and concentration of nanofluids. The temperature and density are increasing, then the enhancement ratio is unfavorable condition and vice versa.

Nomenclature

Cp	Specific Heat(J/kgK)
ER	EnhancementRatio
k	Thermal conductivity(W/mK)
Nu	Nusselt number
Re	Reynolds number

Greek letters

α	Thermal diffusivity(m^2/s)
ρ	Density(kg/m^3)
μ	Viscosity(Pa.s)
ϑ	Kinematic viscosity(m^2/s)
φ	Volumefraction

Subscripts

bf	base fluid
nf	nanofluid
r	ratio

Conflict of Interest

The authors confirm that there is no conflict of interest to declare for this publication.

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