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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_2O3) nanofluid with a base 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 concentration and temperature effect on a heat transfer coefficients have been determined. The maximum concentrations for which the heat transfer enhancement can be attained 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 nano fluids and turbulent region

1. Introduction

In any automobile device, the cooling system is considered as key role to act as in efficient condition. Based on above context to cool the engine continuously, then the engine parts are with help of base fluid and cooling agents. In an automotive engine component's heat must be removed from components to the cooling medium. However, the conventional fluids are very poor to extract the heat from components. This is a limitation for a conventional fluid to improve the heat transfer is the aim of the present investigation. In order 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. A. S Ahuja [1-2] based on his studies to improve the greater heat transfer rates, the application of nanotechnology has 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. [3-5] have presented various experiments to find the properties of Al_2O3 CuO, SiO_2 and ZnO nanofluids. Praveen et al. [6] have determined the properties of CuO nanofluids. Sundar et al. [7] have investigated the improvement of thermal properties of Nano diamond fluids with base fluids. Sahoo et al. [8, 9] carried out experiments with $SiO_2$and Al_2O3 nanofluids to find the properties of nano fluids. Kulkarni et al. [10] performed experiments for the estimation of viscosity with SiO_2 nanofluid. Vajjha and Das [11] were calculated the nanofluids characteristic with forced convection heat transfer coefficients in the turbulent region as a condition and with Al_2O3 (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_2O3 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 mostly undertaken through experiments. The heat transfer enhancement reported by Vajjha et al. [11] is 82% with Al_2O3 nanofluid while Kulkarni et al. [10] reported only 16% with SiO_2 nanofluid at the same volume concentration of 10%. The heat transfer enhancement for Al_2O_3 nanofluids has not been presented by any author in the turbulent region and hence numerical analysis is used as a reference for determining the properties of nanofluids. Usri et al. [12, 13] experiments conducted under the turbulent region for the estimation of properties of nanofluids such as Al_2O3 (13nm) and TiO_2 (50nm) for a maximum concentration of 1.5% for temperature varying between $50\text{-}70^{oC}$. They reported the enhancement of 14.6% in heat transfer for Al_2O3 nanofluid at a concentration of 0.6%, whereas the enhancement for $TiO_2$was observed to be 33.9% with nanofluid at 1.5% volume concentration.

2. 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 [14]. EG-W base fluid properties were obtained from regression equations using ASHRAE [20] data,

$$\rho = 1066.79734 - 0.3071T - 0.00243Tnf^2 \quad 1$$

$$C_{p\ bf} = 3401.21248 + 3.3443T_{nf} + 9.04977 \times 10^{-5}\ Tnf^2 \quad 2$$

$$Kbf = 0.39441 + 0.00112T_{nf} - 5.00323 \times 10^{-6}\ Tnf^2 \quad 3$$

$$\mu bf = 0.00492 - 1.24056 \times 10^{-4}\ T + 1.35632 \times \times 10^{-6}\ T^2 - 5.56393 \times 10^{-9}\ Tnf^2 \quad 4$$

3. NANOFLUID PROPERTIES

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

$$\rho nf = (\varnothing_p / 100)\rho_p + (1 - \varnothing / 100)\rho_{bf} \quad 5$$

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*. [6] given by,

$$k_{nf} = k_{bf}\ (A + B\varnothing) \qquad 6$$

Where A = 1.0806 and B = 10.164. Similarly, viscosity correlation was developed considering the nanofluid viscosity to increase exponentially with the volume concentration by Sundar *et al*. [7] given by,

$$\mu_{nf} = \mu_{bf}\ Ae^{B\varnothing} \qquad 7$$

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 ratio is subjected to regression given by Equation. (8) Employing the data of Usri et al. [13]

$$Nu = 0.0257\ Re^{0.8}\ Pr_{bf}^{0.4}\ (1 + Prnf)^{-0.04297}\ (1 + \varnothing/100)^{5.205} \qquad 8$$

4 Results and discussions

The base fluid and nanofluid properties are found with respect to heat transfer coefficients are validated with the experimental data. The experimental data of base liquid and of EG-W base fluid of thermal conductivities is compared based on Equation. (3). The EG-W base liquid determined using the regressional investigation is kept in comparison with the ASHRAE data [14] and is observed that to be an agreement with a deviation of less than 1%.

4.1 Thermal conductivity

Thermal conductivity of EG-W based nanofluids and water based nanofluids are predicted using equations given by Sharma et al.[15]. Comparisons were made for the thermal conductivity of Al_2O3 nanoparticles distributed in base fluid and EG-W 60:40 as shown in fig.1.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.

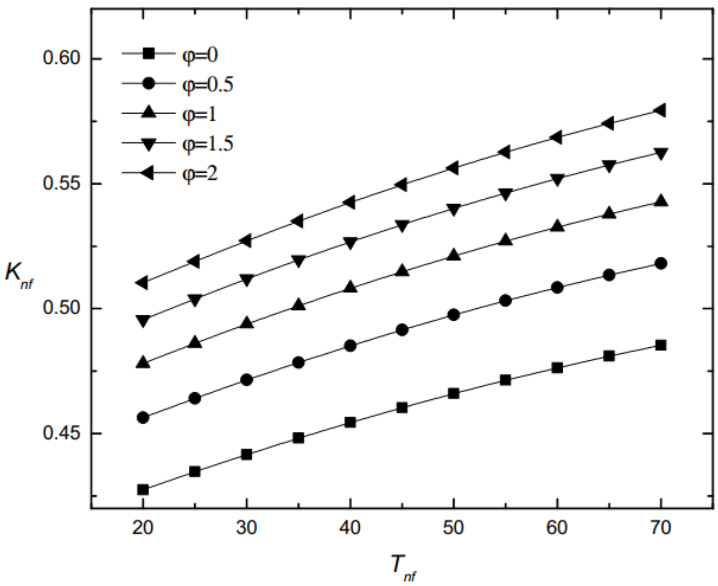

Fig. 1: Comparison of nanoflid concentration and temperature of fluid

4.2 Nusselt Number

Heat transfer coefficients are predicted from the formulated Nusselt equations of Sharma et al.[15-17]. The nano particle concentration increases in a base fluid and find Nusselt number with respect to Reynolds number increases, then Nusselt number decreases while increase concentration this effect are shown in fig.2.

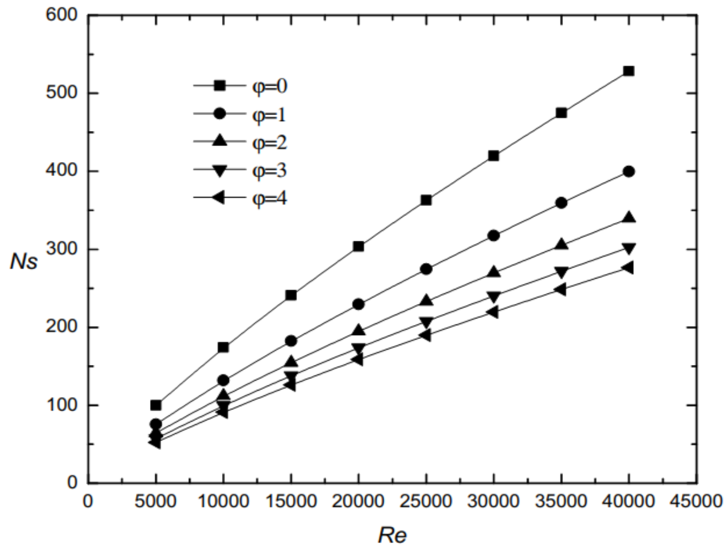

Fig. 2: Comparison of Nusselt Number for Al_2O3 Nanofluids

4.3 Viscosity

Viscosity of Al_2O3 nanoparticles comparisons was made between base fluid and EG-W nanofluids as shown in Fig. 3. It is quite evident that the viscosity of EG is quite higher than water, hence water based nanofluids predicts lower viscosity values than EG-W based nanofluids.

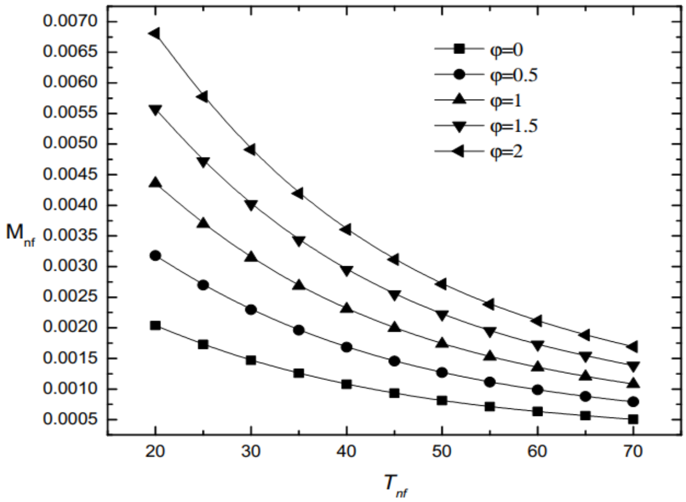

Figure 3: Viscosity Values of Water based and EG-W based Nanofluids

4.4 Enhancement Ratio

The enhancement ratio depends on the concentration and temperature of particle size of fluids it is shown in Fig.4. ER can be depends on the concentration and a given temperature and particle size. The variation of ER in Al_2O3 nanofluid concentrations for 20 ^{oC} to100^{oC} are shown plotted in Fig.4 applicable for turbulent flow condition. It implies that if experiments are undertaken with concentrations greater than the maximum values determined, enhancement in heat transfer with concentration is not feasible.

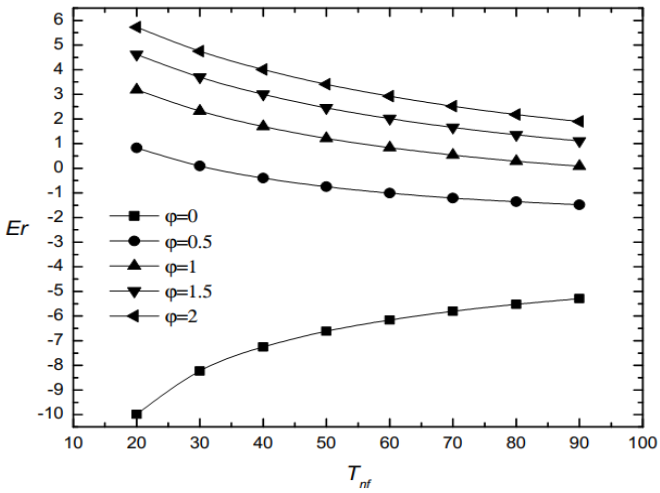

Fig. 4.Variation of ER with temperatures and different concentration of Al_2O3

5. Conclusion

Though water based nanofluids predicts higher thermal conductivities, the comparisons among the base fluid suggest that EG-W based nanofluids shows a higher heat transfer coefficient with a higher Nusselt number. Heat transfer coefficients are increasing when decreasing temperature of the surroundings. It indicates that low temperature regions are good enough to attain higher heat transfer coefficients. The volume of concentration has also good impact on viscosity of nanofluid as shown in Figure 3. The concentration of nanoparticle increases to attain the maximum heat transfer coefficients. The enhancement ratio depends on temperature and concentration of nano fluids. The temperature and concentration are increases then the enhancement ratio is in positive condition and vice versa.

Nomenclature

Cp Specific Heat (J/kgK)
ER Enhancement Ratio
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)
$\varnothing$ Volume fraction

Subscripts

bf basefluid
nf nanofluid
r ratio

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