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Heat Transfer Augmentation of Al_2O_3 Nanofluid in 60:40 Water to Ethylene Glycol Mixture

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Abstract

Convectional coolant plays an important part in removing excess heat generated by automotive component to avoid damage and failure of the system. Through recent studies, nanoparticles suspended in base fluid or known as nanofluid have positive effect heat transfer performance. This paper presents the effect of increment of Alumina nanoparticles dispersed in 60:40 water to ethylene glycol based nanofluids towards heat transfer enhancement. For this purpose, nanofluids are prepared using Aluminium Oxide (Al_2O_3) with average diameter of 13 nm suspended in 60:40 of water to ethylene glycol by volume percentage. The nanofluid is synthesized using two step method and homogenized to lengthen the suspension for volume concentration of 0.2 %, 0.4 % and 0.6 %. The force convection investigation was conducted at a constant heat flux with Reynolds number of less than 20,000 at a constant working temperature of 50 ^oC. The heat transfer coefficient of nanofluids is compared with the base fluid. It was observed that as the loading of nanoparticles suspended in the base fluid is increased, heat transfer coefficient is also higher. The heat transfer augmentation of Al_2O_3 nanofluid at 0.6 % volume concentration is higher than 0.2 % and 0.4 % concentrations.

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Keywords: heat transfer coefficient; nanofluid; aluminium oxide; water:eg mixture

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1. Introduction

For the past decades, nanofluids were studied for its superior thermal properties hence been applied in many engineering systems that require cooling systems. The nanofluids are proved to have better stability and rheological properties, higher thermal conductivities with no significant penalty on pressure drop [1].

The studies that involved nanofluids in experimental forced convection using EG-water based nanofluids are limited. Kulkarni et al. [2] conducted a research on SiO_2 nanofluid dispersed in 60 % EG and 40 % water for three particles size (20, 50 and 100 nm). They studied the fluid dynamics characteristics and convective heat transfer enhancement under turbulent region (3000 < Re < 12000) for concentration range from 2 % to 10 %. The study demonstrated that the heat transfer coefficient increases as the particle concentration and particle size increases and the effect is more significant for temperature under zero degree. Vajjha and Das [3] conducted a study on three types of nanofluids (Al_2O_3, CuO and SiO_2) dispersed in 60 % EG and 40 % water for convective heat transfer under turbulent region. The study discussed on effect of particle volume concentration, thermo-physical properties and particle size to the heat transfer performance of the nanofluids. The findings shows that increase in particle concentration contribute to enhancement in heat transfer coefficient. The objective of present study is to provide the experimental observation of nanofluids heat transfer performance using Al_2O_3 nanofluids in 60:40 water to ethylene glycol mixture.

Nomenclature

A	area, m^2	μ	absolute viscosity, kg/m.s
Al_2O_3	Aluminium Oxide	nf	nanofluid
BF	Base Fluid	Nu	Nusselt number
b	bulk	p	particle
C	specific heat, J/kg K	Pr	Prandtl number
EG	ethylene glycol	Q	heat input, W
exp	experimental value	Re	Reynolds number
ϕ	volume concentration, %	ρ	density, kg/m^3
φ	volume fraction, $\varphi = \phi/100$	S	surface
m	mass, kg ($m = \rho / V$)	T	temperature, ^oC
h	heat transfer coefficient, W/m^2K	V	volume, m^3
I	input current, A	V	input voltage, V
k	thermal conductivity, W/m.K	W	water

2. Experimental Setup

2.1. Preparation of Nanofluid

The nanofluids were prepared by dispersing the nanoparticles in 60:40 ratio of base fluid through proper mixing method. The nanoparticle used is Al_2O_3 in powder form which procured from Sigma-Aldrich, USA. The fine particles of Al_2O_3 have average particle diameter of 13 nm. Distilled water and ethylene glycol are used as the based fluid.

The pre-calculated mass Al_2O_3 nanoparticles using Eq. (1) is dispersed in the mixture base using two step method. In order to prepare the nanofluid at volume concentrations 0.2%, 0.4% and 0.6%, the solutions is diluted using Eq. (2) beginning with higher concentration to lower concentration. Approximately 22 L of the nanofluid is used to conduct the heat transfer experiments. The stability of nanofluid is lengthen using magnetic stirrer and immersed in ultrasonic homogenizer for 2 hours. It was observed stable during the experiment.

$$\phi = \frac{\left(m_p/\rho_p\right)}{\left(\frac{m_p}{\rho_p}+V_{BF}\right)}\times 100 \qquad (1)$$

$$\Delta V = (V_2 - V_1) = V_1\left(\frac{\phi_1}{\phi_2}-1\right) \qquad (2)$$

2.2. Thermophysical Properties

The prepared nanofluids were first measured for their thermal conductivity and viscosity for each concentration using KD2 Pro thermal properties analyzer and Brookfield LVDV-III Ultra Viscometer. Whereas, the density and specific heat of nanofluid are obtained using classical model solid-liquid mixture relation which commonly used by researchers and shown as Eqs. (3) and (4). The summary of thermophysical properties for Al_2O_3 nanofluid in mixture base are presented in Table 1.

$$\rho_{nf} = \varphi\rho_p + (1-\varphi)\rho_{BF} \qquad (3)$$

$$C_{nf} = \frac{(1-\varphi)(\rho C)_{BF} + \varphi(\rho C)_p}{(1-\varphi)\rho_{BF} + \varphi\rho_p} \qquad (4)$$

Table 1. Thermophysical properties of Al_2O_3 nanofluid at temperature 50 ºC

Volume Concentration (ϕ)	Density, (ρ)	Specific Heat (C)	Thermal Conductivity (k)	Viscosity (μ)
0.0	1051.26	3547.72	0.434	0.00162
0.2	1057.17	3526.68	0.441	0.00169
0.4	1063.08	3505.88	0.447	0.00180
0.6	1068.99	3485.30	0.451	0.00189

2.3. Experimental Setup

In order to investigate forced convective heat transfer, a fluid loop experimental system is designed as in Fig 1. The experimental system consists of a test section with installed heater, a control panel, a collecting tank, a circulating pump, a chiller and by pass valve. Details of the experimental setup have been reported elsewhere [1, 4-7].

Initially, the reliability of the experimental setup is established by comparing Nusselt number of base fluid 60:40 ratio (water: ethylene glycol) mixture with single-phase liquid relation by Dittus and Boelter [8] in Eq. (5).

$$Nu = 0.023\,\mathrm{Re}^{0.8}\,\mathrm{Pr}^{0.4} \tag{5}$$

Subsequently, experiments are repeated with three different concentrations loading (0.2 %, 0.4 % and 0.6 %) to estimate the heat transfer coefficients. The heat input is obtained from knowledge of electrical energy supplied presented in Eq. (6) by considering heat losses are negligible. Newton's law of cooling represent in Eq. (7) is rearranged to compute heat transfer coefficient. Thus, Nusselt number using Eq. (8) is tabulated as comparison with base fluid.

$$Q = V \times I \tag{6}$$

$$h = \frac{Q}{A_s\left(T_s - T_b\right)} \tag{7}$$

$$Nu_{\exp} = \frac{h_{\exp} D}{k_{nf}} \tag{8}$$

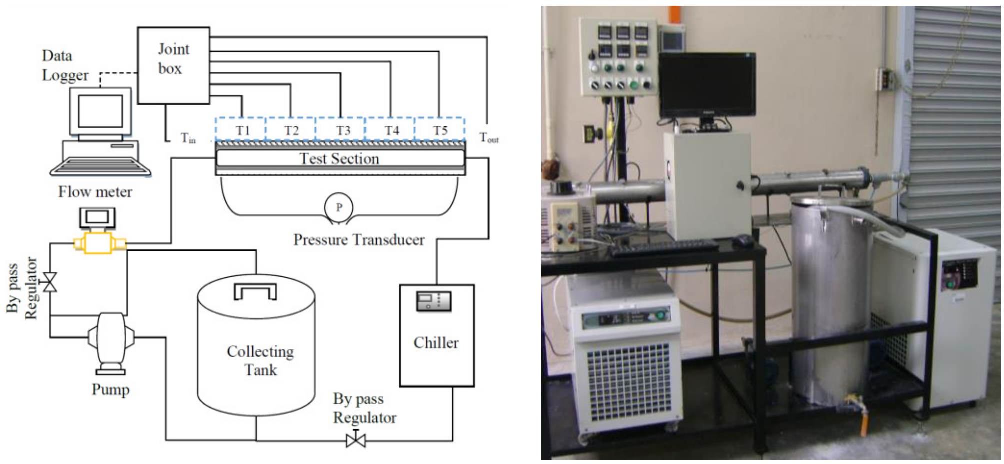

Fig. 1. (a) Schematic Diagram of Force Convection; (b) Force Convection Experimental Setup in laboratory

3. Results and Discussion

Based on good agreement of present experimental data with Eq. (5) shown in Fig 2 (a) , experiments are further undertaken with designated base ratio fluid and Al_2O_3 nanofluid in the volume concentration of 0.2 %, 0.4 % and 0.6 % at various flow rates. Fig. 2 (b) clearly shows that as nanoparticle suspended in the base fluid increase, Nusselt number increase. This pattern also found by Yu et al. [9] which highlighted that the significant increment of Nusselt number due to increment of thermal conductivity. Thus, larger Nusselt number showing higher efficiency of convention process. Wen and Ding [10] points out that such increment are influence by suspended particles near the wall, Brownian motion, particle migration, particles's shape and reduction of boundary layer which agreed by Chandrasekar et al. [11]. Therefore, nanofluid volume concentration could be recommended for implementation in working temperature of 50 ^oC.

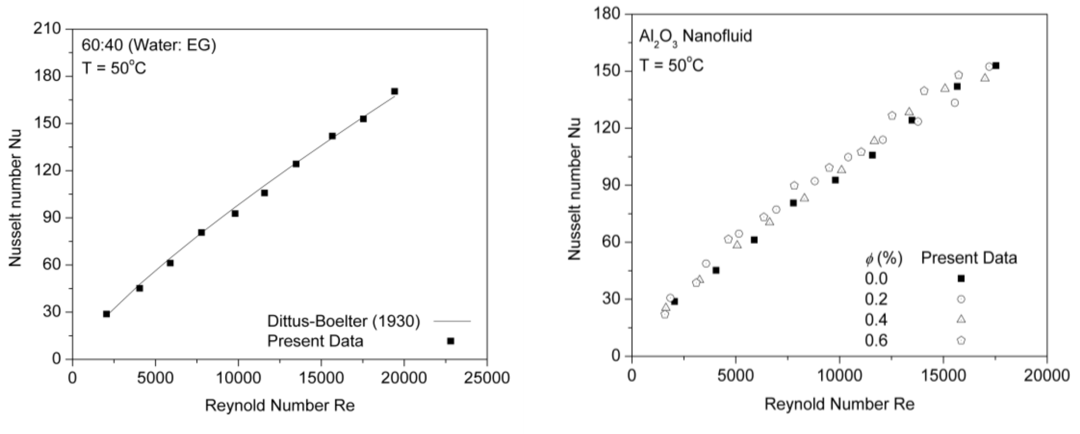

Fig. 2. (a) Validation of based fluid; (b) Experimental Nusselt number for Al_2O_3 nanofluids.

Fig. 3 (a) present the convective heat transfer coefficient of Al_2O_3 nanofluid is higher than their base fluid. It is also seen that the convective heat transfer coefficient increases with respect to Reynolds number. At 0.2 %, the heat transfer coefficient is enhanced by 6.9 % and 0.4 % enhanced the heat transfer rate by 7.3 %. The highest enhancement is found at volume concentration 0.6 % by 14.6 %.This indicates that addition of small amount of nanoparticles to mixture base of water and ethylene glycol (60:40) improved the heat transfer performance significantly. The pattern was also found by previous researchers [1, 11] using different base fluid. The percentage enhancement is shown in Fig. 3 (b).

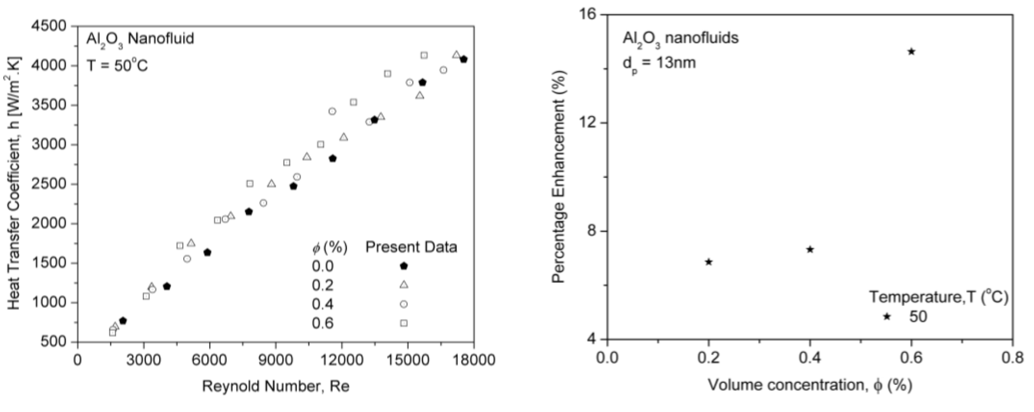

Fig 3. (a) Distribution of heat transfer coefficient (b) Enhancement of heat transfer coefficient

4. Conclusions

The argument of heat transfer enhancement using Al_2O_3 nanofluid in mixture base (60:40) water to ethylene glycol at working temperature of 50 ^oC has been observed. The properties showing positive increment in thermal conductivity and viscosity for Al_2O_3 nanofluid in volume concentration of 0.2 %, 0.4 % and 0.6 %. The convective heat transfer enhanced using Al_2O_3 dispersed in mixture base. As loading of nanoparticles increase, Nusselt number is increase. For volume concentration of 0.2 % and 0.4 %, the percentage of enhancement in heat transfer is observed similarly by 6.9 % and 7.3 %, respectively. However, the highest enhancement was found with 0.6 % by 14.6 %. To sum up this argument, Al_2O_3 nanofluid dispersed in mixture base (60:40) water to ethylene glycol is recommended to use volume concentration of 0.6% for working temperature at 50 ^oC.

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References

[1] W. H. Azmi, K. V. Sharma, P. K. Sarma, R. Mamat, S. Anuar, and V. Dharma Rao, Experimental determination of turbulent forced convection heat transfer and friction factor with SiO2 nanofluid, *Experimental Thermal and Fluid Science*. **51**, 2013, pp. 103-111.

[2] D. P. Kulkarni, P. K. Namburu, H. Ed Bargar, and D. K. Das, Convective Heat Transfer and Fluid Dynamic Characteristics of SiO_2 Ethylene Glycol/Water Nanofluid, *Heat Transfer Engineering*. **29**, 2008, pp. 1027-1035.

[3] R. S. Vajjha, D. K. Das, and D. P. Kulkarni, Development of new correlations for convective heat transfer and friction factor in turbulent regime for nanofluids, *International Journal of Heat and Mass Transfer*. **53**, 2010, pp. 4607-4618.

[4] W. H. Azmi, K. V. Sharma, P. K. Sarma, R. Mamat, and S. Anuar, Comparison of convective heat transfer coefficient and friction factor of TiO2 nanofluid flow in a tube with twisted tape inserts, *International Journal of Thermal Sciences*. **81**, 2014, pp. 84-93.

[5] N. A. Usri, W. H. Azmi, R. Mamat, and K. Abdul Hamid, Forced Convection Heat Transfer Using Ethylene Glycol Based Nanofluid For Application In Automotive Cooling System, presented at the *International Conference on Automotive Innovation and Green Energy Vehicle (AiGEV 2014)*, Kuantan, Pahang, Malaysia, 2014.

[6] K. Abdul Hamid, W. H. Azmi, R. Mamat, and N. A. Usri, Heat Transfer Performance of Titanium Oxide in Ethylene Glycol Based Nanofluids under Transition Flow, in *Applied Mechanics and Materials*, 2014, pp. pp. 684-688.

[7] K. Abdul Hamid, W. H. Azmi, R. Mamat, and N. A. Usri, Effect Of Working Temperature On Heat Transfer Coefficient For Titanium Oxide In Ethylene Glycol Based Nanofluid, presented at the *International Conference on Automotive Innovation and Green Energy Vehicle (AiGEV 2014)*, Kuantan, Pahang, Malaysia, 2014.

[8] F. W. Dittus and L. M. K. Boelter, Heat transfer in automobile radiators of the tubular type. **2**: University of California Publications on Engineering 2, 1930.

[9] W. Yu, H. Xie, Y. Li, L. Chen, and Q. Wang, Experimental investigation on the heat transfer properties of Al 2 O 3 nanofluids using the mixture of ethylene glycol and water as base fluid, *Powder Technology*. **230**, 2012, pp. 14-19.

[10] D. Wen and Y. Ding, Experimental investigation into convective heat transfer of nanofluids at the entrance region under laminar flow conditions, *International Journal of Heat and Mass Transfer*. **47**, 2004, pp. 5181-5188.

[11] M. Chandrasekar, S. Suresh, and A. Chandra Bose, Experimental studies on heat transfer and friction factor characteristics of Al2O3/water nanofluid in a circular pipe under laminar flow with wire coil inserts, *Experimental Thermal and Fluid Science*. **34**, 2010, pp. 122-130.