Properties of Nanofluid as Radiator Coolant by using MgO Nanoparticles

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bstract

This paper studies the experimental result relating nanofluid as coolant. In this experiment, the base fluid used is ethylene glycol and the nanoparticle is magnesium oxide (MgO). This experiment was conducted to identify the effect metal nanoparticle; magnesium oxide in ethylene glycol and ultrapure water. The aim of the experiment is to study the properties of magnesium oxide as nanoparticle in ethylene glycol+Ultrapure water with different concentration. Other than that, this experiment is to identify the effectiveness of this nanofluid as a coolant to apply in automotive and industrial sector. The properties that has been analyzed were specific heat capacity, freezing point and thermal conductivity of magnesium oxide in the ethylene glycol and UPW. For the sample preparation, ethylene glycol was well mixed with ultra-pure water and magnesium oxide powder. As for the specific heat capacity and freezing point properties identification, the experiment were conducted using Differential Scanning Calorimetry, PerkinElmer DSC6000. However, the thermal conductivity experiment were carried out using KD2 Pro Thermal Properties Instrument. The experimental result for thermal conductivity experiment shows that the nanofluid with 0.004vol% of magnesium oxide has the best percentage of improvement with respect to conventional coolant and reference fluid EG-UPW which are 139.94% and 39.29% respectively. The study on the freezing point shows the maximum improvement percentage of 0.004 vol% MgO which is 110.29% while for the specific heat capacity the percentage of improvement is 113.774% respect to reference fluid and 199.745% with respect to conventional coolant.

Keywords: Nanofluid; MgO; Ethylene Glycol; Cp; Freezing point; Thermal conductivity

1. Introduction

Recently, nanofluid has played a pivotal role to act as a better medium to reduce the usage of heat transfer compared to conventional liquids (Sidik et al., 2017),(Hajmohammadi, 2017). Nanofluid is a latest kind of heat transfer medium which consists of nanoparticles which is nanometer sized particles of any shape with the dimension of 1-100 nm (Sidik et al., 2017). These particles suspended colloidally within a base liquid and nanoparticles used are usually made of metals, oxides, carbon nanotubes and carbides are fluid that is processed by dispersing nanometer sized materials (nanoparticle, nanofiber, nanotubes, nanowires, nanorods, nanosheet or droplets) in base liquid (Yu & Xie, 2012). These particles are commonly used in some types of base liquid including water, ethylene glycol and any natural oil.

Nanofluids have their own unique features that make them possibly functional in heat transfer applications uch as microelectronics, fuel cells, pharmaceutical processes, and hybrid-powered engine, engine cooling/vehicle thermal management, chiller, heat exchanger such as plate heat exchanger and double pipe heat exchanger, and also radial flow and electronic cooling device (Asrul et al., 2013), (Kaufui & Omar, 2010).

Nanofluids have several advantages that makes them better than the conventional solid-liquid suspension for heat transfer which including high surface area which drives to increase in heat transfer between particles and fluids and high dispersion stability (Yu & Xie, 2012). It reduces pumping power as compared to pure liquid to reach equivalent heat transfer intensification and also reduces particle clogging as compared to conventional slurries therefore the system will be miniatured. Their modifiable features such as thermal conductivity, freezing point, surface wettability made them suit in different heat transfer application (Asrul et al., 2013).

Nanofluid has been proved by many studies and researches to enhance the rate of heat transfer. Engineers have applied this handy finding in their respective field area for their own benefit such as determining the heat transfer mechanism of equipment performances (Sohel, Saidur et al., 2015). A study has discovered that cooling capability of heavy duty engine coolant has boosted up to 15% when nanographite was added (Zhang et al., 2007), (Yang & Du, 2017).

Many studies have found that the thermal conductivity of nanofluid is greater than conventional fluid. Lee, Choi, Li, & Eastman, 1999 indicates that nanoparticle can raise up to 30% thermal conductivity of water under a non-moving state condition. The nanoparticle used in the experiment was 13 nm diameter and 4.3% volume fraction. Lee et al., 1999 has found that bigger particle with wider diameter that is around 40 nm in average, raises less than 10% of the thermal conductivity. The enhanced thermal conductivity of nanofluids compared with that of conventional coolants such as water and Ethylene Glycol mixture, offer potentials for reducing the size of the heat exchanger used in the fuel cell cooling systems (M. R. Islam et al., 2015). Other investigation carried has concluded that thermal conductivity may increase with the increase of volume concentration and temperature (Sharma et al., 2015), (Pryazhnikov et al., 2017).

The specific heat capacity is one of important properties of a coolant. Several previous studies have investigated the specific heat capacity (cp) of various nanofluids reported the cp of eight different concentrations of alumina and water nanofluids between 20 and 45°C, but this experimental section indicates DSC scans were performed to 70°C (Raud et al., 2017).

As conventional coolant is the mixture of water and ethylene glycol as anti-freeze agent to increase the boiling point and reduce the freezing point of water as reported by Xuan & Li, 2003 the thermal conductitivity of nanofluid is greater than water by itself (Ali et al., 2015).

Nanofluid preparation is the important step in determining the improvement of the thermal conductivity (Zeng et al., 2013). Two preparation process is employed to produce nanofluid which is single step and two step method. Nanoparticle, nanofluid additive plays a significant part in rearranging the thermal transport properties (Sidik et al., 2017).

This method is quite extortionate in term of price and this method cannot synthesize large scale of nanofluids. This step entail the making and dispersing of the particles in fluids both concurrently. Drying, storage, transportation and dispersion processes are circumvented which increase the fluid stability. Two step methods are the most profitable as it is very economic and it produces huge scale of nanofluids. First and foremost, nanoparticles are produced as dry powders which are generated from physical and chemical methods. The nanosized powder are then dispersed into liquid. Nanoparticles have high tendency to aggregate as a result of the high surface area and surface activity (Yu & Xie, 2012).

Since the discovery of nanofluid in engineering applications, it has been successfully used to improve heat transfer in many scope of engineering (Sivashanmugam et al., 2012), (Timofeeva et al., 2011). In mechanical engineering, researches have been made to improve heat transfer of heat exchanger, reduce the heat transfer time and finally increase energy utilization efficiency using nanofluid (Albadr et al., 2013). Nanofluid is also used for electronic cooling system such as flat plate and radiators. Heat transfer over flat plate has been analyzed by researchers. Graphene based nanofluid has been found to improve Polymerase chain reaction efficiency (Mutuku, 2016), (Azmi et al., 2017).

In this study, magnesium oxide is used as nanoparticle. The aim of this study is to identify the properties of magnesium oxide as nanoparticle in ethylene glycol with different concentration and its effectiveness to act as a coolant. This study is also determine the efficiency of the nanofluid to pure ethylene glycol. This research conducted is to identify few main properties of nanofluid such as thermal conductivity, heat capacity and freezing point.

2. Methodology

2.1 Preparation of sample

Water is one of the best heat transfer medium as it is easy to get and can achieve decent thermodynamic physical properties. Since the freezing point of water is 4°C, ethylene glycol is introduced to decrease the freezing point of the water. Ethylene glycol is known as an anti-freezing agent which is mostly used as the main component in a coolant. In preparing the base fluid, the composition of water and ethylene glycol needed is 30% and 70% respectively. The water is an ultrapure water that is obtained from ultrapure water system which being used for research and hospital used. The water and ethylene glycol were mixed based on their composition needed and being distributed in five 200ml conical flasks by 100ml each. The conical flasks were labelled from 0.001 to 0.005 vol%. The nanoparticle that is used in this experiment is Magnesium Oxide. First, the magnesium oxide was weight by using analytical balance based on calculated mass as in equation 1 and then was put in each conical flask that containing the base fluid. The conical flask was being shook in incubator shaker at 25°C and 90rpm for 17 hours.

$$\text{Volume } \% = \frac{\left(\frac{m_{particles}}{\rho_{particles}}\right)}{\left(\frac{m_{particles}}{\rho_{particles}}\right) + base\ volume} \quad \text{................ Equation (1)}$$

Table 1: Number of volume fraction and mass Copper (II) Oxide used for each sample

Sample	Mass of MgO
0.001	0.036 mg
0.002	0.072 mg
0.003	0.108 mg
0.004	0.144 mg
0.005	0.180 mg

2.2 Thermal conductivity

Samples including conventional coolant and ethylene glycol with water that have been shaken for 17 hours is then poured into 7 test tubes. The test tubes were labelled based on the vol% and their respective mass which then arranged in the test tube rack. The water bath was filled with water and was heated to the set temperature which are 30°C, 40°C, 50°C, 60°C and 70°C. The test tube rack was put into the water bath until it reaches the set temperature. After few minutes, the thermal conductivity reading of each sample is taken 3 times to achieve average result by using KD2 PRO device. The readings of each sample were recorded at each set temperature.

2.3 pecific Heat Capacity

This experiment is conducted to obtain the specific heat capacity of the coolant where firstly the coolant is being measured to 10µg for every sample which have six samples 0.001 vol%, 0.002 vol%, 0.003 vol%, 0.004 vol%, 0.005 vol% and ethylene glycol. By using the micropipette device, the sample were taken from the 500mL beaker and filled into the alum pan before being measured by using milligram balance, Model no. AD6000 in the analytical lab. After achieved the value, covered the sample by using the alum pan cover and clamped it together before it being placed in the Differential Scanning Calorimetry (DSC), PerkinElmer DSC6000 to undergo its process.

The temperature of DSC usually is between -83°C to 7°C with nitrogen gas as the purge gas in the machine (50mL min^{-1}). The temperature was set up for DSC6000 software at 25°C for the first four minutes before increase the temperature to 80°C for five minutes. After five minutes, the DSC would be cooled down to 25°C. The result would be recorded automatically when the temperature dropped down below than 50°C. The experiment was repeated to get the result for other sample.

2.4 Freezing Point Determination

Freezing point determination experiment was carried out by measuring the freezing point of every samples (0.001 vol%, 0.002 vol%, 0.003 vol%, 0.004 vol%, 0.005 vol% and ethylene glycol) using the Differential Scanning Calorimetry technique, model PerkinElmer DSC6000. The sample were taken from the 500mL beaker by using micropipette device and placed into an alum pan. Using milligram balance, model no. AD 6000, the sample in the alum pan was weighed until its mass reached 10µg. After the mass of the sample is reached, the alum pan was clamped together with its cover and placed into the left side of DSC tray.

The DSC6000 was programmed according to the specifications. First, the temperature of the DSC would be maintained at 15°C for 1.0 minute. After that, at rate 10°C/min, the DSC would then be cooled down to -110°C and lastly the DSC heated up from -110°C to 15°C at the rate of 10°C/min. The reading for the sample would be recorded and the experiment would be continued for the other sample.

3. Result and Discussion

3.1 Thermal Conductivity

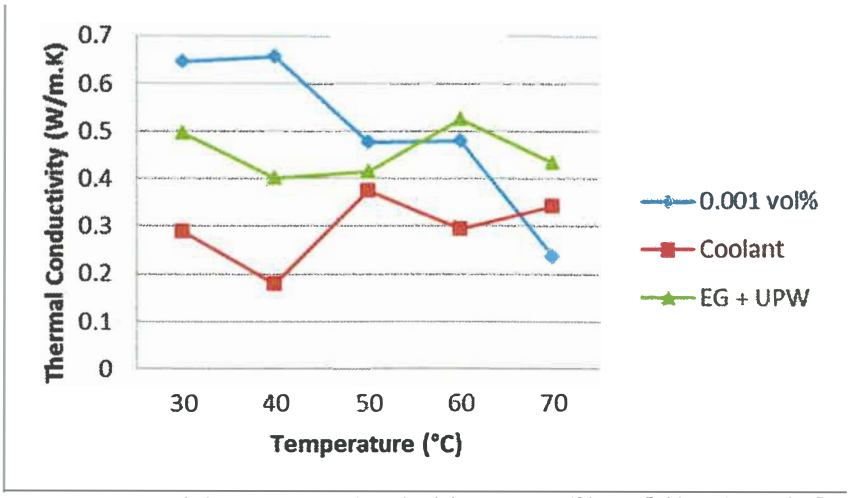

Figure 1: The graph above indicates the thermal conductivity of 0.001vol% nanofluid, coolant and EG + UPW.

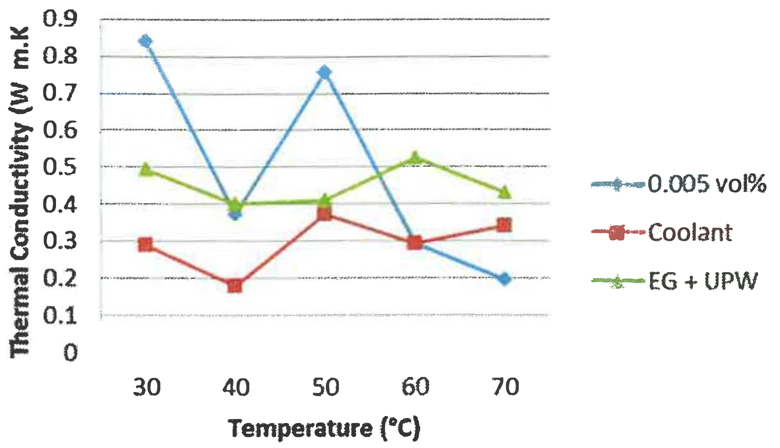

Figure 5: The graph above indicates the thermal conductivity of 0.005vol% nanofluid, coolant and EG + UPW.

In the study, the measurement of thermal conductivity of nanoparticles in UPW-EG (70:30) varies with temperature and particle volume fraction were experimentally studied. To measure the thermal conductivity of MgO with UPW-EG (70:30), new correlations have been introduced by using regression at different solid volume fractions and temperatures.

The figures above shown the variation of thermal conductivity of MgO/UPW-EG (70:30) with different temperatures were recorded in Fig.1, Fig.2, Fig.3, Fig.4, and Fig.5 in different nanoparticles volume fraction. As shown in the Fig.1, the MgO/UPW-EG has better performance than the coolant and the UPW+EG. However, at higher temperature the thermal conductivity reading starting to decrease which same goes to other results. By increasing the temperature from 30°C to 70°C, the maximum improvement of thermal conductivity is found to be 39.29% for 0.004 vol% MgO nanofluids compared with the thermal conductivity of the base fluid. The percentage of improvement to be compared with the coolant is 139.94%. The thermal conductivity of the nanofluids increase as the fact that the nanoparticles alter the fluid composition that effects the energy transport process and interfacial interactions between the nano particles, also the liquid molecules enhance the energy transport inside the liquid (Mohammad Rafiqul Islam et al., 2017).

3.2 Specific Heat Capacity

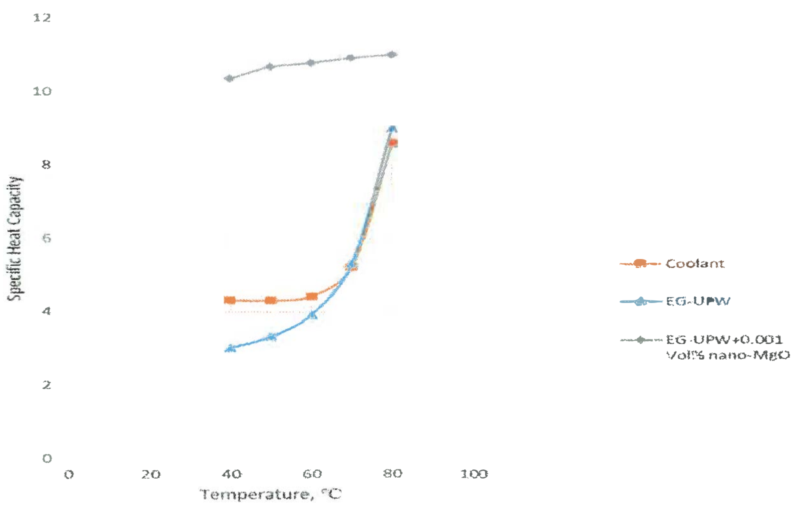

Figure 6: The graph above indicates the specific heat capacity (J/kg) of 0.001 vol% nanofluid, coolant and EG + UPW.