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Characterization of heat transfer on concentric tube heat exchanger using ethylene glycol/TiO_2 nanofluid

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Abstract. This study aims to determine the effect of temperature and volume fraction on heat transfer rate and heat transfer coefficient on concentric tube heat exchanger with nano ethylene glycol / TiO_2 fluid. From the results of tests and analyzes that have been done, it is obtained the best temperature and volume fraction that supports the rate of heat transfer. The best heat transfer rate of 22,430.25 W is done at the condition of the 0.03% TiO_2 Volume Fraction and at a temperature of 100 ° C. The best heat transfer coefficient occurs at a volume fraction of 0.03% and at a temperature of 100 ° C. It can be concluded that, TiO_2 will increase the heat capacity and heat conductivity of the base fluid which will optimize the performance of the fluid.

Keywords: nanofluid, ethylene glycol, heat transfer

1. Introduction

Heating and cooling processes of fluid is a principal necessity in the sectors of transportation, energy, and industry. The thermal properties that the fluid possessed have a significant role in energy efficiency. The fluids used in the heat transfer are ethylene glycol, water, and engine lubricating oil which have a low heat transfer, so in this case, it is necessary to have a development to increase the conventional heat transfer properties.

Nanoparticle technology is currently developing toward a new class of fluid and specifically called a nanofluid, the fluid has a high chance to be applied to a heat exchanger. A nanofluid means a mixture of two phases where the dispersed phase is a solid nanoparticle that sized smaller than 100 nm, very fine and a continuous phase is a liquid fluid. One of the ways to improve heat transfer is by improving fluid properties performance to heat transfer. The fluid used for the cooling medium is generally a fluid with low thermal conductivity. The addition nanoparticles canto improve the fluid properties [4]

This research was conducted experimentally using a heat exchanger modeling tool, with the type of double pipe exchanger concentric tube. This research will observe some factors that influence the heat transfer, including flow properties, Reynolds numbers, Prandtl number,concentration of nanoparticles, and also the temperature. This experiment used water as the cold fluid and ethylene glycol as the hot fluid. Then the hot fluid/ethylene glycol was added with TiO_2. The application in this study when viewed in the Concentric tube double pipe heat exchanger is in the Auxiliary Cooling Water System at the Steam Power Plant to use cooling of bearing and oil. When looking at the diversification of Ethylene Glycol is to cool the combustion system area on the engine, or the cylinder, or jacket water cooling system. In the textile industry, because the high boiling point has a very high heat capacity, it will increase the capabilities of heat storage and absorption, and reduce fuel costs.

2. Methods

2.1. Equipment

The research conducted was an experiment using a heat exchanger modeling tool with the type of concentric tube double pipe exchanger with 2 pipes [9,10]. Cold water pipes with a diameter of 76.2 mm, 1.8 mm thick with a length of 1100 mm and a hot water pipe with a diameter of 38 1 mm, 2 mm thick with a length of 1300 mm where both pipes are steel. The fluids used are water for cold fluid and the hot fluid is a mixture of ethylene glycol and titanium dioxide dispersed with the variations of the volume fraction are 0.01%, 0.02%, and 0.03% with an opposite flow.

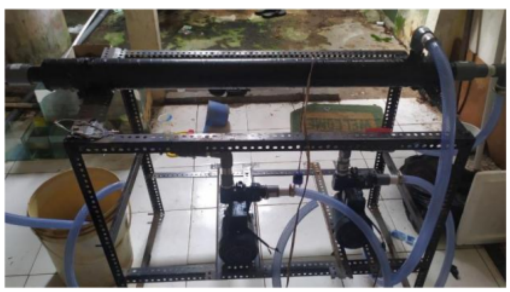

Figure 1. Experimental Apparatus

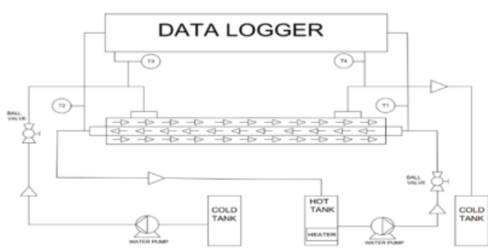

Figure 2. Heat exchanger scheme

2.2. Material used

Nanoparticle used in this study was Titanium Dioxide with 18 nm particle size of US Research Nanomaterials, Inc production. Sample nanofluid is prepared by using magnetic stirrer and ultrasonic vibration for 1 hours to make homogenous fluid and there is not agitation on sample. The temperature was maintained between 30 °C until 100 °C and fraction volume was set by 0.01 %, 0.02 %, and 0.03 %.

2.3. Test procedure

The first experiment used water as the cold fluid then dispersedof ethylene glycol and titanium dioxide as the heated fluid.Next step filled both tanks with fluid. (hot tank with heater and cold tank pumped by a water pump).Then turn on the heater in the tank, the temperature that we want to achieve in this study is 100°C of hot fluid in the form of ethylene glycol with the addition of titanium dioxide that has been dispersed with a mixture variation of 0.01%, 0.02%, and 0.03%, with opposite water flow.Set the temperature of the hot water used, the variation observed is the temperature of the water that has been heated starting from 100°C, 90°C, 80°C, 70°C, 60°C, 50°C, 40°C dan 30°C.

3. Result and discussion

From the test on the double pipe concentric tube heat exchanger, obtained the data of temperature differences on the side of nanofluid inlet temperature and nanofluid outlet temperature, refrigerant inlet temperature, and refrigerant outlet temperature

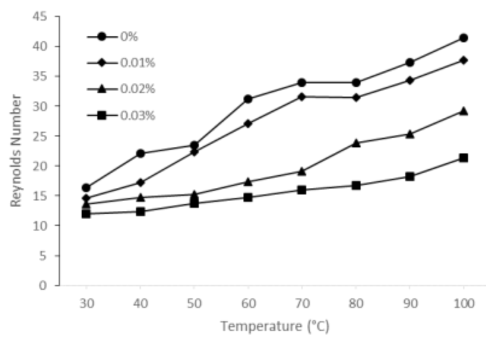

Figure 3. Correlation of volume fraction and temperature on Reynolds number

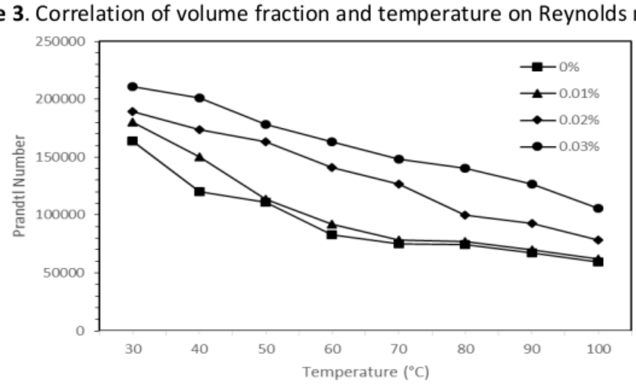

Figure 4. Correlation of volume fraction and temperature on Prandtl number

The increase of Reynolds number is directly proportional to the temperature increase but inversely proportional to the volume fraction. Reynolds number value increases along with the increase in temperature but inversely proportional to the addition of nanoparticles volume fraction. The greatest value of Reynolds number of approximately 41.5 occurred at 0% volume fraction and increased by 3.4% compared to fluid with 0.03% volume fraction at 30°C.

The increase of Prandtl Number is directly proportional to the volume fraction increase but inversely proportional to the temperature increase. Prandtl number increases along with the addition of the nanoparticles volume fraction. The greatest value of the Prandtl number of approximately 163.776 occurs at a volume fraction of 0.03% at temperature of 30°C and increases by 1.2% to base fluid. The addition of TiO_2 nanoparticles with ethylene glycol with a 0.03% volume fraction of TiO_2 has been shown to increase the Prandtl Number.

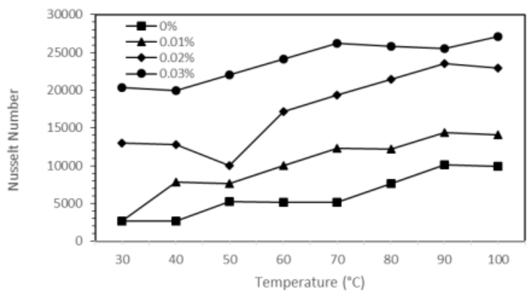

Figure 5. Correlation of Volume Fraction and Temperature on Nusselt Number

The increase of Nusselt number is directly proportional to the increase in temperature and volume fraction.It number increases along with the addition of nanoparticles volume fraction and temperature increase. The greatest value of the Nusselt number of approximately 27,130 occurs at volume fraction of 0.03% at a temperature of 100°C and increases by 2.7% compared to the base fluid. The addition of TiO_2 nanoparticles with Ethylene glycol with a 0.03% volume fraction of TiO_2 has been shown to increase Nusselt number.The influence of volume fraction and temperature is supported by [5,7,9,10].

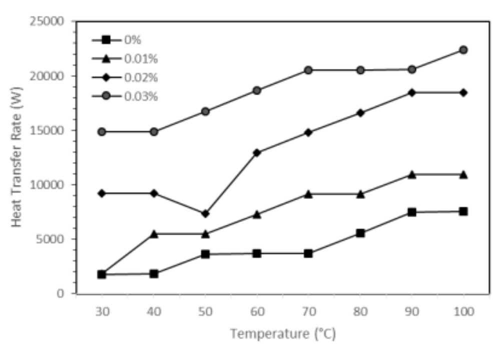

Figure 6. Correlation of volume fraction and temperature on heat transfer rate

The increase in the value of the heat transfer rate is proportional to the increase in temperature and volume fraction. The value of the heat transfer rate increases along with the addition of nanoparticles volume fraction and temperature increase. This case is caused by the Brownian motion, similar to a billiard ball that bounces off each other, the decrease in density causes the Brownian motion to be increasingly outward and increases the transfer rate. The greatest value of the heat transfer rate of approximately 22,430.25 W increases by 12.4% compared to the base fluid occurs at volume fraction of 0.03% at a temperature of 30°C. The addition of TiO_2 nanoparticles with ethylene glycol with a volume fraction of 0.03% has been shown to increase the heat transfer rate. This case is caused by the addition of TiO_2 nanoparticles to the ethylene glycol will increase the heat capacity of the working fluid so that the heat transfer rate will increase [6]. This shows that the volume fraction and temperature can increase the heat transfer rate.

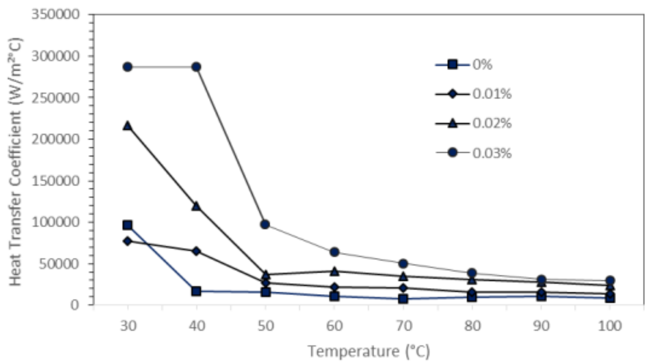

Figure 7. Correlation of temperature and volume fraction on heat transfer coefficient

The addition of TiO_2 with a volume fraction of 0.03% has been shown to increase the heat transfer coefficient. This case is caused by the addition of TiO_2 nanoparticles with a volume fraction of 0.03% to the ethylene glycol will increase the heat capacity of the working fluid so that the heat transfer rate inside the heat exchanger will increase, by the increase of the heat transfer rate will increase the heat transfer coefficient. This data had same trend with [1,2,4,8] that heat transfer coefficient increase.

4. Conclusion

The results of this study can be concluded that:

- The temperature and volume fraction influence on the Nusselt and Prandtl number.Nusselt number increase along increasing temperature. Also, Nusselt number increase along increasing tvolume fraction. Meanwhile, Prandtl number decrease along increasing volume fraction, but Prandtl number increase along increasing temperature.
- The temperature and volume fraction influence on the heat transfer rate.The value of the heat transfer rate increases along with the addition of nanoparticles volume fraction and temperature increase. This case is caused by the Brownian motion, the decrease in density causes the Brownian motion to be increasingly outward and increases the transfer rate.

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