Convective heat transfer of nanofluids TiO$_2$/Thermo Oil XT 32 in concentric tube heat exchanger

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Abstract. This research was conducted to examine the heat transfer characteristic of nanofluids TiO$_2$/Thermo XT 32 oil on a concentric tube heat exchanger. TiO$_2$ nanoparticles with nominal diameter of 21 nm were dispersed in Thermo XT 32 oil as base fluid at three different particles concentration of 0.1%, 0.3%, and 0.5%, respectively. A straight horizontal stainless-steel tube of 1.2 m length, 0.012 m inner diameter, and 0.022 m outer diameter were used as a test section. Collecting data by varying the temperature of the heat transfer nanofluids and nanoparticle volume fraction. Nanofluids prepared using the method of two steps without the addition of a surfactant by using a magnetic stirrer for 1 hour then ultrasonic cleaner for 3 hours. The results of research conducted, the coefficient convection heat transfer of nanofluids TiO$_2$/ Thermo XT 32 oil increases along with the addition of fraction volumes; this is due to the increased thermal conductivity of the fluid as well with the rise of temperature against nanofluids TiO$_2$/Thermo oil XT 32. So it is very worthy of nanofluids applied in industries related to heat transfer processes.

1. Introduction
Heat transfer has an important role in many applications. Such is the Heat exchanger equipment using heat transfer principle. The development of science and technology is increasing rapidly, marked by the tendency of dimensions of a product that is getting smaller while increasing the ability of heat transfer. One way to increase heat displacement is fixing the properties of the fluid used. Generally the fluid used has low thermal conductivity. With added nanometer-sized solid particles are expected to improve the properties of the fluid.

Nanofluids are a mix of the cooling fluid with nano-sized solid particles or commonly called nanoparticles. Nanoparticle size ranging from 1 nm-100 nm. Choi and Eastman [1] introduced the term nanofluids in 1995. They investigated the addition of variations of carbon nanotube and metal
particles of nano-sized who dispersed on several different fluids. The result is an increase in thermal conductivity value 10%-80% with the addition of nano-particles of 0.1% to 10%.

Based on the review conducted by the research Haddad, et al [2] more use of TiO$_2$ nano-particles with water base fluids, while the use of nano TiO$_2$ particles with fluid base oil is still a little bit. So the writers feel interested to conduct research using TiO$_2$ nanoparticles with Thermo oil base fluid XT 32. The selection of TiO$_2$ nanoparticles as fluid nanomaterials easily obtained due to the market and the prices are cheaper compared to relative nanoparticles. While the basic fluid used is Thermo XT 32 Oil, because the oil has the ability to work at high temperature.

Torii [3] research on convection heat transfer of nanodiamond particles suspension with water as the fluid essence. The results showed that the fluid viscosity nano is increasing along with the increased concentration of the nanoparticles. The value of the number concentration and large Reynolds nanoparticles strongly affect the magnitude of the value of the coefficient heat transfer, heat transfer coefficient increase with increasing concentrations of particle, and the value of the thermal conductivity of the fluid work.

Murshed et al. [4] conduct research on the characteristics of convection heat transfer of nanofluids TiO$_2$/water under constant heat flux conditions. The results obtained that the fluid nano shows that there is an increase in convection heat transfer coefficient with increasing volumes of nanoparticles in aqueous solution. Duangthongsuk and Wongwises [5] measure a performance of heat transfer and pressure drop of nanofluids TiO$_2$/air under turbulent flow conditions. The result value of thermal conductivity of nanofluids increases with increasing concentration of volume nanoparticles. The value of the thermal conductivity is higher than with the equation of validation, but still in the same trend. The value of the coefficient of heat transfer of nanofluid is higher compared to the fluid essence, As well as, increased Reynolds number and concentration of the used particle and ranges from 26% higher than the fluid essence.

Putra et al. [6] research on heat transfer of nanofluids convection TiO$_2$/ethylene glycol in a circular tube under constant heat flux conditions. The result is the value of the thermal conductivity of the fluid work experience increased from fluid base with the highest increase in variation of 1% (w/v) of 8.62%. The value of the heat transfer of nanofluids TiO$_2$/EG as a working fluid in the heat exchanger can be seen from the Russell number value retrieved from the calculation. The value of the Reynolds numbers from 400 to 700 improved heat transfer. The highest increase was achieved at a concentration of 1% (w/v) of 30.55%.

Kristiawan et al. [7] measure the convective heat transfer of titanium (iv) oxide nanofluids under turbulent flow conditions. The results also revealed the drag reduction phenomenon in turbulent flow regime in which the friction factors of non-Newtonian nanofluids demonstrated lower trend than those of Newtonian fluid. In addition to the other mechanisms proposed by previous studies, this drag reduction phenomenon might be responsible for the heat transfer enhancement of nanofluids.

Irwanysyah et al. [8] the results of the study concluded that the value of the thermal conductivity of nanofluids increases along with a rise in temperature and volume fraction. At the same temperature, increased concentration of the nanoparticles was able to increase the value of the thermal conductivity of the fluid. While at a fraction of the same volume, an increase in temperature also was able to increase the conductivity of nano-fluid. The increase in the value of the thermal conductivity of nanofluids high of approximately 12% compared with the substantially fluid obtained at a fraction of the volume of 1.5% with temperature plug 44.6 °C.

2. Experiment

2.1. Preparation of Nanofluids

The mixing of nanofluids in this research was done using a magnetic stirrer and ultrasonic vibration. Particles of nano TiO$_2$ is used to obtained from Sigma Aldrich Chemical Pvt Ltd. USA with the size of the diameter of 21 nm. The mixing of TiO$_2$ nanoparticles with Thermo XT 32 Oil without using surfactants, TiO$_2$ with concentrations of 0.1%, 0.3%, and 0.5% depressed against Thermo XT 32 Oil.
with magnetic steering for 1 hour then continued by ultrasonic vibration for 3 hours, so there happen to clump (Figure 1).

Figure 1. Preparation of Nanofluids Equipment; (a) Digital Scale, (b) Measuring Cup, (c) Magnetic Stirrer, (d) Ultrasonic Vibration

2.2. Experimental Setup
The experimental setup consists of a pump, cold water tank, hot nanofluids TiO$_2$ tank, water heater, concentric tube heat exchanger, manometer “U”, flowmeter, thermocouples at the entry and the exit to measure the inlet and the outlet temperature. The flow of hot nanofluids goes into concentric tube heat exchanger is kept constant at the temperature of 60 °C, 80 °C, 100 °C, and 120 °C. In order to get accurate experimental results, first of all equipment is made stable by passing the water through the shell as well as the tube side area. To establish the laminar flow in the concentric tube, the flow rate of the hotter nanofluids TiO$_2$ is made constant as 2.0 LPM. Then the flow rate of the colder fluid is made constant as 2.0 LPM, by adjusting the flow meter. The schematic diagram of the experimental setup that we use is shown in Figure 2.

Figure 2. Schematic diagram of concentric tube heat exchanger
2.3. Experimental Procedure

The equipment consists of 3 research systems, i.e. a system of measurement, the path system in pipe (inner tube), and the system of flow path on the annulus. The path is a path in the pipe is open. Nanofluids heat in the tank, the pump is driven by the heat of nanofluids, nanofluids heat flows through concentric tube heat exchanger, and back to the tank hot nanofluids. Nanofluids heater controlled by thermos-controller to maintain a constant temperature in the tank hot nanofluids. The path of the flow in the annular path is open. The water in the tank is piped to the annulus heat exchanger, and it is coming out of annular immediately discarded.

3. Results And Discussion

3.1. The rate of heat transfer relationship with volume fraction

As shown in Table 1, showing the results of the rate of heat transfer of nanofluids TiO2/Thermo XT 32 oil (inner tube) on the variations of volume fraction 0 Vol% (basic fluid), 0.1 Vol%, 0.3 Vol%, 0.5% and variations of temperature 60 °C, 80 °C, 100 °C, 120 °C as the following.

| Temperature (°C) | 0 Vol%  | 0.1 Vol% | 0.3 Vol% | 0.5 Vol% |
|------------------|---------|----------|----------|----------|
| 60               | 443.69  | 635.15   | 906.83   | 1137.31  |
| 80               | 671.60  | 918.66   | 1381.81  | 1850.03  |
| 100              | 812.70  | 1080.39  | 1626.67  | 2184.05  |
| 120              | 999.49  | 1163.42  | 1801.48  | 2294.58  |

In Figure 4 is shown an increasing temperature of the nanofluids, then the rate of heat transfer is happening also increased. This is because the increased heat capacity base fluid Thermo XT 32 oil with the addition of nanoparticles. The highest rate of heat Transfer at a fraction of the volume of 0.5 Vol% and temperature of 120 °C of 2294.58 W heat transfer rate and lowest at 0 volume Vol% fraction and temperature 120 °C of 999.49 W or 129.57% fluid compared to his base.
3.2. Convection heat transfer coefficient of relationship with volume fraction

As shown in Table 1, showing the results of convection heat transfer coefficient of nanofluids TiO2/Thermo XT 32 oil (inner tube) on the variations of volume fraction 0 Vol% (basic fluid), 0.1 Vol%, 0.3 Vol%, 0.5% and variations of temperature 60 °C, 80 °C, 100 °C, 120 °C (Table 2).

Table 2. Convection heat transfer coefficient of relationship with volume fraction

| Temperature (°C) | 0 Vol% | 0.1 Vol% | 0.3 Vol% | 0.5 Vol% |
|-----------------|--------|----------|----------|----------|
| 60              | 1315.55| 1865.01  | 2972.22  | 4087.54  |
| 80              | 1347.17| 1887.05  | 2995.47  | 4109.60  |
| 100             | 1367.98| 1898.28  | 3001.32  | 4111.94  |
| 120             | 1398.12| 1925.06  | 3001.32  | 4137.66  |

Based on Figure 4, the heat transfer coefficient convection in the pipeline within (inner tube) increases with the addition of nanoparticles against Thermo oil base fluid XT 32. So also with the influence of a rise in temperature of nanofluids. Heat transfer coefficient of convection on highest volume fraction of 0.5% and a temperature of 120 °C, i.e. 4137.66 W/m² (Figure 5). °C and the lowest at fraction 0% (Thermo XT 32 oil) and a temperature of 60 °C, i.e. 1315.55 W/m². °C. This is due to the increase in the rate of heat transfer of nanofluids.
4. Conclusion

Convection heat transfer coefficient of nanofluids TiO2/Thermo oil XT 32 increases along with the addition of volume fraction and increased in line with rising temperatures. This is caused by increased fluid properties (thermal conductivity) of nanofluids. Heat transfer coefficient of convection on highest volume fraction of 0.5% and a temperature of 120 °C, i.e. 4137.66 W/m².°C and the lowest at fraction 0% (Thermo XT 32 oil) and a temperature of 60 °C, i.e. 1315.55 W/m².°C.

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