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EFFECTS PARTICLES CONCENTRATION OF Al_2O_3 AND TiO_2 TO CONVECTION COEFFICIENT ON DOUBLE PIPE HEAT EXCHANGER

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Abstract

Heat exchanger is a device used to transfer heat energy from a fluid to in another fluid. Each fluid has different characteristics. Value of convection heat transfer is determined by the value of the convection heat transfer coefficient (h) which depends on the dimensions and flow conditions. The fluid with the additional of Al_2O_3 nanoparticles (aluminum oxide) and TiO_2 (Titanium dioxide) has great potential for cooling applications. The purpose of this study was to analyze the effect of $A_{l2}O_3$ and TiO_2 particle concentration on the value of the convection heat transfer coefficient in the double pipe heat exchanger with circular straight pipes. Cooling fluid used is pure water, the fluid with the addition of Al_2O_3 nanoparticles and fluid with the addition of TiO_2 nanoparticles at concentrations of respectively 40 ppm and 60 ppm. Flow used in a heat exchanger is the flow of counterflow type. Changes in temperature controlled 95 ° C for hot fluid, 17ºC for cooling fluid. The results show the influence of Al_2O_3 and TiO_2 nanoparticles in the fluid characteristics and an increase in the value of the convection heat transfer coefficient is influenced by the amount of concentration on mixing nanoparticles in the cooling fluid.

Keywords: heat exchanger, convection coefficient, nanoparticles, nanofluid.

1. INTRODUCTION

Advances in technology are currently growing industry increases will have an impact in the industry. Industries that utilize heat transfer phenomena utilizing technology that can improve productivity and efficiency. Industrial world exploiting the phenomenon of heat transfer to a heat transfer process using a device called a heat exchanger or heat exchangers.

Heat Exchanger is a tool that allows heat transfer and could serve as heating as well as refrigerant, The heating medium uses super heated steam and water as cooling fluid. The heat exchanger is designed as much as possible so that the heat transfer between fluid can take place efficiently. Heat exchange occurs by contact, either between the fluid there is a wall separating it and both mixes instantly granted. Heat Exchanger this have an important role in a production process or operation, for example, is often used in industries such as oil refinery, chemical factory nor petrochemicals, natural gas industry, refrigeration, power plants, And of course with various types Heat exchangers are used according to each requirement.

One type of heat exchanger that are widely used double pipe. Heat exchangers of this type has a simple design, with piped straight ahead where there are two pipes, each small pipe on the inside of the large pipe on the outside. heat exchangers of this type typically used for small jobs because of the flexibility, which is designed according to the needs of shape and fluid flow.

Classification of flow in the heat exchanger can be divided into parallel flow, counter flow, and cross flow. These three are distinguished according to its flow direction in which the parallel flow to both the fluid flow in and out on the same side and do not mix. For the counter flow direction of the second fluid flow is parallel but opposite directions and do not mix. As for the second stream crossflow direction perpendicular but do not mix. Of the three types of this flow which ideally is most effective with counter flow direction due to the temperature difference across the wall of the lowest cross section exchangers, generating minimum thermal stress on the walls compared with other flow direction.

In the flow of the coolant fluid used nanofluids Al2O3 and TiO2. Nanofluids is a liquid containing nanometer-sized particles, called nanoparticles. This fluid is engineered with the advancement of technology this time. So therefore, the author tries to analyze the influence of the characteristics of nanofluids Al2O3 and TiO2 to obtain the value of the convection heat transfer coefficient in the double-pipe heat exchanger.

2. METHODOLOGY

This study uses a double pipe heat exchanger with straight pipes. Flow type used is a counter flow stream which has a good heat transfer efficiency than the parallel flow streams. This type of heat exchanger can be used at lower fluid flow rate and high operating pressures.

The process of making nanofluids in this study using the method by mixing each of Al_2O_3 and TiO_2 nanoparticles into the fluid essentially pure water with a mass concentration of each - each amounted to 40 ppm and 60 ppm.

The experiments were performed repeatedly and continuously with the different levels within each retrieval of data. Fluid cooling with a mixture of water and the nanoparticles are taken from the temperature of 17 ° C, and the hot fluid temperature data taken from 95 ºC.

The retrieval of data taken by temperature input and output of each - each fluid and discharge the fluid flow generated within a predetermined time for 2 seconds after the stream that happens to flow constantly, after retrieval of data then proceed with the calculation and analysis of the calculation results.

2.1 Scheme Of Testing Equipment

Double pipe heat exchanger counterflow type in which fluid entered at the opposite ends and ends at opposite ends in the opposite direction as well. Fluid flow will be divided into two streams such as hot fluid flow and the flow of cooling fluid.

Circulation to heat fluid flow from the storage tank that is heated using the heater is pumped into the heat exchanger and then flows back toward the holding tank (heater) to be reheated. The circulation of the coolant flow of nanofluids holding tank is pumped into the heat exchanger and then flows back toward the holding tank and re-circulated nanofluids.

In this heat exchanger using a thermocouple, each mounted on the input side and output side of the hot fluid flow and the cooling fluid flow. Thermocouples are used to detect the temperature value each - each fluid will metampilkan thermometer temperature data on the display.

On a heat exchanger opposite flow direction (counterflow) is the most efficient flow pattern. This means that they will provide the highest overall heat transfer coefficient for double pipe heat exchanger design. In this double-pipe heat exchanger can also handle high pressure and high temperature.

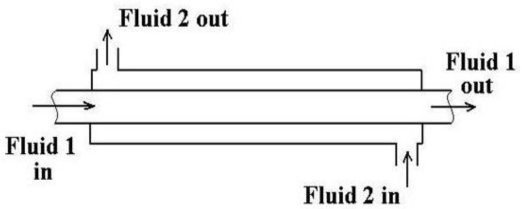

Figure 1. Counter Flow Direction

Here is a schematic drawing of test equipment in this study.

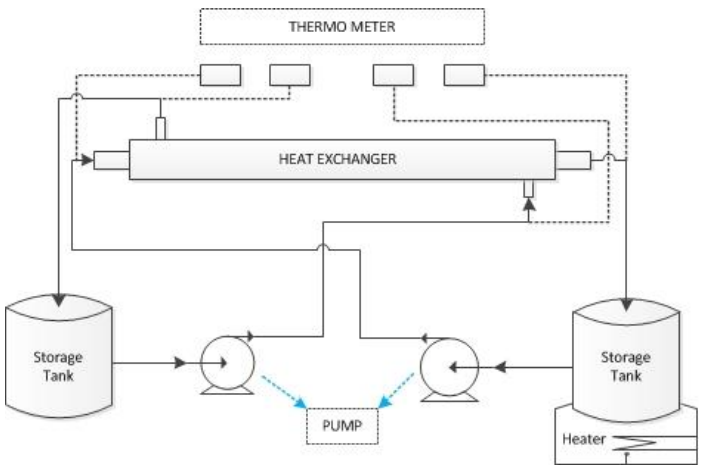

Figure 2. Schematic of Test Equipment

2.2 Set-up Testing

This study used a testing apparatus that consists of a double pipe heat exchanger with counter flow type of flow. In the hot fluid pipes used steel pipes with a length of 1000 mm diameter of 90 mm. Cooling fluid pipes using copper pipes with a length of 1200 mm diameter of 30 mm. To drain the fluid from the reservoir to a heat exchanger used centrifugal pumps for each of the hot fluid and coolant fluid. Heat exchangers used are shown in Figure 3.

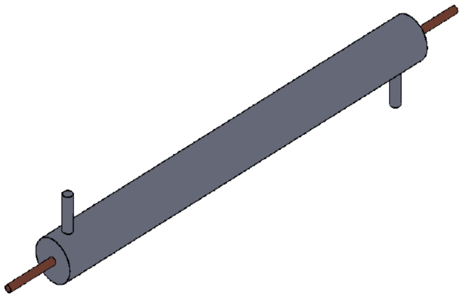

Figure 3. Double Pipe Heat Exchanger

2.3 Equation

The equation of heat transfer convection known as Newton's law of cooling (Newton's Law of Cooling) where for all the mechanisms of transfer of heat, if the temperature difference between the object and its surroundings is small, the rate of cooling of an object is almost proportional to the temperature difference, which is formulated as follows:

$$h = Nu\frac{K}{D}$$

Where :

h = Coefficient of convection ($W/m^2.K$)
Nu = Nusselt number
K = Thermal conductivity of materials (W/m.K)
D = Diameter of pipe (m)

Nanofluids exhibit superior heat transfer characteristics to conventional heat transfer fluids. One of the reasons is that the suspended particles are remarkably increased thermal conductivity of nanofluids. The thermal conductivity of the nanofluid is strongly dependent on the nanoparticle volume fraction. So far it has been an unsolved problem to develop a sophisticated theory to predict thermal conductivity of nanofluids, although there are some semiempirical correlations to calculate the apparent conductivity of a two-phase mixture. Thermal conductivity nanofluids can use the equation:

$$\frac{k_{nf}}{k_{bf}} = \frac{k_p + 2.k_{bf} - 2.(k_{bf} - k_p).\varphi}{k_p + 2.k_{bf} + 2.(k_{bf} - k_p).\varphi}$$

Where :

k_{nf} = Nanofluid thermal conductivity (W/m.K)
K_{bf} = Basefluid thermal conductivity (W/m.K)
k_p = Thermal Conductivity of nanoparticles (W/m.K)
φ = Nanoparticles volumetric concentration (%)

Nusselt number (Nu), which can be defined as the ratio of the convective heat transfer fluid conduction heat transfer fluid in the same condition. So that the Nusselt numbers:

$Nu = 0.023\ Re^{4/5}.Pr^n$ for water- TiO_2

$Nu = 0.0256\ Re^{4/5}.Pr^n$ for water- Al_2O_3

Where :
Re = Reynolds Number
Pr = Prandtl Number
n = 0.4 (for hot fluid)
= 0.3 (for cooling fluid)

The Reynolds number is used to determine the fluid flow is laminar, turbulent, and transitions. can be used as a reference to determine the types of flow that goes in the water. To determine the value of the Reynolds number (Re) for flow in pipes with nanofluids used:

$$Re_{nf} = \frac{\rho_{nf}.v.D}{\mu_{nf}}$$

Where :
Re_{nf} = The Reynolds number nanofluids
ρ_{nf} = Density (kg / m^3)
v = Flow Speed (m / s)
D = Diameter of pipe (m)
μ_{nf} = Dynamic viscosity of nanofluids (Ns/m2)

Prandtl number is the ratio of the kinematic viscosity (v) fluid with heat diffusivity (α), which is the Prandtl number thermodynamic properties of the fluid:

$$Pr_{nf} = \frac{\mu_{nf} Cp_{nf}}{k_{nf}}$$

Where :
Pr_{nf} = Prandtl Numbers
Cp_{nf} = Specific Heat (J/kg.K)
μ_{nf} = Dynamic viscosity of the fluid (Ns/m2)
k_{nf} = Fluid heat conductivity (W/mK)

The specific heat is the heat capacity per unit mass and has a variety of units (J/Kg-K, cal /g-K, Btu / lbm-°F). The specific heat of nanofluids can use the equation:

$$Cp_{nf}.\rho_{nf} = \varphi(\rho_p.Cp_p) + (1-\varphi)(\rho_{bf}.Cp_{bf})$$

Where :
Cpnf = Nanofluid heat capacity (J/kg.K)
cpp = Nanoparticles heat capacity (J/kg.K)
Cpbf = Basefluid heat capacity (J/kg.K)
ρ_{nf} = Nanofluid density (kg/m^3)
ρ_{bf} = Basefluid density (kg/m^3)
ρ_p = Nanoparticles density (kg/m^3)
φ = nanoparticles volumetric concentration (%)

Density is the amount of a substance contained in a unit volume. Density in nanofluids are directly related to the particle volume fraction. A density will decrease in value with increasing temperature of the liquid by means of non-linear. This occurs because the non-linear coefficient of thermal expansion is the difference in basic fluid and nano particles. Density of nanofluids can use the equation:

$$\rho_{nf} = \varphi\rho_p + (1-\varphi)\rho_{bf}$$

Where :

ρ_{nf} = Nanofluid density (kg/m^3)

ρ_{bf} = Basefluid density (kg/m^3)

ρ_p = Nanoparticles density (kg/m^3)

φ = Nanoparticles volumetric concentration (%)

Dynamic viscosity of nanofluids can use the equation:

$$\mu_{nf} = \frac{1}{(1-\varphi)^{2,5}} \cdot \mu_{bf}$$

Where :

μ_{nf} = Nanofluid dynamic viscosity (kg/ms)

μ_{bf} = Basefluid dynamic viscosity (kg/ms)

φ = Nanoparticles volumetric concentration (%)

3. RESULTS AND DISCUSSION

Nusselt number is a measure of convection heat transfer occurring at the surface and the temperature of the flow. Rising temperatures in the hot fluid is water will result in increase in Nusselt number as shown in Figure 4 graph Nusselt number and temperature of hot fluid.

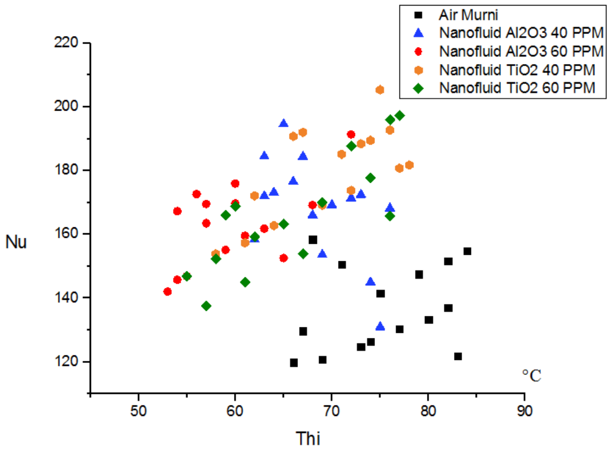

Figure 4. Graph Nu-Thi relation to the hot water with the cooling fluid nanofluids TiO_2 and Al_2O_3.

Based on the graph of Nusselt number and temperature of hot water in Figure 4 above, it can be seen that on average there is a rise in the value of Nusselt number on all hot water with cooling fluid nanofluids Al_2O_3 40 PPM and 60 PPM and nanofluids TiO_2 40 PPM and 60 PPM compared hot water without nanofluids in the cooling fluid. The smallest value Nusselt number with nanofluids are in hot water with cooling fluid nanofluids Al_2O_3 40 PPM at 75 °C with a value of 130.96 and Nusselt number largest found in hot water with cooling fluid nanofluids TiO_2 40 PPM temperature of 75 °C with a value of 205.37.

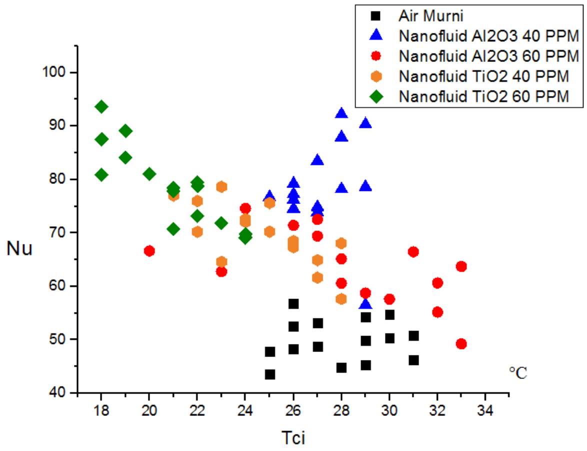

Figure 5 Graph Nu-Tci relation to the cooling fluid nanofluids TiO_2 and Al_2O_3.

Based on the graph of Nusselt number and the temperature of cold water in Figure 5 above, it can be seen that on average there is a rise in the value of Nusselt number on all cold water with nanofluids Al_2O_3 40 PPM and 60 PPM and nanofluids TiO_2 40 PPM and 60 PPM compared with cold water without nanofluids. This can be seen in the chart above, where in the smallest value Nusselt number with nanofluids found in cold water with nanofluids Al_2O_3 60 PPM at a temperature of 33 °C with a value of 49 256 and Nusselt number largest found in cold water with nanofluids TiO_2 60 PPM temperature of 18 °C with a value of 93 647.

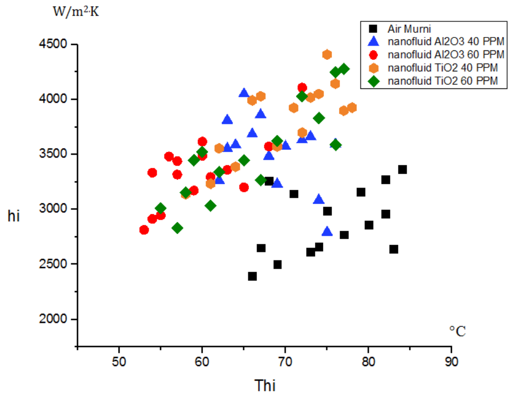

Figure 6 Graph Thi-hi relation to the hot water with the cooling fluid nanofluids TiO_2 and Al_2O_3.

Based on the graph convection coefficient and the temperature of hot water in Figure 6 above, it can be seen that on average there is a rise in the value of the coefficient of convection on all hot water with cooling fluid nanofluids Al_2O_3 40 PPM and 60 PPM and nanofluids TiO_2 40 PPM and 60 PPM compared to hot water without nanofluid in the cooling fluid. This can be seen in the chart above, where in the smallest value of convection coefficient with nanofluids are in hot water with cooling fluid nanofluids Al_2O_3 40 PPM at 75 °C with a value of 2792.94 W/m^2K and convection coefficient biggest there is in hot water with cooling fluid TiO_2 nanofluids 40 PPM temperature of 75 °C with a value of 4408,753 W/m^2K.

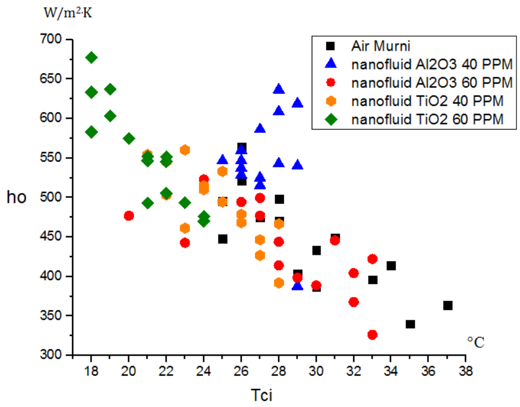

Figure 7. Graph Thi-ho relation to the cooling fluid nanofluids TiO_2 and Al_2O_3.

Based on the graph convection coefficient and the temperature of cold water in Figure 7 above, it can be seen that on average there is a rise in the value of the coefficient of convection on all cold water with nanofluids Al_2O_3 40 PPM and 60 PPM and nanofluids TiO_2 40 PPM and 60 PPM in compared with water without nanofluids. This can be seen in the chart above, where in the smallest value of convection coefficient with nanofluids are in hot water with cooling fluid nanofluids Al_2O_3 60 PPM at a temperature of 33 °C with a value of 326 346 W/m^{2}K and convection coefficient biggest there is in hot water with cooling fluid TiO_2 nanofluids 60 PPM temperature of 18 °C with a value of 677 512 W/m^{2}K.

4. CONCLUSION

1. Al2O3 and TiO2 nanofluid affects fluid characteristics which include density, specific heat, thermal conductivity, and dynamic viscosity values.
2. The value of mass flow rate, equilibrium of heat energy, reynold number, prandtl number, and nusselt number with a mixture of nanofluid Al2O3 and TiO2 is more effective than fluid without nanofluid.
3. Fluid with a mixture of Al2O3 and TiO2 nanoparticles has an increase in the value of convection heat transfer coefficient compared to those without nanofluid.

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