Preparation and Characterization of TiO2 Nanoparticles as Nanofluid in Double Pipe Heat Exchanger

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Abstract. The development of science and technology provides a significant increase. One of the main examples in the field of heat transfer, In the industrial world, there are several categories of heat exchangers, such as the cooling unit as a supporting medium in industrial areas, there is a double pipe heat exchanger which is an engineering illustration of industrial development. In general, the use of liquid work materials in a job on a heat transfer device still uses liquid work materials with a fairly basic heat conductivity scale. Nano-liquid working materials can be defined as solutions that are useful in improving the thermal properties of molten work materials. In this study, using a working medium in the form of a double pipe heat transfer device accompanied by a liquid working material in the form of Titanium Dioxide (TiO2) nanoparticles with a volume fraction variation of 1%, 3%, and 5%, the temperature constant used is 80˚C as the subject. is being studied. In the use of nanofluids as a mixture in the working fluid, there are stages that need to be considered, such as the SEM (scanning electron microscope) test stage, the Nanoparticle Preparation Stage, the Dispersion/Mixing of Nanoparticles with Base Fluids, the Nanofluid Sonification stage, and the Nanofluid Use Stage in the exchanger. Double pipe heat. In determining the quality and scale of optimization on nanofluids, besides being influenced by the value of the volume fraction of nanofluids and the working temperature used. Thus it can be concluded that the nanofluid mixing process is the main factor in determining the optimization scale and nanofluid quality.

Keywords: Double Pipe Heat Exchanger · Nanofluids · Fraction Volume · SEM (Scanning Electron Microscopy) · Titanium Dioxide

1 Introduction

Heat exchange activities require and use several interests, the main ones being related to the temperature that occurs, which is a major role in determining the optimal performance

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of the research process. In this case, the main medium used is none other than a heat transfer device in general. With the main function as a distributor and convert heat effectively [1, 2].

The heat transfer device in this study acts as a condition for the temperature related to the work material used. The steps are carried out by filtering or removing the source of excess heat from the liquid work material being studied. In this study, although it is based on the dissimilarity of several factors such as posture, indications of perfection, as well as several other types of work media. The heat transfer device as a whole has almost the same component characteristics, has a cylinder or plate as a differentiator for each liquid working material [3].

The double-pipe type heat transfer device is defined as an alternative development in the engineering world that is found in the refrigeration unit in the intermediary in the industrial area. Nanofluids working material has the meaning as a new breakthrough in several ranges of other liquid working materials with size characteristics (1-100 nm) which are combined into a single unit. The division is also diverse and varies depending on the needs of the work. It consists mostly of an oxidation system [4].

The titanium-type liquid working material is defined as the chemical substance of titanium being oxidized. The main thing that is seen from this type of liquid working material is its heat properties, chemical properties that are more different from other liquid working materials. From a general work point of view, this type is preferred in paint jobs, sunblocks, and food brighteners. In a term, the main factor that plays a major role in the effect of the ratio of the heat conversion coefficient at the point of forced convection is the concentration value used in the molten work material. This has been stated by researchers and the results of previous relevant studies [5].

The liquid working material that is considered in this study is water – TiO2 with a combined concentration value of 3% in an indication of the effectiveness value of the shell and tube type heat transfer device. And the role of the total effectiveness level found at 80°C and the heat transfer unit at 7561.5 watts plus increasing the effectiveness value by 50% [6].

The stages of understanding in the heat transfer process and at the stage of moving the liquid work material with the medium of water dissolved by TiO2 which moves to adjust the medium through which it passes. In this study, a pipe with a vertical contour makes the movement of the liquid work material laminar and the transition phase by the flux limiting pressure constant hot conditions. The results obtained are quite significant in that the heat transfer coefficient at the convection point increases linearly with the concentration value of the liquid work material which is influenced by the Reynolds value and the posture of the liquid work material. The conclusion is that the reduced pressure on the nanofluids work material is balanced with the basic liquid work material used. By He and friends [7].

The phenomenon of heat transfer at the convective point and the reduced pressure on the base fluid working material contained in the TiO2 liquid work material which moves in the heat transfer device with a horizontal downward movement in a turbulent manner. The working stages in the use of TiO2 liquid work material with a diameter of 21 nm in combination with the basic liquid working material using a concentration value of 0.2 - 2%. The initial thing obtained is that the level of heat transfer coefficient in the nanofluids

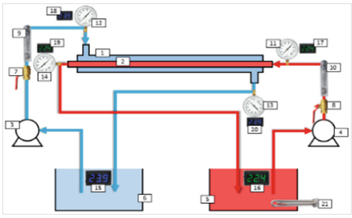

Fig. 1. Schematic of *Double Pipe Heat Exchanger*

work material increases as the Reynolds value increases. Another conclusion obtained is that the coefficient value in the heat transfer process at a concentration value of 2% is lower than the basic liquid working material. And in this written result, the author observes the mixing and digesting process specifically regarding the overall information related to nanofluids working materials as objects that are examined in the heat transfer tool being worked on. By Duang thongsuk and wongwis [8].

2 Research Methods

2.1 Material

2.1.1 Double Pipe Heat Transfer Device

This tool is defined as a research medium/ntermediary used in processing basic liquid work materials combined with nanofluids work materials as research objects.

2.1.2 Nanofluids

The nanofluid used in this research is Titanium Dioxide (TiO2), a chemical compound unit between titanium and oxygen. The advantage of using TiO2 is that it is classified as a nanoparticle that has good thermal properties and includes compounds that are easily dissolved in water and do not settle easily [9].

2.1.3 Research Tools, and Instruments

The following are the supporting components of this research, including:

a. Double pipe heat exchanger
   Designed and manufactured using the following specifications:
   Equirement of outer pipe = 1 pieces; Equirement of outer pipe passes = 1 pieces; Diameter used outside pipe (do,s) = 76.2 mm; Outer pipe inner diameter (di,s) = 72.2 mm; Outer pipe length (Ls) = 1.1 m; Outer pipe thickness = 2 mm; Thermal conductivity (k) = 15.1 W/mºC; Material outer pipe = Stainless Steel 304.
b. Scales
   Scales, are objects that are used as weights of nanoparticles that have been determined based on the calculated volume fraction.

Fig. 2. Scales.

Fig. 3. Measuring Cup.

Fig. 4. Ultrasonicator Cleaner.

iii. Measuring Cup
Measuring Cup is A one of the equipment in a chemistry laboratory, one of its functions is to measure the volume of a solution of a chemical that will be used.

iv. Ultrasonicator Cleaner
Ultrasonicator Cleaner is a tool used in the dispersion process (the process of mixing Nanoparticles with the base fluid evenly adjusted to the volume fraction) (Fig. 4).
Brand = SS-698
Supply = 220 V
Range = 30W – 50W

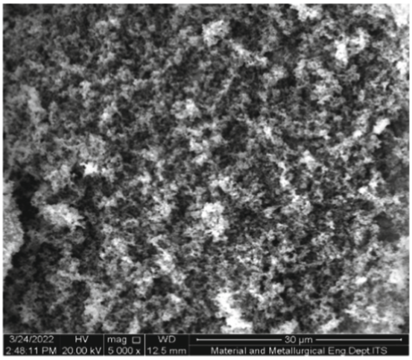

Fig. 5. Test results Electron transfer microscopy method of Titanium Dioxide (TiO2), Nanoparticles magnified 5000 times.

2.2 Methods

2.2.1 Pre-treatment Stage of Nanofluids Working Materials

At this stage, work is carried out in the form of suspensions on nano-liquid working materials as initial work in the initial application of heat transfer applied to nano-liquid working materials. In this stage, 2 methods are used, the nano-liquid working material is prepared with an average posture of 15 nm with a certain type or brand. One of the things to watch out for in this stage is the treatment of hydrophobic surfaces, these surfaces cause uniform deposition or accumulation when not subjected to the mixing stages properly [10].

In addition to the magnitude of the concentration value in the liquid work material, the addition of other substances causes changes in the characteristics of the liquid work material to be observed. With this chemical treatment of TiO2 can maximize the function of the liquid work material. In the stages of mixing the liquid work material there are 2 compositions, namely TiO2 as a nano working material and Water as a liquid working material which is done using ultrasonic vibrations at 45–60 min at 50 w and 30 kHz vibrations [11].

The electron transfer microscope method or commonly known as SEM is a microscope tool that is used to view and study micro-scale objects directly in the form of solid or liquid objects. By using the main function of the focused electrons in a low level which is positioned as a tester on the work object. This method uses the latest type of machine with the FLEXSEM 100 type produced from Japan which features topological deepening of the surface contours of the object under study. Figure 1, Fig. 2, and Fig. 3 define and illustrate the nanofluids working material after being subjected to an initial mixing treatment together with the basic liquid working material in the form of water (Figs. 5, 6 and 7).

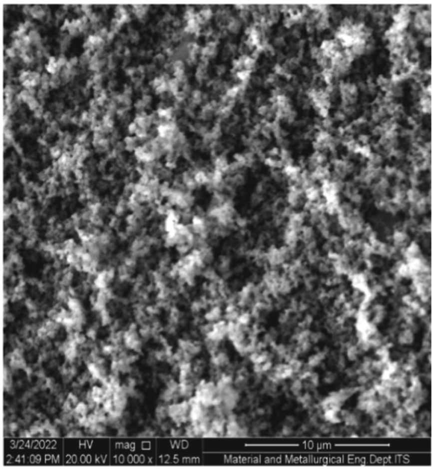

Fig. 6. Test results Electron transfer microscopy method of Titanium Dioxide (TiO_2) Nanoparticles magnified 10.000 times.

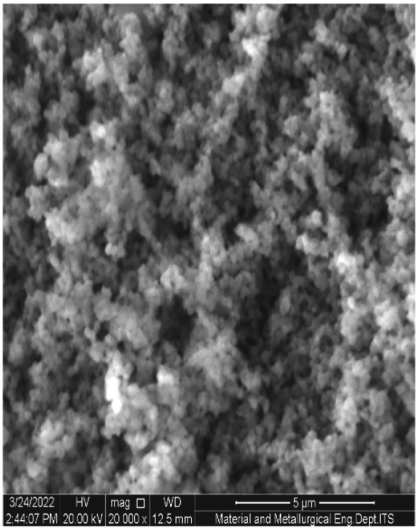

Fig. 7. Test results Electron transfer microscopy method of Titanium Dioxide (TiO2) Nanoparticles magnified 20.000 times.

2.2.2 Related Sources of Nanofluids Working Materials

Before carrying out work and exploring each step that will be carried out on heat transfer at the convection point of the nanofluids work material, it is necessary to first explore the nanofluids work material before use. Assuming the nano-liquid working material is evenly mixed with the basic liquid working material, the concentration value can also be assumed to be linear on each side of the cylinder. The role in determining the assumptions is useful in facilitating the evaluation of the physical properties of nanofluids work materials [12]. For this reason, the following equations are used to find the physical properties of nanofluids:

Based on research conducted by I M Arsana, D R Agista, et al. (2019), in determining the volume fraction of nanofluids can use the following equation.

$$\varphi = \frac{V_p}{V_l} x100\% \tag{1}$$

$$V_p = \frac{W_p}{\rho_l} \tag{2}$$

$$W_p = V_p x \rho_p \tag{3}$$

The density of nanofluids working materials that can be calculated using theory in the mixing process is as follows:

$$\rho = \emptyset\rho_p + (1 - \emptyset)\rho_{bf} \tag{4}$$

The specific heat capacity of the nanofluids working material can be calculated using the following equation:

$$C = \frac{\emptyset\rho_p c_p + (1 - \emptyset)\rho_{bf} c_{bf}}{\rho} \tag{5}$$

The dynamic viscosity of the nano-liquid working material is calculated using the equations proposed by Albert Einstein [14], which is a general indication of the viscosity of aqueous solutions with suspensions occurring at (φ 2%) in the form of small particles, stiff texture, and gestural like ball. The use of equations by Albert Einstein is done because of the occurrence of a fairly dilute suspension process :

$$\mu = \mu_{bf}(1 + 2.5\emptyset) \tag{6}$$

In knowing the problems related to specific calculations on the value of the thermal conductivity effectively that occurs in the work object in the form of nanofluids, you can use the equation by Yu and Choi [27] as follows:

$$k = \left[\frac{k_p + 2k_{bf} + 2\left(k_p - k_{bf}\right)(1 + \beta)^3\emptyset}{k_p + 2k_{bf} - 2\left(k_p - k_{bf}\right)(1 + \beta)^3\emptyset}\right] k_{bf} \tag{7}$$

β is a representation of the thickness ratio that occurs in the original nanoparticles which is interpreted as a result of 0.1 in this experimental study which is useful in data collection related to the value of thermal conductivity effectively in nanofluids. It should also be borne in mind that the main factor to consider is the temperature function which is calculated through the average temperature of the liquid working material between the inlet and outlet (Table 1).

Table 1. Thermophysics owned by TiO2 Nanoparticles [10]

Property	Density ρ (kg/m^3)	Heat capacity Cp (J/kg.K)	Thermal conductivity k (W/m.K)
Water	992	4182	0.618
TiO_2	4250	686.2	8.9538

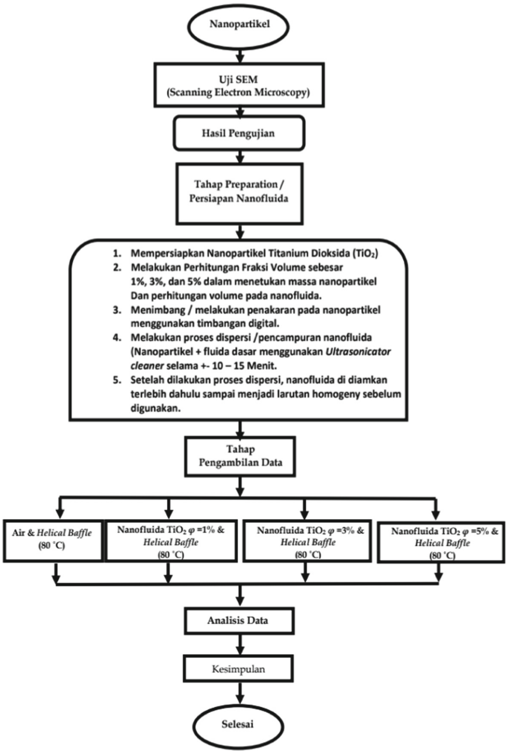

Fig. 8. Nanofluid Mixing *Flowchart.*

1. **Variation of Temperature and volume fraction**

   Temperature variations were carried out on hot fluids with a temperature constant of 80 °C and volume fraction variations of 1%, 3%, and 5%.
2. **Nanofluids Mixing Flowchart**

   (See Fig. 8).
3. **The Stages of Making Nanofluids**

Table 2. Fraction Volume 1%, 3%, and 5% Nanofluida TiO_2

FRAKSI VOLUME	VOLUME AIR (L)	MASSA NANO PARTIKEL (GRAM)
1%	0,5	2,115 g
3%	0,5	6,345 g
5%	0,5	10,575 g

A. Preparation Stage/Nanofluid Preparation

Nanofluids are made by mixing nanoparticles (TiO2) into the base fluid, namely water. In this study, the size of the nanoparticles used was 20 nm, where the nanoparticles were subjected to a dispersion treatment/mixing process until the nanoparticles were evenly distributed with the base fluid. For +- 10-15 min. Before mixing, the nanoparticle mass calculation is carried out by multiplying the density of the nanoparticles by the volume of the nanoparticles. Then the value of the mass of nanoparticles will be obtained for each different volume fraction.

Based on these calculations, the results are obtained according to the use of the volume fraction. The following is the mass of nanoparticles that have been determined with the base fluid, namely, H2O (Water) (Table 2).

After obtaining the results from the above calculations, there are several further stages in the nanoparticle preparation process to become nanofluids, as follows.

1. Weighing/measuring the nanoparticles to be used using a digital scale, here for the use of Titanium Dioxide (TiO2) nanoparticles with Water (H2O) base fluid.
2. Titanium Dioxide (TiO2) nanoparticles were prepared for the dispersion stage (mixing process so that the substance can be evenly distributed) in water with a volume fraction concentration (1,3,5 vol %).
3. For the method of mixing the volume fraction of the nanofluid itself, it is by doing a comparison of the volume of the base fluid used with the volume of the nanoparticles used. For example, for the volume fraction 1% = 1% of the volume of TiO2 nanoparticles divided by 1% of the volume of the base fluid used (1% of 1 kg of nanoparticles and 1% of the volume of the base fluid × 100%), so that the result is The whole nanofluid was tested, and for mixing the 3% and 5% volume fractions were carried out in the same ratio. In this study, 0.5 L of base fluid was used.
4. Next, Titanium Dioxide (TiO2) nanoparticles are mixed with the base fluid, namely Water (H_2O) using the Ultrasonic Cleaner Sunshine SS-968. This mixing is adjusted to the mass calculation that has been carried out, after that the nanoparticle dispersion process in the base fluid is carried out, the process is carried out for ± 5 min – 10 min.
5. The final step in this mixing process, the TiO2 Nanofluid is allowed to stand for a while until it becomes a homogeneous solution (having the same properties at every point/side), after which the TiO2 Nanofluid can be used as a working fluids.
6. **Preparation stage for data collection**

After the nanoparticles are obtained according to the volume fraction that has been determined, the Double Pipe Heat Exchanger test equipment needs to be checked again as follows.

1) Conditioning the volume of hot fluid in the inlet hot fluid reservoir
2) Conditioning the cold fluid volume in the cold fluid intake reservoir.
3) Hot fluid pump and cold fluid pump to circulate the incoming fluid
4) Condition of the valve on the double pipe heat exchanger piping

    a) Opening the cold fluid inlet by pass valve
    b) Open the cold fluid drain valve to thecold fluid inlet tank
    c) Close the cold fluid drain valve to the cold fluid inlet tangki
    d) Opening the by-pass valve for the hot fluid inlet
    e) Close the hot fluid drain valve to the hot fluid inlet tank

5) Condition of cold fluid tank and hot fluid and heater to heat hot fluid
6) The situation of the installation of fluid pipes and cylinders on double cylinder heat transfer equipment does not experience leakage when used using cold liquid pumps and hot liquids both of which will flow to the heat transfer section.
7) Regulator on the flow meter to determine the flow rate
8) Thermocontrol to set the temperature and display the temperature connected to several thermocouple sensors.

III. **Data Collection Stage**

Declared ready and the experimental equipment is also checked, the test can be carried out with the following procedure.

1. Turn on the heaterelement to heat the hot fluid in the hot fluid tank to a temperature of 80 °C.
2. Conditioning the cold fluid inlet temperature at a temperature of 30 °C if the temperature is less than 30 °C then treatment can be given, mixing a little hot water in the cold fluid until the temperature is uniform, namely 30 °C. Meanwhile, if the cold fluid temperature is more than 30 °C then you can use the air conditioner (AC) in the room to condition the temperature to exactly 30 °C.
3. Turn on the cold fluid pump, so that cold fluid enters the DPHE in the outer pipe until the condition is stable (steady) with the required time of ± 4 min.
4. Set the flowmeter regulator to determine the cold fluid flow rate of 6 lpm, by adjusting the position of the float on the flowmeter of 6 lpm.
5. Conditioning the inlet temperature of the hot fluid at a temperature of 80 °C with a thermocontrol.
6. Open the hot fluid drain valve to the hot fluid inlet.
7. Turn on the hot fluid pump, so that the hot fluid enters the DPHE in the inner pipe until the condition is stable (steady) in the sense that there is no change in temperature with the required time of ± 2 min.

8. Adjust the flow parameters to determine the acceleration of movement in hot liquids of 4 lpm by setting the float position in the flow parameter of 6 lpm. Hot liquid in the inner pipe and cold liquid in the outer pipe, in this position both will be subjected to a heat exchange process, from this process data related to temperature conditions will be taken. Here it takes a minimum of 2 min for hot and cold liquids to come out.
9. Titanium Dioxide (TiO2) nanofluid which has been dispersed using an ultrasonic cleaner, and the nanofluid has become a homogeneous solution, is then inserted into the hot fluid tank after the Double Pipe Heat Exchanger is started running for about 10–15 min.
10. Record the pressure that occurs in the cold fluid line and the hot fluid line on the pressure gauge.
11. Record the temperature that occurs in the cold fluid inlet on the thermocontrol display measuring instrument.
12. Record the temperature that occurs in the hot fluid inlet on the thermocontrol display.
13. Record the temperature that occurs in the cold fluid out on the thermocontrol display measuring instrument.
14. Record the temperature that occurs in the hot fluid out on the thermocontrol display measuring instrument.
15. Replacing/adjusting the replacement of nanofluids with volume fractions of 3% and 5%, and continued with data collection from the volume fractions adjusted according to the above procedure by testing 3 times.

IV. Final Stage of Data Collection

After carrying out the testing and data collection process, there are several steps that need to be followed :

1. Turn off all thermocouple sensors at each point.
2. Turn off the switch on the fluid pump and thermocontrol heater.

3 Result And Discussion

Based on the results obtained in the mixing stage using the concentration values of 1%,3%, and 5% obtained and considered through the equation for calculating the mass of liquid working materials combined on nanoparticles. And the following are the results obtained based on the mixing stage of the process of mixing nanoparticles with a predetermined density of 2.115 grams combined with 0.5 L of water (Fig. 9).

After the nanoparticle mass weighing process is complete, the Nanofluid dispersion process is carried out, as follows (Fig. 10).

And when ± 10–15 Min the Dispersion process is carried out, the following is the result of the TiO2 Nanofludia which has been dispersed in a volume fraction of 1% (Fig. 11).

Fig. 9. Treatment process/weighing the mass of TiO2 Nano Particles at 1% Volume Fraction

Fig. 10. Nanofluid Dispersion Process Titanium Oxide (TiO2) 1%

Fig. 11. Dispersion Process Results on TiO2 Nanofluids at 1% Volume Fraction.

From the results of the mixing, it can be seen that the level of viscosity of the nanofluids dispersed using a volume fraction of 1% looks concentrated which is dominated by the dominant nanoparticle structure and the nature of the nanoparticles that are not easily dissolved causing the conditions of the concentrated mixing results as shown in Fig. 16.

Furthermore, for the calculation of the volume fraction of 3% nanofluid with a nanoparticle mass of 6.345 grams with 0.5 L of water (Fig. 12).

After the nanoparticle mass weighing process is complete, the Nanofluid dispersion process is carried out, as follows (Fig. 13).

And when ± 10 – 15 Min the Dispersion process is carried out, then the following is the result of the TiO2 Nanofludia which has been dispersed in a volume fraction of 3% (Fig. 14).

Fig. 12. Treatment process/weighing the mass of TiO2 Nano Particles at 3% Volume Fraction

Fig. 13. Dispersion Process Results on TiO2 Nanofluids at 3% Volume Fraction.

Fig. 14. Dispersion Process Results on TiO2 Nanofluids at 3% Volume Fraction.

From the results of the mixing, it can be seen that the level of viscosity of the dispersed nanofluid using a volume fraction of 3% looks more concentrated due to being dominated by the combination of water and TiO2 nanoparticles which have become a homogeneous solution and no precipitate has occurred.

And the last is the calculation process for the 5% nanofluid volume fraction with a nanoparticle mass of 10.575 g with 0.5 L of water (Fig. 15).

Fig. 15. Treatment process/weighing the mass of TiO2 Nano Particles at 5% Volume Fraction

Fig. 16. Dispersion Process Results on TiO2 Nanofluids at 5% Volume Fraction.

After the nanoparticle mass weighing process is complete, the Nanofluid dispersion process is carried out, as follows (Fig. 16).

And when ± 10–15 Min the Dispersion process is carried out, the following is the result of the TiO2 Nanofludia which has been dispersed in a volume fraction of 5% (Figs. 17 and 18).

From the results of mixing it can be seen that the level of viscosity of the nanofluid dispersed using a volume fraction of 5% looks very concentrated but when observed closely and touched with a finger, the condition of the solution is very soft without any traces of TiO2 powder that feels caused by the combination of water and TiO2 nanoparticles were properly and properly dispersed and had become a homogeneous solution.

Fig. 17. Dispersion Process Results on TiO2 Nanofluids at 5% Volume Fraction.

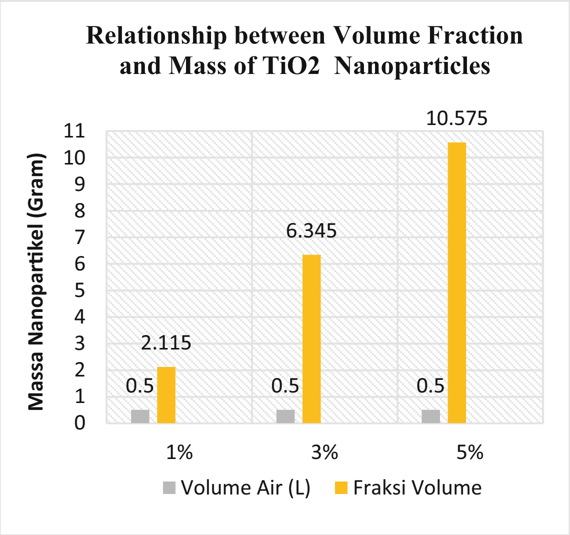

Fig. 18. Relationship between Volume Fraction and Mass of TiO2. Nanoparticles

4 Conclusion

Based on the results obtained from the mixing stage of Titanium Dioxide (TiO2), especially in the initial mixing stage on nanoparticles until the process of working on nano work materials as work objects. Produce some specific conclusions, including :

1. Nanofluids with higher volume fraction values can affect the physical characteristics of the solution. Which is caused by the dominance of the nanoparticles used with the higher the volume fraction value, the viscosity of the nanofluid will be more

concentrated and with a good and correct dispersion process, when the nanofluid has become a homogeneous solution, the physical condition is very soft without traces of TiO2 powder.
2. With the increasing value of the viscosity of the nanofluid content, it becomes easier to increase the heat transfer coefficient due to the increase in the thermal conductivity of the work object which affects the effectiveness of its use in double pipe heat transfer equipment.

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Authors' Contributions. I Made Arsana and Theodorus Wiyanto conceived of and designed the study. Muhaji analyzed and in- terpreted the data. Handini Novitasari drafted the paper and Lilik Anifah and Akhmad Saiffudin critically revised it for important intellec tual content. All authors gave final approval of the version to be published.

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