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Effect of Titanium Oxide Nanoparticle on Thermo Physical Properties of Polyalphaolefin

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ABSTRACT

In this article, the effect of titanium oxide (TiO_2) nanoparticles on thermo physical of polyalphaolefin (PAO) is being studied and conducted. Polyalphaolefin is one of the synthetic hydrocarbon liquid, a specially designed chemical made from alpha olefins. The hydrogenated polyalphaolefin lends an excellent thermal stability to its molecules due to the existence of hydrogen-saturated olefin-carbons. The dispersion of the nanoparticles is aided with indirect sonification for better distribution of nanoparticles in the base fluid. The applications of nanofluid include cooling, manufacturing, medical treatment and cosmetics. The research conducted to study the effect of titanium oxide to the heat capacity of polyalphaolefin (PAO) as the base fluid. This experiment used thermal analysis technique that looks at how a material's heat capacity (c_p) is changed by temperature. This technique is aided with Differential Scanning Calorimetry or DSC 6000. From the results, it is expected the PAO that being added to TiO_2 nanoparticles contain more heat capacity than only the base fluid. The results are being affected by other factor such as the nanoparticles are not dispersed uniformly and the formation of agglomerates particles. It is found that the percentage of increment is negative enhancement because of the oxidation occur in the samples. When the specific heat capacity increase, the energy consumption of PAO also increase. Thus, the thinning effect will be reduced. The experimental results show that the specific heat capacity of nanofluids did not agree with the theoretical results. The results show that the base fluid without adding the TiO_2 nanoparticles has higher specific heat capacity than the base fluid that was added with TiO_2 nanoparticle. Different from the results of the experiment, the theoretical findings it shows that adding TiO_2 nanoparticles will increase the specific heat capacity of the PAO.
KEYWORDS: Polyalphaolefin, Nanofluid, Titanium Oxide Nanoparticle, Specific Heat Capacity.

INTRODUCTION

Friction between two surfaces in contact can reduce engine performance, can cause wear on the moving surface and undesirable heat generation. Lubricant is introduced to reduce all the deteriorations above. Furthermore, it has wide functions such as transporting foreign particles, transmitting forces and cooling or heating surfaces. The performance of contact dependent of the tribofilm layer which is supported by the presence of additive. It acts as sacrificial layer and low shear inter-facial layer to reduce wear and friction respectively [12].

Polyalphaolefin is one of the synthetic hydrocarbon liquid, a specially designed chemical made from alpha olefins. The olefin is bonded in alpha position of one of the complex branches of polyalphaolefin. The hydrogenated polyalphaolefin lends an excellent thermal stability to its molecules due to the existence of hydrogen-saturated olefin-carbons [5]. These stable molecules are pure petrochemical feedstock produced by steam cracking and has an excellent pour point [8].

Nanofluid is a base fluid containing nano-sized particles known as nanoparticles. Base fluid can be water or organic liquid while nanoparticles are usually chemically stable oxides or carbon in various form with size ranged from 1-100nm. The size of the nanoparticle can pass some unique effect on the base fluid including enhanced energy, momentum and mass transfer as well as reduced tendency for sedimentation and erosion of surfaces. The dispersion of the nanoparticles is aided with indirect ultra-sonication for better distribution of nanoparticles in the base fluid [4].

The applications of nanofluid include cooling, manufacturing, medical treatment and cosmetics. Nanofluid with oxide nanoparticles is cheaper and easily produced compared to metallic or carbon nanotubes nanoparticles [6].

The research is conducted to study the effect of titanium oxide to the heat capacity of polyalphaolefin (PAO) as the base fluid. In general, the heat capacity of a substance is the heat required to change its

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temperature by 1°C for a specified mass. This experiment is conducted by using Differential Scanning Calorimetry (DSC 6000). According to [17], the effect of nanoparticles toward the heat capacity of nanofluid is insignificant and is neglected due to low nanoparticles volume fraction. However, in some cases, it is also believed that the heat capacity of nanofluids is strongly dependent on this small fraction of nanoparticles.

This experiment used thermal analysis technique that looks at how a material's heat capacity (c_p) is changed by temperature. This technique is aided with Differential Scanning Calorimetry or DSC. A sample of known mass is heated or cooled to track the changes in heat flow to measure its heat capacity. The advantages of DSC are the ease and speed in which transition in materials can be measure. Due to this advantage, it is widely used in pharmaceuticals, polymers, food and manufacturing. For this reason, DSC is the most common thermal analysis technique and is found mostly in analytical laboratory, quality assurance and R&D laboratory.

Basedon the experiment conducted by [10], using pin-on-disc tribometer, the result showed that the reduction of coefficient of friction increase when using the smallest load of 4 kg compared to 6 kg. The significant reduction of coefficient of friction can be seen when 0.3wt% titanium oxides nanoparticles were added in the lubricating oil for a given load. When 0.4wt% of titanium oxides is used, the coefficient of friction decreases. The best result was found with suspension of nanoparticles of 0.5wt%. The suspension with 0.5wt% of non-carbon coated nanoparticles and carbon coated nanoparticle exhibited 50% and 31% of wear reduction respectively. The increase in the concentration of nanoparticles diminished their positive effect on the tribological behavior of the base oil [14].

Recently, researchers are very interested not only the effect of titanium oxide nanoparticles to the heat capacity of nanofluid but the enhancement of the thermal conductivity due to the titanium nanoparticles additive [16, 13]. For instance, thermal conductivity of Al_2O_3nanofluid is enhanced from 30°C to 70°C. In [2] also stated that for all volume concentration of Al_2O_3, they provided enhancement more than 10% for temperature higher than 40□.

Besides, increase in volume fraction also lead to increment of thermal conductivity [15]. The effective thermal conductivity and viscosity of SiO_2-water nanofluid is at 20-50 °C for particles size 12nm with volume concentration of 0.4-1.85 [1].

Addition of nanoparticles into base fluid also enhanced its viscosity. Under high temperature, lubricant become more viscous since the light components evaporate, oil oxidation and nitration [3]. When copper nanoparticles are dispersed in ethylene glycol by sonicator, the viscosity increases four times of that predicted by Einstein Law of viscosity [7].

Nanofluid preparation meets its challenge such as settling and agglomeration when more nanoparticles it added into the base fluid [9]. It is believed that the size of nanoparticles affects the volume of nano-layers surrounding the particles [11].

The main objective of this research is to study the effect of titanium oxide nanoparticles to the specific heat capacity of polyalphaolefin. Besides, from this experiment, the best amount of additive can be determined and proper action can be taken to sustain future development in oil lubrication.

METHODOLOGY

Sample Preparation of Polyalphaolefins(PAO) With Titanium Oxide (TiO_2) Nanofluids

About 900 ml of polyalphaolefins (PAO) was prepared and distributed equally in six bottles of amber glass with 150 ml each. TiO_2 with size of 21 nm, 0.01wt%, 0.02wt%, 0.03wt%, 0.04wt% and 0.05wt% TiO_2 is added into the bottles containing PAO respectively. The nanofluids solution is shaken vigorously until there is no precipitate and suspended solid in the solution. The solution was left for about 24 hours in ambient temperature.

Specific Heat Capacity Measurement of Nanofluids

The specific heat capacity of PAO with TiO_2nanofluids was determined by using differential scanning calorimetry DSC6000 for thermal analysis technique that looks at a material's heat capacity by changing the temperature. A sample of known mass is heated or cooled and the changes in the heat capacity are tracked as changes in the heat flow. The measurement was taken with two empty samples to obtain a base line. By using a pan containing sapphire standard disk and an empty pan, the reference curve was obtained. Approximately, 6mg of PAO is weighed by using AD6000 auto balance. Then, the measurement on a pan containing sample and an empty pan was carried out. Next, the heating was performed at temperature of 25 to 80□ with 20□/min heating rate. The heating procedure consisted of three steps:

1. Equilibrate and remain isothermal at 25□ for four minutes.
2. Ramp to 80□ at 20□/min.
3. Remain isothermal at 80□ for four minutes.

The step was repeated three times for each samples of TiO_2 with 0.01wt%, 0.02wt%, 0.03wt%, 0.04wt% and 0.05wt%.

RESULTS AND DISCUSSION

In this study, the specific heat capacity of PAO with and without TiO_2 nanofluids was determined and the results was recorded in the table below. The weight of the samples was fixed approximately 6mg to get accurate readings of the experiment. The highest specific heat capacity obtained is from the PAO followed by PAO+0.02wt% TiO_2, PAO+0.04wt% TiO_2, PAO+0.05wt% TiO_2, PAO+0.01wt% TiO_2 and PAO+0.03wt% TiO_2 which are 11.5576, 11.5327, 11.4834, 10.9728, 10.9705 and 10.7921 J/g*°C respectively at temperature 70°C.

Table 1 Specific heat capacity of PAO with different amount of TiO2 at various temperatures.

Temperature, T	PAO	PAO + 0.01wt% TiO_2	PAO + 0.02wt% TiO_2	PAO + 0.03wt% TiO_2	PAO + 0.04wt% TiO_2	PAO + 0.05wt% TiO_2
°C	Specific Heat Capacity, c (J/g*°C)					
25	10.6029	10.4148	10.5572	10.3346	10.4619	10.3999
30	11.1731	10.7584	11.1017	10.5902	11.0009	10.7568
35	11.3981	10.8797	11.3201	10.6855	11.2531	10.8969
40	11.4756	10.9167	11.4009	10.7199	11.3446	10.9343
45	11.5076	10.9319	11.4380	10.7363	11.3878	10.9457
50	11.5214	10.9406	11.4612	10.7490	11.4128	10.9505
55	11.5315	10.9477	11.4798	10.7593	11.4318	10.9548
60	11.5404	10.9542	11.4972	10.7692	11.4493	10.9599
65	11.5486	10.9616	11.5142	10.7800	11.4663	10.9660
70	11.5576	10.9705	11.5327	10.7921	11.4834	10.9728

Table 2: Area under the curve and percentage of increment

Samples	Area Under the Curve	Percentageof Increment (%)
PAO	494.9568	-
PAO + 0.01wt% TiO_2	471.8445	-4.6696
PAO + 0.02wt% TiO_2	492.3968	-0.5172
PAO + 0.03wt% TiO_2	463.9368	-6.2672
PAO + 0.04wt% TiO_2	489.7562	-1.0507
PAO + 0.05wt% TiO_2	472.1758	-4.6026

Table 2 shows that the percentage of increment for every samples is negative enhancement, which means that the specific heat capacity is reduced even though TiO_2 is added in the base oil as additives. Perhaps, this is due to the oxidation occurs in the samples. The oxidation is undesirable since it will deteriorate the quality of the PAO. So, in further research, it is preferable to use Fourier transform infrared spectroscopy (FTIR) to detect the oxidation occurred. FTIR is needed to obtain an infrared spectrum of absorption of substances.

Based on the Figure 1-6, the specific heat capacity depends on the temperature. The results showed that the specific heat capacity increased when the temperature increased. Based on the Figure 7, at temperature 70°C, PAO has the highest specific heat capacity compared to the PAO with the additives of TiO_2 which is 11.5576 J/g*°C, the lowest specific heat capacity obtained was PAO with 0.03wt% TiO_2 which is 10.7921 J/g*°C. Theoretically, when the PAO is added with TiO_2 nanoparticles, it will increase the specific heat capacity. In this experiment, the highest specific heat capacity was observed in the sample containing only PAO at every temperature. The results were affected by the dispersion of nanoparticles and the presence of agglomerates in the solutions. A larger nanoparticles size will form more agglomerates since it will coagulate more easily and cause decrement in distance between particles and the attraction of the van der Waals also increases [4].

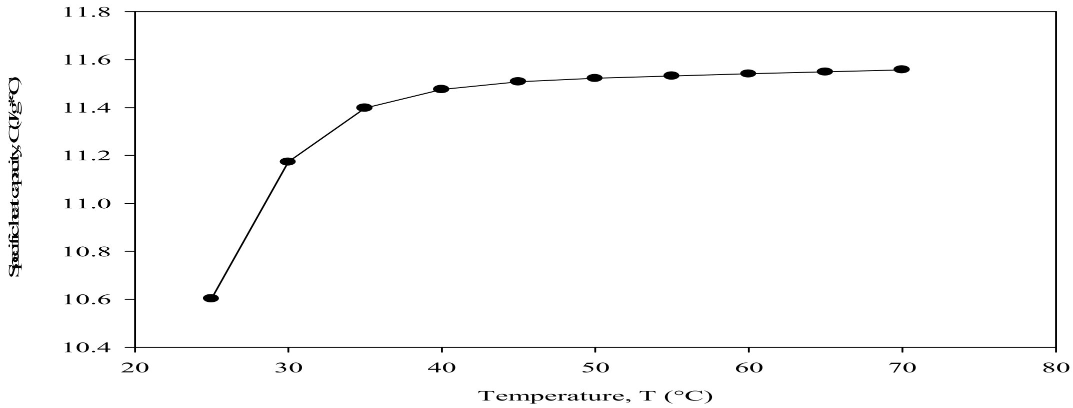

Figure 1: Specific heat capacity of PAO against temperature

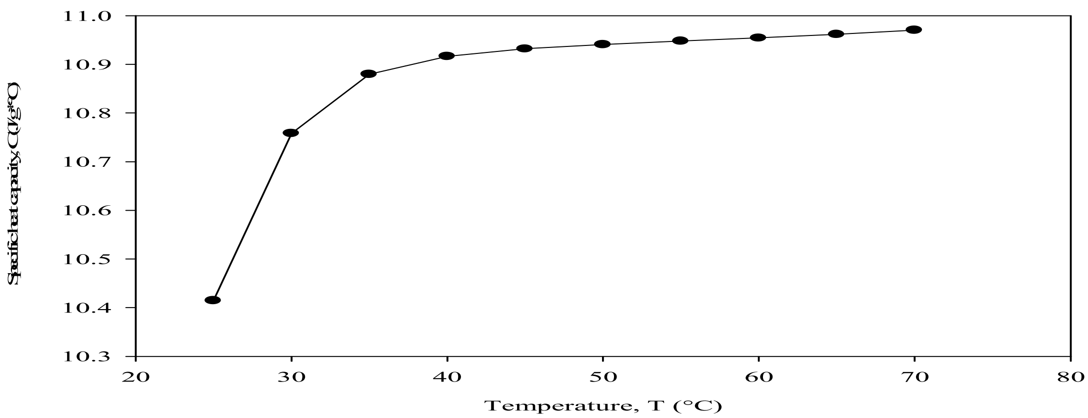

Figure 2: Specific heat capacity of PAO + 0.01wt% TiO_2 against temperature

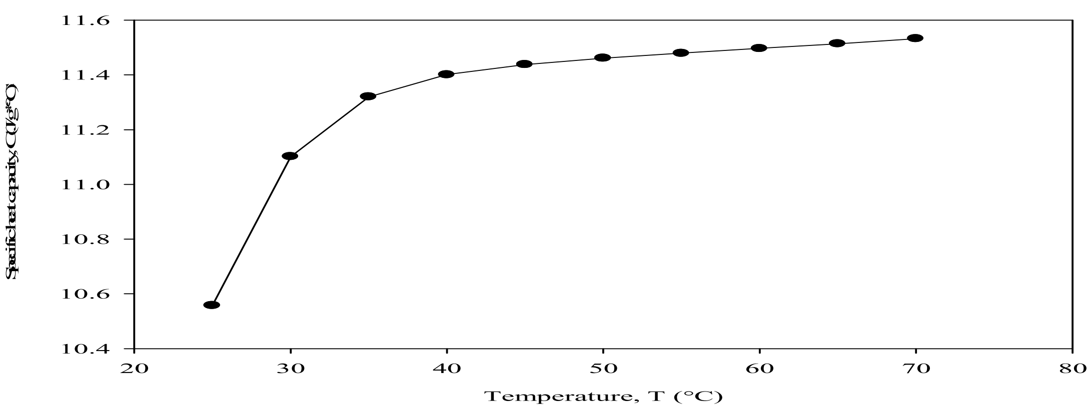

Figure 3: Specific heat capacity of PAO + 0.02wt% TiO_2 against temperature

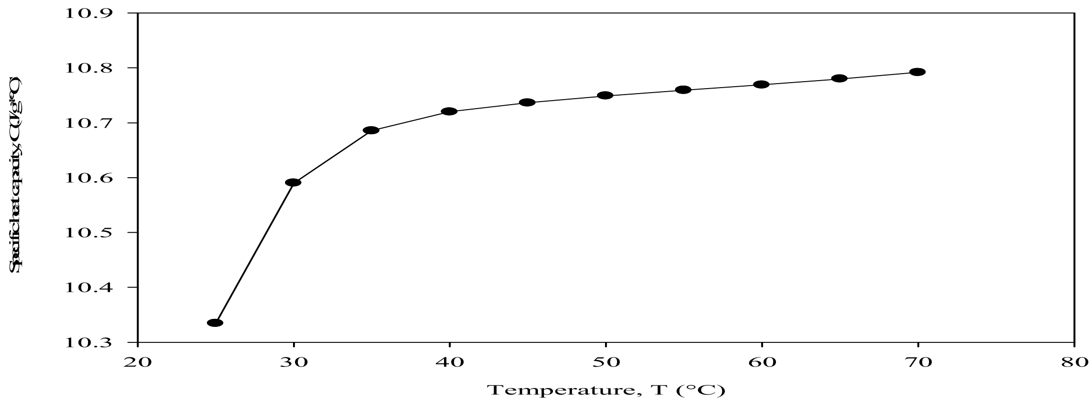

Figure 4: Specific heat capacity of PAO + 0.03wt% TiO_2 against temperature

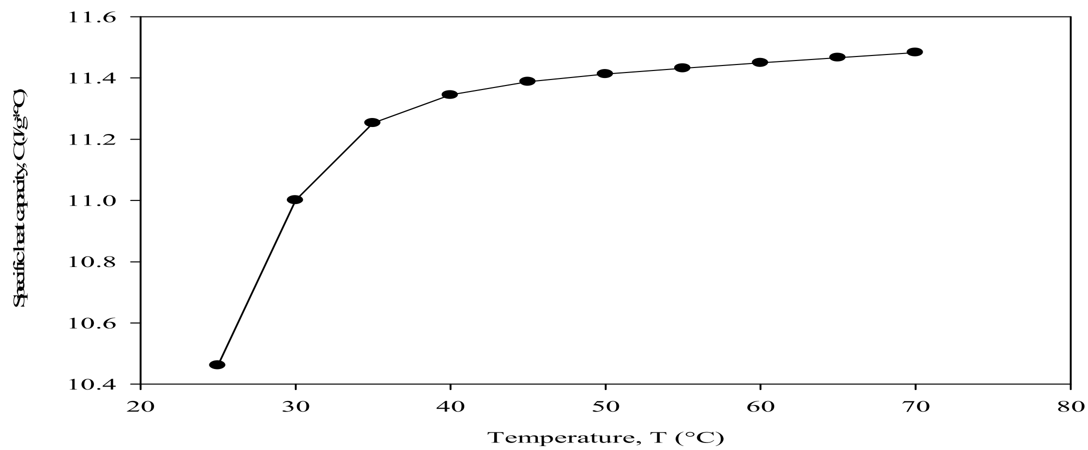

Figure 5: Specific heat capacity of PAO + 0.04wt% TiO_2 against temperature

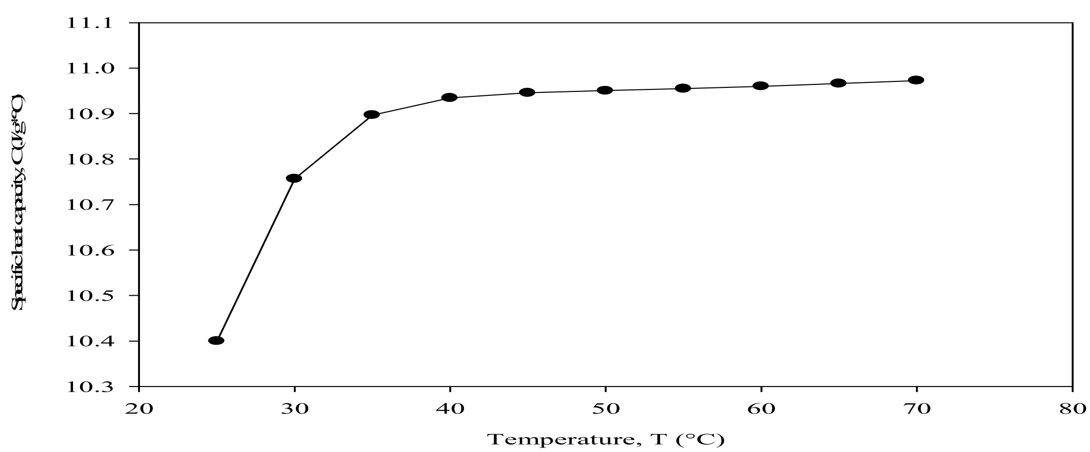

Figure 6: Specific heat capacity of PAO + 0.05wt% TiO_2 against temperature

Besides, the Figure 7 illustrates the relationship between temperature and specific heat capacity. The higher the temperature, the higher the specific heat capacity of the samples. This is because when the solutions heat up, the temperature of the molecules increases, so the kinetic energy of the molecules will be higher and the molecules collide with each other. Therefore, the internal energy will be raised and increase the specific heat capacity. The viscosity of the nanofluids can be sustained by adding the additive of TiO_2 in the base oil. Low viscosity of nanofluids will lead to high energy and fuel consumption to overcome the friction occurs in the molecules [3]. The specific heat capacity is crucial because when the specific heat capacity increases, the energy consumption of PAO also increase, thus the thinning effect will be reduced. The higher the specific heat capacity, the more heat can be absorbed.

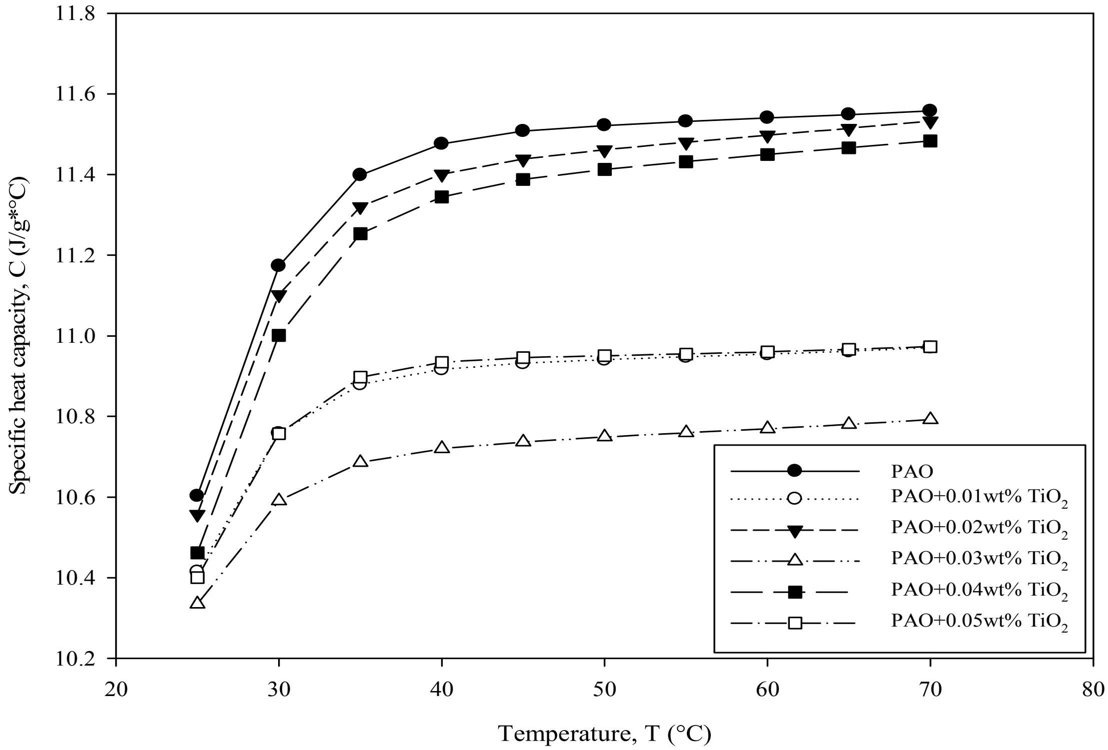

Figure 7: Comparison of specific heat capacity against temperature between the samples

CONCLUSION AND RECOMMENDATIONS

In this study, the main objective is to study the effect of titanium oxide nanoparticle to thermo physical properties of polyalphaolefins. However, the size of nanoparticles plays a crucial role in affecting the physical properties of the base fluids. This paper also covers the review of the specific heat capacity of PAO with and without adding the TiO_2 nanoparticles. The experimental results show that the specific heat capacity of nanofluids did not agree with the theoretical results. It is found that the specific heat capacity varies with different weight percent of TiO_2 being adding to the PAO. This is because it is affected by different factor such as dispersion of TiO_2 on every sample. The results show that the base fluid without adding the TiO_2 nanoparticles has higher specific heat capacity than the base fluid that was added with TiO_2 nanoparticle. Different from the results of the experiment, the theoretical findings it shows that adding TiO_2 nanoparticles will increase the specific heat capacity of the PAO. In the future, it is recommended for the next researcher to add surfactants to disperse nanoparticles uniformly within the base oil. By using the ultrasonic device it can also help the TiO_2 nanoparticle to disperse uniformly within the base oil to get the accurate readings and best results.

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