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Effects of Copper to Viscosity and Heat Capacity of an Engine Oil

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ABSTRACT

Lubricants are substances that are introduced between two moving or sliding surfaces to reduce the friction or frictional resistance between them. The effects of additional additives on the viscosity and the heat capacity of the lubricating oil have been determined as the purpose of these experiments. For sample preparation, copper powder was measured in different masses for each sample by using an analytical balance. For sample 1, 0 mg of copper powder, 2.5 mg for sample 2, 5.0 mg for sample 3 and 7.5 mg for sample 4. The experiment for heat capacity was conducted by using a bomb calorimeter and each sample was measured by consistent amount and weight of 0.9977 g. The samples were being tested three times and the average heat capacity was determined. The result of this experiment showed that the specific heat capacity of sample 4 was the highest compared to sample 1, sample 2 and sample 3. For the viscosity-temperature relationship, Grace Instrument M3600 Viscometer was used in this experiment. About 180 mL of all samples were prepared and tested under different temperatures with constant shear rate of 600 sec^{-1} and temperature correction of 5 °F. The value of shear stress and time taken was recorded at 240 seconds for each sample. The performance of the viscosity-temperature relationship was determined using 1/3 Simpson's Rule. The value area under graph for the viscosity versus shear rate showed that sample 3 has the highest efficiency, while the value area under the graph for viscosity versus temperature showed that sample 4 has the best efficiency compared to the other samples. The overall conclusion that can be concluded from the experiment is that sample 4 is the most efficient for overall improvement of lubricant properties. Sample 4 was able to maintain its viscosity at an almost constant rate under varying temperatures and has the highest heat capacity, which leads to the conclusion that as the amount of copper added to the lubricant increases, the efficiency of lubricant also increases.
KEYWORDS: Additives, Efficient, Heat Capacity, Lubricant, Viscosity.

INTRODUCTION

Lubrication is provided by all liquids, although some do it better than others [1]. Lubricants are substance that is introduced between two moving or sliding surfaces to reduce the friction or frictional resistance between them. The purpose of a lubricant is to keep the moving surfaces apart, reduce friction and destruction of the material, to act as a barrier that prevents direct metal to metal contact between the two rubbing surfaces and reduces wear and tear of the material. Moreover, metal expansion due to friction can also be reduced as lubricants can act as a coolant to the metal and at the same time help to create a smooth flow of relative motion, lower maintenance cost and power loss in internal combustion engines.

In simpler terms, viscosity can also be identified as fluid friction. Like friction between moving solids, viscosity transforms the kinetic energy of (macroscopic) motion into heat energy [3]. Viscosity is significantly affected by temperature whereby as the operating temperature increases, the viscosity of liquids decreases which in turn causes the lubricating oil to become thinner. Ergo, the viscosity of a good lubricating oil should not vary much with respect to temperature changes, so that it can be used at all times under varying conditions of temperature.

Heat capacity is usually denoted as C and is also known as the thermal capacity of a singular body. By definition, it simply is the total of heat needed to change a body's temperature by a given amount. In the International System of Units (SI), heat capacity is expressed in units Joules per Kelvin [2]. In addition, the heat capacity of a substance is the amount of heat required to raise the temperature of a given quantity of a substance by one degree celsius and its units are J/°C. Heat capacity is an extensive property. The extensive property measured value is corresponding to the quantity of matter [10].

According to [5],nanoparticles are defined as a nano-sized particles cover a range between 1 and 100 nanometers.Nanoparticles are claimed to have the ability to decrease wear when acting as lubricant additives. A study regarding the tribological properties of diamond and SiO_2 nanoparticles when added to paraffin was performed by [6]. It is further investigated by [7] that study the performance of lubricants by means of evaluating its friction and wear between two surfaces in contact. It was found that the friction coefficient of

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liquid paraffin is directly proportional to the time due to adhesion between the contact surface. The friction coefficient is stabilized after the diamond or SiO_2 nanoparticles were added to the base fluid.

Concentration of nanoparticles isan important parameter for friction and wear reduction [7]. Since the nanoparticle may carry a proportion of load and separates the two surfaces in contact from adhesion, thus benefiting the friction and wear reduction properties. According to [8], concentration of less than 2 wt% was found as an optimum to improve the friction and wear behavior. In [9] performed a series of experiments to evaluate the friction and wear characteristics of the sliding elements by introducing lubricant at the interface, with and without the addition of nanoparticles into the lubricating oil. They found that at 1.5% of nanoparticle concentration, the stable and homogeneous solution is formed.

The solid is diamagnetic. In terms of their coordination spheres, copper centers are 2-coordinated and the oxides are tetrahedral. The structure thus resembles in some sense the main polymorphs of SiO_2, and both structures feature interpenetrated lattices. Copper (I) oxide dissolves in concentrated ammonia solution to form the colorless complex $[Cu\ (NH_3)_3]^+$, which is easily oxidized in air to the blue $[Cu\ (NH_3)_4(H_2O)_2]^{2+}$. It dissolves in hydrochloric acid to give solutions of $CuCl^{2-}$. Dilute sulphuric acid and nitric acid produce copper (II) sulphate and copper (II) nitrate respectively.

With the addition of 0.1-0.6% of copper nanopowder to lubricant oil and lubricant grease will form a self-lubricating and self-repairing coating film on the contact surface, lower its anti-friction and anti-wear performance. Copper ions may cause toxicity once they exceed the physiological tolerance range, whereby the threshold toxicity value of exposure by inhalation is 0.075-0.12 mg/m^{-3} which is considered a lethal dosage and exposure by digestion is 10-20 g of copper. Among the symptoms caused by such exposure is metal fume fever which causes upper respiratory irritation, chills and muscle aches.

The main objective of this experiment is to study the effects of copper powder on the viscosity and the heat capacity of the engine oil.

METHODOLOGY

Sample Preparation

Copper powder was measured by using an analytical balance and the weight recorded in Table 1. Next, four beakers were filled with 500 ml each of the lubricant and was appropriately labelled. Then, the copper powder was added to each beaker with respect to its mass. These samples were then stirred in a jar tester at 200 rpm and 25°C for 4 hours.

Table 1: Mass of copper powder used for each sample

Sample	Mass of Copper (mg)
1	0
2	2.5
3	5.0
4	7.5

Heat Capacity Analysis

The test was conducted by using a bomb calorimeter. Each sample was measured with a consistent amount and weight of 0.9977g. Adiabatic operating condition for bomb calorimeter was used. Three repeated tests for each of the samples was performed and the average heat capacity was determined.

Viscosity-Temperature Relationship

About 180 mL 0f samples were prepared for the viscosity-temperature experiment. Grace Instrument M3600 Viscometer, a true Couette, coaxial cylinder, rotational viscometer with rotor radius of 1.7245 cm and a bob effective is 3.8 cm has been used to perform this experiment. This is an automated rotational viscometer. All tests were run at temperature 40℃, 50℃, 60℃, 70℃, 80℃, 90℃ and 100℃ with a constant shear rate of 600 sec^{-1} and temperature correction of 5℉. Throughout the experiment, the value of shear stress was recorded. The absolute viscosity of each sample at different temperature was measured by means of shear rate. The time taken was recorded for the sample to reach each temperature. The performance of the viscosity-temperature relationship were determined using 1/3 Simpson's Rule by figuring out the area under the curve.

FINDINGS AND DISCUSSION

Heat Capacity Analysis

Lubrication is simply defined as the use of a substance that provides an enhancement in the smoothness affecting the movement of one surface over another and the material, which used to perform lubrication is called lubricant. The physical and chemical interactions between lubricants and the lubricating surfaces must be understood to provide the engine parts with satisfactory life span. The test was conducted using a bomb calorimeter. All samples were measured by consistent amount and weight of 0.9977 g. The operating condition for bomb calorimeter was set to adiabatic. Three tests were repeated for each of the samples and the average heat capacity was determined. Furthermore, the increment of heat capacity was affected by the time taken from sample to reach the temperature of 100℃. Heat capacity or thermal capacity is the measurable physical quantity that characterizes the amount of heat required to change a substance's temperature by a given amount. The higher the heat capacity, the better the lubricant will absorb heat. The results of the experiment showed that sample 4 has the highest specific heat capacity compared to the other samples. This suggests that sample 4 will be able to retain heat better than the other samples when the same amount of heat is used to raise samples temperature. This high heat content does not allow internal energy to be lost completely even at unusual frozen temperatures. In motor engine oil, the internal energy enables the engine to start faster because the heat lost by the engine is stored as an internal energy in the lubricating system.

VISCOSITY-TEMPERATURE RELATIONSHIP

Effects of Viscosity on Shear Rate

The experimental data were obtained by testing the samples using the Viscometer Grace at 27ºC (80ºF) with values of shear stress, which ranging from 30.01 rpm to 600 rpm for 240 seconds for each sample. The results obtained are illustrated in Figure 1.

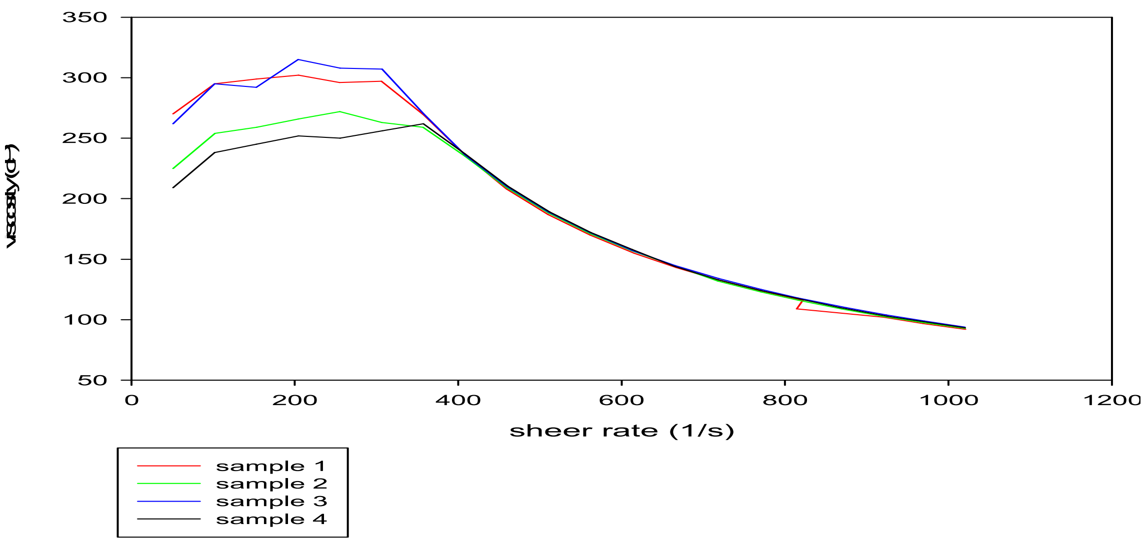

Figure 1: Viscosity of all samples versus shear rate

Figure 1 compares the viscosity between all four samples with increasing value of shear rate. Different amounts of copper powder were added to each sample. Sample 1 is the control sample with no copper powder added to it, sample 2 was mixed with 2.5 mg of copper powder, sample 3 was mixed with 5.0 mg of copper powder and sample 4 was mixed with 7.5 mg of copper powder.

Based on Figure 1, it can see that sample 3 has the highest viscosity value initially when compared with samples 2 and 4. When comparisonbetween samples 1 and 2, it was illustrated that sample 2 has a much lower viscosity. Once the shear rate reaches 400 s^{-1} both samples had almost similar results with their viscosity decreasing gradually as the shear rate increases. The area under the graph corresponds to the efficiency of the sample and therefore when calculated, sample 1 was far more effective when compared with sample 2. When calculated, the values of the area under the graph for sample 1 and sample 2 are 188535.44 and 177908.44 respectively. This shows that sample 2 has lowered the efficiency of the lubricant by 48.55%.

The comparison between sample 1 and sample 3 shows that sample 1 has the higher viscosity value initially, but it was then exceeded by sample 3 as the shear rate increases and as both sample approached 400 s^{-1} they experienced a decrease in viscosity in a gradual manner as the shear rate increases. Although initially sample 1 may have the higher viscosity value, in fact sample 3 was more effective as proven by the value of the area under the graph of sample 3 when compared with sample 1. When calculated, the values of the area under the graph for sample 1 and sample 3 are 188535.44 and 191046 respectively. This shows that sample 3 has improved the properties of the lubricant by 50.33%.

On the contrary, sample 4 is less effective when compared with sample 1. As illustrated above, sample 4 has a very significantly lower initial viscosity value compared with sample 1. Upon reaching 400 s^{-1}, both samples experience a gradual decrease in viscosity as shear rate increases. When comparing the value of the area under the graph of both samples, sample 1 is more effective compared to sample 4. When calculated, the values of the area under the graph of sample 1 and sample 4 are 188535.44 and 174540.92 respectively. This shows that sample 4 has lowered the efficiency of the lubricant by 48.07%.

A similar experiment was conducted by [4], where the effects of adding inorganic metals as additives to the viscosity and heat capacity of an engine oil were tested. The results of the experiment showed a similar trend in the decrease of efficiency of the engine oil. Although in the experiment, the decrease in efficiency was seen in the heat capacity of the engine oils. In [4] stated that the reduction of the engine oil's efficiency is not limited to the heat capacity, but also in shear stress and viscosity values. It can be found that the addition of additives to the engine oil is in the negative direction. It means that by adding the additives to the engine oil, it will reduce the quality of the oil itself.

To conclude, the properties of the lubricant can be improved by 50.33% with the addition of 5.0 mg of copper powder to the lubricant. The sample 3 is the most effective in increasing the properties of the lubricant at 80°f followed by sample 2 then sample 4.

Effects of Temperature on Viscosity

The experimental data were obtained by testing the samples using the Viscometer Grace at a constant shear stress value of 600 rpm at temperatures ranging from 40ºC (104°F) to 100ºC (212°F) for 240 seconds for each sample. The results obtained are illustrated in the Figure 2.

Figure 2 compares the viscosity between all four samples with increasing temperature. Just as before, sample 1 was the control sample with no copper powder added to it, sample 2 was mixed with 2.5 mg of copper powder, sample 3 was mixed with 5.0 mg of copper powder and sample 4 was mixed with 7.5 mg of copper powder.

Based on Figure 2, it can be observed that sample 2, sample 3 and sample 4 displayed a significant increase in their initial viscosity when compared to sample 1.Sample 2 displayed an immediate increase in its initial viscosity when compared with sample 1, but it decreases gradually as the temperature rises above 120°F. When calculated, the value of the area under the graph of sample 1 and sample 2 are 7044.6 and 6235.8 respectively. This shows that sample 2 decreases the lubricant properties by 46.95%

Similarly, sample 3 also displayed an increase in its initial viscosity and it remains almost constant until the temperature rises above 120ºF where it decreases slowly until it began showing a drastic drop in viscosity as temperature rises above 140ºF. As the temperature approaches 180°F, the viscosity decreases even more in a gradual manner until it reaches the final reading at 212°F. When calculated, the value of the area under the graph of sample 1 and sample 3 are 7044.6 and 6207.6 respectively. This shows that sample 3 decreases the lubricant properties by 46.84%.

Although sample 4 also displayed an increase in its initial viscosity, the value remains almost constant until it approaches 180ºF whereby the viscosity gradually decreases as temperature increases unlike the previous reading displayed by sample 2 and sample 3. When calculated, the value of the area under the graph of sample 1 and sample 4 are 7044.6 and 8931 respectively. This shows that sample 4 improves the lubricant properties by 55.90%.

To conclude, the properties of the lubricant can be improved by 55.90% with the addition of 7.5 mg of copper powder to the lubricant which concludes that sample 4 is the most effective followed by sample 3 then sample 2.

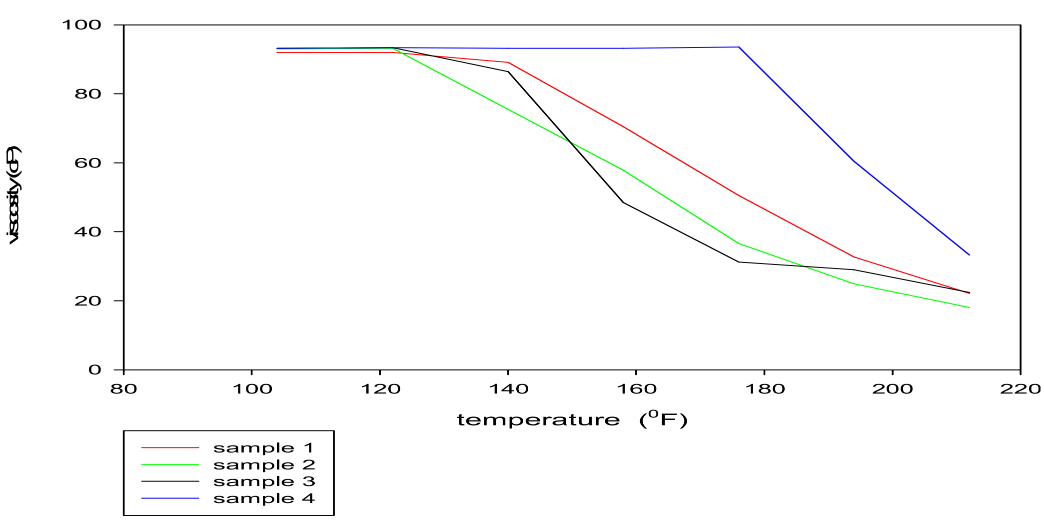

Figure 2: Viscosities of all samples versus temperature

CONCLUSION AND RECOMMENDATIONS

In conclusion, sample 4 is more efficient for overall improvement of lubricant properties. This is because sample 4 under viscosity temperature that can maintain the viscosity and high heat capacity. Besides that, sample 4 can maintain the viscosity in long time under different temperature at 600 rpm compared to other samples. From the oil analyst's perspective, determining the source, nature and state of copper is essential to correctly interpreting the alarm in terms of engine reliability and the appropriate response. For the heat capacity analysis, higher value in heat capacity indicates the effectiveness of the lubricant to adsorb heat. The experiment shows that sample 4 have high value of specific heat capacity compared to other sample. Even in the unusual frozen temperature, the high heat content does not allow internal energy to be lost. Based on the viscosity versus shear rate graph, the value area under graph show that sample 3 has higher efficiency of the lubricant compared to other samples. From the viscosity versus temperature, it shows that sample 4 was improving the lubricant properties with the addition of 7.5 mg of copper powder and the most effective followed by sample 3 then sample 2. As the amount of copper added to the lubricant increases, the efficiency of the lubricant also increases. The effect of additional additives on the viscosity is the operating temperature increases, the viscosity of liquid decrease causes lubricating oil to become thinner.

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