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INORGANIC METAL AS LUBRICANT CONTAINING ADDITIVES IN SAE 10W-30 ENGINE OIL

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ABSTRACT

This paper study on suitability and effect of inorganic metal as additives in Malaysian commercial grade engine oil such as arsenic oxide, aluminum oxide, cadmium nitrate, cobalt chloride, copper, ferum (II) nitrate, nickel (II) nitrate hexahydrate and titanium (IV) oxide to engine oil heat capacity and viscosity. By appending inorganic metal in the engine oil, it will cause the improvement in its thermal properties and thus the fluctuation of the viscosity to the temperature may be altered. The validation of these improvements was assessed by measuring engine oil viscosity-temperature relationship, heat capacity, kinematic viscosity and viscosity index. Viscosity-temperature relationships were obtained using rotational viscometer. Tests were made under constant shear rate of 600 s-1 and temperature setting started from 40 ^{0}C to 100 ^{0}C. By collecting the information of the viscosity-temperature relationships, engine oil performance measurement was taken place by measuring the area under the curve for each of samples graph. Heat capacity for each sample was determined using a bomb calorimeter in adiabatic mode of operation. Kinematic viscosities of engine oils were assessed using VH2 Viscometer Houillion at 40 ^{0}C and 100 ^{0}C and viscosity index was calculated according to ASTM D2270 method. The results found that the dissolution of arsenic oxide, cadmium nitrate, copper and ferum (II) nitrate had the best viscosity and heat capacity improvement about 7.44% and 2.01% of reference oil (base fluid).All compounds appended in exhibiting viscosity-temperature relationships, time, kinematic viscosity, viscosity index and heat capacity enhancement compared to reference oil (MCG). MCGT2 had better performance than MCGT1, exhibiting higher area under the curve for the viscosity-temperature relationship and also higher value of heat capacity.

Keywords: engine oils, viscosity, additive, kinematic viscosity, viscosity index, heat capacity.

INTRODUCTION

Today's lubricant market, a lot of types of lubricants are being sold. All of them are intentionally designed to meet specific purposed such as industrial, hydraulic system, machining and automotive. Not only that, they are also needed to meet the specification of specific purpose by designing them in different viscosity. This is due to the significance of this physical property of lubricant to the engine performance. Lubricant viscosity is strongly dependent on temperature, pressure and shear rate [1-3]. Viscosity is defined as a measure of oil's resistance to flow or its readiness to flow at different temperature. As the temperature increase, lubricant viscosity encounters 'thinning effect' (reduction in oil viscosity). The most reasonable to clarify this phenomenon is due to molecular distances among molecules in the lubricants. When the temperature of liquid is changed, the molecules vibrate more rapidly at random and in doing so establish a space around them which is proportional to their kinetic energy [4]. This characteristic is called the coefficient of expansion with temperature. The liquid with low coefficient of expansion will generally have lower viscosity-temperature coefficients than those which have high coefficients of expansion. The viscosity must be high enough (for example, temperatures up to 100 ^{0}C in the case of an automobile engine) to maintain a lubricating film, but low enough (for example, a cold start in the case of an automobile) that the oil can flow around the engine parts under all conditions [5]. Some researchers reported that with lower viscosity at high temperature operating engine condition, the lubricant could provide a reduction in friction and may lead to the high fuel consumption efficiency. Measurement of viscosity therefore requires means for evaluating shearing stress and rate of shear or their equivalents [6]. Many methods are available such as the use of capillary tube, a rotational viscometer, a falling or rolling ball viscometer and so on.

Combustion process occurs during operating engine usually releasing heat significantly higher than 100 ^{o}C. This may lead to the engine overheating. By this consequence, lubricant is needed as a cooling agent for the engine. Most of the heat energy is taken by the lubricant. Clean oil passages, proper viscosity and low contamination provide a sufficient flow rate of the engine oil and effective cooling. One of the key parameters that could represent the ability of the lubricant to absorb heat is heat capacity. 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.

Recently, researchers have shown an increased interest in the development of inorganic metal as additives in lubricating oil due to the improvement. It can offer to the tribological properties of the base oil such as displaying good friction and wear reduction characteristics even at low concentrations [7-10]. Furthermore, the addition of inorganic metal also showed significantly improved the performance of lubricant at elevated

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temperature[9]. However, research in inorganic metal based still on-going in the development process.

This paper studied the influence of arsenic oxide, aluminum oxide, cadmium nitrate, cobalt chloride, copper, ferum (II) nitrate, nickel (II) nitrate hexahydrate and titanium (IV) oxide utilized as additives in lubricating oils. This research studies the viscosity-temperature relationship and heat capacity behavior of arsenic oxide, aluminum oxide, cadmium nitrate, cobalt chloride, copper, ferum (II) nitrate, nickel (II) nitrate hexahydrate, and titanium (IV) oxide as additives in SAE 10W-30 Malaysian commercial grade engine oil using rotational viscometer and bomb calorimeter analysis. Kinematic viscosity was assessed and its viscosity index calculated.

METHODOLOGY

Samples preparation

Sample from SAE 10W-30 mineral engine oils were used in the experiment works, which is Malaysian commercial grade engine oil. Three samples were prepared; two samples with different concentration of arsenic oxide, aluminum oxide, cadmium nitrate, cobalt chloride, copper, ferum (II) nitrate, nickel (II) nitrate hexahydrate and titanium (IV) oxide are as listed in Table-1 and one sample acts as reference oil (refer as MCG-Malaysian commercial grade). Samples are then shaking in shaking incubator for 24 hours at ambient temperature and 150 rpm setting to uniformly disperse all particles in the samples.

Table-1. Samples composition.

Inorganic Metals	Mass (in kg)	
	MCGT1	MCGT2
Arsenic oxide	$3.0x10^{-5}$	$3.0x10^{-5}$
Aluminum oxide	-	-
Cadmium nitrate	$3.0x10^{-5}$	$3.0x10^{-5}$
Cobalt chloride	$3.9x10^{-4}$	
Copper	$1.2x10^{-4}$	$1.2x10^{-4}$
Ferum (II) nitrate	$1.5x10^{-5}$	$1.5x10^{-5}$
Nickel (II) nitrate hexahydrate	$5.1x10^{-5}$	-
Titanium (IV) oxide	$1.2x10^{-5}$	-

Heat capacity of engine oils was evaluated by the IKA Calorimeter system C5000 control (bomb calorimeter). The operating condition for the system was set to adiabatic. All 4 samples were measured by consistent amount and weight of 0.9977 g in crucible pan and fit in into decomposition vessel. In this experiment works, cotton thread was used as an ignition wire to the system. Repeatability test was run and the average heat capacity is determined. 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.

Viscosity-temperature analysis

Approximately 180 ml of samples was prepared for this experiment. A viscosity-temperature relationship was performed using Grace Instrument M3600 viscometer, a true Couette, coaxial cylinder, rotational viscometer with rotor radius of 1.7245 cm and bob effective length is 3.8 cm. This is an automated rotational viscometer. All tests were run for a constant shear rate of 600 s^{-1} at temperature start from 40 ^{0}C (104 ^{0}F) to 100 ^{0}C (212 ^{o}C) with temperature correction 5^{o}F. The shear stress was recorded throughout each test by means of shear rate to measure the absolute viscosity of samples at different temperature. Time consuming for each sample to reach a temperature of 100^{o}C also was recorded. The performance of viscosity-temperature relationships were characterized using 1/3 Simpson's Rule by determining the area under the curve.

Kinematic viscosity analysis

The test is conducted in Automated Viscometer Houillon VH2 (ASTM 2270 method). Kinematics viscosity of engine oils is determined by temperature 40 ^{0}C (104 ^{0}F) and 100 ^{0}C (212 ^{0}F). The unit represent in this equipment is in mm^2/s or cSt.

Viscosity index of oil

The viscosity index is calculated using ASTM D2270 method. This calculation covers the calculation of viscosity index from sample kinematics viscosity at 40 ^{0}C (104 ^{0}F) and 100 ^{0}C (212 ^{0}F). According to this ASTM D2270 method, the results obtained from the calculation of VI from kinematic viscosities determined at 40 °C and 100 °C are virtually the same as those obtained from the former VI system using kinematic viscosities determined at 37.78 °C and 98.89 °C.

RESULTS AND DISCUSSION

Heat capacity

The heat capacity results had shown that Test 2 exhibits higher heat capacity than Test 1. Figure-1 indicates the heat capacity comparison for MCG, MCGT1 and MCGT2. The heat capacity for MCGT1 and MCGT2 are 45436.33333 J/K and 45458.33333J/K. The results had shown that for MCGT1 increase the heat capacity about 1.96% (143 J/K) and MCGT2 is 2.01% (165 J/K) from reference sample.

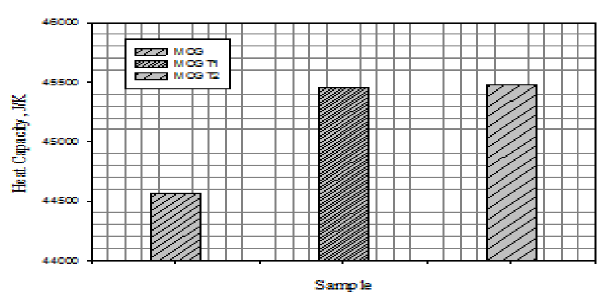

Figure-1. Heat capacity comparison for MCG, MCGT1 and MCGT2.

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Generally, the amount of heat capacity of MCG will increase as the number of inorganic additives being blended in is increased. However, increase in number of inorganic additives blended in does not necessarily have an impact in increasing the amount of heat capacity of MCG as demonstrated from results in Figure-1. MCGT1 have more types of inorganic metal blended compared to MCGT2, but the results show otherwise. This happens most probably due to the effects of an individual inorganic metal, either it brings a negative effect or a positive effect to base fluid.

Viscosity-temperature

Figures-2a-2c illustrates the improvement in viscosity to the temperature relationships from 40 ^{0}C (104 ^{0}F) to 100 ^{0}C (212 ^{0}C) for compound concentrations in MCG. However, results for each test differed depending on the concentration and types of compound appended in. The lowest viscosity-temperature relationship was obtained from MCGT1 and the highest was for a MCGT2. Both types of tests therefore exhibited clearly different viscosity to the temperature relationships for diverse compound concentrations combination. The MCGT2 exhibited the best performance in terms of viscosity and heat capacity as indicated in the Table-2. The performance of all tests was determined by evaluating the area under the curve using 1/3 Simpson's Rule. The area under the curve is an indicator to the performance measurement in which area that exhibits lower in value is not beneficial to the operating engine that generally performing a combustion process that significantly releasing temperature greater than 100 ^{0}C. The viscosity sustains and dropped slowly over the temperature increment usually exhibited higher value for the area under the curve, seems advantageous and promote long service life of the engine. The area under the curve for MCGT1 and MCGT2 for viscosity is 9488.333483 and 9552.544233 respectively.

Time taken for samples heated to 100 ^{0}C has further supported the results and enhanced that being made to MCG. It is improved by an average of 1.54 min from the reference sample MCG. This is probably due to the additive effect to the base fluid. As the amount of heat capacity increased, the time taken from a base fluid to be heated increased. This also correlates with the results improvement as shown in Figure-1.

Table-2. Test comparison improvement for engine oils.

Test	Time Taken (min)	Percent Improvement (%)	
		Viscosity	Heat Capacity
MCG	36.67	-	-
MCGT1	38.05	6.72	1.96
MCGT2	38.37	7.44	2.01

Data tabulated in Table-2 shows a higher best improvement atMCGT2, which results in improvement of about 7.44% and 2.01% of viscosity and heat capacity of base fluid (MCG).

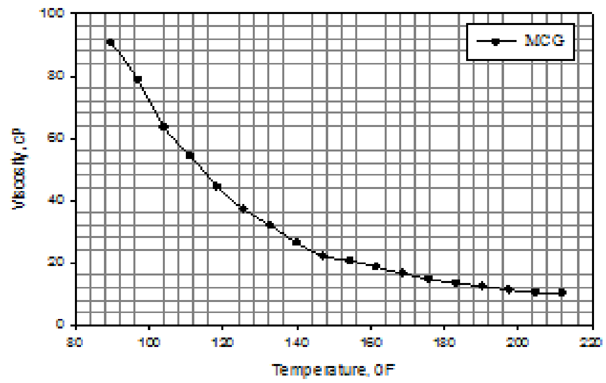

Figure-2(a). Viscosity-temperature relationship of MCG at temperature 40 ^{0}C to 100 ^{0}C.

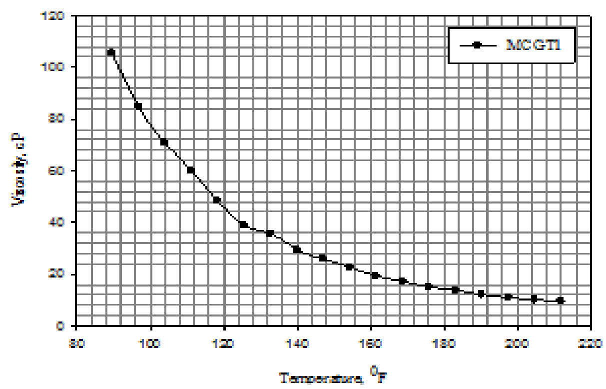

Figure-2(b). Viscosity-temperature relationship of MCGT1 at temperature 40 ^{0}C to 100 ^{0}C.

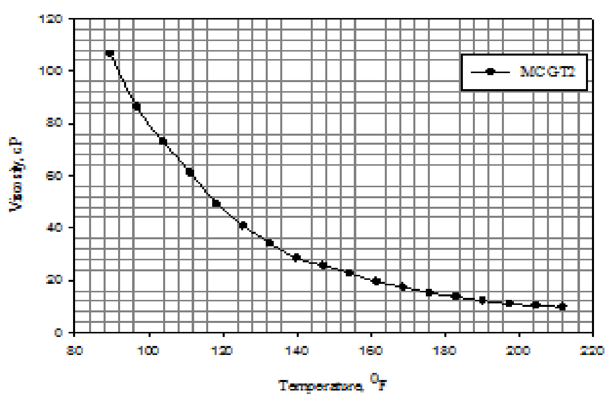

Figure-2(c). Viscosity-temperature relationship of MCGT1 at temperature 40 ^{0}C to 100 ^{0}C.

Kinematic viscosity and viscosity index

The kinematic viscosity of the samples was analyzed at 40 ^{0}C and 100 ^{0}C according to ASTM D445 standards as shown in Figure-4. MCGT1 showed consistently higher kinematic viscosity values than MCGT2 and MCG.

The viscosity index of engine oil was assessed at temperature of 40 ^{0}C and 100 ^{0}C. The results shown that, all samples tested were having viscosity index greater than 100. Test 1 and 2 had shown the same values of viscosity index with a value of 139. Higher viscosity index implies slow fluctuation of viscosity to the temperature. It has increased about 7 from the MCG viscosity index, 131.

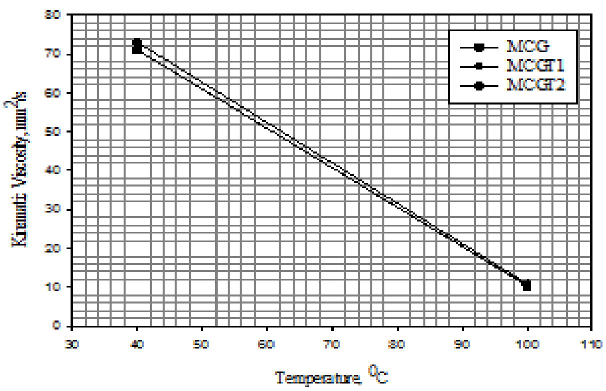

Figure-3. Kinematic viscosity over temperature for MCG, MCGT1 and MCGT2.

CONCLUSION

In conclusion, all inorganic compounds that appended in exhibited viscosity-temperature relationships, time, kinematic viscosity, viscosity index and heat capacity enhancement compared to reference oil (MCG). MCGT2 had the best performance than MCGT1, exhibiting higher area under the curve for the viscosity-temperature relationship and also higher value of heat capacity.

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REFERENCES

[1] A. H. Batte, R. González, J. L. Viesca, J. E. Fernández, J. D. Fernández, A. Machado, R. Chou and J. Riba. 2008. CuO, ZrO_2 and ZnO nanoparticles as antiwear additive in oil lubricants. Wear. 265(3): 422-428.

[2] C. McCabe, S. Cui andP. T. Cummings. 2001. Characterizing the viscosity–temperature dependence of lubricants by molecular simulation. Fluid Phase Equilibria. 183: 363-370.

[3] E. Höglund. 1999. Influence of lubricant properties on elastohydrodynamic lubrication. Wear. 232(2): 176-184.

[4] M. J. De Carvalho, P. R. Seidl, C. R. Belchior and J. R. Sodre. 2010. Lubricant viscosity and viscosity improver additive effects on diesel fuel economy. Tribology International. 43(12): 2298-2302.

[5] P. Ye, X. Jiang, S. Li and S. Li. 2002. Preparation of $NiMoO_2S_2$ nanoparticle and investigation of its tribological behavior as additive in lubricating oils. Wear. 253(5): 572-575.

[6] M. Hadi. 2013. Investigation on turning of AISI H13 with applying minimum quantity of lubricant. Indian Journal of Science and Technology. 6(2): 4094-4097.

[7] Taylor R. I. 2002. Lubrication, tribology and motorsport. SAE paper 2002-01-3355.2: 1-13.

[8] Haycock R., Caines A. J., Haycock R. F. and Hillier J. E. 2004. Automotive Lubricants Reference Book. 2nd Ed. John Wiley and Sons: New York; USA.

[9] Y. Y. Wu, W. C. Tsui and T. C. Liu. 2007. Experimental analysis of tribological properties of lubricating oils with nanoparticle additives. Wear. 262(7): 819-825.

[10] B. S. Zhang, B. S. Xu, Y. Xu, F. Gao, P. J. Shi andY. X. Wu. 2011. Cu nanoparticles effect on the tribological properties of hydrosilicate powders as lubricant additive for steel-steel contacts. Tribology International. 44(7):878-886.