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Research Article

EXPERIMENTAL INVESTIGATION ON THE TRIBOLOGICAL PROPERTIES OF LUBRICANT OIL WITH NANO-PARTICLE ADDITIVES

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ABSTRACT

The present work aims in understanding the tribological properties of lubricant oil with additives such as SiO_2, TiO_2, and Al_2O_3 as nano-particles. For tribological applications, the nano-particles were added into lubricating oil to improve extreme pressure, anti-wear and friction reduction properties. Samples are prepared by adding different proportion of additives in the oil and their properties were evaluated. The nano-particles dispersion was carried out carefully and their properties such as flash and fire point, viscosity, density and pour point are tested. The friction and wear experiments were performed using pin-on-disc tribotester. From the experimental results it has been inferred that, the mixing of SiO_2, TiO_2 and Al_2O_3 nano-particles as additives in engine oil improves the lubricating oil properties and significantly reduces the friction and wear rate. Thus, it is evident from the experimental studies the addition of nano-particles reduces friction and improves the anti-wear properties of the lubricating oil. The results of the tests obtained from the blend show that the most important properties such as viscosity, density, flash point, increases with increase in additive concentration. It is recommended that additives should be used to achieve the desired properties of the engine oil for enhanced engine performance.

INTRODUCTION

One of the major losses occurring in the engine of an automobile is due to friction between its moving parts. This loss is significant and approximately 15% of the total loss of energy and has a direct impact on the efficiency and durability of the engine (Asrul, *et al*., 2013). Different mechanical systems require a variety of functional lubricants to reduce the friction and wear of contacting surfaces as well as a significant reduction in the total energy consumed by mechanical systems. Lubricants play a major role in reducing the wear and friction between the two surfaces in contact with each other. Due to relative movement between the machine components, a resistive force called friction is developed which causes wear and tear of machine parts. The main function of a lubricant is to keep two metal surfaces wet thus minimising friction and avoiding wear. Research studies have reported that the nano-particle dispersed lubricants are found to have a significant effect on reducing the friction and wear rate (De-Xing and Cheng-Hsien, 2010). It is also observed that the friction and wear also depend on the shape, size and concentration of the nano-particles added in the lubricating oil.

Nanoparticle research is currently an area of intense scientific research, due to a wide variety of potential applications in biomedical, optical, and electronic fields. Nanoparticles are of great scientific interest as they are effectively a bridge between bulk materials and atomic or molecular structures. Alumina is the most cost effective and widely used material

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in the family of engineering ceramics. Alumina nanoparticles are light, nontoxic and non-sparking. The important factors in selecting it are that it can be easily formed, machined or cast. Silica nanoparticles are produced via the condensation of silanes to form nanoparticles that consist of an amorphous network of silicon and oxygen. Titanium oxide is available in the form of nanocrystals or nanodots having a high surface area. Adequate lubrication is a key to engine performance (Jianhua and Jinlong, 2010). Therefore the properties of lube oil plays important role in enhancing engine performance. So, improving its characteristic is very important and it is achieved by additives added to the lubricants to enhance its properties.

EXPERIMENTAL STUDY

The present work is an attempt to study the effect of inclusion of nano-particles on the thermal conductivity, pour point and the flash point of lubricating oil. For this purpose, Al_2O_3 nano-particles have been chosen as an additive because of its excellent dispersibility and high surface area stability characteristics when compared to that of the other oxide nano-particles (Jianhua and Jinlong, 2010; Luan and Qian, 2012). The nanoparticle Al_2O_3, SiO_2 and TiO_2 has been chosen in different concentration which has been added with the engine oil. The operational characteristics of lubricants have been determined and compared with different volume concentrations like 0.5%, 1.0%, and 1.5% at different temperatures. The testing and the evaluation of characteristics of the proposed lubricants have been performed as per the American Standard for Testing Materials (Sudeep, *et al.*, 2013; Wu, *et al.*, 2006).

The nano-particles dispersion was carried out carefully and their properties such as flash and fire point, viscosity, density and pour point are tested. The properties of the SAE20W40 engine oil are shown in the Table 1. There was significant change observed in the physical and chemical properties of the lubricant SAE20W40 with the addition of SiO_2, Al_2O_3 and TiO_2 nanoparticles. Short tube and cone on plate viscometers were used to measure the kinematic and dynamic viscosities of the lubricant respectively. ASTM D97 and ASTM D92 standards were used to measure the pour point and flash point of the lubricant respectively. The viscosity of the nano-lubricants was measured using a Redwood viscometer. 50 ml of oil was used for each trial. Time required for emptying 50 ml of oil was measured and viscosity was calculated using Redwood formula.

A series of experiments were conducted to evaluate the friction and wear characteristics of the sliding elements with the addition of nano-particles into the lubricating oil. The various results for the given samples of lubricating oil with nano-particles additives were done on pin-on-disk apparatus. The pin-on-disk tribometer serves for the investigation and simulation of friction and wear processes under sliding conditions (Victor and Simon, 2016). It can be operated for solid friction without lubrication and for boundary lubrication with liquid lubricants. The anti-wear property is a function of additive concentration in base oil.

RESULT AND DISCUSSION

In the present work, SiO_2, Al_2O_3 and TiO_2 nano-particles were used as additives which were mixed with the engine oil SAE20W40 in different concentrations. The required quantity of nano-particles was accurately weighed using a precision electronic balance and mixed with the lubricating oil. The nano-particles are mixed with engine oil was kept in a test tube and stirred for 50mins using WENSAR Ultrasonicator at room temperature and frequency of 40 kHz. After the dispersion of the nano particles, the testing was carried to evaluate their properties (Wu, *et al.*, 2006). The properties such as viscosity, flash and Fire point, Pour point, density are evaluated. The Table 1 shows the properties of the oil sample.

The (Fig. 1) represents the temperature ranges of the five different oil samples based on its flash and Fire point property. The maximum temperature of about 302°C was attained by the sample 5 which has the composition of 0.5% SiO_2+1.5% Al_2O_3+1.5% TiO_2. The

Table 1. Experimental value of the properties of lubricating oil samples.

Ratio (wt %)			Sample	Kinematic Viscosity (cST)	Density (kg/m^3)	Flash Point (°C)	Fire Point (°C)	Pour Point (°C)
SiO_2	Al_2O_3	TiO_2						
Base Oil (SAE 20W40)			S	10.10	0.879	200	220	-21
0.4	1.5	1	S1	10.85	0.918	285	327	-13
0.6	1.5	1.5	S2	10.98	0.919	289	330	-15
0.4	1	1	S3	11.38	0.920	295	332	-17
0.5	1	1	S4	11.55	0.920	297	333	-19
0.5	1.5	1.5	S5	11.67	0.921	302	335	-19

minimum temperature is 285ºC attained by sample 1 consist the additives of 0.4% SiO_2, 1.5% Al_2O_3 and 1% TiO_2. The maximum temperature of about 302ºC was attained by the sample 4 having composition of 0.5% SiO_2, 1.5% Al_2O_3 and 1.5% TiO_2. The minimum temperature is 285ºC attained by sample 1 consist the additives of 0.4 SiO_2 + 1.5 Al_2O_3 + 1 TiO_2

The viscosity of the nano-lubricants was measured using a Redwood viscometer. 50 ml of oil was used for each trial. The Kinematic Viscosity of the oils has been evaluated at 100ºC according to ASTM D445 standard. Time required for emptying 50 ml of oil was measured and viscosity was calculated using Redwood formula. The maximum kinematic viscosity is 11.65 cST which result by the sample 5 and the minimum value is 10.85 cST by the sample 1 in this study. The result in this graph reveals a gradual increase of the kinematic viscosity and finally the sample 5 decreases in its value. The (Fig. 2) depicts the change in the Kinematic Viscosity of oil Samples. The sample 1 has the viscosity equal to the base oil 20W40 and also the density of the oil is comparatively less compared to other samples. From the experiments conducted it has been inferred that the addition of nano-particles in the base oil increases the viscosity.

A series of experiments were conducted to evaluate the friction and wear characteristics of the lubricating oil with and without the addition of nano-particles into the lubricating oil. The anti-wear property is a function of additive concentration in base oil. (Fig. 3) shows the plot of wear rate with respect to time. From the obtained graph it proves that the sample 5 shows less wear when compared to other results. The sample with the composition of 0.5% SiO_2+1.5% Al_2O_3+1.5% TiO_2 results in smaller wear rate value which gives out the better value in the wear resistance. The sample 1 comparatively exhibited a higher wear rate value which is estimated from the test carried out by Pin-on-disk apparatus.

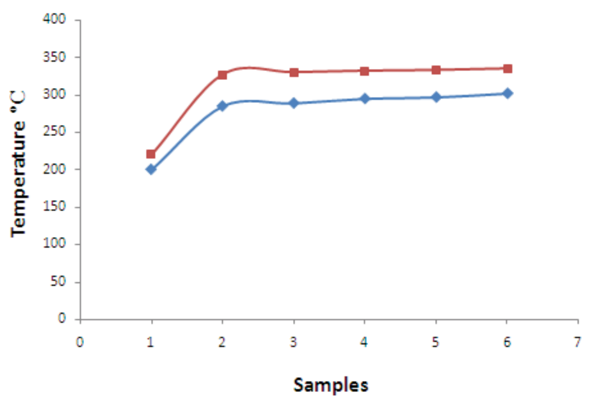

Fig. 1 Flash and fire point of oil samples.

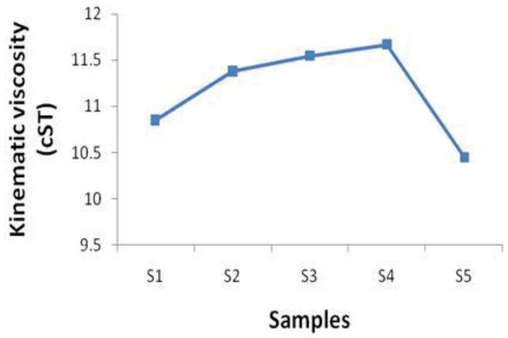

Fig. 2 Kinematic viscosity of oil samples.

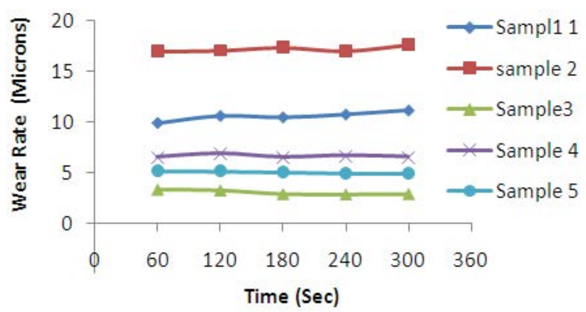

Fig. 3 Wear rate of oil samples.

CONCLUSION

The following conclusions have been drawn from the conducted research work, friction-reduction properties of base oil are enhanced by the addition of SiO_2, TiO_2 and Al_2O_3 nano-particles to a moderate concentration. Addition of nano-particles in oil increases the viscosity of oil. From the experimental results it has been inferred that, the mixing of SiO_2, TiO_2 and Al_2O_3 nano-particles as additives in engine oil improves the lubricating oil properties and significantly reduces the friction and wear rate. Thus, it is evident from the experimental studies the addition of nano-particles reduces friction and improves the anti-wear properties of the lubricating oil. The results of the tests obtained from the blend shown that the most important properties such as viscosity, density, flash point, increase with the increase in additive concentration. Thus, it is evident that the addition of nano-particles improves friction reduction and anti-wear properties of the lubricating oil.

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