Friction and wear characteristic of different natural oil-based lubricants with carbon nanotubes as additive

K.F. Yong[1,2,*], B.T. Tee[1,2], M.F.B. Abdollah[1,2], I.S. Mohamad[1,2], C.T. Chong[3]

[1)] Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2)] Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[3)] Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

[*]E-mail: francisyong92@yahoo.com

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ABSTRACT – The advantages of natural oil-based lubricant are sustainability and eco-friendly. It is important to study their tribology properties as alternative mineral oils as lubricant. This work investigates the prospects of natural oil-based lubricant for automotive applications in contrast to the available conventional lubricant. The experiment is conducted to obtain the friction and wear characteristics by using four-ball tester set-up. The natural oil-based lubricants involved in this study are refined glycerin and oleic methyl ester with CNT as additive. The results of friction and wear scar diameter for both types of lubricant were shown and compared in this work. From the experiment, refined glycerin with 1% CNT is found to have better friction reduction compared with refined glycerin.
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1. INTRODUCTION

The tribology study of metal processing has been emphasized nowadays due to the trend is directed toward the machinery world. To increase the life span of machinery system, lubricant is needed. Global environmental awareness encouraged the replacement of mineral lubricant with renewable, sustainability, high biodegradability and eco-friendly lubricant. Palm oil based lubricant constitute as one of the natural oil-based lubricant has the potential to replace the mineral lubricant as alternative lubricant for industrial processes. The performance of lubricants is mainly depending on the friction and wear characteristic [1]. This work investigates the prospects of natural oil-based lubricant for automotive applications in contrast to the available conventional lubricant.

2. METHODOLOGY

To obtain the different characteristics of friction and wear between natural oil-based lubricants with and without the additive, friction and wear test are conducted by using four ball tester. The homogeneous process of lubricant and additive is carried out by using homogenizer instrument. The working principle of four ball tester is that three of the steel ball will be placed at the bottom ball pot and one on the top in the ball chuck. The upper ball is hold in a ball chuck. The bottom three balls are held in a ball pot containing the test lubricant and pressed against the upper rotating ball. The standard ASTM D-4132 B test condition is as shown in Table 1.

Table 1 Test conditions.

Parameter	**Condition**
Load (Kg)	40
Duration (Sec)	3600
Temperature (ºC)	75±2ºC
Speed (rpm)	1200±60

For lubricant with carbon nano-tube CNT additive, additive of 1 gram and lubricants of 100 gram are measured by using digital mass measurement instrument. Mixture of lubricant and additive in beaker were put into another metal basin which is filled with water located in the homogeneous instrument. The homogenizer instrument is set to 50 rpm and run for 1 hour. For the four ball tester experiment, all parts in the four-ball were thoroughly cleaned by using acetone and wiped using tissue. Three of the steel ball bearings were placed into the ball pot assembly. The upper spinning ball was locked inside the chuck and tightened into the spindle. The test lubricant was applied into the ball pot assembly with the level which coated all the voids in the test cup assembly. The test lubricants used include refined glycerin (RG) and oleic methyl ester (OME).

The ball pot assembly were fitted in four ball tester machine then connected with the temperature sensor. Once the setting temperature is reached, the drive motor will be operated. After 60 minutes, the heater was turned off and the oil cup assembly was removed from the machine. The test oil in the oil cup was then drained off and cleans it again with acetone. The wear scar area was wiped using a tissue and then viewed by using microscope.

3. RESULTS AND DISCUSSION

After the experiment, the result from four ball tester measurement for Coefficient of Friction (COF) is recorded in Microsoft Excel in computer, the wear scar diameter (WSD) on the three ball-bearings in each experiment was observed and measured using Digital

Microscope as shown in Figure 1. The average values of the wear scar diameter were taken. Under the applied conditions, RG with additive delivered the highest average WSD compared to RG without additive. For OME, same result obtained where the WSD for lubricant with additive is higher than the one without additive. The WSD results for both lubricants are shown in Table 3 below. The results show that for both lubricant without additive perform better in forming a thin lubricant film with adsorption of fatty acid which bring to less metal to metal contacts as indicated in previous study [2]. The metallic soap film was rubbed away during the sliding, leading to the production of the non-reactive detergents that increased the wear [3]. The lubricants viscosity was determined under temperature of 40ºC which is as shown in Table 2. From viscosity test, RG show the highest viscosity which show that is perform better compare to OME. Viscosity increase indicates that lubricant has deteriorated by oxidation, while a decrease usually indicates dilution by lower viscosity oil or by fuel [4].

Table 2 Viscosity of Lubricants in cSt.

Parameter	RG	OME
Without additive	404.3	9.5

Table 3 Average WSD on ball bearing in µm.

Parameter	RG	OME
With 1% additive	145.47	173.53
Without additive	136.06	162.51

Figure 1 Sample of measured WSD of RG and SEM.

From friction tests the steady-state condition of the COF is shown in Figure 2. Based on the figure, it indicates that the lubricant layer between ball-bearings was stable and no severe breakdown of lubricant film was occurred. The average values of the COF were calculated for both lubricants with and without adding additive as shown in Table 4.

Table 4 Average of coefficient of friction for different lubricant in µm.

Parameter	RG	OME
With 1% additive	0.059116	0.094960
Without additive	0.071493	0.085170

Referring to table 4, it's shown that, COF of RG with the additive is lower than the one without addictive. This indicates that it perform better than the one without additive in reducing's the friction between two contact surfaces as mentioned in previous study [5]. However for OME it is different case as the one without additive perform better than the sample with with additive. Figure 2 show the COF for OME lubricant with and without additive.

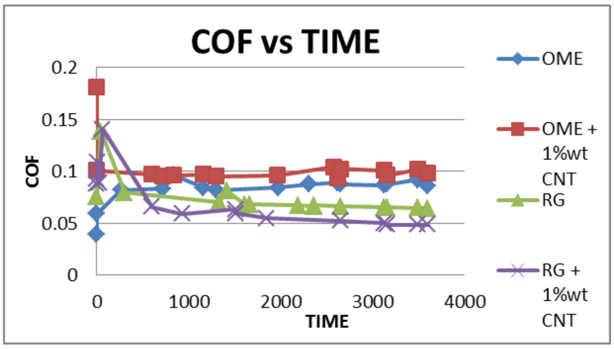

Figure 2 COF of Lubricant.

4. CONCLUSION

The friction and wear characteristic evaluations of natural oil-based lubricants were conducted using a four-ball tester along with lubricants performance analysis with CNT as additive. The addition of additive into lubricating oil has significant influence on the wear mechanism. From the observation on the surface topography of the worn surface, the rough surface that formed helped to create an oil reservoir of the lubricant, and prevented metal-to-metal contact as supported in the previous studied [6-7]. Further tests with different temperature and additive portion will be conducted in future investigation.

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