EFFECT OF LOAD AND TEMPERATURE ON FRICTION USING BANANA PEEL BLENDED WITH PARAFFIN OIL UNDER HIGH LOADING CAPACITY

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ABSTRACT

Increased severity in operating conditions coupled with the environmental and toxicity issues related with using conventional lubricants. In addition, high price of fossil fuels has led to exploration of new kind natural additives as bio-lubricant. Banana Peel as agricultural wastes are potential to be developed as bio-oils that to replace the petroleum products, due to their environmentally friendly characteristics, biodegradable, nontoxic and renewable. The purpose of this study is to produce lubricant oil from Banana Peel (BP) as bio additives in paraffin oil, as well as to determine their physical and tribological properties as bio-lubricant under severe operation conditions to identify their ability for lubricants. Tribological performance of Banana Peel (BP) as a bio-lubricant was tested using four-ball test machined under extreme pressure conditions, according to ASTM D 2783-03. Experimental results showed significant improvement in overall performance with increased BP content compared with paraffin oil (PO) through Coefficient of Friction parameter (COF) at 100 ˚C, lower value of COF which 0.086 for 50 %BP followed by 20% BP, 5% BP and 100 %PO at values 0.089, 0.456 and 0.595 respectively. As results, banana peel as Extreme Pressure and Anti-Wear additives has been proven itself able for use in lubrication applications for gear and engine oils.
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Keywords: Bio-Lubricant, Banana Peel, High loading capacity, Temperature, Friction.

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1. INTRODUCTION

Tribology can be defined as the science and technology of interacting surface in relative motion which are present in various machined elements (Nosonovsky & Bhushan 2010; Banjac et al. 2014). In almost every aspect of our daily lives, some appearances of tribology such as sliding, brushing, gripping, holding, machinery works, friction between skin and clothes, movement of artificial hip joints etc (Mattei et al. 2011; Gaikwad et al. 2013).

Friction is the force that resisting the relative motion of solid surface, fluid layers and material elements sliding against each other. There are many types of friction like, lubricated friction, fluid friction and dry friction. An important consequence of many types of friction is wear which lead to decline in performance and/or damaged to components. Wear can be defined as undesired removal of material due to mechanical action (Berman et al. 2013a; Golshokouh et al. 2014). The rough surface, deep valley of asperities that formed helped to create an oil reservoir of the lubricant and prevented metal to metal contact (Azmi et al. 2015).

Lubrication is the process or technique employed to reduced friction between two surface and wear of one of them or both. Most of friction and wear are created during start-up and shout down of engines, whereas Boundary Lubrication (BL) occur at low speeds (Tuszynski 2006; Berman et al. 2013b; Dou et al. 2016). The major reasons of using lubricants in engines are to control friction properties, reduce wear, and improve the efficiency. Other reasons are for cooling, sealing, load balancing, cleaning and rust prevention (Linke-Diesinger 2008). Engine oils consist of the base oil and additives. Mineral based oil is used in most application to increase effectiveness in lubrication of various industrial parts fixed and mobile. Although this oil is very useful, it is also an environmental hazard, poses damage on human, high price and is non-renewable source (Pettersson et al. 2008; S. Syahrullail, Nuraliza, et al. 2013). Vegetable oils are known as renewable resources, environmentally friendly, non-toxic fluids, and are readily biodegradable (Adhvaryu et al. 2004; Tiong et al. 2012; Shahabuddin, Masjuki & Kalam 2013; Shahabuddin, Masjuki, Kalam, et al. 2013) . The bio-based lubricant is promising to protect the surfaces from wear and damage in comparison with the mineral oil due to lower value of dynamic pressure (Nazri et al. 2013). In recent years, great development in engines and requirement on load carrying capacity of new and environmentally friend source (agricultural waste) especially at severe operating conditions. Vegetable oils as additive have several properties which can achieve this purpose comparable to mineral oils, such as high lubricity, low volatility, high viscosity index, environmental friendly, more biodegradability, low Coefficient Of Friction (COF) and low wear scar (Waara 2006; Alves et al. 2013; Quinchia et al. 2014). Low oxidation stability is one of the major factors hampering industry acceptance of vegetable oil-based lubricants(Erhan et al. 2006; Fox & Stachowiak 2007; Mustafa et al. 2015).

Banana skin been often referred as slipping tool by literatures. Based on Mabuchi et al. 2012, friction under banana skin was measured on flat panel common floor material during the sliding motion of shoes sole. The frictional coefficient was about 0.07 and this much lower than value on common materials and similar on well lubricated surfaces (Mabuchi et al. 2012). Bananas are one of the most popular fruits on the world market. It is well known that fruits contain various antioxidants (Someya et al. 2002; Gonzalez-Montelongo et al. 2010; Baskar et al. 2011; Espinosa & Santacruz 2017). The dispersion of banana peel in paraffin is stable and smooth without any sedimentation problem. Moreover, oil shows good and promising tribological characteristic of lubricant (Hamid et al. 2015). In this study, Banana Peel (BP) had been investigated as an additive in lubrication system. This is a novel attempt to use banana peel in lubrication system. Hence, it is important and necessary to evaluate the characteristics of BP as lubricant additive to show their effect of load and temperature on friction performance to test their validity in industry application.

2. EXPERIMENTAL SET UP

2.1 Material Preparation

Cavendish Banana belongs to Musaceae family under subgroup of triploid Authentication, Authorization and Accounting (AAA) cultivar group. They include commercially important cultivars like the ‘Dwarf Cavendish’ and the ‘Grand Nain’ (Hallam 2003).Cavendish banana skin or banana peel (BP) which is pericarp (outside skin) had been chosen as natural additives in paraffin oil. Paraffin oil as based-oil has been mixed with banana peels because of simple structure, unique tribological behavior and flexible for use under different percentage in preparation of lubrication samples by using ultrasonic homogenizer. It is also chemically composed of saturated hydrocarbons, consisting of a mixture of hydrocarbons chiefly of the alkene series and it is one of the higher members of alkane series which largely constitute the commercial form of this substance (Zhou et al. 2001). Ball bearings are common in mechanical studies, because they are widely used in automotive industry. The rolling balls have a much lower coefficient of friction as compared if two flat surface sliding against each other. However, ball bearings tend to have lower load capacity for their size than other kinds rolling element bearing due to the smaller contact area between the balls with inner and outer barriers (Taher 2011).

2.2 Lubricant Composition

There were four types of lubricant samples which are state in Table 1 below.

Table 1: Composition of lubricant samples

Lubricant samples	Composition of Lubricant sample
Sample A	100% Pure Paraffin oil
Sample B	Paraffin oil +5% Banana Peel

Sample C	Paraffin oil +20% Banana Peel
Sample D	Paraffin oil +50% Banana Peel

Ultrasonic Homogenizer was used to mix the paraffin oil with banana peel in one hour. The mixing of paraffin oil and banana peel was refined by using the clothe filter. Preparation of lubrication samples was determined by using Equation 1. Volume percentage was referred after solution was made by mixing two liquids. Total volume for each lubricant sample fixed to 100 ml that contained of banana peel and paraffin oil.

$$C\%\ v/v = \frac{V\ Substance}{V\ Solution} * 100\% \qquad (1)$$

Where, C% v/v is volume/volume percentage, (V solution) is volume of solution and (V substance) is the volume of substance.

2.3 Friction Test

Three design parameters were performed which are percentage of lubricant, temperature and load. The four sample of lubricant are test under the temperature of 27, 80 and 100℃ which the load gradually increased until obtaining load capacity. Test temperature were selected for imitation of real engine temperature which begin at 27℃ and 80℃ is ideal temperature during engine running. Friction test were carried out according to standard test methods for measurement of Coefficient Of Friction (COF) and Extreme Pressure (EP) properties of lubricants until obtaining welding point on four-ball testing, according to ASTM D 2783-03 (ASTM 2003). The test has been conducted for 30 minutes on four samples and the loads on ball bearings were in the range of 500 N to 1750 N.

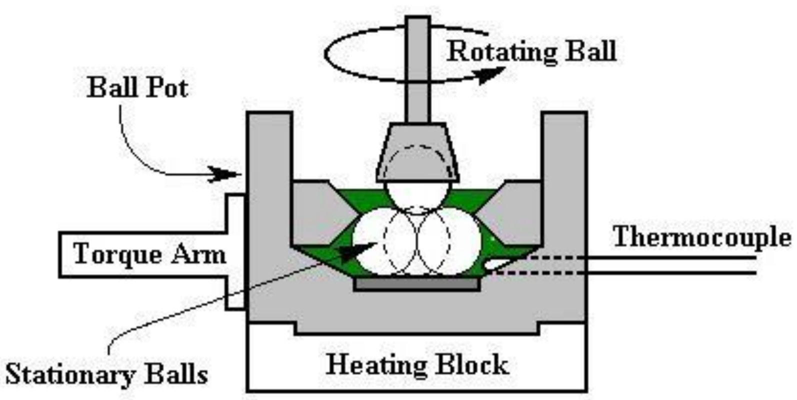

Figure 1: Schematic diagram of Four ball tester

2.3 Coefficient of Friction Calculation

The Four ball machine was purposed for the first time by Boerlage. The Four ball apparatus can be used to test load carrying capacity, welding point, coefficient of friction and anti-wear properties of lubricating oil under standard operating conditions. Table 2 shows the specification for using four ball test machines.

Table 2: Specifications for using four ball test machines

Parameter	Unit	TR 30L
Load	Newton (N)	Max. 10,000
Spindle Speed	RPM	1000-3000
Power	V/Hz/VA	380/50/30/2000
Scar range	Micron	100-4000
Temperature	(˚C)	Ambient to 100 ˚C
Drive motor	KW	1.5

Suitable weight was selected for end of lever arm and weights to give required test load until obtaining weld point. Values coefficient of friction (COF) was investigated through a series of friction test. Coefficient Of Friction of sample was investigated through a series of 4 ball friction tests and calculated by frictional torque, spring constant and applied load as equation 2, similar to calculation as used by (Ing et al. 2012)(S. Syahrullail, Kamitani, et al. 2013) (Zulkifli et al. 2014).

$$\mu = \left[\frac{T\,6^{0.5}}{3}\right] r \tag{2}$$

Where, μ is coefficient of friction, T is frictional torque in kg.mm, r is distance from the center of the contact surface on the lower balls to the axis of rotation, which is 3.67 mm and W is applied load in kg.

3. RESULTS AND DISCUSSION

3.1 Analysis of Coefficient of Friction, COF

Coefficient of Friction had been reduced significantly by dispersing different concentration of banana peel compare to paraffin oil at all temperatures. This because of banana peel made both “ball bearing effect” and ‘polishing effect”, and consequently smoothing the rough friction contact surfaces. Mabuchi et al. (2012) (Mabuchi et al. 2012) estimated that polysaccharide follicular gel played the dominate role in lubricating effect of banana skin after the crush. Some authors reported that banana contain a good source of natural oxidations, such as vitamin C, vitamin E, carotene, dopamine, flavonoids (Kanazawa & Sakakibara 2000). Figure 2 show, at 27 ˚C and 700 N, values of coefficient of friction for lubricants 100% paraffin oil, 5% banana peel, 20% banana peel were 0.118, 0.086 and 0.098 until welding points of steel balls at 1100, 1500 and 1650 N with values of 0.605, 0.162 and 0.11 respectively.

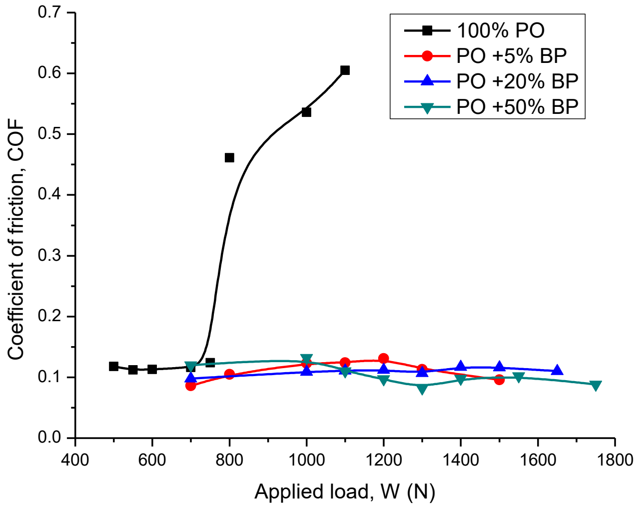

Figure 2: Effect of applied load, N on Coefficient of friction, COF at 27 ˚C

Figure 3 shows paraffin oil at 80 ˚C, there was a significant increase in COF value from starting to welding point 0.18 to 0.538 for loads 500 N and 1000 N respectively. Others lubricant has increasing superiority compared to at 27 ˚C. There clearest superiority was by bio-lubricants, where trend of the curves was decreasing, except sample 5% BP after 1000 N. Values of COF for lubricants 5% BP, 20% BP and 50% BP at start and welding point were 0.131, 0.128, 0.149 and 0.152, 0.114, 0.094 respectively. On top of this, behavior of these samples was more stable in comparison with temperature at 27 ˚C, which shown excellent anti-friction performance and high load carrying capacity. The higher load differentiated the behavior of tested additive compositions at elevated temperatures.

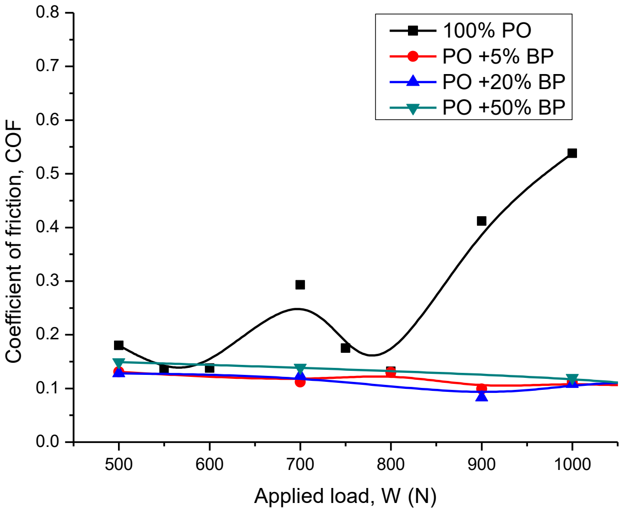

Figure 3: Effect of applied load, N on Coefficient of friction, COF at 80 ˚C

Figure 4 shows lubricants 5% BP, 20% BP, 50% BP at having lower values of COF compared with values at 27 ˚C and 80 ˚C. More severe conditions influenced the COF intensification in case PO because the surface protection was much worse in comparison with bio-lubricant. Therefore, PO obtained highest values for COF up to welding point because of the breakdown of the lubricant film at this load. The curves for other lubricants decreased except for sample 5% BP at weld point 1475 N. Figure 4 below show at 100 ˚C, values of COF for all lubricants of 100% PO, 5% BP, 20% BP and 50% BP at start and welding point were 0.12, 0.121, 0.121, 0.13 and 0.595, 0.456, 0.089 and 0.086 respectively.

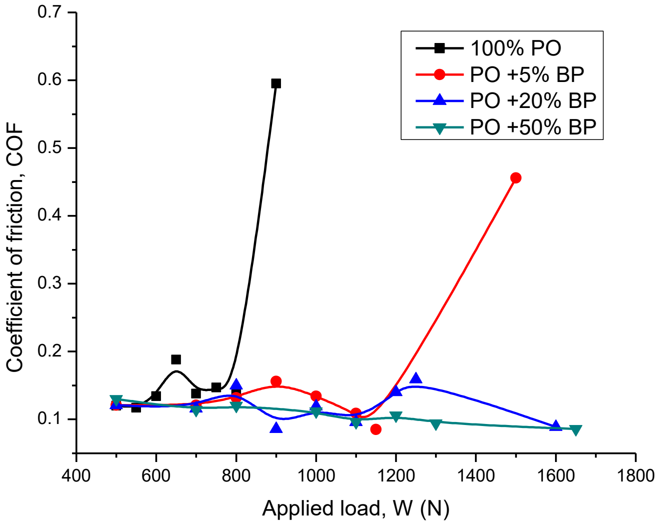

Figure 4: Effect of applied load, N on Coefficient of friction, COF at 100 ˚C

Figure 1, 2, 3 and 4 shows that there was no clear relation between the load and COF. This behavior has been reported by many authors such as Jiyuan, Quan and Lixia (2001) (Jiyuan et al. 2001), Rastogi and Yadav (2003) (Rastogi & Yadav 2003), Syahrullail et al. (2013) (S Syahrullail et al. 2013), Zulkifli et al. (2013) and Hamid et al. (2015). These figures show that better friction resistance was at 50% follow by 20% and 5% of BP respectively with lower values of COF compared with PO in all cases. As a result, it can be said that the friction resistance and stability increased with increasing load and temperature until welding point, which largely depends percentage of BP mixture. A similar effect was observed by Adhvaryu et al. (2006), where there was sharp decrease in COF with increasing natural additive concentration like Cottonseed, canola and olive oils in hexadecane (99% + anhydrous). A similar result was found by Adhvaryu, Erhan and Perez (2004) (Adhvaryu et al. 2004) on soybean oil and their derivatives in hexadecane.

3.2 Effect of Temperature on Coefficient of Friction

The results of variation value of COF with applied loads for various lubricants under different temperature shown in Figure 5. In case of 20% BP at all temperatures, similar behavior was observed by this lubrication with its counterpart of 50% BP with results more superior as reflected in the shape of chart. In the case of 50% BP, progressive reduction of COF at all temperature was observed. Anti-friction action of additive can be explained by the formation of the protect film (Hamid et al., 2015). 50% BP showed a better result of friction reduction and test state was in boundary lubrication. Besides, tests at lower temperature could not supply reliable information about oxidative stability and sometimes cannot evaluate the presence of protective film or anti-oxidation compound (Gonzaga & Pasquini 2006). At elevated temperature, a film was formed on the metal surface during thermal decomposition, containing effective compounds, resulting in the friction reduction thus COF reduction (Hamid et al., 2015). Hence, for bio-lubricant, mechanism of friction reduction could be achieved by increasing the content of banana peel in paraffin oil, especially at 100 ˚C, for lubricant 20% BP and 50% BP.

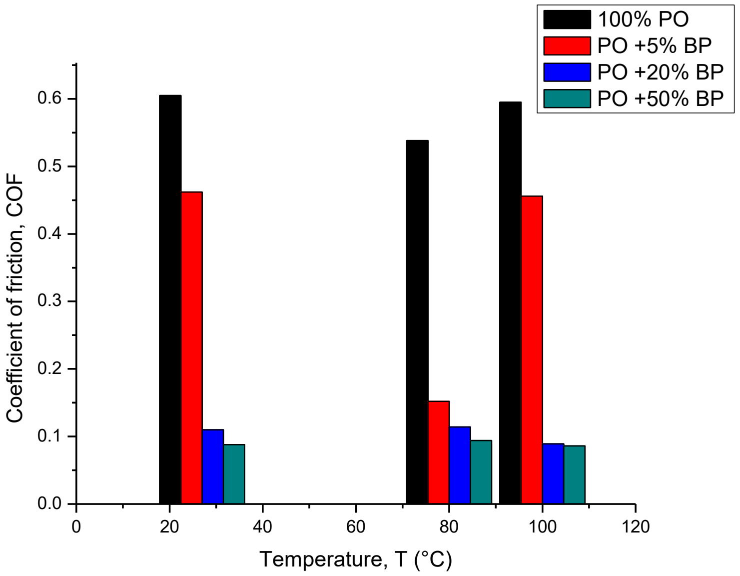

Figure 5: Effect of temperature (˚C) on value of Coefficient of friction, COF

Weld points were selected for comparison between lubricants used at temperature of 27, 80, and 100 ˚C. Moreover, metal debris moved between the balls. Hence, the surface became highly worn with increased temperature. This was due to the fact at elevated temperature, the lubricant film formed by PO tended to be less stable or was more likely to break down. Related results were found by Ing et al. (2012a)(Ing et al. 2012) . Moreover, metal to metal contact between balls would increase the frictional resistance. As a result, COF increase compared to bio-lubricant at region welding.

4. CONCLUSION

The Coefficient of friction was found to decrease with increase of banana peel content. The behavior of the lubricant under extreme pressure conditions became better with increase of the banana peel content. The value of Coefficient of friction at 100 ˚C was 0.086, 0.089, 0.046, 0.595 was refer to 50% BP, 20% BP, 5% BP and 100% PO respectively. Banana peel as natural additives has ability to improve physical and tribological properties of paraffin oil.

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