Optimization on Wear Performance of Anti Wear Additive Added Biolubricant

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Abstract Waste cooking oil is hard to dispose of and harmful to the environment. Recently, a considerable amount of research has been done to improve the properties of engine oil. In this study, engine oil was blended with waste cooking oil and an oil treatment solution. The blended oil was tested in a tribological wear tester. There are three parameters (rotational speed, loads and ratio of waste cooking oil) was consider in the experiments. Tribology wear and properties of the blended oil were investigated in FESEM. It was found that abrasive wear, adhesive wear, fatigue wear and corrosive wear were introduced during the course of the experiments. Normally, corrosive wear was found to be the main dominant in the tribology wear. It was discovered that 5% addition of waste oil to the engine oil treatment and base lubricant performed better than other oil blends.

Keywords Lubricant · Speeds · Engine · Waste

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1 Introduction

Lubricants are widely used in all fields of manufacturing and industrial applications and commonly used to reduce overheating and friction in a variety of engines, machinery, turbines, and gearboxes. They can also aid in maintaining reliable machine functions, expedite operations and the smooth operations and reduce the risks of failure. Furthermore, lubricants can reduce wear and heat loss from the contact of surfaces in motion, prevent rust, reduce oxidation on the contact surfaces and to act as a seal against dirt, dust and water [1]. Due to that, Therefore, petroleum was initially used as the main base stock lubricant, due to its low cost and superior performance. Unfortunately, the rising price of crude oil all over the world, the environmental awareness from various sectors and the depletion of the crude oil spurred scientists to start developing an alternative fuel and lubricant product from natural resources and agricultural feedstock aiming to replace the fossil products [2]. From the reported works, alternative forms of oil should increase to a volume about 36 billion gallons in 2022 [3]. From 2010 until now, several biolubricants are under investigation in different countries [4], e.g., soybean oils (The USA and South America), rapeseed oil (Europe), Jatropha oil [5, 6] and palm oil, (Asia), [7–10]. Most of the works show results regarding their properties. It was noted that vegetable oil-based bio-lubricants exhibit a high results on their properties and it was perceived that using vegetable oil-based bio-lubricants exhibits high lubricity, a high viscosity index (VI), high flash point and low evaporative losses. Moreover, researchers have reported that biolubricants provide better lubricity than petroleum-based oils [11]. Waste cooking oil can be considered the most promising bio-oil feedstock. As reported by many researchers, bio-fuels produced from waste cooking oils have numerous advantages such as low pollution (CO_2, CO and NOx), low cost and acceptable brake specific fuel consumption. Interest has drawn towards the potential of using waste cooking oil as a lubricant. Kalam [12] experimentally investigated the friction and wear characteristics of a normal lubricant, that is, an additive added lubricant and waste vegetable oil (WVO)-contaminated lubricants. The WVO-contaminated lubricants with amine phosphate as antiwear additive reduced the wear and friction coefficient and increased viscosity. Thus, waste palm oil with a normal lubricant and amine phosphate additive could be used as a lubricant substitute (maximum 4%). Based on four ball tribo testing results, the WVO contaminated lubricant with the presence of antiwear additives shows promising result to do better thermal and oxidative properties of waste vegetable oil consisting long chain saturated fatty acids [13]. Tribological behaviour measurements/factors such as the coefficient of friction (COF), specific wear rate and wear mechanism, play an important role in identifying the tribological performance of the bio-lubricant. In an internal combustion engine, mechanical friction occurs between engine components in contact with each other leading to wear and significant loss of efficiency. Loss of energy due to friction between the piston ring and cylinder liner constitutes 20–40% of total mechanical loss and is regarded as the greatest mechanical friction loss [14]. Different engine lubrication regimes significantly affect the tribological performance of the engine [15]. Wear occurs on all sliding surfaces. Since wear is a chaotic process, wear studies are mostly hence wear studies are mostly done experimentally due to the limited ability to accurately to simulate wear [16]. There are several mechanisms of wear which include seizure, melting, oxidation, adhesion, abrasion, delamination, fatigue, fretting, corrosion, and erosion [17]. A better lubricant which has great properties can reduce the amount of wear loss. The main objective of this study is to modify the current engine oil properties with waste cooking oil to reduce wear.

2 Experimental Setup

The base oil that was used in this experiment is SAE 40. The oil was obtained from the hostel cafeteria. For the preparation of waste cooking oil as bio-lubricant, waste cooking oil undergoes three different processes: coarse filtering, dewatering, and fine filtering. Figure 1 shows the schematic diagram for the filtration of waste cooking oil. Three samples were explicitly prepared, namely, Sample A which is SAE 40 as a reference lubricant (0% volume composition of waste oil), Sample B which are composed of 95% SAE 40+ 5% waste oil added with 0.3% oil treatment (EOT), Sample C, which is composed of 90% SAE 40+ 10% waste oil added with 0.3% (EOT) oil treatment.

The wear test was conducted under the lubricated sliding condition in compliance with ASTM G133-05 standard. The wear testing involves making linear

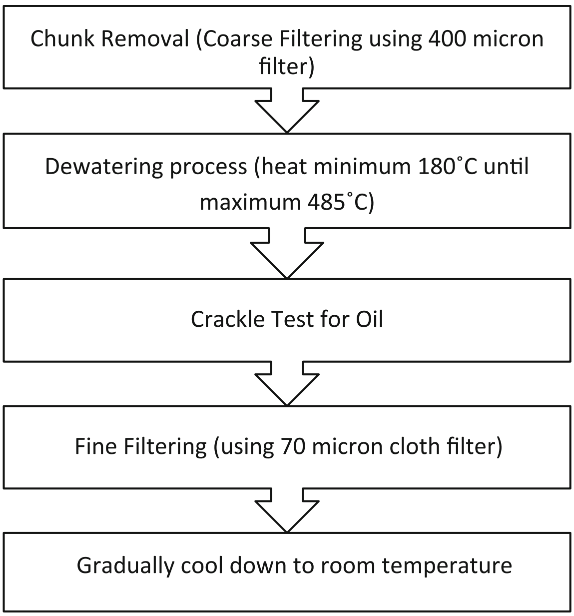

Fig. 1 Schematic diagram for filtration of waste cooking oil

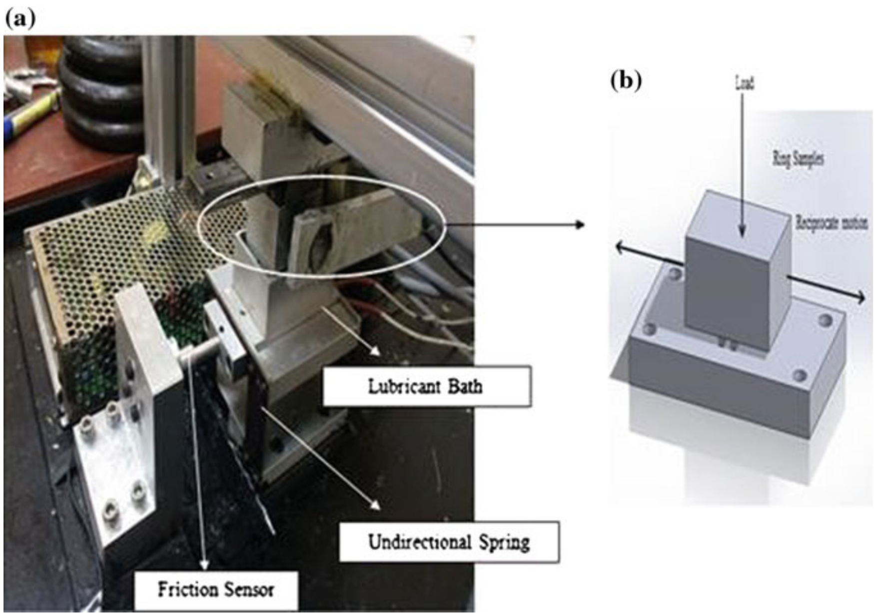

Fig. 2 Experimental setup

movements similar to a cylinder-piston pair operating under real conditions. Figure 2 depicts the wear tester. Normal loads applied to the device by hanging weights on the bearing lever where the piston ring sample is attached in order to produce the desired load. The test will be conducted at engine speed at 200–300 RPM with normal loads 2–9 kg. The temperature that will be used is room temperature and the operating time is 10 min per specimen. The coefficient of Friction (COF) was measured using ARDUINO and the wear rate was determined via weight differences using a weighing scale with a sensitivity of 0.1 mg. The test conditions are presented in Table 1.

The type of material for specimen used in this experiment is Aluminium 6061-T6 which is the material that commonly used for the piston. Flatbar Aluminium 6061-T6 was cut using a band saw and each specimen was prepared 45.12 mm long, 25.14 mm wide and 6 mm thickness. The block was drilled to each side of the rectangle using 4 and 6 mm drill bit. The chemical and physical properties for Aluminium 6061-T6 are shown in the Tables 2 and 3 [18, 19].

Table 1 Tribology test condition

Test specifications	Values
Load, kg	2.0–9.0
Engine Speed, rpm	200–300
Temperature	Room temperature
Operating time	10 min per specimen

Table 2 Chemical composition for Aluminium 6061-T6

Sample	Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn
Percentage (wt%)	95.8	0.04	0.15	0.7	0.8	0.15	0.4	0.14	0.25

Table 3 Physical properties of Aluminium 6061-T6

Properties	Value
Density (g/cc)	2.7
Thermal conductivity (W/m-K)	167
Modulus of elasticity (GPa)	68.9
Specific heat capacity (J/g.°C)	0.896
Melting point (°C)	652

3 Result and Discussion

3.1 Physico-Chemical Properties of Waste Cooking Oil in Base Lubricant

The data were used to evaluate the differences between base lubricant stock (SAE 40) and to serve as a basis for comparing the blended lubricant of palm oil and waste oil. Table 4 shows the properties of base oil (SAE 40), palm oil and waste oil. A good lubricant should have a high boiling point, adequate viscosity, low freezing point, high oxidation resistance, non-corrosive properties and good thermal stability. The most important property of oil is viscosity. It indicates resistance to flow and is directly related to temperature, pressure, and film formation. High viscosity initiates low resistance to flow [1]. Lubricants generally are less dense than water. If the density of an object is less than that of water, then that object will float. This is why if there is a moisture problem in the lubrication system that the water settles to the bottom of the sump and is drained out first whenever the plug is pulled or the valve is opened. The density of a lubricant fluid can provide indications of its composition and nature [20]. Less moisture content in lubricating oil also indicates rust and corrosion prevention.

Table 4 Properties of oil and blended oil

Properties	SAE 40	Waste oil	5% waste oil + SAE 40+ 0.3% EOT	10% waste oil + SAE 40+ 0.3% EOT
Viscosity (mpa.s)	179.2	180.6	176.0	163.2
Density (g/cm^3)	0.8609	0.9049	0.8624	0.8644
Moisture content (%)	0.19	0.28	0.14	0.19

3.2 Microstructure and Wear Mechanism

There are various types of wear in a mechanical systems such as abrasive wear, adhesive wear, fatigue wear and corrosive wear. Since the lubricant regime occurred in this experiment was boundary lubrication, therefore, abrasive wear, adhesive wear, fatigue wear and corrosive wear were observed in the wear regions [7]. There were many deep furrows and some corroded areas can be easily seen on surface lubricated with lubricant sample C as shown in Fig. 3a whereas the surface lubricated with lubricant sample A and lubricant sample B are relatively smooth although mark with wear debris due to the rough surface layer on the hard surface from the liner samples touched the soft surface for the piston samples and had close relationships with the thickness of lubricant film as shown in. According to earlier studies, corrosive wear is the main wear mechanism [21] for biolubricant and since the moisture content in the waste oil high which is 0.28% it does give the corrosion effect on the specimen. In sample C it was also observed that the surface of the pins was damaged due to adhesion [22], eventually leading to scuffing and tribochemical reactions of sliding contact surfaces as shown in Fig. 3b.

FESEM images of the aluminium plate were obtained using various types of volume concentrations of waste cooking oil blended with engine oil. Referring to Fig. 4, it was found that the honing lines decrease at 5% concentration compare with SAE 40 and wear start to increase when using 10% waste oil concentration [21]. This is due to 5% concentration of waste oil shows the highest viscosity results when compared to 10% concentration because high viscosity (thick) engine oils help to maintain a barrier between moving part and also drag in the movements between two contact surfaces. 10% also show the corroded area on the specimen [19]. According to EDX analysis as in Fig. 4, all specimens have a low percentage of oxygen in the surface of the specimen.

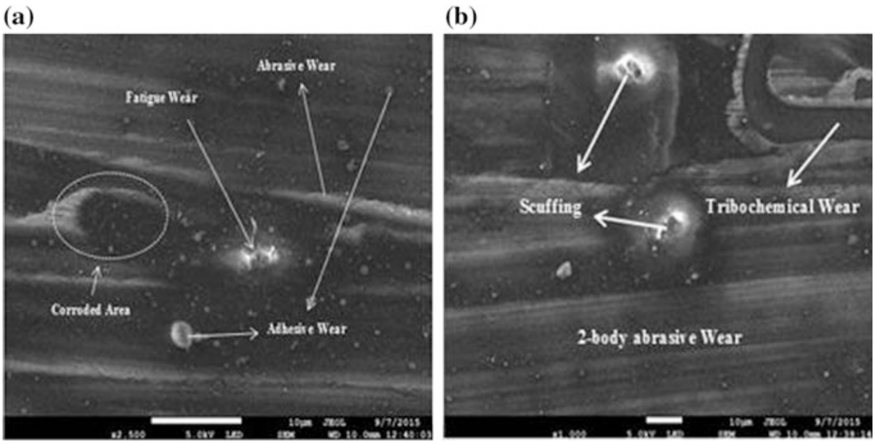

Fig. 3 **a** Sample C with 2500X magnification; **b** Sample C with 1000X magnification

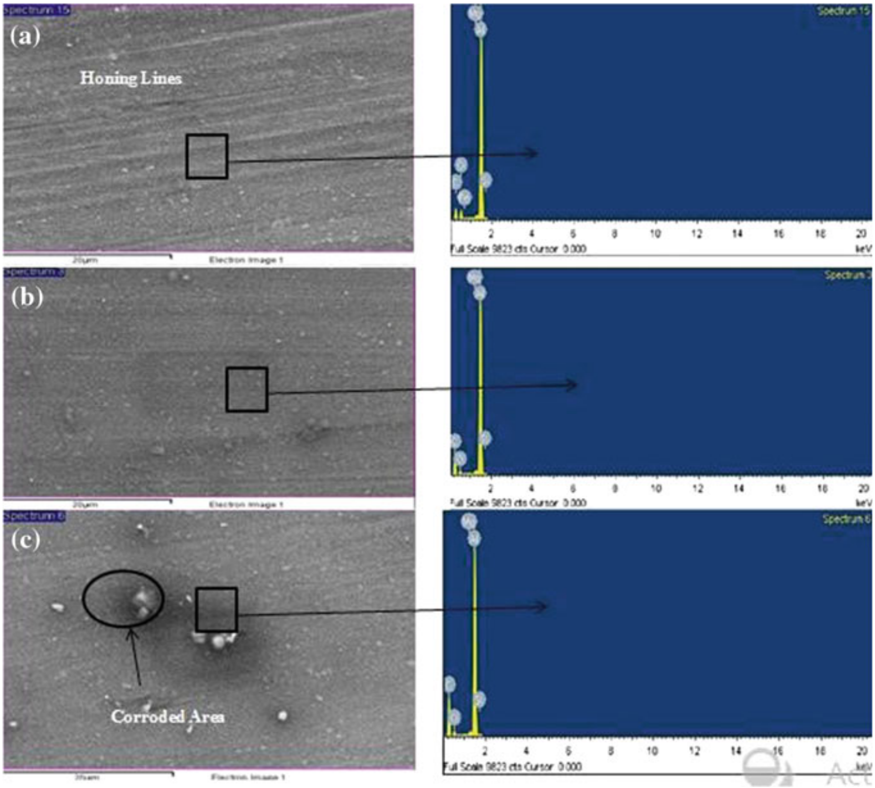

Fig. 4 **a** Sample A; **b** Sample B; Sample C

That means the oxidation occurs during the sliding process due to the water content in the waste palm oil.

4 Conclusion

Based on the experimental study,

(a) According to SEM analysis on the worn surfaces, the maximum wear occurs on at 10% waste oil concentration, while minimum wear occurs at 5% waste oil concentration. concentration of waste oil while minimum wear occurs in 5% concentration waste oil. This shows that waste cooking oil has anti-wear characteristics when small amounts of waste cooking oil are present, and means that using waste cooking oil as an additive for engine oils will not have any severe wear causing consequences, which could potentially lead to premature failure.

(b) In terms of their physico-chemical properties, 5% waste oil added with engine oil treatment were almost identical with the base lubricant.
(c) Engine lubricants formulated from waste oils are renewable, eco-friendly and biodegradable. However, the challenge is an improvement of their performance specifically, with reference to their oxidative stability.

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