Experimental Investigation on The Lubricity of Vegetable Based and Mineral Engine Oils Using Four-Ball Tribotester

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Abstract - Vegetable oil is one of the bio-oils that have been promoted to replace petroleum-based products due to its eco- friendly characteristics. Mahua oil has high productivity rate, and so it could fulfil the demand for a bio-lubricant. In this work, the friction and wear performance were investigated for a Mahua oil and compared with mineral engine oil using four ball tribotester. The normal load was 40 kg. All experimental works were conforming to ASTM D 4172. The results exhibited that the Mahua oil has coefficient of friction nearly equal to that of mineral engine oil. Similarly Wear scar for Mahua oil is also nearer to that of Mineral engine oil. Mahua oil has good performance in terms of capability to reduce friction and wear.

Keywords – Mahua oil, Engine oil, Friction, Wear

I. INTRODUCTION

Lubrication is very important in industrial world where it is widely used in transportation and all machinery. Lubricant is used in order to reduce the friction between two moving surfaces or reduce metal to metal contact. It also can improve the efficiency of machine or engine where it protects them against wear and corrosion hence maximizes their life. The use of lubricant is very important in an internal combustion engine to lubricate parts and help to protect and prolong the engine life. The quality of the lubricating oil used in the engine plays an important role in prolong the engine life and improve the performance of an engine [1].

Lubricating oil is used in all most all mechanical instrument and rotary machines. Various type of lubricating oils are being used nowadays in this purpose including mineral oil, synthetic oil, refined oil and vegetable oil. Most of lubricants are based on mineral oil, extracted from petroleum oil which is not apt to maintain the safety of environment due to their toxicity and non-biodegradability. Nowadays, due to the detrimental characteristics of fossil fuel, the usage of petroleum oil based lubricants are creating concern regarding environmental issues. At this circumstance, an alternative lubricating oil source based on vegetable oil can be played a vital role to reduce the usage of petroleum oil based lubricating oil as well as the renewable source of lubricant. Vegetable oils based lubricants have numerous advantages over mineral lubricant since they are renewable, environmentally friendly, less toxic, more biodegradable and contain higher stearic acid. Therefore, vegetable oils based have the potential to substitute petroleum based lubricating oil as well as the interest in the use of animal fats and vegetable oils derived lubricant is increasing precipitously. The rapid depletion of the crude oil and higher price has drawn the attention to use bio-lubricants instead of petroleum based lubricant.
Many work is made on the Vegetable based oils such as Jatropha, Jatropha blended, Palm olein and Soyabean on Friction and Wear characteristics and they are compared with the commercial mineral oil ([1]-[15]).

Mahua based oils have a huge potential owing to their abundant availability, renewability & biodegradability. Also, they are non-edible vegetable based lubricants. But, because of their low oxidative stability, they cannot be used in their raw form. Hence, suitable modification like hydrogenation and epoxidation are required. Vegetable oils consist of glycerol molecules with 3 long chain fatty acids attached via ester linkages having polar fatty acid chains, which provide high strength lubricant films that interact strongly with metallic surfaces, reducing both friction and wear. Mahua oil is unusual in containing non-lipid associates often loosely termed as “bitter” and organic sulphur compounds that impart a pungent, disagreeable odor. Mahua seed contain 30-40% fatty oil called Mahua oil [16].

The oxidation stability of vegetable oils can be improved by chemically modifying the oil structure by techniques such as:

- modifying the carboxyl groups
Esterification
Epoxidation
- modifying the fatty acid chain
- modifying the cultivations of natural vegetable oils

Engine oils from different manufacturers with the same SAE (Society of Automobile Engineers) viscosity grade available in market does not mean it will have the same lubricity for an engine. The best lubricant performance would have minimum friction and wear at the same time able to operate at any temperature.

Due to these factors, the lubricant has been the topic of research for different aspects such as friction and wear. This study is made to determine the anti-wear, anti-friction ability of two different engine oils one conventional mineral oil and other Vegetable based oil i.e Mahua seed oil.

II. EXPERIMENTAL PROCEDURE

Four-ball tribotester is used for the experiment to determine the anti-friction and anti-wear ability of the test lubricant. Figure 1 shows the schematic diagram of four-ball tribotester which contain oil cup assembly, collet and ball bearings [2]. Wear test is carried out by following procedure.

- Clean thoroughly test balls in hexane solution.
- Clean thoroughly ball pot and collet.
- Insert one ball into collet and push into spindle.
- Assemble 3 balls in the pot, place the retainer ring to centralize the balls, tighten lock nut by torque wrench.
- Fill in sample oil to a level above the tip of balls.
- Place the ball pot over the antifriction disc below top ball.
- Switch on controller, set 1200 rpm speed, test duration 60 min, heat the ball pot to 75^{0}C. Slowly without shake bring the loading lever to horizontal position, Apply a load of 392 N (40kg) on the loading pan.
- Press START push button on controller to begin test, spindle starts rotates and timer starts.
- Test stops automatically after an hour.
- Remove ball pot and place on base plate.
- When oil temperature reaches room temperature discard the lubricant in to waste collector. Mark scar on 3 balls and measure wear scar on microscope.
- Taking two measurements on each of the three scars, one along the striations and other across the striations.
- Average the six readings and report as scar diameter in mm.

The four ball tester is used to determine wear preventive (WP), extreme pressure (EP), frictional, fatigue and shear stability behaviour of lubricants. The machine consists of following sub-assemblies:

The mechanical tester consists of spindle assembly, motor, ball pot assembly, loading arrangement. There is a built-in accessory storage and ball tray to hold test balls.Sensors, Signal conditioning electronics, PC based machine control, data acquisition system and display.

A rotating steel ball is pressed against three steel balls firmly held together and immersed in lubricant under test. The test load, duration, temperature and rotational speed are set in accordance with standard test schedule. A unique device “Collate Master” makes it very easy to insert and remove test ball in collate.

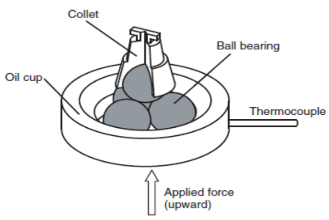


Fig. 1 Four ball Tribotester

TABLE I SPECIFICATION OF FOUR BALL TRIBO-TESTER

Parameter	
Speed (RPM)	1000-3000
Max Axial Load (N)	10000
Temperature (C)	Ambient to 100
Test ball Dia (mm)	12.7
Scar Range (micron)	100-4000
Drive Motor (KW)	1.50
Power (V/Hz/VA)	380/50/2000

III. TEST MATERIAL AND CONDITIONS

The testing material comprised of selected commercial mineral engine oil and vegetable based Mahua oil.

TABLE II MINERAL OIL: CASTROL EDGE 5W30

Name	**EDGE 5W30**
Relative density (g/mol)	0.8513
Viscosity @ 40^0 C (cS)	70
Viscosity Index	169
Pour Point (C)	-42
Flash Point (C)	202
Ash sulphated (% wt)	0.64

TABLE III VEGETABLE BASED OIL: MAHUA OIL

Parameters	
Viscosity @ 40^0 C (cS)	14
Viscosity Index	208
Flash Point (C)	172
Fire Point (C)	184
Acid value (mgKOH/g)	3.11
Saponification value	187.2

The experiments were carried out according to American Standard Testing Material ASTM D 4172 conditions.

Spindle speed (top ball speed) = 1200 rpm
Normal load =40 KG
Oil Temperature =75^0C
Test duration = 3600 Sec

IV. RESULTS AND DISCUSSIONS

In this chapter, analysis on the experimental results is carried out. The purpose of conducting the analysis is to find out the parameters which significantly affect the quality characteristics (Frictional torque, Wear scar) under vegetable oil mode is compared with mineral oil. The data is acquired as in the Table IV.

TABLE IV DATA ACQUIRED

Samples	**Applied Load (N)**	**COF**	**Scar Dia in mm for 1st ball**		**Scar Dia in mm for 2nd ball**		**Scar Dia in mm for 3rd ball**		**Average of 6 readings in mm**
			Major axis	**Minor Axis**	**Major axis**	**Minor Axis**	**Major axis**	**Minor Axis**	
Mineral oil (Test 1)	392	0.09247	0.52	0.50	0.53	0.52	0.44	0.40	0.49
Mineral oil (Test 2)	392	0.08716	0.58	0.54	0.48	0.43	0.52	0.48	0.50
Mahua oil (Test 3)	392	0.11127	0.57	0.56	0.52	0.49	0.52	0.51	0.53
Mahua oil (Test 4)	392	0.09488	0.57	0.55	0.54	0.50	0.47	0.42	0.51

A. *Coefficient of Friction*

The friction coefficient was calculated according to IP-239, and is expressed as follows:

[illegible] × T/W
Where
[illegible] is the coefficient of friction
T is the frictional torque (kg.mm)
W is the applied load (kg)
The frictional torque data were recorded by a computer and the friction coefficient was calculated.

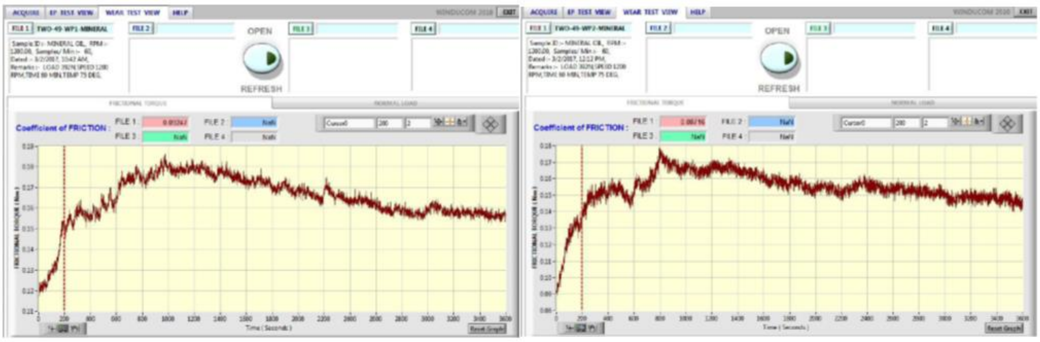
From Fig. 2 and 3, the Mean frictional torque for Mahua oil is observed to be closure to that of Mineral oil.

The frictional torque is varies with time more consistently for Mahua oil compared to Mineral oil. This behaviour is related to the existence of the fatty acids in the Mahua oil; these fatty acids help to maintain the lubricant layer, giving a lower coefficient of friction.

So, at the same speed and load, both lubricants were able to increase the fluid film thickness and create high separation distance between the two surfaces. That's why both lubricants have lower coefficient of friction.

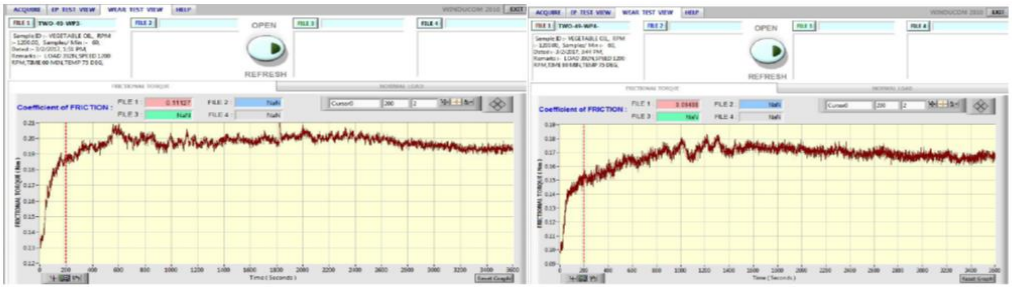
TABLE V AVERAGE WEAR SCAR

Sample	Number of runs	Average Wear Scar Dia in mm
Mineral oil (MRO)	2	0.49
Mahua oil (VBO)	2	0.52



Test 1 Test 2

Fig. 2 Chart of frictional torque as a function of time for mineral oil



Test 3 Test 4

Fig. 3 Chart of frictional torque as a function of time for vegetable oil

B. Average wear scar

Table V shows the measured wear scar diameter for both MRO and VBO. From this, it is observed that the wear scar diameter of VBO is very near to that of MRO. The temperature increase contributed to a decrease in the test lubricant viscosity. Low viscosity lubricants tend to create only a thin film. Increasing temperature causes the lubrication film to become less stable and eventually to break down. As a result, the metal-to-metal contact area will increase and produce an increase in the wear scar diameter under high pressure conditions. The wear scar will also increase due to the removal of the metallic soap film. Wear scar is observed to be as similar in the Fig. 4.

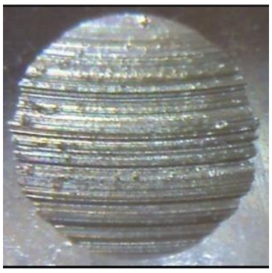


Fig. 4 Typical scar on the ball

V. CONCLUSIONS

This experiment was conducted to determine and compare the anti-wear ability of different engine oils available in market at particular temperature and speed. The following conclusions can be drawn based on the findings of the study.

1. The Mean frictional torque for Mahua oil is observed to be closure to that of Mineral oil. The frictional torque is varies with time more consistently for Mahua compared to mineral oil.
2. Wear scar diameter for MRO and VBO oil is 0.49 mm and 0.52 mm respectively.Lubricant will

have a good anti-wear ability when the wear scar diameter is lower.
3. The closeness of quantities of frictional torque and wear shows the lubricity performance of the VBO oil.

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