PERFORMANCE EVALUATION OF TRIBOLOGICAL PROPERTIES OF COTTON SEED OIL FOR MULTI-CYLINDER ENGINE

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ABSTRACT

A lubricant is a substance that reduces friction and wear by providing a protective film between two moving surfaces. Good lubricants possess the properties such as low toxicity, high viscosity index, high load carrying capacity, excellent coefficient of friction, good anti-wear capability, low emission into the environment, high ignition temperature. So tribology related problems can be minimized by proper selection of lubricant from wear consideration. Today, the depletion of reserves of crude oil, the growing prices of crude oil and concern about protecting the environment against pollution have developed the interest towards environment-friendly lubricants. Because of these the purpose of this work is to evaluate the anti-wear characteristics of cottonseed oil and to check the suitability of cottonseed oil as a lubricant for multi-cylinder engine. Four ball testing machine is used for anti-wear testing as per ASTM D 4172. The wear preventive characteristic of cottonseed oil is obtained by measuring wear scar diameter. The present study shows the potential of cotton seed oil as an alternating lubricant.

KEYWORDS— ASTM D 4172, anti-wear, Four-ball tester, cottonseed oil.

INTRODUCTION

For the effective and efficient operation of an automobile at operating conditions requires proper lubrication between the moving parts so that the parts slide smoothly over each other. To decrease energy losses, reduction of wear and friction has a key importance in engines and drive trains. In engines from a long time mineral oils have been used as a lubricant. However, Mineral oil is a product of the distillation of crude oil, so that it can be used until crude oil is available. Also, the disposal of mineral oils leads the problem of pollution in aquatic as well as in terrestrial ecosystems. In addition, the combustion of mineral oil lubricants have been emit traces of metals as zinc, calcium, magnesium phosphorous and iron nano-particles. Today, the depletion of reserves of crude oil, the growing prices of crude oil, and concern about protecting the environment against pollution have developed the interest towards environment-friendly lubricants as a replacements for mineral oils in engines. In comparison with mineral oil and synthetic oils, vegetable oil based lubricants possess the properties such as low toxicity, high lubricity, high viscosity index, high load carrying capacity, excellent coefficient of friction, good anti-wear capability, low emission into the environment, high flash point. Because of polar groups in the structure of vegetable oil and presence of long fatty acid chains obtain both boundary and hydrodynamic lubrications. Many of the researchers have used vegetable oil as a blend in engine fuel, but only few of the researchers have reported vegetable oil-based lubricants for automotive applications.

H.M. Mobarak et.al presented the potential of vegetable oil-based bio-lubricants as an alternative lubricant. This is because of a bio-lubricants are renewable lubricants that is non-toxic, biodegradable and emits net zero greenhouse gas. In this paper the study about bio-lubricants are presented in three parts. In first part authors discussed the different sources, properties as well as advantages and disadvantages of the bio-lubricant. In the second part authors presented the potential of vegetable oil-based bio-lubricants as alternative lubricants for automobile applications. The final part discussed about the world bio-lubricant market as well as its future prospects [1]. Avinash Kumar Agarwal studied the necessity of petroleum-based fuels because of increasing industrialization and motorization of the world. Due to limited reserves of petroleum-based fuels it is necessary to look for alternative fuels which can be produced from resources available locally within the country such as alcohol, biodiesel, vegetable oils etc. This paper reviews the properties, production, characterization and current statuses of vegetable oil and biodiesel as well as the experimental research work carried out in various countries [2]. Sachin M. Agrawal et.al determined the influence of lubricant on wear and frictional force using pin on disc machine with M2 HSS tool. Authors used the cottonseed oil for their research because of increasing crude oil prices emphasis on the development of renewable and environmentally friendly fluids [3].

K Balamurugan et.al studied the performance of soyabean oil as a lubricant for diesel engines using both four ball wear test machine and diesel (single and twin-cylinder) engines. Diesel engines were lubed with various SBO formulations as crude SBO, Soyabean Methyl Ester (SBME), SAE 40+SBME, SBME+ POME+ Castor oil. From the results it is clear that bio-degradable additives (POME, Castor oil) improve the wear resistance and oxidation stability of SBME [4]. N.H. Jayadas et.al and Chacko Preno Koshy et.al evaluated the tribological and thermo-physical properties of coconut oil. Authors used different testing machines such as a modified pin-on-disc tribometer, four-ball tester and a test rig to test the wear on two stroke engines. Also, the influence of an anti-wear/extreme pressure (AW/EP) additive i.e Zinc-Dialkyl-Dithio-Phosphate (ZDDP) and molybdenum disulfide (MoS_2) nano-particles (unmodified and surfactant-modified) on the tribological performance of coconut oil was evaluated by doing experiment. For comparison, the tests were repeated on a different mineral lubricant oils. The results of the experiments show that anti-wear and extreme pressure properties of coconut oil were improved due to addition of suitable concentration of AW/EP additive [5, 6].

K. S. V. Krishna Reddy et.al explored in this study that vegetable oil as a substitution for mineral oil in a CI engine without adding any additives. The experiments have been conducted with different compositions of palm oil and mineral oil. Blends of palm oil and mineral oil in different compositions 0, 25, and 50 (by volume %) were added to base SAE 20W40 mineral oil to obtain different lubricant blends. The engine performance and emission tests were carried out on a single cylinder, water cooled, 4-stroke CI engine. After successful experimentation the study made conclusion that the palm oil provides more potential for the successful utilization as base for lubricant oil [7]. G Senthil Kumar et.al studied the tribological and exhaust emission characteristics of sunflower based lubricant. For the testing Sunflower Methyl Ester (SFME) was mixed with manufacturer's recommended oil (MAK 2T oil) in definite proportions. Nano copper particle was used as an additive in SFME. Emission analysis for smoke was performed using an exhaust gas analyzer. Thus study made conclusion that vegetable oil can be used as a blend of lubricating oil with added additives [8].

S.M. Alves et.al studied the tribological behavior of soyabean oil, sunflower oil, and mineral oil, synthetic oil lubricants with nano-particles of oxides (ZnO and CuO). These oxide nano-particles used as additive for extreme pressure. High Frequency Reciprocating Rig equipment and SEM/EDS was used to study the anti-wear behavior of CuO and ZnO. The friction coefficient was measured using piezo-electric force transducer. The results showed that with the addition of nano-particles to conventional lubricant, the tribological properties can be significantly improved. Also, lubricants developed from modified vegetable oil can replace mineral oil by improving the tribological properties and environmental characteristics [9]. The ASTM journal covered the standard test method for wear preventive characteristics of lubricating fluid. In this journal they listed different terminologies related to the test as lubricant, wear. This ASTM journal gave the detailed specifications of four ball wear test machine with significance and use. Material of the balls, test conditions, preparation of apparatus and detailed procedure are elaborated in this journal [10].

The aim of this work is to evaluate the wear characteristic of cottonseed oil and also check the suitability of cotton seed oil as a lubricant for multi-cylinder engine. For this research anti-wear testing of lubricant is performed on four ball testing machine.

PHYSIO-CHEMICAL PROPERTIES

Table no. 1 show the physio-chemical properties/specifications of commercial oils under test (SAE 20W50 and SAE 20W40) and vegetable oils [2]. Also comparing the properties of commercial oils and vegetable oils found that vegetable oils can be efficient and inexpensive substitutes to petroleum based oils. Vegetable oils have valuable and useful physio-chemical properties and offer several technical advantages.

Table No. 1 Properties of oils

Properties→ oil↓	Kinematic Viscosity (at 40˚c) cSt	Flash point (˚c)	Pour point (˚c)	Cloud point (˚c)	Density (kg/l)
SAE 20w50	149	202	-30	-	0.886
SAE 20w40	134.1	252	-24	-	0.884
Corn oil	34.9	277	-40.0	-1.1	0.9095
Linseed oil	22.2	241	-15.0	1.7	0.9236
Peanut oil	39.6	271	-6.7	12.8	0.9026
Rapeseed oil	37.0	246	-31.7	-3.9	0.9115
Soyabean oil	32.6	254	-12.2	-3.9	0.9138
Sunflower oil	33.9	274	-15.0	7.2	0.9161
Palm oil	39.6	267	-	31.0	0.9180
Cottonseed oil	33.5	234	-15.0	1.7	0.9148

EXPERIMENTATION

3.1 FOUR-BALL TESTING MACHINE

The four ball testing machine is widely used for evaluation of the tribological properties of lubricant such as wear preventive characteristic, extreme pressure and shear stability. The apparatus can be used to measure coefficient of friction, anti-wear and load carrying capacity of lubricating oils under standard operating conditions. The four ball apparatus is as shown in figure 1. The test system is capable of carrying out a number of standards applicable to lubricant characterization and its capabilities extend beyond the scope of these standards, allowing users to perform a variety of customized tests. This machine uses four balls, three at the bottom which are clamped together and one on top. The bottom three balls are clamped together in a ball pot containing the lubricating oil under test and pressed against the test ball. The top ball is made to rotate at the desired speed while the bottom three balls are pressed against it.

In this paper only the anti-wear property of pure cottonseed oil is evaluated and compared with the commercially available SAE lubricating oils. The procedure for the determination of anti-wear properties is described by standard ASTM D 4172. The SAE oils and cottonseed oil under test is characterized by evaluating the wear scar formed on the bottom three balls after the test.

Figure 1: Four ball test rig

ISSN No - 2394-3696

3.2 PREPARATION OF TESTING

Properly clean four test balls, oil cup and clamping parts with acetone. Assemble three clean test balls in the oil cup with the help of wrench is as shown in figure 2.

Figure 2: Oil cup assembly

Pour the oil into the test-oil cup in such way that oil cup is being completely filled without air pockets. Tighten the one test ball into the spindle of the machine and install the oil cup in the chamber as shown in figure 3.

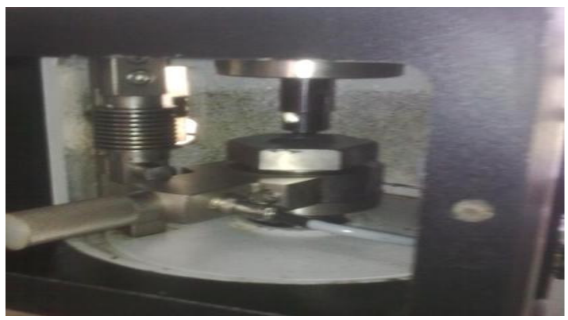


Figure 3: Installation of oil cup assembly

3.3 OPERATING PARAMETERS

This test method covers procedure for making a preliminary evaluation of the anti-wear properties of lubricants by means of the four-ball wear test machine. Test Balls are made of chrome alloy steel from AISI standard steel E-52100, having diameter of 12.7 mm [0.5 in.] and Grade 25 EP (Extra Polish). Such balls are described in ANSI B3.12. The extra-polish finish is not described in that specification. The hardness of steel ball is in the range of 64 to 66 RC. The top ball is pressed with a force of 392 ± 2 N [40 ± 0.2 kgf] into the cavity formed by the three clamped balls for three-point contact. The temperature of the test lubricant is controlled at 75 ± 2°C [167 ± 4 °F] and then the top ball is rotated at 1200 ± 60 rpm for 1 hr. Lubricants are compared by using the average size of the wear scar diameters measured by image acquisition system on the worn three lower balls.

RESULTS AND DISCUSSION

4.1 COEFFICIENT OF FRICTION

The coefficient of friction (μ) between two solid surfaces is defined as the ratio of the tangential force (F) which required sliding or rolling and the normal force applied between the surfaces (N). It can be presented mathematically as,

$$F = \mu N$$

The values of the coefficient of friction for SAE 20W50, SAE 20W40 oil and cottonseed oil are as shown in table no. 2.

ISSN No - 2394-3696

Table No. 2 Coefficient of friction of tested oils

Coefficient of friction (μ)→ Oil↓	Test 1	Test 2	Test 3
SAE 20w50	0.1114	0.1151	0.1097
SAE 20W40	0.0884	0.0842	0.0854
Cottonseed oil	0.0631	0.0662	0.0615

4.2 WEAR SCAR DIAMETER

Table no. 3 shows the wear scar diameter for the tested oils with the help of image acquisition system. The image acquisition and magnification are done with the help of Winducom 2014 software.

Table No. 3 Wear scar diameter for the tested oils

Wear Scar Diameter (micron)→ Oil↓	First ball	Second ball	Third ball	Average
SAE 20w50	483	542	555	526.66
	557	530	508	531.66
	472	517	548	512.33
SAE 20W40	363	433	418	404.66
	413	408	375	398.66
	398	422	383	401
Cottonseed oil	672	654	632	652.66
	640	655	683	659.33
	628	672	645	648.33

4.3 AVERAGE VALUES

Average values of the coefficients of friction and wear scar diameters for SAE 20W50, SAE 20W40 oil and cotton seed oil are as shown in table no.4.

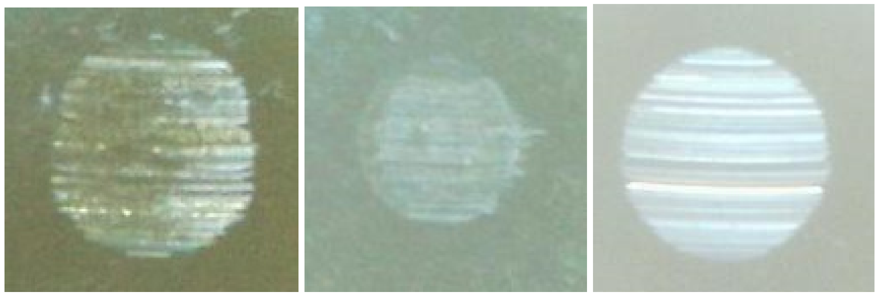
Table No. 4 Average values of Coefficient of friction and wear scar diameter for tested oils

Oil	Coefficient of friction (μ)	Wear scar diameter (micron)
SAE 20W50	0.1121	523.55
SAE 20W40	0.086	401.44
Cotton seed oil	0.0636	653.44

From the table it is clear that coefficient of friction for cottonseed oil is lower than that of both commercial oils but the wear scar diameter is larger. Increase in wear when vegetable oils are used as boundary lubricants is due to the continuous removal of metallic soap film. This film is a result of the reaction of the oil with the metallic surface during sliding [6]. The metallic film is continuously reformed by further chemical reaction. Since shear strength of the metallic soaps are low, the coefficients of friction will be low.

5.4 IMAGE ACQUISITION SYSTEM

The image acquisition system shows the different wear surfaces of the worn balls. Pictures of wear scars on the balls that operated with lubricants SAE 20W50, SAE 20W40 and cottonseed oil are shown in figure 4. Figure clearly shows that wear scar diameter for cotton seed oil is larger than the tested commercial oils.



(a) **(b)** **(c)**

Figure 4: Symbolic images of wear scar diameter for (a) SAE 20W50 (b) SAE 20W40 (c) Cottonseed oil.

CONCLUSION

Only wear preventive characteristic of cottonseed oil is considered in this research work. Though coefficient of friction for cottonseed oil is lower compared to commercial lubricants, the wear scar diameter is larger. Hence cotton seed oil cannot be used as a lubricant in the unmodified form. The anti-wear characteristic can be improved by chemical modification of oil or adding suitable anti-wear additives in the oil.

ACKNOWLEDGEMENT

The author would like to thank Principal, Dr. G. J. Vikhe-Patil, HOD Prof. A. K. Mishra of Mechanical Engineering Department, AVCOE, Sangamner, for their valuable guidance and Prof. V. D. Wakchaure, Prof. V. S. Aher, Prof. P. N. Nagare for skilful assistance with the work.

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