POTENTIAL OF COTTON SEED OIL AS AN ALTERNATING LUBRICANT 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 properties like low toxicity, high load carrying capacity, excellent coefficient of friction, high viscosity index, good anti-wear capability, low emission into the environment, high ignition temperature. Hence tribology related problems can be minimized by proper selection of lubricant. Now a day depletion of reserves of crude oil, growing prices of crude oil and concern about protecting the environment against pollution have created the interest towards environment-friendly lubricants. Hence paper work is related to check the suitability and to evaluate the anti-wear characteristics of cottonseed oil as a lubricant for multi-cylinder engine. Anti-wear testing is carried out on four ball testing machine as per ASTM D 4172. Image Acquisition System is used to check wear preventive characteristic of cottonseed oil by measuring wear scar diameter.

Keywords — ASTM D 4172, Anti-wear, cottonseed oil, Four ball tester, Image Acquisition System.

I. INTRODUCTION

Lubrication between the moving parts is required for effective and efficient working of an automobile at operating conditions. Good lubrication takes part in smooth sliding of parts over each other. To decrease energy losses, reduction of wear and friction has a key importance in engines and drive trains. Mineral oils have been used as a lubricant in engines since a long time. But, Mineral oil is a product of the distillation of crude oil hence it can be used until availability of crude oil. Also, the disposal of mineral oils is a major problem in now a day. Disposal of mineral oil leads the problem of pollution in aquatic as well as in terrestrial ecosystems. In addition to that combustion of mineral oil lubricants have been emitted traces of metals as zinc, iron, magnesium phosphorous and calcium nano-particles. Today 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 an alternative for mineral oils in engines. As compared to mineral and synthetic oils, vegetable oil based lubricants having properties of low toxicity, high lubricity, high viscosity index, and excellent coefficient of friction, high load carrying capacity, 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. Most of the researchers have been used vegetable oil as a blend in engine fuel, but only few of the researchers have reported vegetable oil based lubricants for automotive applications.

Avinash Kumar Agarwal presented the necessity of petroleum-based fuels because of increasing industrialization and motorization of the world. But 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 gives review of properties, production, characterization and current statuses of vegetable oil and biodiesel. Also he dictated the experimental research work carried out in various countries [1].

N. H. Jayadas et.al and Chacko Preno Koshy et.al carried out experiments on coconut oil as an alternative for mineral oils. Authors have evaluated tribological and thermo-physical properties of coconut oil on the basis of experimentation. Authors used various testing machines 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 that is Zinc Dialkyl Dithio Phosphate (ZDDP) and molybdenum disulfide (MoS_2) nano-particles (unmodified and surfactant-modified) on tribological performance of coconut oil was evaluated. For comparison, tests were repeated on different mineral oils. The results showed that anti-wear and extreme pressure properties of coconut oil were enhanced by addition of suitable concentration of AW/EP additives [2, 10].

K Balamurugan et.al studied and presented the performance of soya-bean oil as a lubricant for diesel engines using both four ball wear test machine and diesel (single and twin-cylinder) engines. Authors have done experiments on number of formulations on soya-bean oil.

Diesel engines were lubed with various SBO formulations as crude SBO, Soya -bean Methyl Ester (SBME), SAE 40+SBME, SBME+POME+Castor oil. From the results of experimentation it is clear that bio-degradable additive (POME, Castor oil) improve the wear resistance and oxidation stability of SBME [3]. G Senthil Kumar et.al evaluated 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 particles was used as an additive in SFME. Exhaust gas analyzer was used for emission analysis of smoke. Hence authors made conclusion that vegetable oil can be used as a blend of lubricating oil with added additives [5].

S. M. Alves et.al examined the tribological behavior of soya-bean oil, sunflower oil, mineral oil and synthetic oil lubricants with nano-particles of oxides (ZnO and CuO). These oxide nano-particles have been used as an extreme pressure additive. High Frequency Reciprocating Rig equipment and SEM/EDS were 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 an 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 [6].

H. M. Mobarak et.al presented the potential of vegetable oil based bio-lubricants as an alternative lubricant. This is because of advantages of bio-lubricants such as non-toxic, biodegradable and emits net zero greenhouse gas. In this paper the study about bio-lubricants were 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 [7]. 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 [8].

K. S. V. Krishna Reddy et.al explored 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 authors made conclusion that the palm oil provides more potential for the successful utilization as base for lubricant oil [9]. The ASTM journal covered the standard test method for wear preventive characteristics of lubricating fluid. In this journal different terminology related to the test such as lubricant, wear were elaborated. 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 also elaborated in this journal [4].

The present paper work is related to check the suitability and to evaluate the wear characteristic of cottonseed oil as a lubricant for multi-cylinder engine. So that anti-wear testing of lubricant is performed on four ball testing machine.

II. Physio-chemical properties

Table I show the physio-chemical properties or specifications of commercial oils under test (SAE 20W50 and SAE 20W40) and vegetable oils [2]. 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 I 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

III. Experimentation

A. Four-Ball Testing Machine

Four ball testing machine is widely used for evaluation of the tribological properties of lubricant oil 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 testing machine is as shown in figure 1. This machine consists of 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.

This paper work only contains evaluation of anti-wear property of pure cottonseed oil and comparison of it with commercially available SAE lubricating oils. The procedure for experimentation of anti-wear property 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.

Fig.1 Four ball test rig set up

B. Preparation of Testing

First of all properly cleaning of 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.

Fig. 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.

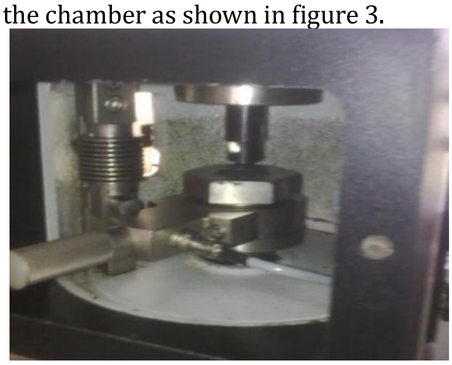

Fig. 3 Installation of oil cup assembly

C. Operating Parameters

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.

IV. RESULTS AND DISSCUSSION

A. 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,

$$F = \mu N$$

Experimentation shows the values of coefficient of friction for SAE 20W50, SAE 20W40 oil and cottonseed oil which are mentioned in Table II.

Table II 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

B. **Wear Scar Diameter**

Table III 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

C. Average Values

Average values of coefficient of friction and wear scar diameters for SAE 20W50, SAE 20W40 oil and cotton seed oil are as shown in Table IV.

Table IV 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.

B. Image Acquisition System

The image acquisition system figure 4 shows the different wear surfaces of worn out balls. Pictures of wear scars on the balls that operated with lubricants SAE 20W50, SAE 20W40 and cottonseed oil are shown in figure 5. Figure clearly shows that wear scar diameter for cotton seed oil is larger than the tested commercial oils.

Fig. 4 Image Acquisition System

(a) (b) (c)

Fig. 5 Symbolic images of wear scar diameter for (a) SAE 20W50 (b) SAE 20W40 (c) Cottonseed oil.

V. Conclusion

This research work contains only wear preventive characteristic of cottonseed oil. Though coefficient of friction for cottonseed oil is lower compared to commercial lubricants (SAE 20W50 and SAE 20W40), 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.

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