Tribological Evaluation of Vegetable oils as a lubricant

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Abstract - Lubricants are essential machine elements, which are important for efficient transportation, industrial production and contribute greatly to energy savings and the fuel economy. But continued increasing environmental concerns forced to increase the usage of vegetable oil utilization in lubricants for many applications. The vegetable oils offer significant environmental benefits because of its inherent qualities like renewability, biodegradability. Also, from India's point of view, India has a great potential of producing vegetable oil based lubricants. Because of these, suitability of vegetable oils i.e. cottonseed oil and soya bean oil is checked as a lubricant. Four ball testing machine is used for experimentation as per ASTM D 4172 standard. Finally it is observed that combination of SAE 20W40 oil +10 % by vol. cottonseed oil +0.5 % by wt graphite is the best suitable lubricant for multi-cylinder engine.

Keywords- Lubricant, vegetable oil, cottonseed oil, soya bean oil, ASTM D 4172.

1. INTRODUCTION

In recent years, an accidental loss of lubricant to the environment by means of evaporation, leakages, and spills. This leads to major concerns regarding to protect the environment against pollution. Also, the increased petroleum costs, decreased petroleum reserves open a route for bio-lubricant as alternatives in many applications. Also, the disposal of petroleum oils leads the problem of pollution. Due to these problems, scientists have searched for alternative products that are renewable, clean, reliable, and economically feasible. So, the replacement of petroleum base oils with biodegradable products is one of the best ways to decrease the adverse effects on both aquatic and terrestrial ecosystem caused by the use of petroleum lubricants [1, 2]. Vegetable oil-based bio-lubricants have a potential as alternative lubricant. In the first two parts of the paper the authors presented the different sources, properties, advantages and disadvantages of the bio-lubricant and 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 [3]. Vegetable oils have several properties that are required in a lubricant as a high viscosity index, high lubricity, low volatility, low toxicity and high biodegradability compared to mineral oil. Vegetable oils are a renewable resource finding their way into lubricants for industrial and transportation applications. Waste disposal is also of less concern problem for vegetable oil-based products because of their environment-friendly and non toxicity properties. Bio-lubricants can typically be made from plant oils such as rapeseed, palm, soybean, sunflower, and coconut, wax esters and plant polymeric carbohydrates [4].

Sachin M. Agrawal et.al investigated the effect of wear on M2 steel using SAE 40 oil and cottonseed oil as a lubricant. For that purpose pin on disc machine was used with M2 HSS tool. Authors studied the effect of different lubricating conditions on wear and frictional force at various sliding speed and load. Cottonseed oil was used in this research because of its low cost and availability in India [6]. K Balamurugan et.al studied the performance of soyabean oil as a lubricant for diesel engines. For the experimentation four ball wear test machine and diesel (single and twin-cylinder) engines were used. Diesel engines were lubed with various SBO formulations and results were compared with SAE 40 oil. From the results it was cleared that bio-degradable additives such as POME, Castor oil improve the wear resistance and oxidation stability of SBME [7]. N.H. Jayadas et.al evaluated the tribological properties of coconut oil using a four-ball tester and two stroke engine with and without Dialkyl-Dithio-Phosphate (ZDDP) AW/EP additive. Test results were compared with commercial lubricant SAE 20W50 oil. The results of four ball tester and test rig showed that coconut oil cannot be used in unmodified form due to higher wear rate than the 2T oil. Anti-wear and extreme pressure properties of coconut oil were improved by the addition of suitable concentration of Zinc-Dialkyl-Dithio-Phosphate (ZDDP) additive [8]. Iman Golshokouh et.al examined the physical properties of jatropha oil in varying temperatures and loads. Four ball tribo-tester was used for experimentation and results were compared with hydraulic oil to analyze its viability as an effective lubricant [9]. Kailas M. Talkit et.al studied the physico-chemical properties such as viscosity, acid value, saponification value, iodine value of different vegetable oils and their blends. In this research vegetable oils like soybean oil, castor oil, groundnut oil, and cottonseed oil were used for comparison [10].

Yu Su et.al evaluated the tribological properties of graphite nano-particle as an additive in LB2000 vegetable based oil on pin-on-disk friction and wear tester. From results it was found that graphite nano-particle improves the friction reducing and anti-wear properties of pure LB2000 vegetable oil due to formation of physical deposition film on the friction surfaces [11]. Zhenyu et al. studied lubricant additives based on inorganic nano-particles coated with organic outer layer can reduce wear and increase load-carrying capacity of base oil remarkably [12]. M. Gulzar et.al evaluated the anti-wear (AW) and extreme pressure (EP) ability of chemically modified palm oil (CMPO) by adding nano-particles. Nano-lubricants were synthesized by adding copper (II) oxide (CuO) and molybdenum disulfide (MoS2) nano-particles to CMPO. This study was used four-ball testing machine and sliding wear test for evaluation of anti-wear and extreme pressure properties The MoS2 nano-particles exhibited the better AW/EP properties than the CuO nano-particles. The addition of 1 wt % oleic acid as a surfactant facilitated the reduction of agglomerates [13]. Tiong Chiong Ing et.al studied the lubricity characteristics of vegetable oils using four ball test machine and compared with the petroleum based oil. RBD palm olein and additive free paraffinic mineral oil were used as lubricants in this experiment. From the test results, the authors confirmed that RBD palm olein showed satisfactory performance in terms of friction reduction [14].

N.W.M. Zulkifli et.al examined and compared the tribological properties of two lubricating oils i.e. paraffin oil and bio-lubricant which was derived from palm oil-based TMP (trimethylolpropane) ester added with TiO_2 nano-particles used as additives. Experimentation concluded that TMP ester added with nano-particles is environmentally desired to mineral oil based lubricants [15]. S. Syahrullail et.al tested the performance of oils (commercial stamping oil, commercial hydraulic oil, jatropha oil, RBD palm olein and palm fatty acid distillate) as a lubricant using a four ball tribometer under extreme pressure conditions as per ASTM D2783. Results of wear scars of vegetable oil are slightly lower than that mineral oil so authors made a conclusion that vegetable oils have potential as lubricants [16].

India is one of the largest oilseeds producing country in the world. Thus, there is an opportunity for developing countries like India to expand the market share of lubricants. Also, some of the researchers have been used vegetable oils as a fuel but no report on use of vegetable oils as a lubricant in multi-cylinder engine is come across me. This paper will show the possibility of replacement of mineral oil based lubricants with vegetable oil based lubricants.

2. PROPERTIES OF LUBRICATING OIL

Vegetable oils have numerous valuable and useful physico- chemical properties and offer several technical advantages over the mineral oils. Table 1 shows the comparison chart of the properties/specifications of commercial lubricating oil SAE 20W40 and vegetable oils used in this research [5].

Table no. 1
Properties of Lubricating Oil

Properties → Oils ↓	**Kinematic Viscosity (at 40˚c) cst**	**Flash point (˚c)**	**Pour point (˚c)**	**Cloud point (˚c)**	**Density (kg/l)**
SAE 20W40 oil	134	252	-24	-	0.884
Cottonseed oil	33.5	234	-15.0	1.7	0.9148
Soya bean oil	32.6	254	-12.2	-3.9	0.9138

3. EXPERIMENTATION

3.1 Sample Preparation

Samples are prepared approximately 20 ml by taking SAE 20W40 oil for both cottonseed oil and soya bean oil with graphite additive in three concentrations. Addition of nano-particles in lubricating oil requires properly weighting of the nano-particles. So the weight of graphite additive is measured on digital weighing machine with accuracy in milligrams. Dispersion of nano-particles in lubricating oil is also an important parameter of experimentation. So in this research work the magnetic stirrer is used for mixing of nano-particles in oil. Table 2 shows the properties of graphite nano-particles.

Table No. 2
Properties of Graphite Nano Particles

Nano-particle	**Purity (%)**	**APS (nm)**	**Density (g/cm^3)**
Graphite	99.9	< 100	2.267

3.2 Four Ball Testing machine

DUCOM's four ball tester TR-30 family is designed to evaluate anti-wear (AW), extreme pressure (EP) and shear stability behavior of lubricants. This apparatus measures the coefficient of friction (COF), wear scar diameter and load carrying capacity of lubricating oils under standard operating conditions. So to evaluate the wear preventive characteristics of lubricant we have selected a standard four ball testing machine with standardized testing method i.e. American Society for Testing and Materials (ASTM D 4172). The four ball testing machine uses four balls made of chrome alloy steel AISI standard steel no.E-52100, with diameter of 12.7 mm (0.5 in.).Out of four balls, three at the bottom and one on top which is tighten into the spindle of the test machine. The bottom three balls are assembling in the test oil cup containing the lubricating oil under test. The top ball is rotating at the desired speed while the bottom three balls are pressed against it. The lubricant under test is characterized by evaluating the wear scar diameter formed on the bottom three balls after the test [17]. The Ducom four ball testing machine is as shown in Fig.1.

Fig.1 Ducom Four ball Tester

4. RESULTS AND DISCUSSION

The experimental results obtained from anti-wear tests for lubricating oils with and without graphite additive are discussed in this section.

4.1 Wear Behaviour

Average values of wear scar diameters for SAE 20W40 oil and cottonseed oil and soya bean oil are listed in Table 3. From the table it is observed that the wear scar diameters for both vegetable oils are larger than the commercial SAE 20W40 oil. Increase in wear of vegetable oils is because of the continuous removal of metallic soap film. Formation of such film is due to the reaction of the oil with the metallic surface during sliding. The metallic film is continuously reformed by further chemical reaction.

Table No. 3
Wear Scar Diameters

Oil	Wear Scar diameter (μ)
SAE 20W40 oil	401.44
Cottonseed oil	653.44
Soya bean oil	674.88

The anti-wear test results for pure vegetable oils i.e. for cottonseed oil and soya bean oil with graphite additive are not positive from our research point of view so that we have decided to use cottonseed oil and soya bean oil as a blend in SAE 20W40 oil with graphite as an additive. Both cottonseed oil and soya bean oil is added in SAE 20W40 oil with different concentrations like 10, 30, 50 % by volume and graphite additive with concentrations as 0.5, 1, 2 % by weight. The observations of wear scar diameter for blend of SAE 20W40 oil and cottonseed oil with graphite additive and for blend of SAE 20W40 oil and soya bean oil with graphite additive are listed in Table 4 and 5 respectively.

Table No.4

Average Wear Scar for Cotton seed oil Blend with SAE20W40

Test No.	CSO (% Vol.)	Graphite (% Wt.)	Wear scar diameter (micron)
1	10	0.5	383.77
2	10	1	407.33
3	10	2	420.89
4	30	0.5	450.66
5	30	1	480.33
6	30	2	492.77
7	50	0.5	782.66
8	50	1	803.77
9	50	2	842.44

The wear scar diameters form the table 4 and 5 shows that the anti-wear behavior of blend of SAE 20W40 oil and cottonseed oil with graphite additive and blend of SAE 20W40 oil and soya bean oil with graphite additive is better than the SAE 20W40 oil. It is also cleared that anti-wear ability of cottonseed oil blend in SAE 20W40 oil is better than the soya bean oil blend. Fig. 3 shows the scar diameter for best combination of SAE 20W40 oil + 10% Vol. CSO + 0.5 % Wt. graphite.

Table No. 5

Average Wear Scar for Soyabean oil Blend with SAE20W40

Test No.	Soya bean oil (% Vol.)	Graphite (% Wt.)	Wear scar diameter (micron)
1	10	0.5	391.66
2	10	1	412.66
3	10	2	429.33
4	30	0.5	462.33
5	30	1	493.66
6	30	2	502.44
7	50	0.5	785.88
8	50	1	809.33
9	50	2	857.11

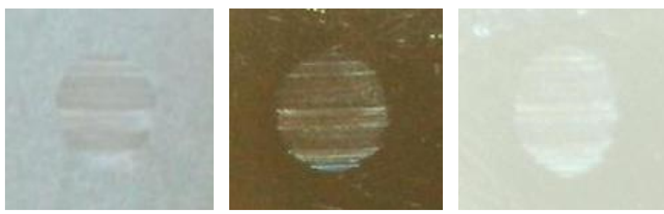

Fig. 2. Scar Images for SAE 20W40 + 10% Vol. CSO + 0.5 % Wt. graphite

5. CONCLUSION

From experimental results of anti-wear test it is observed that the wear scar diameter for both cottonseed oil and soya bean oil is more than the commercial SAE 20W40 oil. Pure cottonseed oil and soya bean oil with graphite additive doesn't show good anti-wear characteristics than commercial oil. But the combination of SAE 20W40 oil + 10 % vol. cottonseed oil + 0.5 % wt. graphite additive shows lower wear scar diameter than pure SAE 20W40 oil and combination of SAE 20W40 oil + 10% vol. soya bean oil + 0.5% wt. graphite additive. Hence blend of SAE 20W40 oil and cottonseed oil with 0.5 % wt. graphite additive is the best suitable lubricant.

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