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Effect of ZDDP additive on Properties of Cottonseed oil used as a Lubricant

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Abstract: Vegetable oils are biodegradable and renewable compared to mineral based lubricants. But they have some unsatisfactory tribological properties. Lubricant used in this investigation is cottonseed oil, focused on the issues related to environmental pollution, toxicity and its cost. Even though cottonseed oil lubricant is one of the best choices for lubrication purpose, however the properties are slightly lesser than mineral oil. A common solution for this problem is to provide effective additives into the base stock of cottonseed oil which leads to significant improvement to the lubricant by enhancing thermal properties, tribological properties and anti-oxidation capability. This research work is an attempt to appraise the performance of Zinc-Dialkyl-Dithio-Phosphate (ZDDP) as an anti-wear additive in cottonseed oil to improve its anti-wear, anti-friction, thermal stability, viscosity index, pour point, flash point, good tribology properties. This has promoted research into developing and using cottonseed oil as alternative base oil for environmentally gentle lubricant. The experimentation for tribological properties is carried out on Four Ball Tribometer with ASTM D 4172 procedure and the physio chemical properties are tested in the lab with ASTM procedures.

Index Terms: Vegetable oil, Cotton seed oil, ZDDP, ASTM D 4172.

INTRODUCTION

Lubricants and lubrication were inherent in a machine ever since man invented machines. The recent research on the adverse effect of mineral oil-based lubricants on the environment has reconfirmed its role in polluting groundwater for up to 100 years and its effects on reducing the growth of trees and the life span of aquatic life. This awareness, of the use of ecofriendly processes and materials, increases interest in Tribology for the use of natural esters in lubrication processes [1]. Vegetable oils have several properties that are required in a lubricant, such as a high viscosity index, high lubricity, low volatility, and advanced properties that can be compared to mineral oil, including low toxicity and high biodegradability. The vegetable oil based lubricants has all the properties as lubricant with its outstanding physical properties but has poor thermal and tribological properties which has caused restriction for its use as lubricant at elevated temperatures [2]. Many researchers were worked on different vegetable oils and tested their tribological properties. K Balamurugan *et.al* evaluated the performance of soyabean oil as a lubricant for diesel engines by using four ball tester [4]. N.H. Jayadas et.al studied that the antiwear and extreme pressure tribological properties can be improved by adding Zinc Dialkyl Dithio Phosphate (ZDDP) as an AW/EP additive [5]. Many researchers worked on Soya bean oil, Jathropha oil, Olive oil, Karanja oil, Linseed oil, Palm oil, Sunflower oil, Coconut oil, Cotton seed oil and found that vegetable oil can be used as a lubricant by adding proper nano additives[8,9]. The different additives used by researchers as anti-wear property improver are Cu, Fe, CuO, ZnO, TiO_2, Al_2O_3, Graphite, Nano Diamond ZDDP, hBN [5,6,7,8,10].
Cotton seed oil is one of the vegetable oil which is abruptly available in Gujrat and Maharashtra and also having good lubricant properties. Cotton production plays a vital role in Indian economy, providing employment for more than one million farmers and employees in the domestic textile industry.

2. VEGETABLE OILS AS ALTERNATIVE LUBRICANTS

Vegetable oils have several advantages and disadvantages when considered for industrial and machinery lubrication because of their good inherent qualities [11, 12, 13]. It has been seen that vegetable oils have valuable and useful physico - chemical properties and offer several technical advantages. Table 1 shows the properties of various vegetable oils [3].

Table 1: Physio-chemical Properties of vegetable oils

Properties → Vegetable oils↓	**Kinematic Viscosity (at 40˚c) cSt**	**Flash point (˚c)**	**Pour point (˚c)**	**Cloud point (˚c)**	**Density (kg/l)**
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
Rape seed oil	37.0	246	-31.7	-3.9	0.9115
Soya bean 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**

3. EXPERIMENTAL

3.1 Lubricant selection

In context to Indian scenario cottonseed oil is available abundantly in India especially in Maharashtra and Gujarat. Moreover, cost of cottonseed oil is cheaper as compared to others. Therefore the present work is an attempt to touch the potential of cottonseed oil as an alternative lubricant compared to mineral oils. For comparison 20 W 50 lubrication oil is selected. Additive plays important roles in lubricating oil. In this research work, Zinc Dialkyl Dithio Phosphate (ZDDP) is selected. The properties of Base oils are as shown in the table 2.

3.3 Sample Calculation

Total volume of sample = 20 ml
Weight of RCSO oil = Volume X Density
= 20 (ml) X 0.9204 (gm/ml) = 18.408 gm
Wt of ZDDP = 18.408 X 1/100 (% wt.) = 0.184 gm
Vol of ZDDP = Weight of ZDDP / Density of ZDDP
= 0.184 (gm) /1.1668(gm/cm3) = 0.1577 ml
Actual volume of RCSO sample = 20 - 0.1577
= 19.84 ml

Table 2: Lubricant Properties

Sr. No.	**Lubricant→ Properties ↓**	**SAE 20W50 oil**	**Cotton Seed Oil**
1	Specific gravity	0.8954	0.9060
2	Kinematic Viscosity (at 40˚c) cSt	174.8	33.5
3	Kinematic Viscosity (at 100˚c) cSt	19.1	13.51
4	Viscosity index	124	192.29
5	Flash point (˚C)	229	290-292
6	Fire Point (˚C)		304-306
7	Pour point (˚C)	-30	-18
8	Density (kg/l)	0.886	0.9204
9	Moisture content	0.12	0.14

3.2 Sample preparation

ZDDP anti wear additive is added at 1%, 1.5% and 2% wt. concentrations in refined cotton seed oil (RCSO) to prepare the test samples. The dispersion is subjected to magnetic Stirrer. The dispersion process with the help of magnetic stirrer improves the dispersion stability. The sample calculation is described below. Other sample calculations are also done in same way.

Table 3: Sample Concentrations

Sample Name	**Base oil**	**% of Additives in Base Oil by wt. (gm)**	**Additive (% vol.) ml.**	**Base oil (% vol.) ml.**
A	RCSO	0%	0.000	20.00
B	RCSO	1%	0.1577	19.84
C	RCSO	1.5%	0.236	19.764
D	RCSO	2%	0.315	19.685

3.4 Lubricant analysis

The anti-wear properties of all testing samples were tested on four ball tribotester with ASTM D 4172. The wear scar diameter (WSD) is measured with image acquisition system. The best result of wear test was taken for further comparison. The Physio-chemical properties of 20W50 are taken from catalog and of RCSO and best sample of wear test are tested in the lab with ASTM standard. The most important properties of lubricants Specific gravity, Kinematic Viscosity (at 40˚c), Kinematic Viscosity (at 100˚c), Viscosity index, Flash point (˚C), Fire Point (˚C),

Pour point (˚C), Density (kg/l), Moisture content were tested.

Table 4. Wear Test Conditions

Parameters	Condition
Load	392 ± 2 N
Temperature	75 ± 2 ^{o}C
Speed	1200 ± 60 rpm
Time	60 ± 1 min

4. RESULT AND DISCUSSION

4.1 Wear characterization

The wear scar diameter of RCSO is decreasing with increasing the concentration of ZDDP additive. The 2% ZDDP with refined cotton seed oil shows lowest value of wear scar diameter. This is because ZDDP forms a reactive film layer which prevents direct contact between metal surfaces. The protecting layer may act as a cushion between the metal surfaces. ZDDP also reacts with the peroxides present in the lubricants and it prevents the formation of corrosion wear on metal surfaces. ZDDP reacts with iron oxides present in the lubricant and form an iron phosphate which can help to reduce the wear on the metal surfaces. The results of the wear test for all samples are obtained from Four Ball Tester in terms of wear scar diameter. The results are shown in the table 5. Coefficient of friction also reduces as concentration of ZDDP increased. COF for refined cotton seed oil is more than 20W50 but it gives considerable reduction in the COF as ZDDP added. The COF of RCSO + 2% ZDDP is 0.06602 which is very less than COF of 20W50 which is 0.08839. The fig 1, 2, 3 shows the behavior of frictional torque vs time which also show that for RCSO + 2% ZDDP frictional torque is more initially and then starts reducing and almost remains constant.

Table 5: Results of Wear Test

Sample	Wear Scar Diameter (µm)	Coefficient of Friction
20W50	530	0.08839
RCSO	696	0.09259
RCSO+1% ZDDP	427	0.0980
RCSO+1.5% ZDDP	415.33	0.08452
RCSO+2% ZDDP	**392.33**	**0.06602**

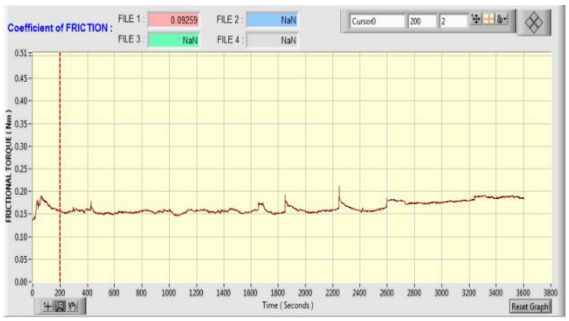

Fig.1: Graph of frictional torque (Nm) Vs time (sec) for refined cottonseed oil

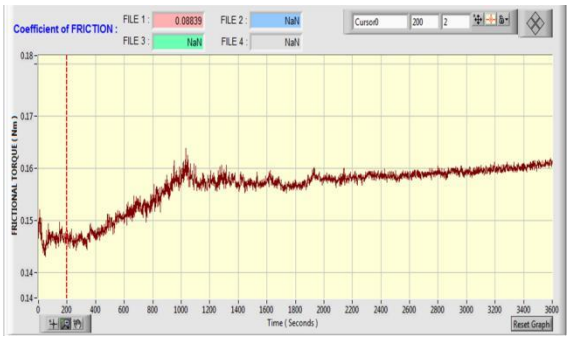

Fig.2: Graph of frictional torque (Nm) Vs time (sec) for SAE 20W50 oil

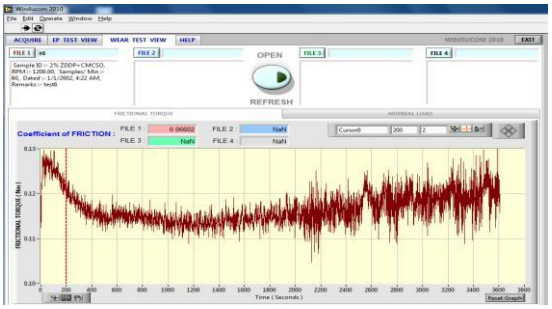

Fig. 3: Graph of frictional torque vs time for test RCSO + 2% ZDDP

4.2 Physio-chemical properties characterization

The results obtained are as shown in the table 6. It shows that the physio chemical properties of RCSO also improve by increasing percentage of ZDDP. It shows better result for 2% ZDDP in RCSO. As compare to 20W50 the properties like kinematic Viscosity of RCSO with ZDDP are less but these properties can be improved by adding some viscosity improvers.

Table 6: Physio-chemical properties

Sample	Specific gravity	Kinematic Viscosity (at 40˚c)	Kinematic Viscosity (at 100˚c)	Moisture contain	Viscosity index	Flash point (˚C)	Fire Point (˚C)	Pour point (˚C)
20W50	0.8954	174.8	19.1	0.12	124	229	--	-30
RCSO	0.9204	24.37	8.34	0.098	183.65	290	304	-6
RCSO+2% ZDDP	0.9260	22.11	8.44	0.027	193.14	296	310	-8

5. CONCLUSION

The experimental work shows that the properties of refined cotton seed oil can be improved considerably by adding anti wear additive ZDDP. The anti-wear property improved significantly. The WSD of RCSO+2% ZDDP is lower than WSD of 20W50. Kinematic viscosity improved by adding ZDDP but this improvement is not sufficient if it is compared to mineral oil 20W50. The other physio-chemical properties of RCSO show significant improvement by adding ZDDP. Overall it can be concluded that the cotton seed oil can become an alternative for mineral oil by adding some additives.

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