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# "Investigating The Tribological Behaviour of Bio-Lubricant Enhanced with Additives"

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**Abstract—** Due to the industrial revolution, the use of mechanical machinery and sales of the automobiles are increasing which leads to an increase in demand for lubricants. A lot of used synthetic lubricants is disposed of in the environment which is non-degradable, toxic and harmful in nature so the development of biodegradable lubricant is a necessity for the future generation to maintain a green environment. Bio-lubricant are the future need which is expected to decrease the dependence on imported petroleum products. Due to above reasons, this research was carried out to develop bio-lubricant and suitable blends of bio-lubricant to replace conventional lubricant in the automobile sector. There are two types of vegetable oil edible and non-edible vegetable oil. Non-edible plants can be grown on waste lands,land unsuitable for cultivation, railways roads, irrigation canals, Poverty stricken area, degraded forests. We are study on non-edible based bio-lubricant. Non-edible oil is selected as suitable vegetable oil for preparation of bio-lubricant from it because of having high oxidation stability, high viscosity index. We are select synthesis method for bi-diesel is esterification and synthesis method for bio-lubricant is tan- esterification. In the prepare the bio-lubricant, to improve the anti-wear properties anti-wear additives ZDDP (Zinc Dialkyl Dithio Phosphate) was added in 3% and 5% to prepare blend-1 and blend-2 respectively. The application selected for analysis is piston ring and cylinder lining of diesel engine. To check the wear rate and coefficient of friction between the piston ring and cylinder lining, the pin is prepared of piston ring material EN47 and disk is prepared of cast iron FG200 and mounted upon tribometer. The test for wear rate and coefficient of friction was conducted using prepared pin and disc and using veedol oil (20W40), Prepared Jatropha oil, blend-1 (3%ZDDP) and blend-2 (5%ZDDP) lubricant on pin on disc tribometer. Then compare wear and coefficient of friction of veedol oil, Jatropha oil, blend-1 (3% ZDDP), and blend-2 (5%ZDDP) in graphical format. Upon comparison, it was found thatblend-2 shows a reduction I n wear rate than veedol oil (20W40). Hence veedol oil with the addition of anti-wear additives ZDDP can replace the conventional used veedol oil (20W40) as engine oil.

**Keywords—**Bio-lubricant, Non–edible oil, Green environment, synthesis, Additives.

## 1. Introduction: -

The tribological properties of mating components of engines and machines, where relative motion is involved, generally depend on factors such as load,temperature, speed, sliding time, base oil, and additive. From study we observed a reduction in friction force with the vibration, amplitude of vibration, relative sliding speed, and roughness of rubbing surfaces, type of material, humidity,temperature, and lubrication. As the operating conditions of the engines and machines become simpler, more trouble occurs at the contacting surfaces due to damage caused by wear, fretting, pitting, etc. Wear is sometimes affected by corrosive environments under constant or varying contact load, resulting in failure of the componentsdue to severe wear [1].

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Surfaces in contact with relative motion will produce friction, which produces unwanted heatand leads to material wear. It is difficult to prevent damage of this kind; there are many ways to minimize this undesirable wear, one of which is bythe lubrication. Lubricants are those substances which are used to reduce the force of friction between two surfaces. Lubrication is basic need of mechanical machines and equipment's. Lubricants have important role in industrial and economic development. About 38 million metric tons of lubricants have been used per year globally in the last decade which is majority of petroleum based. The function of lubricant is to reduce friction and wear and prevent rust, dirt and oxidation. The lubricant creates protective layer between two mating surfaces and reduce friction. Lubricant alsoacts as sealing agent against dust, dirt and water. Inany mechanical equipment, the moving parts or themetal surfaces come in contact and producesfriction results in loss of material due to abrasion. Good lubricants have properties like thermalstability, resistance to oxidation, low coefficient offriction, low wear and high viscosity index. Now a days demand of lubricating oil is increasing day by day and conventional petroleum oil-basedlubricants are high in cost. Also, petroleum oil-based lubricants depleting rapidly and would be exhausted in few decades. Due to availability issues, toxicity and non-biodegradable nature ofconventional lubricants many of the researchermoved towards biodegradable lubricants such asvegetable oils. Property such as high viscosity index, high lubricity, low volatility, comparable energydensity, cetane number. Bio-lubricants tend to havemany advantage over conventionally used lubricants such as having higher lubricating property, viscosity property, shear stability and high load carrying capacity. Vegetable oil are Triglycerides and three fatty acids connected to glycerol. Fatty acids are long hydrocarbon chain attached to hydrogen and othergroups and terminating chain have carboxylic acid.If a single bond is present between Carbone molecules then this is saturated fatty acid and if thedouble bond is present then they are unsaturated fatty acids. The properties of current used engine oil have better lubrication performance due to theirhigh viscosity, high flash point, low frictioncoefficient, low pour point and high oxidation stability. The properties of vegetable are partially fulfilling the engine oil properties as they havehigh viscosity, high flash point, high fire point,high density but poor oxidation stability, low pour point and cloud point. Density is sufficient property of lubricant which affects the mass flow rate of lubricating oil and the cooling capacity the density of lubricating oil should be high. The jatropha curcas oil has density 881 Kg/m^3 which nearly equal to currently used lubricant oil. The cloud point of oil should be low because it affects fluid volatility, fluid flow and its usability in a coldregion. Mahua oil, Nicotine Tabacum, sunflower oil, Jatropha curcas oil, and rice bran oil has a low cloud point. Fuel having low pour point limits the use of oil in the cold region. Jatropha curcas oilhas low pour point (0.18 °C).Normally the flash point of engine oil greater than 200°C.Flash point shooed be high. Flash point of Mahua oil (208°C) and Jatropha oil (164 °C) which is nearly equal to the currently used lubricating oil.

## 2. Literature Review: -

**N. Nuraliza, et al. [1]** have studied on tribological effect of vegetable oil as alternative lubricant. The aim of this study is to investigate the friction and wear characteristics of double fractionated palm oil (DFPO) as bio-lubricant on pin-on-disk setup for different loads. Lubrication properties of palm oil are compared with hydraulic oil and engine oil(SAE40).From the study it is revealed that all the mechanism of the wear such as abrasive wear, adhesive wear, fatigue wear and corrosive wearand lubricant palm oil is able to sustain its properties by forming layer between contacting surface. The conclusion of the study is DFPO showed best overall performance in terms of wear, coefficient of friction, viscosity, etc.

**A.Z syahir, [2]** has studied improve thetriobological properties of synthesis & bio based lubricant by using additive ionic liquid at contact with steel- steel condition. They test tribological performance of synthetic and bio-based lubricant by adding ionic liquids additive under boundary lubrication regime using four ball and high frequency reciprocating rig tribotesters. By using optical microscope, profilometer, scanning electronic microscopy and energy dispersive spectroscopy for examine the surface morphology and the chemical composition of elementsdeposited on worn steel surface. When added additive in synthesis &

bio based lubricant a bio based lubricant are reduce the friction, wear, improve the overall surface finish and also higher pressure viscosity coefficient as compare synthesislubricant.

**S.M Alves, [6]** has studied the development of vegetable based lubricants and the addition of oxide-nano particles (Zno & Cuo) as additive for extreme pressure oil base influence tribological behavior. When addition of oxide nanoparticles inconventional lubricant the tribological propertiescan be improve but oxide nanoparticles added in vegetable oil like sunflower & soybean oil the tribological properties cannot be improved. Oxide nanoparticles do not show the good anti wear ability in vegetable oil like sunflower & soybean oil. Zno are excellent performance in friction & wear combined with mineral oil. Synthetic oil tribological properties improve with addition of Cuo. A vegetable oil shows poor oxidative and thermal stability due to presence of unsaturation. Improve the thermal properties using some chemical modification such as epoxidation, trans- esterification.

**S,Rani [7]** has presented the thermal propertieslike flash point & fire point of rice brain oil are much better than SAE20W40. Improve theviscosity range & oxidation Stability to rice brain oil by using proper additives. Wear rate of rice brain oil is less compared to other vegetable oildue to presence of anti-oxidant substances. From the study it is revealed that increasing acidic number & iodine number reduce the coefficient of friction but increase the wear. The main reason for use vegetable oil it biodegrability, renewability,low toxicity & excellent lubricating performance. The paper give idea about how to tested the vegetable oil and compare with other vegetable oil and mineral oil. The rice brain oil is environmental friendly.

**S.Baskar, [8]** has studied measuring oil film pressure of journal bearing under influence of various Nano based lubricants. A pressure sensor used for measure the oil film pressure of the lubricant between journal and bearing. From the study it is revealed that oil film pressure is affectedby viscosity and viscosity index. A predicated fuzzy & experimental result were very close toeach other which represented that the developmentfuzzy model is used to evaluate the oil film pressure of journal bearing with nano based lubricants. Nano based lubricant improve journal bearing safety through greater oil-film thickness.

## 3. Experimental analysis

**3.1. Preparation of test setup tribometer:-** Tribometer is an instrument is used to measure tribological quantitates such as frictional force, acoefficient of friction,wear between twocontacting surfaces. A pin disc tribometer consist apin which is stationary and it is loaded againstrotating disc, the disc is rotated with the help of amotor. The pin is a cylindrical shape having flatsurface on both sides. The test of prepared blendswas taken by varying speed in between 1500 rpm to 2000 rpm and the load is applied in between 1kg to 8 kg.

**Table.1.Technical specifications of pin and disc tribomete:-**

| Sr.no | Parameter | Value | Unit | Range |
|---|---|---|---|---|
| **1** | Disc speed | 200-2000 | Rpm | Step 1 rpm |
| **2** | Normal load | 1-200 | Newton | Step 5 N |
| **3** | Frictionalforce | 0-200 | Newton | 20 kg beam type |
| **4** | Wear | 2 | Mm | +/- |
| **5** | Wear track diameter | 50-100 | Mm | |

| | | | | |
|---|---|---|---|---|
| **6** | Sliding speed | 0.5-10 | m/s | |
| **7** | Timer | 99,59, 59 | Hrs, Min, Sec | Maximum |

1 pin size:- φ8 mm, length 32 mm

2 flat circular disc size: φ 170mm, thickness 8 mm.

### 3.1. Tribometer disc image and material:-

The material of the disc is cast iron FG200, with the dimensional specification of 170 mm diameter and 8 mm thickness is manufacturing by thecasting process.

Figure 1 Image of Tribometer disc

**3.2. Tribometer pin image and Material: -** The material of pin is EN 47(Spring steel), with diameter 12mm and length 32mm.

Figure 2 Tribometer pin

### 3.3. The test procedure for the pin on disc tribo meter

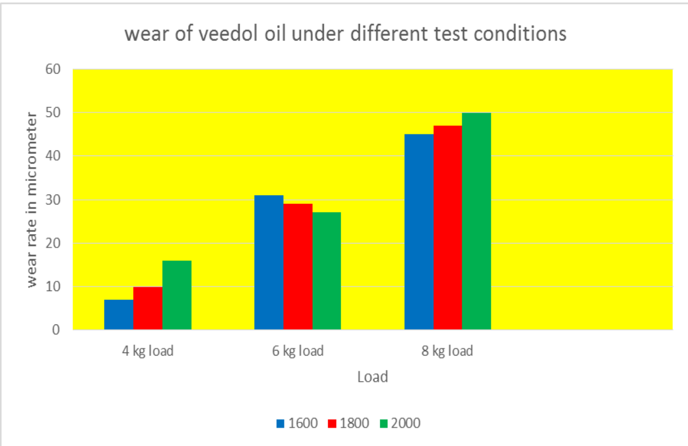
The steps of operating pin on disctribo meter are to first switch on controller and allow 5 min for normalizing all electronic items then clan disc thoroughly with solvent and clamp it on hold using screw. Further, clean testing with the ambient condition, insert specimen pin inside hardened jaws and tighten the specimen holder. Also, set the height of the specimen pin above the worn disc using heightadjustable block and then swivel off the heightadjustable block away from it. Finally, insert compensating dead weight on the lever. Then, initialize wear display to zero on the controller, by loosening LVDT lock screw and rotating thumbscrew near to it. Initialize frictional force to zero on the controller by pressing the corresponding ZERO button on the controller. Set the time by pressing push button in time /revmode and speed (rpm of the disc) by rotating rpm knob in a clockwise direction (till required speed is achieved). Check the connection of data acquisition cable between controller and pc. Follow the procedure given below. Open the software winducom 2010, click on mode run continuously icon on the software screen. It activities the screen and plots the graph of wear, frictional force and coefficient of friction during the test operation. Place the required weight on loading pan toapply normal load. Press the START push button on the controller front panel to start the test, simultaneously data is transmitted to PC. The test stops automatically after completion of the present time or count. The system can also be manually stopped, by actuating the STOP button on the controller. Open view file to display the graph of a single test with test parameters. Also compare file option is used to compare test parameters of different test files.

**Figure 3. Tribometer experimental test setup**

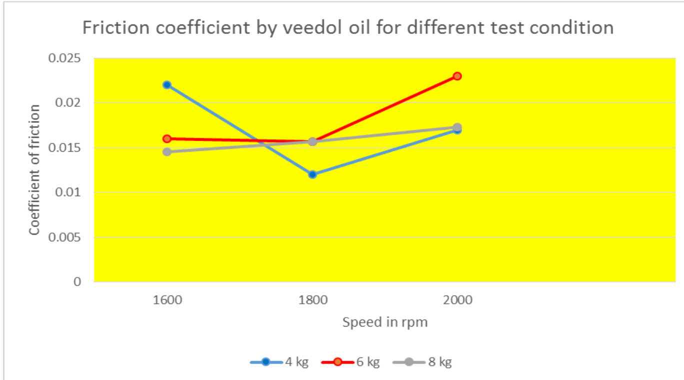
## 4. Result and Discussion: -

### 4.1. Tribological analysis of prepared bio-lubricant:-

As tests for veedol oil, jatroph oil-based bio- lubricant, blend 1 (ZDDP 3%) and blend 2 (ZDDP 5%) were conducted on a pin on disc tribometer. The results of the coefficient of friction, wear rate and frictional force are analyzed for different load and speed conditions and plotted on a graph. Following two graphs shows the behaviour of wearrate and COF for veedol oil.




**Graph 1 Wear of Veedol oil under different fordifferent loading and speed condition**

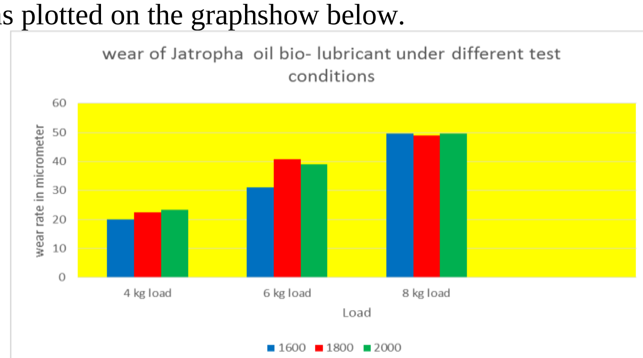



**Graph 2 Frictional coefficient of veedol oil**

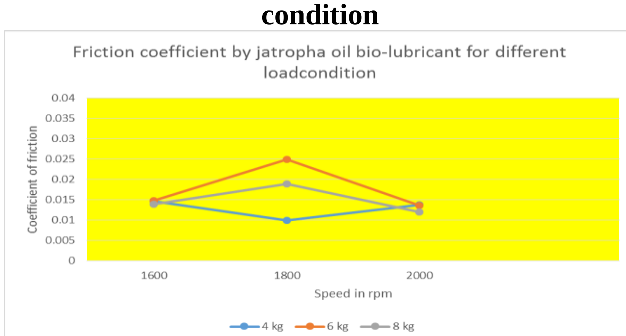
Under different loading and speed condition Graph 1 and Graph 2 shows the variation of wearrate and coefficient of friction for veedol oil (SAE20W40) for different test conditions. It is tested forthree different speed i.e. 1600 rpm, 1800rpm,2000rpm, and three loads i.e. 4kg, 6kg, 8kg. wearshould increases with the increases in load forconstant speed, and cpoefficient of friction shows adecreasing trend with an increase in speed becauseas speed increases dynamic action increases whichhelp to from a thin lubricating film which reducesfriction between pin and disc.

## 4.2. Behavior of wear rate and COF forJatropha oil based bio-lubricant.

The test for wear rate and COF was conducted on pin on disc tribometer using Jatropha oil based bio-lubricant. Then result was plotted on the graphshow below.




**Graph 3 Wear of Jatropha oil based bio-lubricant under different for different loading and speed condition**




**Graph 4 Frictional coefficient of jatropha oilbasaed bio-lubricant under different loading and speed condition**

Graph 1 and Graph 2 shows graph of wear rate of jatropha oil based bio-lubricant and COF for different load and speed condition. From graph we were observed that wear of jatropha oil is more than veedol oil. So, there is a need for improvement in anti-wear and frictional properties of jatropha oil.hence added selected additives ZDDP in 3% and 5% and make blends of jatropha oil,then test wear rate and COF of this blends pin oan disc tribometer.

**Conclusion:-**

The study framed the effect of jatropha oil, bio and the addition of ZDDP additive to study the tribological Properties of bio-lubricant. From this set of experiments and analysis study, it can be concluded that Jatropha oil shows Potential for development as an automotive lubricant. Jatropha oil is selected as suitable vegetable oil for the preparation of biolubricant from it because of having high oxidation stability, high viscosity index and Jatropha oil is suitable for automotive lubricating. Non-edible plants can be grown on waste lands, land unsuitable for cultivation, railways, roads, irrigation canals, Poverty stricken area, degraded forests. Zinc di-thiophosphate (ZDDP) is selected as the best suitable additives for improving anti-wear and friction properties of Jatropha oil. Esterification is selected as a chemical modification process because it improves the oxidation stability of vegetable oil at high temperature. Esterification reaction where triglycerides react with alcohol that is methanol and produces bio-diesel with catalyst sodium hydroxide or potassium hydroxide and glycerol as a by-product. Trans-esterification reaction prepare biodiesel is again reacted with trimethylolpropane with sodium methoxide as a catalyst which is forms trimethylopropane ester which is required bio-lubricant and methanol as a by-product. By observing the graphs of wear and COF of Jatropha oil, Jatropha oil blends with 3% and 5% ZDDP and Commercial oil (veedol oil) it is observed that wear rate and COF is less for jatropha oil blend-2 with 5% ZDDP than Veedol oil.

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