Tribological Investigation of Mahua Oil Based Lubricant for Maintenance Applications

Amit Suhane[1], A. Rehman[2], H.K.Khaira[3]
[1]Assistant Professor, [2]Professor, [3]Ex-Professor
Mechanical Engineering Department, M.A.N.I.T., Bhopal, M.P. India-462051

ABSTRACT

Limited crude reserves, consistently rising oil prices, unsafe disposal of the harmful lubricants and its guaranteed adverse aftereffects has increased concern for replenishing the environment. Development of environmental friendly lubricants and its appropriate usage is an option of prime importance which can overcome such problems. This paper investigates the prospects of Mahua oil based lubricant for maintenance applications. Mahua oil is blended with conventional gear oil (90T) in different ratios. Tribo pair used is plain carbon steel cylindrical pin and mild steel disc . Friction and wear parameters have been studied on Pin on Disc Tester under varying conditions. Worn out pins suggests pronounced abrasive and adhesive wear pattern under boundary film lubricated conditions. Experimentation reveals that addition of mahua oil blended with 90 T oil has good wear reducing traits apart from environmental benefits.

Key words: Mahua Oil, Bio-Lubricant, Non-Edible Vegetable Oil, Mineral Oil, Blending, Viscosity

I. INTRODUCTION

Lubricants acts as lifeguards of any tribosystem for wide range of utilities and applications. In general lubricants are the multifaceted agents required for smoother tribo-pair operations. Depending upon the properties required, availability, technology, compatibility ; they have oscillated from the nature based to conventional mineral based through the ages[1-2]. Worldwide population growth has forced the excessive extraction of limited crude reserves in variety of applications. Conventional lubricants made from the mineral oils and additive package are potentially toxic to water and soil due to their heavier composition and lower biodegradabilities. Escalating raw oil prices , improper disposal methods, absence of lubricant usage norms worldwide threatening environment has unconditionally drew its attention towards the natural counterparts[3-5]. Vegetable oils pretend to be the better alternatives to the conventional counterparts. Vegetable oils are chemically triglycerides containing long chain unsaturated free fatty acids attached at hydroxy groups via ester linkage. Variations in physical and chemical properties and the behaviour depends on these basic blocks[6].They are preffered over toxic counterparts mainly due to their competitive technical properties like higher oiliness, viscosities and indices, higher flash points, lower evaporative losses and lower full accounting cost including the operation cost and nature replenishment cost. Although they do have certain inferior traits like reduced oxidation and thermal stabilities, poor cold flow properties, lower shelf life; but by rigorous modification techniques and systematic research they can be improved[7-11]. Oils can be edible or non edible. Innumberable varieties are present worldwide , but only fewer of them have been tapped depending upon their potential. Researchers have done extensive work worldwide on the edible oils. Harnessing edible oils for non food applications (fuel/lubricant) disturbs household requirements. India being the largest edible oil importer in the world and consistent increasing bills for ever increasing population affects our economy badly. On the other hand alternatives in the form of non edible varieties do not pose any such threat and infact adds to the rural economy. Fewer or limited attempts have been reported for the lubricant formulations from alternative sources despite the reported advantages[12-16]. Mahua is one such variety with certain work reported in biofuel applications but consideration for lubricant formulation still needs attention[17-18].

Mahua is an important tree having vital socio-economic value belongs to family Sapotaceae. The two major two species of mahua found in India are Madhuca Indica (Bassia latifolia, Madhuca latifolia) and Madhuca longifolia (Bassia longifolia) . It is deciduous in nature. It grows widely under dry tropical and sub-tropical climatic conditions throughout the greater part of India. Mahua is adopted to a wide range of soils, including bouldery hill tops. The tree is strong light demander and gets readily suppressed under shade. Mahua is a tree valued for its timber, flowers and fruits. Besides, it provides large amount of biomass. The seeds provide oil and oil cake. The oil is used for non-edible purposes and the oil cake for manuring. It is a multipurpose tree providing food, fuel, timber, green manure, oil, oil cake, liquor and raw materials for several products. It also has a high bio-aesthetic value. Annual production of mahua oil is 1,80,000 tons.Mahua seed contain 30-40 percent fatty oil called mahua oil. It is rich in sugar (73%) and next to cane molasses constitute the most important raw material for alcohol fermentation. Fatty acid composition of mahua oil contains saturated components - 24% palmatic and 24% stearic acid , unsaturated components - 40% of oleic and 12% of linoleic acid[19-20].The present investigation is an attempt to look in to the prospects of mahua oil based lubricant against the conventional servo grade gear oil for maintenance applications.

II. EXPERIMENTATION

2.1 Lubricant Preparation and Test Material

The conventional lubricant used in the reported work is servo grade (90T) gear oil which finds common application in medium to high pressure gearings. The conventional lubricant contains base oil added over with additive package for specific and enhanced performance. On the contrary, non edible refined mahua oil is being used as blending agent in the conventional servo grade oil with the aim of comparing and analyzing the tribological characteristics of the servo grade and the mahua based blend. In all six lubricant samples different ratios have been used and further analyzed. 90T Oil is blended with mahua oil in prepostitions varying from 5%-25% by volume. Total five blends have been prepared by homogenous mixing at warm conditions over hot plate with magnetic stirrer. The plain carbon steel pin used is cylindrical in shape and is tested against the circular mild steel disc. Pin dimension used is 30mm x 6 mm , whereas disc dimension is 160mm x 8mm.Pin and disc material has carbon % (0.20-0.35) and (0.40-0.55%) respectively.

2.2 Test Set Up

The set up used in the experimentation is (ASTM G99) Pin on Disc Machine **Fig.1.**connected with data acquisition system. POD machine comprises of stationary pin mounted on a pin holder with sliding contact against a rotating disc at a specified speed in presence of lubricating oil. The friction and wear of the test materials can be obtained in sliding action under non abrasive conditions. A variable speed (60-600 rpm) motor capable of maintaining constant speed under varying load pumps the lubricant from the sump tank to the lubricating chamber at the point of contact between the pin and the disc. The pin specimen is pressed against the disc at a specified load usually by means of an arm or lever and attached weights. Parameters like friction, wear and coefficient of friction etc. are measured and stored in the data acquisition system and are further analyzed .

Fig.1 Test Set Up

2.3 Test Procedure

A starting load of 10 N was applied at the contact zone of pin and disc with constant flow of test lubricant directed thereof. The disc is rotated at 100 RPM for duration of 30 Minutes. Specific wear (w) and coefficient of friction (μ) are measured with the help of friction and wear measuring system for the particular load and speed. The observations are recorded in the data acquisition system. Further tests are carried out at successively higher loads up to 60 N and disc speed 500RPM which are further analyzed. The lubricant test oil samples are 90T oil, blend 1, blend 2, blend 3, blend 4 and blend 5 as shown in **Table 1.**

Table 1:Blending Ratio

Vol %	Blend1	Blend2	Blend3	Blend4	Blend5
90T	**95**	**90**	**85**	**80**	**75**
Mahua	**5**	**10**	**15**	**20**	**25**

The viscosities(η) evaluated for different samples through digital viscometer are shown in**Table.2**

Table 2.Kinematic Viscosity

η cP	90T Oil	Mahua Oil	B1	B2	B3	B4	B5
27^0	400	260	380	340	290	250	190
100^0	20	10	20	15	15	10	10

On the basis of the tests, curves are drawn for all the oils on sigma plot which shows the effect of load on the specific wear and coefficient of friction.

III. 3. RESULTS AND DISCUSSION

3.1 Friction and Wear Evaluation

3.1.1 Specific Wear

The fig.2-6 shown below depicts the effect of normal loadings on specific wear of pin material at disc speed ranging from 100-500 rpm for lubricant samples in different blending ratio.

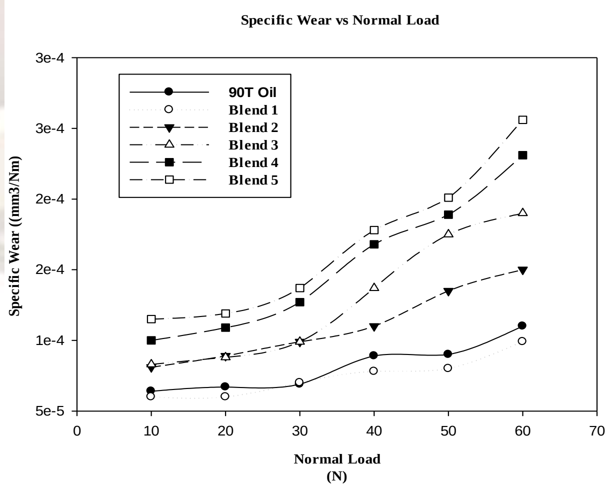

Fig.2.Specific Wear vs Normal Load at 100 RPM

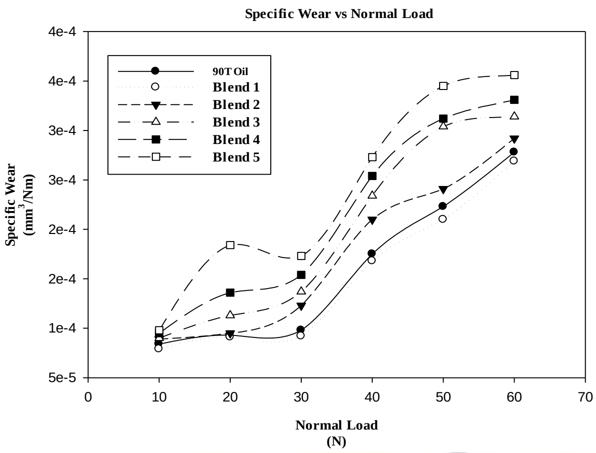

Fig.3.Specific Wear vs Normal Load at 200 RPM

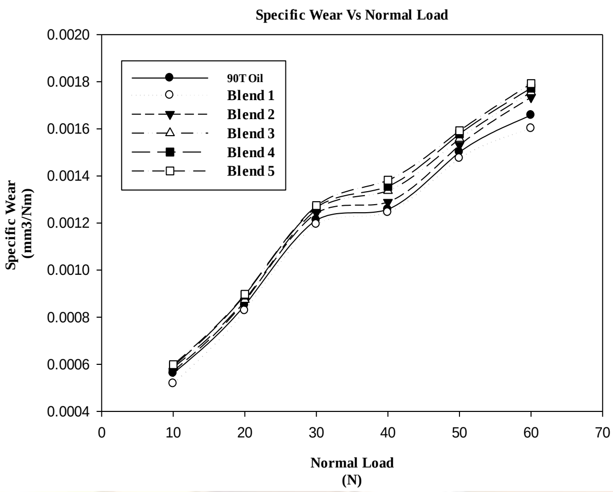

Fig.4.Specific Wear vs Normal Load at 300 RPM

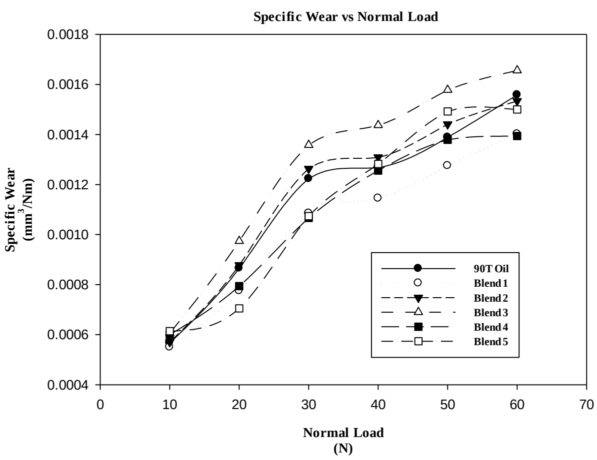

Fig.5.Specific Wear vs Normal Load at 400 RPM

It is observed that 90T oil and blend1 are having almost similar attributes when subjected to above stated operating conditions. In general vegetable oils are natural lubricants having better viscosities. As per graphical plots

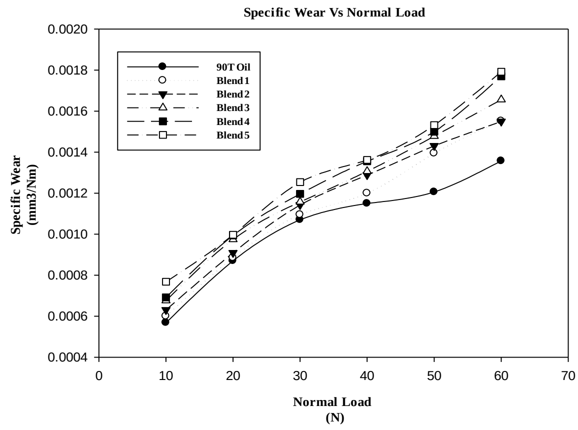

Fig.6.Specific Wear vs Normal Load at 500 RPM

the specific wear for given loadings and speed for all the oil samples more or less are increasing and reportedly in the range of 0.000064 mm^3/Nm to 0.001792 mm^3/Nm. But the rate with which the wear is increasing is far lesser in case of 90T oil and almost similar in blend1 and in certain cases blend2.The other three blends showed comparative higher wear rates to the premium oil and primary blend. This could be due to the reduced capability and compatibility at higher blending ratios. Also increase in applied loadings on any tribo pair increase the average surface temperature, thus affecting the overall lubricant temperature. Wear mechanisms are significantly affected by lubricant temperature. Wear particles formation is pronounced at higher lubricant temperature thus resulting in increased wear [21]. The graphical plots clearly suggests that wear rate of pin material is better poised with blend1 when environmental factors are taken in to considerations. This findings also suggests that blend1 with 10% mahua oil composition has almost maximum ability among its counterparts to avoid surface interactions due to its ability to retain lubricant film and suspend the wear particles thus reducing the specific wear .

3.1.2 Coefficient of Friction

The fig.7- fig.11 shown below are the graphical plot between coefficient of friction (μ) and normal load at varying disc speed. The values for different samples followed a downward trend during increase in loadings for a particular speed and an upward trend during increase in speed for a particular load. Coefficient of friction values reported during experimentation in the range of 0.014 to 0.03 clearly suggests the regime at contact zone to be boundary lubrication.

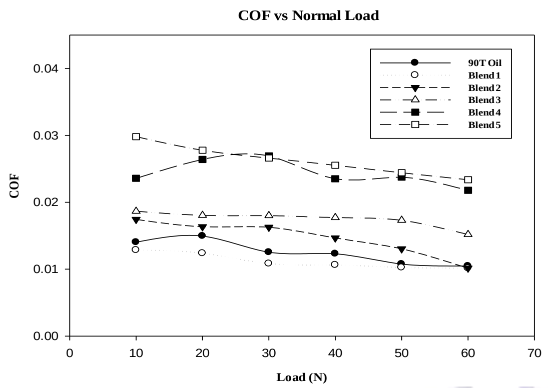

Fig.7.COF vs Normal Load at 100 RPM

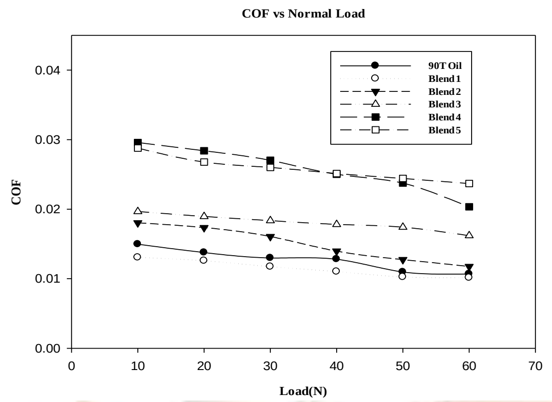

Fig.8.COF vs Normal Load at 200 RPM

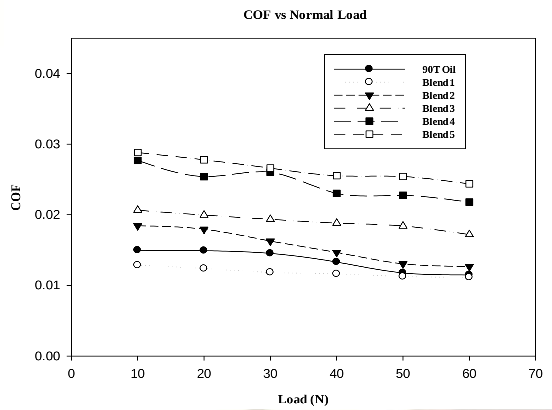

Fig.9.COF vs Normal Load at 300 RPM

Blend1 showed comparative lower COF values to all other samples for all the speeds at designated loadings. This could be probably due to the formation of stable fatty acid layer in the form of oxides at the contact zone avoiding the regular contact. This phenomenon is more dominant at lower speeds and higher loads. But at higher speeds ,the lubricant temperature at contact zone being higher retards oxide film formation. As a result thickness of lubricant film at the contact zone reduces leading to increased chances of interactions between the two thus promoting wear.

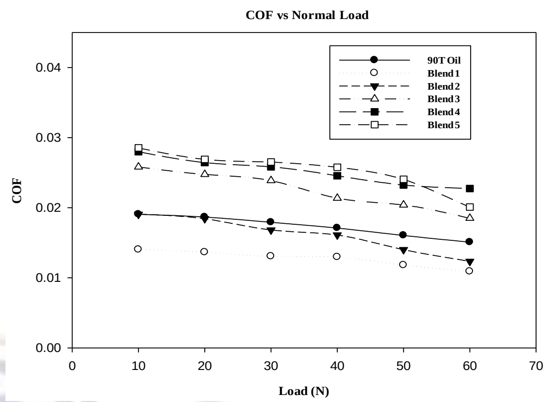

Fig.10.COF vs Normal Load at 400 RPM

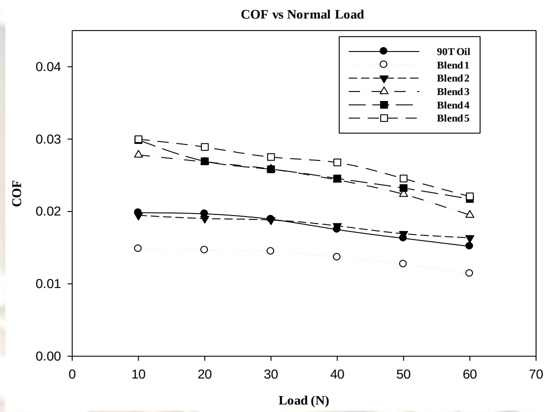

Fig.11.COF vs Normal Load at 500 RPM

3.1.3 Surface Texture

The surface interactions between pin and disc can be easily seen from the fig.12 shown underneath. Worn out surface of pins suggests pronounced abrasive and adhesive wear pattern under prevailed boundary film lubricated conditions.

Fig.12. Fresh and Used Cylindrical Pin Surface

IV. CONCLUSIONS

The experimentation performed with the given set of lubricants under different operating conditions and its reported observations can be concluded as follows:

1. Friction and wear rates depends upon various factors but the major ones are speed and the normal load.
2. COF increases as speed increase for corresponding loads.
3. COF decreases as load increase for corresponding speeds.
4. Wear rate reflects an increasing trend for increased loads and corresponding speeds.

5. Increased loadings renders greater wear particles in the tribo-system pronouncing wear and suppressing COF.
6. Specific wear rates and COF values for Mahua based blend ie. Blend 1 and 90T oil are comparable in terms of maintenance perspectives.
7. Surface texture of pins revealed more of the adhesive and abrasive wear patterns which are pronounced at greater load and speeds.

The observations from the experimentations suggests that addition of 5-10% mahua oil in the 90T oil has good wear reducing traits for maintenance purpose at different operating conditions.

REFERENCES

[1] **Theo, Mang ,W. Dresel,** " Lubricants and Lubrication" 2nd Ed. 4,2007 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim ISBN: 978-3-527-31497-3.

[2] **"**Margins Indian Lubricant Industry", CRISIL report, 2005.

[3] **Ioan S.,**"On the Future of Biodegradable Vegetable Lubricants Used for Industrial Tribo Systems",Gal I Fascicie 2002;VIII:pp 1221-4590.

[4] **WilfriedJ. Bartz,** "Ecotribology: Environmentally Acceptable Tribological Practices", Tribology International, Vol. 39, 2006, pp728–733.

[5] **Adhvaryu A, Biresaw, G., Sharma, B.K., Erhan, S.Z.,** "Friction Behavior of Some Seed Oils: Biobased Lubricant Applications", Ind. Eng.Chem. Res. 45, 2006, pp 3735-3740.

[6] **Willing, A.,** "Lubricants Based on Renewable Resource – An Environmentally Compatible Alternative to Mineral Oil Products" Chemosphere, 2001, Vol. 43, pp 89–98.

[7] **Erhan, S. Z., Asadauskas, S.,** "Lubricant basestocks from vegetable oils", Industrial Crops Production,Vol.11,2000,pp277–282.

[8] **Wagner, H., Luther, R., Mang. T.,** " Lubricant Base Fluids Based on Renewable Raw MaterialsTheir Catalytic Manufacture and Modification",Appl. Catal. A, 2001,Vol.221, pp 429–442.

[9] **Sevim, Z. Erhan, Brajendra, K. Sharma, Joseph, M. Perez ,** "Oxidation and Low Temperature Stability of Vegetable Oil-Based Lubricants", Industrial Crops and Products,Vol.24, 2006, pp. 292-299.

[10] **Asadauskas, S., Pérez, J.M., Duda, J.L.**, "Oxidative Stability and Antiwear Properties of High Oleic Vegetable Oils", Lubrication Engg Vol.52, 1996, pp877-882.

[11] **Emmanuel, O., Aluyor, K. O., Obahiagbon, Mudiakeoghene Ori-jesu,** "Biodegradation of Vegetable Oils: A review", Scientific Research and Essay, 2009, Vol.4(6), pp543–548.

[12] **Shahabuddin,M., Masjuki, S.S., Kalam, M.A.,** Experimental Investigation in to Tribological Characteristics of Biolubricant Formulated from Jatropha Oil", Procedia Engineering, 2013, Vol.56, pp 597-606.

[13] Singh, A.K., "Castor Oil-Based Lubricant Reduces Smoke Emission In Two-Stroke Engines", Industrial Crops and Products, 2011,Vol.33, pp 287–295.

[14] **Bekal, S., Bhat N.R.,** " Bio-lubricant as an Alternative to Mineral Oil for a CI Engine—An Experimental Investigation with Pongamia Oil as a Lubricant", Energy Sources, Part A. Taylor & Francis, 2012, Vol.34, pp 1016–1026.

[15] **Jain,A.K., Suhane,A.,** "Research Approach & Prospects of Non Edible Vegetable Oil as a Potential Resource for Biolubricant - A Review", Advanced Engineering and Applied Sciences Journal, 2012, Vol.1(1), pp 23-32.

[16] **Chinchkar,D.S., Satpute,S.T., Kumbhar, N.R. ,** "Castor Oil as Green Lubricant-A Review", International Journal of Engineering Research & Technology, 2012, Vol. 1 (5), pp1-3.

[17] **Pugazhvadivu, M., Sankaranarayanan, G.,** "Experimental Studies on a Diesel Engine Using Mahua Oil As Fuel", Indian Journal of Science and Technology, 2010, Vol. 3 (7), pp 787-791.

[18] **Puhan, S., Vedaraman, N., Rambrahamam, B.V., Nagarjan,G.,** Mahua Seed Oil- A Source of Renewable Energy in India", Journal of Scientific & Industrial Research, 2005, Vol.64, pp890-896.

[19] **"**6th R&D Report on Tree Borne Oilseeds, 2010-11", National Oilseeds and Vegetable Oils Development Board, Ministry of Agriculture, Govt. of India, pp 1-112.

[20] **Chauhan,P.S., Chhibber,V.K.,** "Non-Edible Oil as a Source of Bio-Lubricant for Industrial Applications: A Review" , IJESIT, Vol.2(1), 2013, pp2 99-305.

[21] **Araji,Al,Nofal,Hussein,Sarhan,.**"Effect of emperature on Sliding Wear Mechanism under Lubrication Conditions" International Journal of Engineering, Vol.5(2) 2011, pp176-184.