Performance of Jatropha Biolubricant for Hydrodynamic Journal Bearing Lubrication

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Abstract - *Rapid depletion of petroleum resources and environmental hazards alarms to use eco-friendly alternative. Jatropha is a non-edible sourced Bio-lubricant shows excellent coefficient of friction, noble anti-wear capability, low environmental emission. Recent research states Jatropha have higher viscosity and improves the load carrying capacity. Comparative tribological study of popular synthetic lubricant (i.e. ISO VG 32, 46, 68 and SAE-40 oil) with Jatropha oil has been carried out. Tribological properties of Jatropha is computed experimentally and the performance of hydrodynamic journal bearing using Jatropha Bio-lubricant is theoretically investigated and validated analytically by using CFD Software. The theoretical results for maximum pressure at different eccentricity ratio and journal speed have been evaluated.*

Key Words: Bio-lubricant, Jatropha, journal bearing, load carrying capacity, pressure distribution and viscosity.

1. INTRODUCTION

Lubricant is a substance that reduces wear and friction by formation of thin oil film in between the contacting areas of two mating bodies. Removal of heat, prevention against corrosion, transmission of power is the basic functions of lubricating oil. Lubricants act as seal between the two moving boundaries and hence trap and remove the wear particles forms in between. To perform this role lubricating oil must possess some specific chemical and physical characteristics. The viscosity of the lubricant is the principal characteristic of the lubricating oil which greatly influences the friction and wear reduction and thus increases the overall efficiency of power transmission. [1]

At present the world is dealing with increasing crude oil price, depletion of crude oil reserves and global environmental concern about preventing the environment from pollution, have generated awareness in the society for developing and using the environment friendly alternative lubricant from derived sources. Non-edible vegetable oil based bio-lubricants are environment friendly as they are bio-degradable, non-toxic and having zero contribution in greenhouse effect. Overall vegetable oil based lubricants exhibits several excellent properties compared to the mineral oils. Potential of these non-edible sourced bio-lubricants for automotive application is discussed. Non-edible sourced lubricants lave enhanced lubricity, good antiwear property, higher viscosity and viscosity index, low evaporation and emission, increased equipment life and high load carrying capacity. [2]

Vegetable oil can be used as lubricants in their natural form. Advantages of vegetable oil are that they show higher viscosity index and flash point compared with the mineral oil. Limiting side is that they are susceptible to oxidation hence low oxidation stability, low temperature limitation and unpleasant smell, filter clogging tendency at lower temperature. [3]

Tribological properties of Jatropha oil contaminated biolubricant are determined by using Cygnus wear and four-ball tribo testing machines. Jatropha oil (JO) by volume fraction of 10-50% has been blended with the base lubricant SAE-40 to formulate the bio-lubricants. Results showed that the lubrication regime occurred during the test was boundary lubricated while the main wear mechanisms are abrasive and adhesive wear. Lowest wear was found with the addition of 10% Jatropha oil in SAE 40 and above 20% concentration of JO in SAE 40, the wear rate get increased considerably. The result of tribotest shows an addition of Jatropha oil in the base lubricant shows excellent lubricant additive characteristics, which reduce the friction and wear scar diameter by maximum 34% and 29% respectively during the tribo test. The application of 10% bio- lubricants in the automotive engines will enhance the mechanical efficiency and take part to reduce the dependency on petroleum oil as well. [4]

2. JATROPHA BIO-LUBRICANT

Jatropha Bio-lubricant is a non-edible sourced vegetable oil which shows potential characteristics to be used as bio lubricant as it have high viscosity and viscosity index compared to other vegetable oils which are close to the commercially used synthetic oils. Comparative analysis showed that the values of viscosity, density, thermal conductivity and pour point for Jatropha oil were higher than the values of SAE 40 engine oil while specific heat, flash point and refractive index values of Jatropha oil were less than the values of SAE 40 engine oil. [5] The performance of Jatropha oil under journal bearing lubrication is investigated in this study.

2.1 Properties of Jatropha oil

Viscosity is the most important property of oil. Viscosity indicates the resistance to flow and it is directly related to the temperature, pressure and film formation. Following properties are derived experimentally using standard test practice and use further throughout the study for theoretical calculation.

Table -1: Jatropha oil properties with Test standards

Property	Unit	Value	Testing Standard
Viscosity at 40°C	cst	35.81	ASTM D 445
Viscosity at 100°C	cst	7.861	ASTM D 445
Viscosity Index	-	199	ASTM D 2270
Density	Kg/m^3	904	IS 1448

ASTM-American Society of Testing Materials
IS-Indian Standard

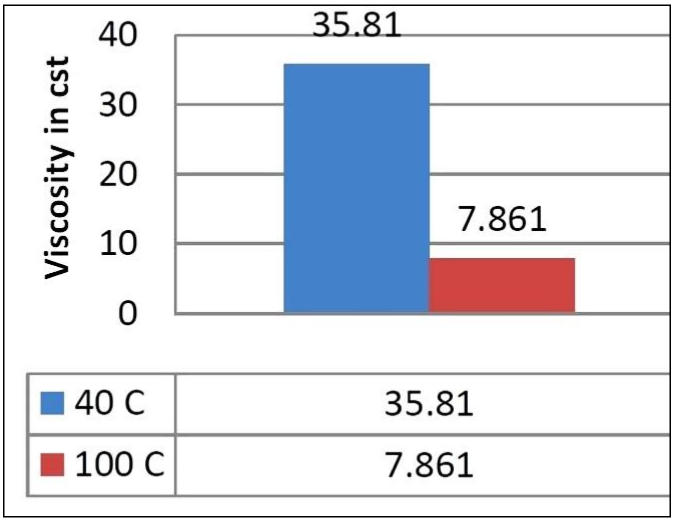

Chart -1: Viscosity of Jatropha at 40°C and 100°C

2.2 Property Comparison

Table 2 shows the various important properties comparison of Jatropha oil along with the other synthetic oils which are widely used for journal bearing lubrication.

Table -2: Property comparison of Jatropha with different commercially used lubricants

Property	ISO VG 32	Jatropha Oil	ISO VG 46	ISO VG 68	SAE 40
Flash point	218	214	221	223	238
Pour Point	-18	6	-23	-20	-16
Viscosity at 40°C	31	36.92	44.5	65.1	134
Viscosity Index	102	181	98	95	97
Specific Gravity	0.873	0.904	0.881	0.88	0.85

3. HYDRODYNAMIC JOURNAL BEARING

Hydrodynamic journal bearing is the important component of any rotating machinery. The performance of hydrodynamic journal bearing depends upon the performance of its lubricant during the lubrication. Journal Speed and eccentricity ratio plays an important role in the performance of journal bearing. A finite length short journal with L/D ratio 0.5 is used throughout the study. All dimension of hydrodynamic journal bearing used in this extensive study are as shown in table 2.

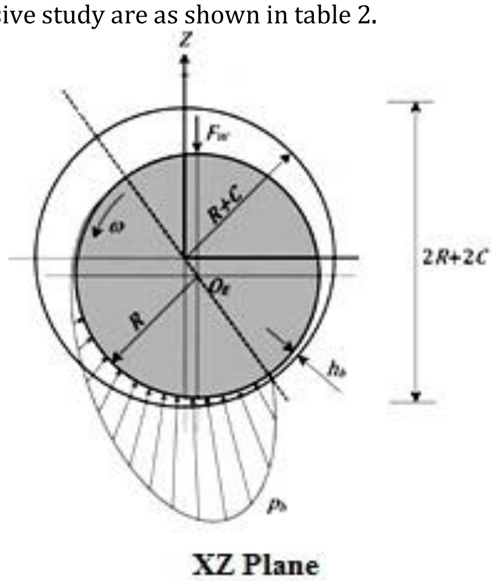

Fig -1: Schematics of journal bearing with its pressure distribution

4. THEORETICAL CALCULATION

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The theoretical calculation of hydrodynamic journal bearing for obtaining the maximum pressure has been done using following equations. The dynamic viscosity of Jatropha Bio lubricant is use in this calculation.

Eccentricity Ratio $\epsilon = e/C$ (1)

Journal Velocity $\omega = 2\pi r n_s$ (2)

Initial Bearing Pressure (MPa)

$$P = \frac{W}{2rl} \quad (3)$$

A derived **Reynolds Equation**

$$\frac{\partial}{\partial x}\left[h3.\ \frac{\partial p}{\partial x}\right] + \frac{\partial}{\partial z}\left[h3.\ \frac{\partial p}{\partial z}\right] = 6\,\mu\,U\,\frac{dp}{dz} \quad (4)$$

Sommerfeld number

$$S = \left(\frac{r}{c}\right)^2 \frac{\mu n_s}{P} \quad (5)$$

Calculation of maximum pressure is done by using standard values for P/Pmax ratio which are obtained from tribology handbook for respective eccentricity ratio and Sommerfeld number.

Table -3: Bearing Dimensions

Bearing Dimensions	
L/D ratio	0.5
Bearing Length L	25 mm
Journal Radius R	25 mm
Radial Clearance C	0.05 mm
Eccentricity ratio ϵ	0.2, 0.4 0.6 0.8 0.9
Journal speed N	1000, 2000, 3000, 4000, 5000 rpm

Table -4: Results for theoretical calculation at constant journal speed

ϵ	Journal Speed (rpm)	S	Load (N)	Max pressure (MPa)
0.2	1000	2.0300	18.23173	0.027887
0.4	1000	0.7790	47.51016	0.086164
0.6	1000	0.3190	116.0201	0.254223
0.8	1000	0.0923	400.9796	1.201335
0.9	1000	0.0313	1182.441	4.591657
0.2	2000	2.0300	36.46346	0.109245
0.4	2000	0.7790	95.02033	0.172329
0.6	2000	0.3190	232.0402	0.508447
0.8	2000	0.0923	801.9592	2.40267
0.9	2000	0.0313	2364.883	9.183313
0.2	3000	2.0300	54.6952	0.163867
0.4	3000	0.7790	142.5305	0.258493
0.6	3000	0.3190	348.0603	0.76267
0.8	3000	0.0923	1202.939	3.604005
0.9	3000	0.0313	3547.324	13.77497
0.2	4000	2.0300	78.87777	0.236318
0.4	4000	0.7790	190.0407	0.344658
0.6	4000	0.3190	464.0805	1.016893
0.8	4000	0.0923	1734.798	5.197455
0.9	4000	0.0313	4729.766	18.36663
0.2	5000	2.0300	91.15866	0.273111
0.4	5000	0.7790	237.5508	0.430822
0.6	5000	0.3190	580.1006	1.271116
0.8	5000	0.0923	2004.898	6.006674
0.9	5000	0.0313	5912.207	22.95828

5. CFD ANALYSES

Computational fluid dynamic analysis is performed to valided the theoretical calculation for hydrodynamic journal bearing. A CAD geometry created in CATIA software is imported to ANSYS Workbench 16 software. CFD Model is then created using FLUENT module, a structured hexahedral meshing done to accurately mesh small dimensions in fluid geometry. Fluid properties are defined in the fluent matrial property module. A Laminar fluid model is been used for the numerial analysis with oil inlet supply pressure as atmospheric pressure and outlet fluid pressure is considered to be zero pascal, different boundary conditions are set at the fluid inlet and outlet. Inner surface of the bearing is kept fixed hence defined as a stationary wall where as outer surface of journal is assigned as rotational moving wall , different rotational speeds are inputed to obtained desired results. Simplec solution is used as it gives quick solution. Number of iteations are performed for more accurate solution. Important input parametes for the various eccentricity ratio such as dynamic viscosity and density are feeded to CFD software(Fluent).

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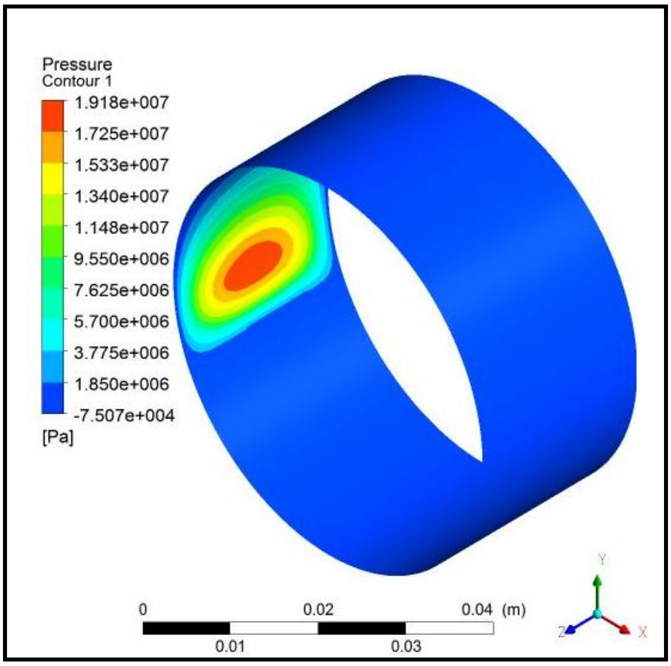

Fig -2: Graphic Image showing pressure distribution contour at ϵ=0.9 at 5000 rpm

6. RESULTS AND DISSCUSSION

Jatropha pure oil shows the intermediate behavior as that of the ISO VG 32 and ISO VG 46. SAE 40 shows the maximum pressure value hence has the maximum load carrying capacity than other oil. (Fig 1)

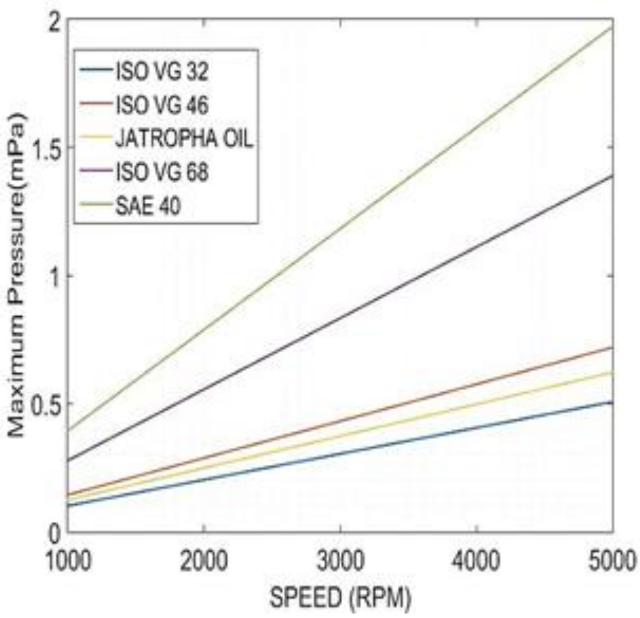

Fig -3: Schematics of journal bearing with its pressure distribution

Table -5: Results for theoretical calculation at constant eccentricity ratio.

ϵ	Journal Speed (rpm)	S	Load (N)	Max pressure (MPa)
0.8	1000	0.0923	400.9796	1.20134
0.8	2000	0.0923	801.9592	2.40267
0.8	3000	0.0923	1202.939	3.60401
0.8	4000	0.0923	1734.798	5.19746
0.8	5000	0.0923	2004.898	6.00667

Table 5 shows that the pressure developed in the bearing is increases with increase in journal speed and similar results are also found analytically as shown in fig 4, which shows the pressure profiles for the Jatropha oil with eccentricity ratio=0.8 at different circumferential angle for various journal speeds. The maximum value of pressure is obtained with 5000 rpm.

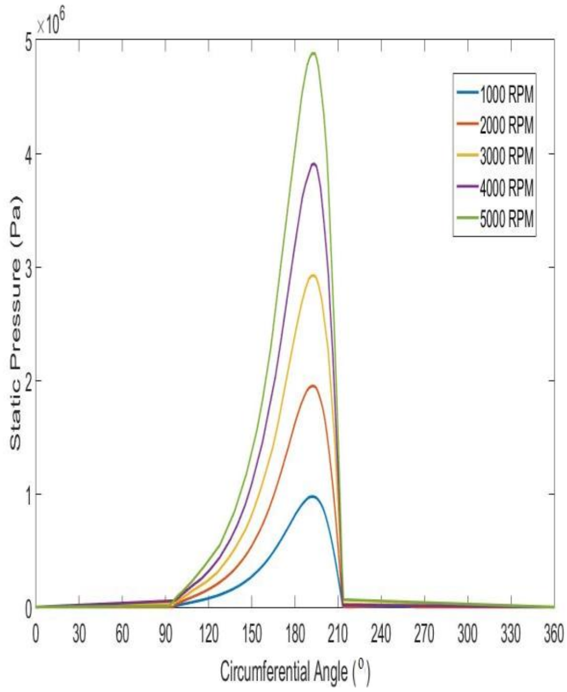

Fig -4: Schematics of journal bearing with its pressure distribution

The load carrying capacity of the lubricant is based on the maximum pressure developed in the bearing due to the hydrodynamic effect. Fig 5 and fig 6 shows the increase in pressure and load carrying capacity of the Jatropha lubricant with increase in journal speed and eccentricity ratio.

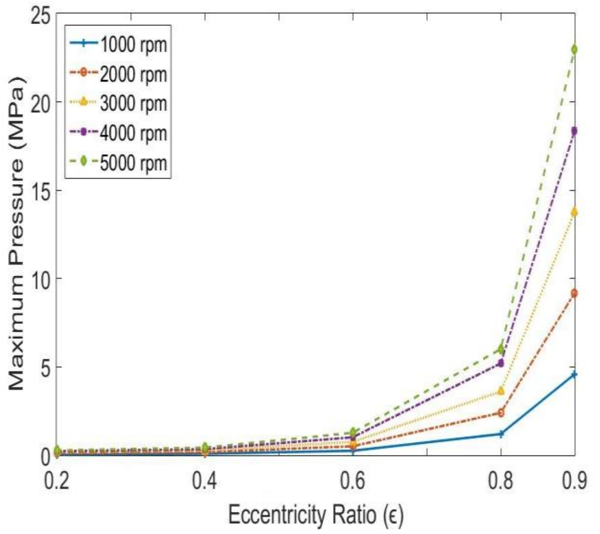

Fig -5: Maximum pressure developed at different journal speed and eccentricity ratio

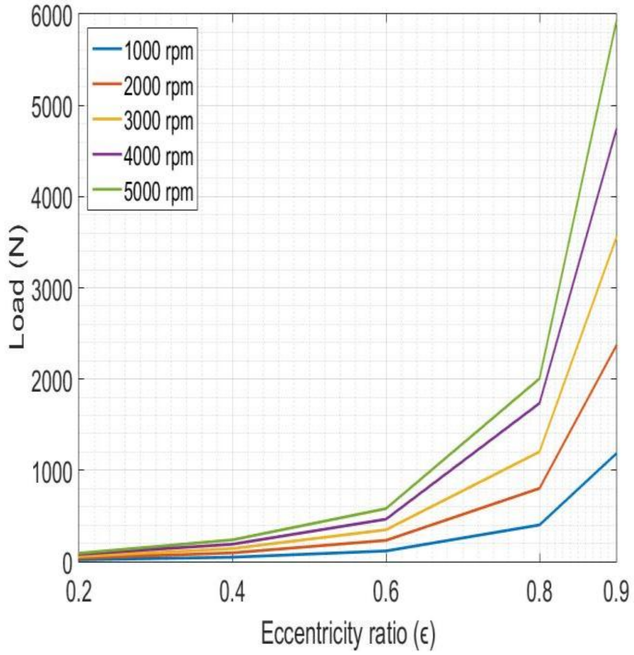

Fig -6: Load carrying capacity at different journal speed and eccentricity ratio

7. CONCLUSION

Jatropha Biolubricant shows the intermediate hydrodynamic behavior for pressure and load carrying capacity as that of the ISO VG 32 and ISO VG 46. Both theoretical and analytical results shows enhancement in maximum Pressure and load carrying capacity of the Jatropha bio-lubricant rises with increase in journal speed and eccentricity ratio. Jatropha oil shows several good characteristics high viscosity and increased load carrying capacity hence can be used as alternative bio-lubricant for journal bearing application.

NOMENCLATURE

ϵ	= Eccentricity Ratio
C	= Radial Clearance (mm)
R or r	= Journal radius (mm)
l	= Length of Bearing (mm)
N	= Journal speed in (rpm)
n_s	= Journal speed (rps)
h	= Fluid film thickness (mm)
μ	= Dynamic Viscosity of Lubricant (Pa.s)
W	= Load on journal (N)
P	= Initial pressure due to load W (Pa)
Pmax	=Maximum pressure (Pa**)**
ω	=Angular velocity journal (rad/sec)

FUTURE SCOPE

Recent trends in tribology show that the thermo-physical and chemical properties of the Bio-lubricant like Jatropha oil can be enhanced by modifying its composition or by altering its Tribological properties for enhancing the performance of Biolubricant.

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