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Simulation of Wear Characteristics of Cylinder Liner -Ring Combination with Diesel and Biodiesel

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ABSTRACT

An alternative diesel fuel that is steadily gaining attention and significance is biodiesel, which is defined as the monoalkyl esters of vegetable oils and animal fats. India has vast resources of non edible seeds from which oil can be derived to develop bio-diesel, depending upon the potential and specific needs in the locality.

The desirability of developing alternative fuels and decreasing the dependency on petroleum based fuels has been discussed by many over the last few decades. However the tribological aspects of the cylinder liner/piston ring combinations with alternative fuels have not been sufficiently investigated.

This paper addresses the issue of wear characteristics of diesel engine cylinder liner- piston ring combinations under lubricating conditions with lube oil contaminated with biodiesel and diesel through a bench test facility called pin on disc machine. The advantage of this type of bench test is that many different cases can be tested in a relatively short period of time and costs only a fraction of the engine test. It is also easy to separate out the contribution of each component.

The discs were cut out of actual engine cylinder liner using wire cut EDM. Pins were made from the top piston ring. Several tests were conducted on pin on disc machine for specific wear rate and friction characteristic of cylinder liner and ring combinations with lube oil contaminated with jatropha oil methyl ester and diesel each. Frictional force was measured by strain gauges mounted on vertical sides of the cantilever arm to record the horizontal bending stresses induced in the lever. Tangential frictional force and wear are monitored with electronic sensors and recorded.

Results indicated that lube oil contaminated with Jatropha Oil Methyl Ester has lower wear, friction coefficient over diesel contaminated lube oil under similar operating conditions. Thus usage of biodiesel in long run will have a positive impact on engine life.

KEYWORDS

Cylinder Liner, Piston Ring, Friction Coefficient, Friction Force, Wear, Pin On Disc, Biodiesel, Diesel

INTRODUCTION

Energy is one of the major inputs for the economic development of any country. The world is presently confronted with the twin crisis of fossil fuel depletion and environmental degradation.
In recent years, systematic efforts were undertaken by many researchers to determine the suitability of vegetable oil and its derivatives as fuel or blend to the diesel [1-6].
So far several biodiesel fuels have been tested in CI engines. Among these Jatropha biodiesel is promising in Indian context. It is non edible and has a high calorific value and Cetane number. Water requirement for Jatropha plant is negligible and also it can grow anywhere even in rocky soil. The average jatropha plantation per hector on waste land is of the order of 2500 and the average oil yield per tree is of the order of 1kg.

LUBRICITY AND WEAR BACKGROUND

Fuels such as hydrogen, methanol etc., while having some advantages in certain situations, have considerable implications on lubricant performance. For example the use of methanol as a fuel in countries such as Brazil has been found to result in increased corrosion problems and the anti- corrosion properties of the lubricant required augmenting. Recently, the advent of ultra low sulfur diesel fuel (<15 ppm sulfur in US and <10 ppm in Europe) has raised the concern over the ability of these fuels to sufficiently lubricate diesel engine components in fuel injection system. The removal of polar oxygen and nitrogen containing compounds, which occur simultaneously with the removal of sulfur species, is the actual reason for the poor lubricity of low sulfur diesel fuels.
The lubricity of petroleum diesel fuel was at one time believed to be directly related to the viscosity of the diesel fuel. Although viscosity and fuel temperature tend to be correlated with a high lubricity diesel fuel, researchers have determined that other compounds of fuel such as polycyclic aromatic types with sulfur, oxygen and nitrogen content are responsible for the natural lubricity of diesel fuel [8]. They have also determined that the removal of oxygen and nitrogen during de-sulfurization has resulted in a diesel fuel that is low in lubricity.

Barbour, Rickard [9] reported that oxygen definitely contributes to the natural lubricity in diesel fuel, but that nitrogen is a more active lubricity agent than oxygen. They determined that diesel fuels that were high in sulfur but low in nitrogen exhibited poor lubricity. According to Mitchell [10] oxygen and nitrogen have been shown to impart natural lubricity in diesel fuel.

Keith and Conley [11] noted that special hydro-treating which was used to reduce the sulfur content of diesel fuel also lowered the lubricity of diesel fuel. Keith and Conley further theorized that the compounds (Oxygen and nitrogen) 'may be rendered ineffective as a result of severe hydrotreatment to desulfurize the fuel'.

M A Maleque et al [12] reported that in general esters are considered to show better wear and scuffing behavior than hydrocarbon based fuels. Also, esters have high affinity towards a metal surface, owing to their polar functional groups and thus form a protective layer on the surface.

The purpose of the present work is twofold. One is to study the wear and friction characteristics of liner ring combination under lubricated condition with diesel and biodiesel contaminated lube oil separately. The ring pack- liner frictional losses approximately amounts to be 35 % of total friction losses of an engine. Secondly, to see whether biodiesel can play the role of additive in mineral oil based lube oil for improving its anti-friction and anti-wear characteristics.

A pin on disc machine was employed to conduct bench tests. Bench test is gaining importance in view of vehicle testing is costly, inherently variable and time consuming. Consequently, many field problems are reproduced in simplified bench tests. These tests can provide valuable data in a timely and cost effective manner but they also need to be treated with some caution.

EXPERIMENTAL

MATERIALS

A new cylinder liner and ring pack of TV1 Kirloskar engine was procured from local dealer of Kirloskar engines. Oil from Jatropha Curcas was procured from Agrwal oil mills, Udaipur Rajastan. Methanol, catalyst & silica gel were procured from A to Z chemicals, Nagpur. Un-doped diesel was obtained from one Indian refinery for reference. Jatropha Oil Methyl Ester (JOME), 10% by volume, was premixed with commercial oil-based lubricant (SAE 20W-40) to investigate the tribological behavior of JOME. Mixing was effected using a stirrer. The 10% by volume contamination is based on the fact that the permissible maximum value of diesel fuel contamination in the lube oil is of the order of 7 % with the possibility of crankcase explosion[13]. Since the biodiesel has much higher flash point than diesel, up to 10 % contamination has been considered for the present study. Similarly, 10% (by volume) of diesel was premixed with commercial oil-based lubricant (SAE 20W-40).

BIODIESEL PREPARATION AND CHARACTERIZATION

Biodiesel from Jatropha C. was prepared in-house by single stage transesterification of the vegetable oil with methanol at 65 ^{0}C in presence of KOH as catalyst. After separation of glycerol, biodiesel was purified and washed with sprayed hot water at 70 ^{0}C and then dried using silica gel. Characterization of diesel and biodiesel was carried out as per ASTM standards. Table 1 indicates different properties of biodiesel and diesel fuel.

PREPARATION OF LINER DISC AND PISTON PIN SAMPLES FOR PIN ON DISC MACHINE

Since the experiments were designed for simulating the wear behavior of cylinder /ring tribological systems of real engines, the discs were made of real cylinder material. Precise discs were obtained from a new cylinder liner using wire cut electrical discharge machine (EDM). The top piston ring segment in the form of pin was fitted in a pin groove of pin holder in the slotted region and was made fixed using metal binder. The liner disc and top ring pin were cleaned using acetone and compressed air before and after the test for accurate weight measurement. Fig. 1 shows the cut disc surface grounded and mounted in disc holder along with pin.

PIN ON DISC TYPE WEAR AND FRICTION MONITOR TEST DESCRIPTION (ASTM G -99)

To establish the wear characteristics of cylinder liner piston ring of CI engine using diesel and biodiesel contaminated lube oil, wear and friction monitor test rig was used. The wear and friction monitor is a pin on disc type machine with facilities to monitor wear & friction in sliding contacts under dry and lubricated conditions. Sliding occurs between a stationary pin and a rotating disc. The principle of sliding was a cantilever loaded pin in the form of piston ring segment against a horizontal rotating cylinder liner disc, superimposed and bolted in oil bath. Normal load, rotational speed and wear track diameter can be varied to suit the test conditions. Fig. 2 shows the schematic diagram of the experimental set up. The operating conditions for wear and friction monitor test were set as indicated in Table 2. Separate disc and pin were used for diesel and biodiesel contaminated lube oil tests. The lubricating medium (SAE 20W- 40 engine oil contaminated with 10 % diesel and 10 % biodiesel by volume) flow rate was same for the given laod, speed and other operating conditions.

<u>Cumulative weight loss</u>

The disc and pin were weighed before and after the test for determining the weight loss using a highly precise electronics balance up to an accuracy of ± 0.1 mg.

<u>Frictional force and wear</u>

Frictional force was measured by strain gauges mounted on vertical sides of the cantilever arm to record the horizontal bending stresses induced in the lever. Tangential frictional force and wear were monitored with electronic sensors and recorded. These parameters are available as function of load, speed or lubrication condition for continues monitoring.

Friction coefficient

Average value of friction coefficient between the stationary pin and rotating disc with running time (sec) and sliding distance (m) was obtained using wear and friction monitor test rig described earlier.

RESULTS AND DISCUSSION

EFFECT OF BIODIESEL CONTAMINATED LUBE OIL ON FRICTION CHARACTERISTICS OF LINER RING COMBINATION

Though the machine is wear tester, it does not completely match the characteristic of liner ring combination, good results for the lubricity in terms of friction coefficient and wear for surfaces for different lubricating fluids (diesel and biodiesel) were achieved. Variation of friction coefficient (μ) with respect to time (sec) and sliding distance (m) for experiments with diesel and biodiesel contaminated lube oil is shown in Fig. 3. The friction coefficient with biodiesel shows considerable difference than diesel however in both the cases the trend is matching. The coefficient of friction for biodiesel blending is almost 63 % lower than that for diesel blending. It clearly indicates that biodiesel reduces friction more effectively than diesel when contaminated with lube oil for given loading and temperature conditions. The rotating liner disc hardness being much lesser than that of the stationary top ring pin, the material removal between the wearing surfaces disconnects the contact between them after a certain time interval. It is earlier in case of diesel due to higher wear rate and much later in case of biodiesel. In the initial stage, the friction coefficient for both the cases observed to be high as the new surfaces are getting in touch with each other. It remains constant for a considerable span of time till the disc wear out marginally enough to disconnect the contact between disc and pin. The sudden fall in the value friction coefficient indicates this behavior. Similar trend was observed in case of wear.

EFFECT OF BIODIESEL CONTAMINATED LUBE OIL ON WEAR CHARACTERISTICS OF LINER RING COMBINATION

The weight loss of two discs, one for diesel and another is for biodiesel is measured with weighing balance with accuracy of the order of ± 0.1mg. Weight loss of the disc is only taken in to account as the hardness of the piston ring is much higher i.e. 71.2 H_{RC} than that of the cylinder liner i.e. 89 H_{RB}. In order to be very precise, the repeatability of the readings was kept for five times. It is to be noted that the disc samples must be cleaned thoroughly with compressed air and acetone and must be made complete dry to avoid errors while measuring their weights. Fig. 4 shows the variation of wear (μm) for experiments with diesel and biodiesel contaminated lube oil with respect to time (sec) and sliding distance (m). It is observed that the value of wear (μm) for biodiesel is 55 % lower than that of diesel under similar operating conditions. This can be attributed to the fact that the presence of oxygenated moieties in JOME, with the presence of double bonds leads to an additional improvement in the overall lubricity. In case of Jatropha oil methyl ester contaminated lube oil, the film formed between the stationary pin and rotating disc surface may compose of esters, monoglycerides and diglycerides that have a high affinity towards a metal surface, owing to their polar functional groups and thus form a protective layer on the surface. The same may not be available in case of low sulfur diesel due to hydrotreating process which was used to reduced the sulfur content which in turn simultaneously remove the polar compounds of oxygen and nitrogen that imparts lubricity. Thus, the neat fatty compounds of methyl ester (biodiesel) possesses low friction coefficient and wear hence improved lubricity.

CONCLUSION

The results obtained have shown that the actual contamination of biodiesel fuel in lube oil reduces the coefficient of friction and wear as compared to diesel contaminated lubricant. Biodiesel as a lubricating fluid shown lower cumulative weight loss and hence lower wear than diesel for moving components of pin and disc machine. The reduction in friction coefficient, wear of biodiesel over diesel indicates that biodiesel has excellent lubricity over diesel. From physical observations on wear surfaces of specimens it can be suggested that JOME acts as an anti-wear lubricant additive and friction modifier. However the exact amount (% vol) needs to be optimized in view of its thermal degradation behavior. Also, the existing form of the JOME needs to improve by suitable anti-oxidants. The present study of has showed that wear scar surfaces in the biodiesel contaminated lube oil test appear to be much smoother thus having less material removal. JOME, apart from an alternative fuel is an additive in the lube oil and has a positive impact on engine life.

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Table 1
Various properties of biodiesel and diesel fuel

Properties	ASTM Test No	JOME Biodiesel	Diesel Oil
Density (kg/m^3)	-	878	840
Viscosity (40 ^{0}C) (cSt)	D445	4.25	2.67
Flash point (^{0}C)	D93	164	47.5
Fire point (^{0}C)	-	182	51.0
Pour point (^{0}C)	ASTM D-97	-7	-9
Cloud point (^{0}C)	ASTM D-2500	7	-
Calorific value (kJ/kg)	-	38400	42390

Table 2
The experimental test conditions were as under

S. No.	Parameters	Value
1	Normal load (N)	50
2	Temperature (^{0}C)	120
3	RPM	300
4	Track length (mm)	10
5	Lubricating medium flow rate (gm/min) (Lube oil contaminated with diesel and biodiesel each)	18
6	Total test duration for diesel and biodiesel each (Hrs)	02
7	Disc –(cylinder liner) hardness on B scale ($H_{RB)}$)	89
8	Pin (piston ring) hardness on C scale (H_{RC})	71.2
09	Pin diameter (piston ring width) (mm)	03
10	Sliding velocity (m/s)	0.314

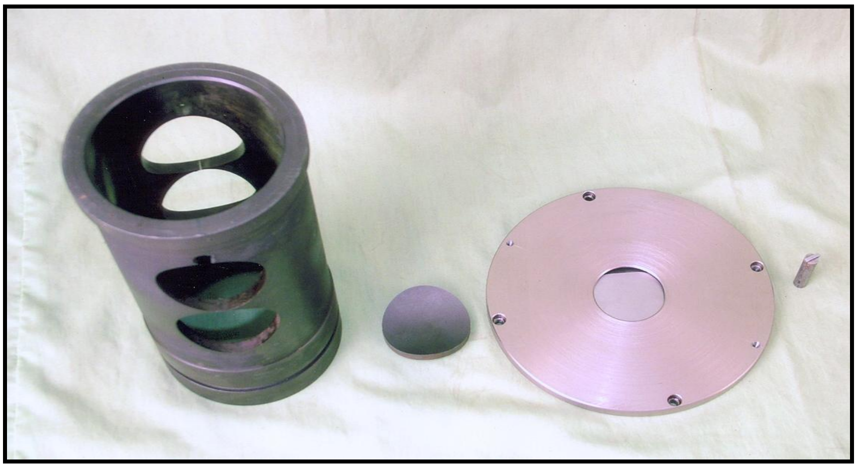

Fig. 1. The cylinder, cut disc, disc in disc holder and pin in pin holder

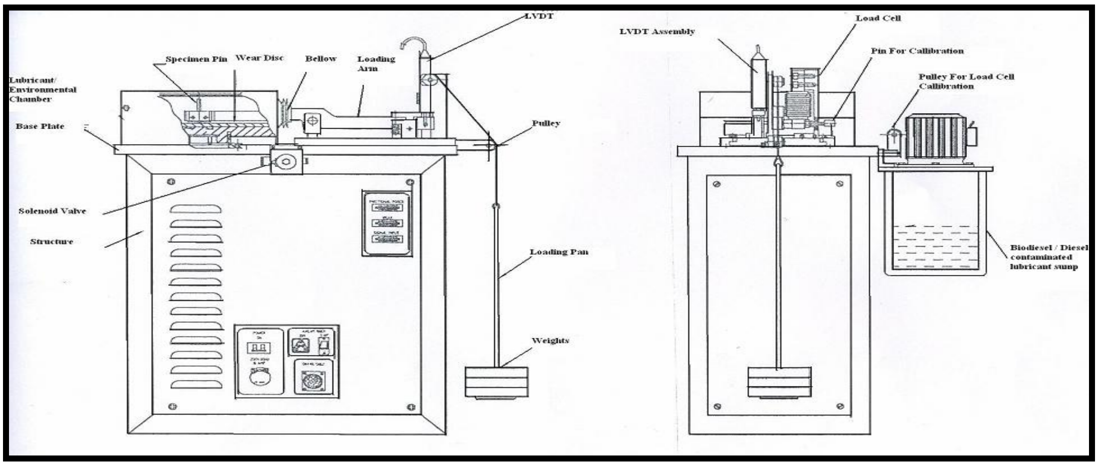

Fig. 2. Schematic diagram of pin on disc machine

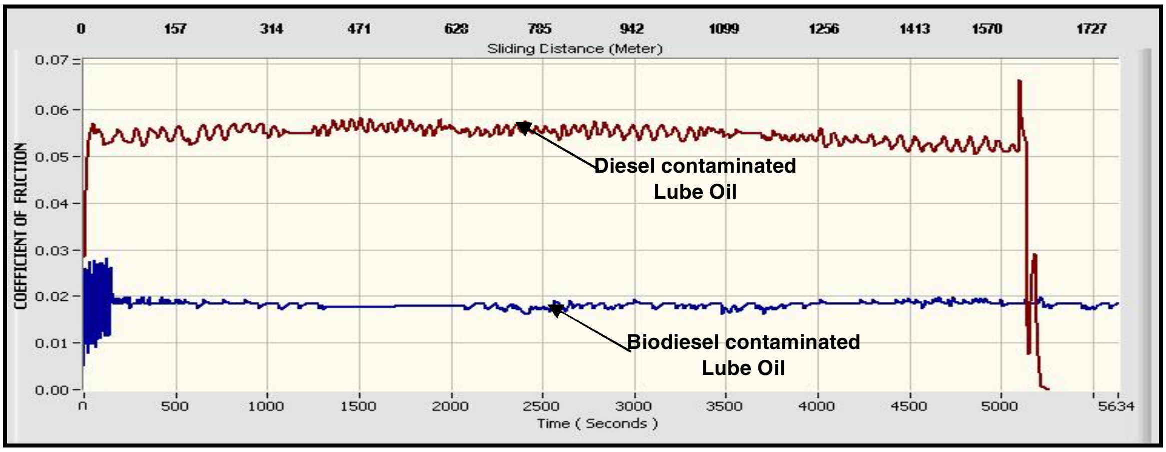

Fig. 3. Variation of coefficient of friction for liner ring combinations with diesel and biodiesel contaminated lube oil

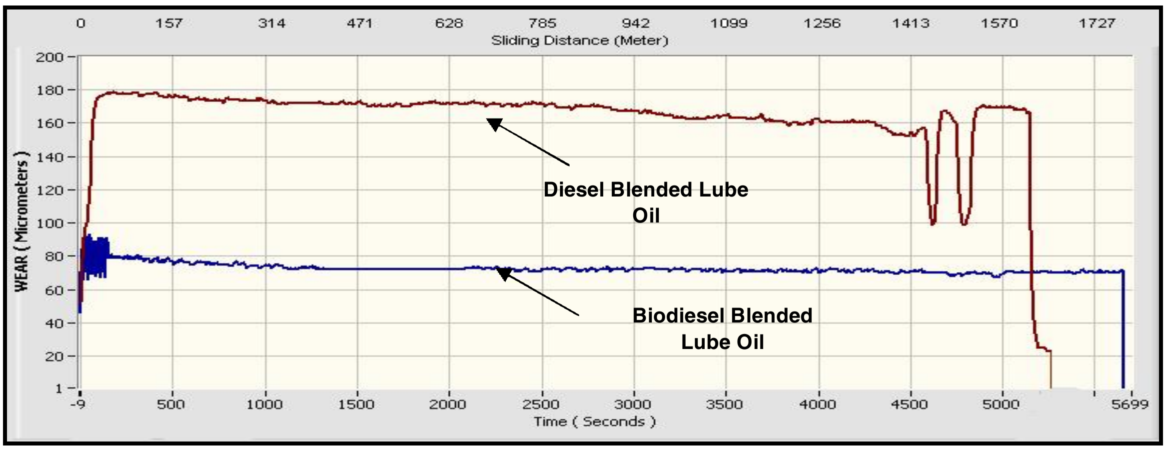

Fig. 4. Variation of wear for liner ring combinations with diesel and biodiesel contaminated lube oil