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Full Length Article

Effect of bio-lubricant on wear characteristics of cylinder liner-piston ring and cam-tappet combination in simulated environment

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ABSTRACT

The present investigation focuses on need of bio-based lubricants which are biodegradable and environmental-friendly along with improved oxidative stability. The global demand for lubricants is expected to increase as the demand for engine oil for new motor vehicle increases with the increase in number of vehicles. The depleting nature of mineral oils and its adverse impacts on environment has raised the attention of scientists towards the utilisation of renewable bio-based lubricants. The increased environmental awareness is a primary driving force for the new technological developments. In the present study, waste cooking oil (WCO) biodiesel is used as a feedstock for blending with lubricating oil as it is the economical source for the production of biodiesel. WCO was chemically modified by transesterification process. The effect of friction and wear behaviour on performance of cylinder liner-piston and cam-tappet in valve train under lubricating condition has been studied using high frequency reciprocating test rig (HFRR) and pin on disc tester (POD). In addition, the investigations of lubricant variants after the test were also carried out with analytical ferrography to analyse the wear debris in the lubricants. The 10% blending of SAE20W40 with WCO biodiesel exhibits improved results in terms of coefficient of friction and wear scar diameter (WSD).

1. Introduction

The increase in the demand of crude oil along with its adverse effect on human health and pressure of the international appeals like ‘Kyoto agreement’ to diminish the greenhouse gases emissions (GHGs) have led the research interest towards biogenic fluids. The depleting nature of fossil fuels and its bad impacts on environment is also a concern. Globally various activities have been done to increase the usage of environmental friendly fuels to decrease the dependency on fossil fuels in the automotive sector. Development in technical advancement like exhaust gas recirculation, environment friendly alternate fuels, controlled burning techniques, etc. are some feasible ways to minimize the adverse impact of vehicles pollution on environment. In this regard, biodiesel seems to be the probable alternative as fuel to overcome these problems due to its suitability and similarity in properties as diesel fuel. Therefore, the research is concentrated on various feedstocks (edible/non-edible) along with its methyl esters (biodiesel) as a potential source of transportation fuel [1–3]. In general, biodiesel is clean burning mono-alkyl esters based oxygenated fuel derived from long chain fatty acids edible and non-edible oil, animal fat, micro-algae, etc. [4,5].

Lubricants are commonly produced from petroleum fuels [6]. The global demand for lubricants is expected to increase at the rate of 2.0% per year to reach 45.40 million metric tons by 2020 due to the usage of 600 million automobiles by 7 billion populations in the world [7,8,35]. Moreover, about half of the used lubricants (5 million tonnes) is not appropriately disposed off in Europe and hence, adversely affect the environment through evaporation. Both the terrestrial and aquatic ecosystems have been degraded due to the disposal rate of used lubricant [9]. The combustion of lubricants also leads to the emission of metal traces like iron particles, zinc, magnesium etc. [10]. So, it is imperative to find alternates which are renewable and eco-friendly for the lubricant production. Progress in developing sustainable green chemistry innovative products draws the attention of researchers towards the use of plant oil for lubrication purposes also. It is preferable to use these oils instead of fossil fuel based lubricants due to its numerous advantages like low environmental pollution, existence of a CO_2 cycle in burning period, easy additive combinations, biodegradability (95% higher as compared to mineral oil), high lubricity, availability, low sulphur contents, low aromatic compounds, low toxicity, high flash points, etc. [11–14]. In spite of this, they also have better lubricity and higher viscosity because of the presence of esters. The disposal rate of plant oils is 25–35% faster than petroleum based lubricants which leads to lower cost of disposal [15,16]. Plant oils have the environmental and economic advantages. After some appropriate chemical modification

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Nomenclature

HFRR	high frequency reciprocating monitor
POD	pin on disc tester
SWR	specific wear rate
TAN	total Acid Number
GHG	greenhouse gas emissions
ZDDP	zinc dialkyldithiophosphates
WCO	waste cooking oil
WSD	wear scar diameter

Plant oils are used for various industrial purposes like lubricants, fuel for compression-ignition engine, etc. The excellent lubricity of oil makes their derivatives as base stock for lubricants and efficient fluids. In boundary and hydrodynamic lubrication region application of vegetable oils as lubricants is adorned with their chemical structure with long chained fatty acid [17]. Moreover, low oxidative stability and higher melting points have been recognised for vegetable oils [18]. Transesterification is the most crucial and cheapest method to enhance the viscosity index and thermo oxidative stability [19].

The consumption of cooking oil increases per year throughout the world and its disposal to the environment create problems due to their uneven disposal ways. Some countries prescribed policies to chasten for the disposal of waste oil inside the water drainage because of its adverse effect on environment [21,22]. The best approach to exploit the WCO is to convert it in biodiesel.

There are different lab tests have been done for the investigation of bio-based lubricants effect on wear and friction on the contact surfaces. Mobarak et al. [20] had nicely reviewed promiscuous studies on bio-based lubricants. The researchers have found out that bio-based lubricants have provided better surface as compared to other petroleum based lubricants. They also stated that bio-based lubricants can be the most promising feedstock for replacing fossil fuel based lubricants as these lubricants are environment friendly, efficient etc. Due to the improved results with bio-lubricant, they become more popular. Some aspects with bio-based lubricants like reactivity of hydrocarbon chain, oxidative stability, its corrosive nature, etc. are crucial and hence, necessary to study.

A lot of work has been done by researchers on the use of bio-lubricants for diesel engines. But there is very less literature available on tribological aspects associated with waste cooking oil (WCO) biodiesel. The distinctive objective of the present investigation is to emphasize on the perspective of WCO in the automotive sector. The probable feasibility of this bio-based lubricant contributes to the limitations made by government bodies like environmental protection organizations, etc. towards the use of biogenic fluids in place of mineral oils.

The aim of the present study is to indicate the effect of WCO biodiesel blending with lubricant (SAE20W40) on the tribological performance of cylinder liner-piston ring and cam-tappet in valve train combination by using HFRR and POD. Lubricant helps in reducing wear and friction between the cylinder liner-piston ring and cam-tappet in valve train and increase the engine life. The total acid number (TAN) and ferrography tests were also conducted for testing the degradability of oil and to check wear debris in the used lubricating oil after the test.

2. Materials and methods

2.1. Experimental setup

Lubricity is assessed in terms of friction coefficient between disc and ball with lubricating conditions by means of reciprocating friction monitor or HFRR (Ducom made, 536B) which is connected with the controlled data acquisition system. This equipment is mainly used to study the friction coefficient, frictional force, specific wear or wear resistance of the tested materials with different type lube oils, stroke length, temperature, applied load, frequency etc. The disc is fixed in the groove provided inside the machine and the ball is reciprocated on the disk. The stroke of the top specimen is controlled by the angle of oscillation of servomotor according to the value set in the computer. The load is applied on the top specimen. The schematic diagram of reciprocating friction monitor test setup is shown in Fig. 1.

Similarly, POD wear and friction monitor tester (Ducom made, TR-20LE) is also connected with the controlled data acquisition system. This is also used to study the friction coefficient, frictional force, specific wear, etc. of the tested materials with different operating conditions. The disc is rotated about the disk centre with the help of DC-servomotor and speed is controlled by the controller as per the value set in the computer. The tangential force on the pin is measured with the load cell. The schematic diagram of POD test setup is shown in Fig. 2. The specifications of POD tester and HFRR are given in Table 1.

2.2. Lubricants used

WCO biodiesel and SAE 20 W40 blends are used in ratio of 0:10 (LUBE1), 1:9 (LUBE2), 2:8 (LUBE3) and 3:7 (LUBE4) by volume. WCO was collected from the canteen at National Institute of Technology, Hamirpur (Himachal Pradesh), India. In the first step, suspended particles are removed and it is cleaned with water. Then, this filtered oil was heated for 60 min to remove the water contents. To remove the sediments, the WCO was heated at 95 °C for 60 min with 3% of ortho-phosphoric acid. The most frequently used chemical reaction transesterification is used for the production of WCO biodiesel. KOH and H_2SO_4 were used as a catalyst in 0.75% by weight of oil and oil is used in a molar ratio of 1:6 with methanol. The oil and methanol mixture is heated in the presence of a catalyst for about 90 min on a magnetic stirrer with a hot plate at 600 rpm stirring speed. The final product is then allowed to settle for 24 h in separating funnel. Then, this mixture was separated, neutralized and distilled. For removing excess alcohol and catalyst, the separated biodiesel was washed with hot water and acetic acid added. By taking the above stated conditions, the yield of WCO biodiesel was approximately 85%. The properties of the feedstocks are shown in Table 2.

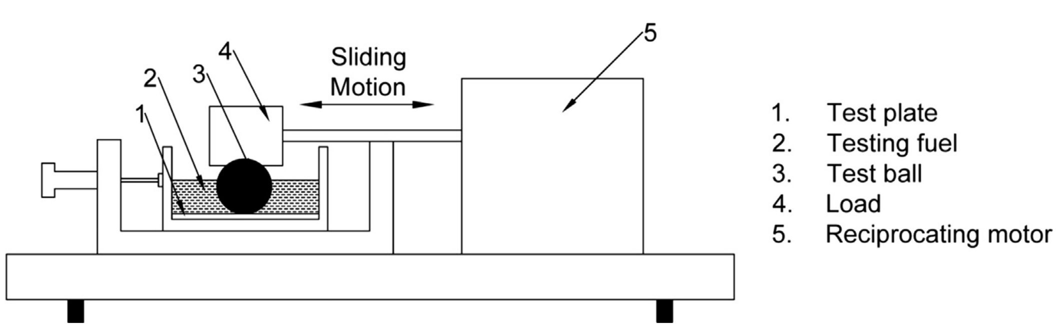

Fig. 1. Schematic diagram of high frequency reciprocating rig.