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# Effects of biodiesel blends on lubricating oil degradation and piston assembly energy losses

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Fuel is considered a major influencing parameter for engine oil condition during extended engine operation. Its effects on engine oil performance is required to be investigated with the implementation of the worldwide biodiesel mandate in various countries. This research monitored the influence of biodiesel on the condition of engine lube oil by long duration testing on three fuels: DF as the baseline; 20% palm biodiesel and 80% DF (PB20); and 20% jatropha biodiesel and 80% DF (JB20). The tests were carried out on a single-cylinder CI engine. Sump oil samples were collected at regular intervals during 200-h tests, after which the rheological, tribological, and chemical properties of the samples were investigated. Results showed that the B20 fuels decreased the viscosity and increased the acidity of the engine oil. Piston ring-cylinder and piston skirt-cylinder tests, in which a high-stroke reciprocating test rig was used, showed a slight increase in friction and wear losses near the intervals of oil draining for the B20 fuels. Chemical analysis by Fourier transform infrared spectroscopy and ASTM standard testing showed a decrease in soot loading but an increase in the fuel residue, corrosiveness, and oxidation of the engine oil samples for B20 fuelled engine tests.



## 1. Introduction

Amidst concerns over energy security, environmental legislation, and increasing costs of fossil fuels, many countries are taking action to promote the use of biodiesel [1]. The implementation of the biofuel mandate in different countries has reduced dependence on fossil fuels, mitigated climate change, and created demand for domestic feedstocks as energy sources. Around the world, 419.2 thousand barrels of biodiesel are being consumed each day. The two largest biodiesel consumers are the European Union and the United States, accounting for 218.4 and 60 thousand barrels per day, respectively [2]. The sharply growing global trend of biodiesel consumption is illustrated in Fig. 1.

Biodiesel is composed of fatty acid methyl esters (FAME), synthesized by the transesterification of crude vegetable oils and animal oil/fats. Common biodiesel feedstocks include corn and soy oil (US), rapeseed oil (Europe), and palm and jatropha oil (Southeast Asia). The physicochemical properties of biodiesel depend on feedstock and reaction kinetics, and its characteristics significantly differ from those of petroleum diesel. These features raise concerns over the effects of biodiesel on the lubricity and quality of engine oil. Related risks include excessive fuel residue, increased acidity, oxidation, soot loading, corrosiveness, and increased wear loss [3–5]. Diesel fuel (DF) can accumulate in lubricating oil, particularly in vehicles equipped with diesel particulate filters (DPFs). Biodiesel accumulates to a greater extent than diesel fuel because of its high boiling temperature; this accumulation means that biodiesel can remain in an engine oil sump for long periods [1]. Additionally, the esters in FAME are hydrolyzed, thus resulting in high concentrations of weak acids in lubricants [4]. Such phenomena decrease oil drain intervals and promote engine wear and corrosion. High rate of lubricant degradation accounts for a major proportion of the million tons of

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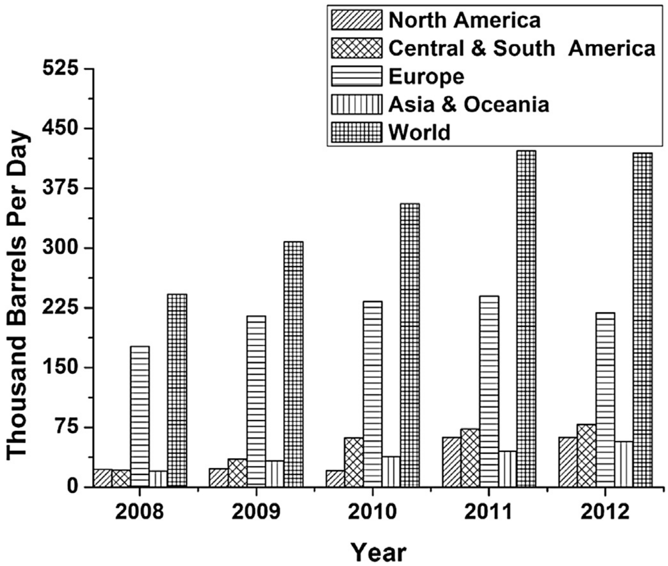


**Fig. 1.** Trend of regional yearly biodiesel consumption [2].

annually produced oil wastes, which are hazardous and non-biodegradable [6]. Given that different studies highlight the effects of biodiesel on engine oil performance, automobile companies have cautiously recommended the use of biodiesel blends, allowing a maximum of 20% biodiesel (B20) to be blended with fuels for certain vehicles [1]. The ACEA European specifications for diesel engine oils require the implementation of OM646LA [7] and OM501LA [8] engine tests to ascertain the ability of biodiesel to preserve the performance of lubricating oil. Few studies have been devoted to the impact of biodiesel on lubricating oil performance under extended engine operation. Previous investigations involved endurance engine testing, in which degraded oil samples were collected, and DF, ultra-low-sulfur diesel (ULSD), and a few biodiesel feedstocks were analyzed. The extensively used feedstocks in previous research include rapeseed, soybean, and linseed biodiesels [1,9–12]. The general conclusions presented in the literature are consistent with one other; specifically, these indicate that high biodiesel blends increase fuel residue [13], accelerate engine oil degradation [4,14], and increase corrosion [4,14]. These key findings underscore the need to reduce the oil drain intervals for vehicles running on blends that comprise a biodiesel content of more than 5% (B5). No significant difference in soot loading and engine wear has been found between vehicles using ULSD and specific biodiesels [1,4,15].

One of the major factors that drive variations in engine oil condition is the change in biodiesel feedstocks. With the emergence of a variety of feedstocks for biodiesel production, the influence of biodiesel fuel manufactured from these raw materials requires investigation, specifically in relation to engine oil performance under extended engine operation. This study aspires to fill this need by conducting 200 h of engine tests on two biodiesel blends: 20% palm biodiesel and 80% DF (PB20) and 20% jatropha biodiesel and 80% DF (JB20). The tests were carried out on a single-cylinder diesel engine. For comparison, engine test was also performed on the DF under the same testing conditions as those applied in the tests on the B20 fuels. For each test, several engine oil samples were collected to analyze oil degradation. Oil analysis comprised three stages: (1) rheological analysis of oil physical characteristics by ASTM standard testing; (2) chemical analysis by Fourier transform infrared (FTIR) spectroscopy and ASTM standard testing; and (3) tribological analysis for the laboratory-based friction and wear testing of the piston ring–cylinder and piston skirt–cylinder interactions.

## 2. Materials and methods

A naturally aspirated, single-cylinder diesel engine was used in the experiments. The engine specifications for relevant parameters are given in Table 1. Engine testing was performed on three different fuels which include diesel fuel (DF), 20% palm biodiesel and 80% DF (PB20); and 20% jatropha biodiesel and 80% DF (JB20). For the DF and B20 fuels, the necessary fuel properties were measured on the basis of ASTM standards (Table 2). A fully formulated lubricant, 15W40, which conforms to API specification CJ-4, was employed in the endurance tests. Table 3 provides the technical specifications of the engine oil used in this study.

### 2.1. Engine oil sampling

To evaluate the effects of each of the fuels on lubricant degradation, the single-cylinder diesel engine was tested at 10-Nm loading for 200 h. The engine was coupled to an eddy current dynamometer and data acquisition system. The schematic of the experimental setup is shown in Fig. 2. The Dynomax 2000 software was used to operate the engine at the required test conditions. Engine maintenance was conducted and oil samples were collected at regular intervals of 40 h. At each interval, the minimum volume required for the oil analysis was extracted to reduce the amount of fresh makeup oil for maintaining the oil level.

### 2.2. Rheological analysis

In the rheological analysis, engine oil viscosity, density, and acidity were examined by adopting ASTM standard testing procedures. The kinematic viscosity and density was measured using ASTM D7042 standard. In this study, calorimetric titration was used to examine the TAN characteristics of new and degraded oil samples, in accordance with the ASTM D664 standard. An alcoholic solution of KOH was used to neutralize 2 g of each sample oil and the TAN values are reported in mgKOH/g of oil.

### 2.3. Chemical analysis

For chemical analysis of oil samples, FTIR spectroscopy was used to investigate the fuel residue, oxidation, and soot loading while corrosion resistance was analyzed using ASTM standard testing.

#### 2.3.1. FTIR spectroscopy

The lubricant samples were analyzed by FTIR spectroscopy for fuel residue, oxidation, and soot loading. These parameters were evaluated with a PerkinElmer Spectrum 400 FTIR spectroscopy instrument with a data acquisition system. A background

**Table 1**
Relevant engine specifications.

| Parameter | Specification |
|---|---|
| Model | YANMAR TF 120-M |
| Configuration | Single cylinder |
| Air aspiration | Naturally aspirated |
| Maximum power | 7.7 kW |
| Maximum speed | 2400 rpm |
| Fuel injection | Mechanical direct injection |
| Displacement | 0.638 L |
| Oil capacity | 2.8 L |
| Oil change interval | 200 h |