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Comparative characteristics of compression ignited engines operating on biodiesel produced from waste vegetable oil

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ABSTRACT

Performance and emission characteristics of two compression ignited engines of different compression ratios, number of cylinders, cooling system, and power output are studied. Waste vegetable oil-derived biofuel is used. Engines are fueled with B0, B20 and B100 mixtures. Thermal efficiency, brake specific consumption and engine emissions (CO, Unburned HC, O_2 and NO) are reported and comparisons are made for fuel mixtures running on both engines. Trends of emissions and performance curves are compared to the literature of the available data. It is noted that the biofuel certainly affects unburned HC emissions regardless of engine specifications and/or operating conditions. However, the type of fuel or adding biofuel to diesel may not affect parameters such as exhaust gas temperature and emissions (CO, Unburned HC, O_2, NO). These parameters may change as functions of engine specifications and operating conditions regardless of biofuel or diesel being used. These findings are supported by separate investigations using different biofuels in literature.

1. Introduction

Biodiesel fuels of different origins have become new energy sources and important alternatives in recent years. Investigations and scientific reports have tremendously increased due to demand in alternative fuels. Studies usually focus on biodiesel production methods, its performance and emission characteristics in combustion engines and characteristics of its blends with other fuels. Extensive reviews of biodiesel production [1–6] and its performance characteristics and characterizations [7–9] are reported in the literature.

In spite of extensive work in the literature, there is still research focusing on production, performance and emission characteristics of biofuels. This is partially because biofuels might have different properties and resulting characteristics because of conditions of making these as well as changing parameters under which these fuels are used such as adjusting or modifying engine conditions.

Although biofuels are alternative energy sources, their cost could get high based on the sources or oils they are made of. Biofuels derived from vegetable oils could be expensive and not cost-effective as compared to petroleum-based diesel currently. Due to that, waste vegetable oil shows a promising alternative to unused vegetable oils to make biodiesel. In addition, waste vegetable oils are usually thrown in home and restaurant drains that cause environmental problems in large scale [10]. Therefore, the use of waste vegetable oils instead of neat vegetable oils is a cost-effective way while reducing environmental problems due to waste-oil disposal. Detailed review of technical aspects of biodiesel made of cooking oil is reported in the literature [11,12].

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The previous work in the literature regarding emissions and performance of waste vegetable oil-derived biofuel includes its use in a single engine or furnace while focusing on only emissions or other performance aspects [13–17].

The work reported herein uses waste vegetable oil-derived biofuel and its blends with conventional Diesel No. 2. Biodiesel was prepared based on ASTM D6751-10 and it met the standard specification. Effects of biofuel-diesel mixing on the emissions and performances of two 4-cycle and direct injection diesel engines of different compression ratio, number of cylinders, rated power and engine cooling are investigated for B0, B20 and B100 fuels at different loads between no-load and full-load conditions. Furthermore, trends of engine emissions and performance curves are compared to literature data available under different engines and/or operating conditions. It is concluded that unburned HC emissions are affected by both biofuel, engine specifications and operating conditions. Exhaust gas temperature, CO, O_2 and NO emissions are not significantly affected by adding biofuels but engine specifications and operating conditions have profound effects on emissions and performance characteristics.

2. Measurements of physical properties

2.1. Viscosity

A Koehler KV3000 Digital Constant Temperature Kinematic Viscosity Bath was used. It is electrically heated and temperature is controlled by means of a digital PID process controller. Calibrated Cannon-Fenske glass capillary viscometers are used to measure to fuel viscosities based on ASTM D446-07 standard procedure. The kinematic viscosity was determined by multiplying the elapsed time and the viscometer constant provided by the manufacturer. Table 1 shows viscosities of standard diesel and biofuel blends at 25 °C.

As expected and seen in Table 1, diesel fuel lubrication characteristics is slightly different from biofuels but the difference grows as the mixing ratio of diesel-biofuel goes to zero (B100).

2.2. Density

ASTM metric thermo hydrometers conforming to the specifications of ASTM E100 are used. ASTM D287 standard procedure is used to measure densities of fuels. Values are reported in Table 2. As seen in the table, diesel fuel has a lower density than neat biofuel.

Table 1 – Viscosity of biofuel-diesel blends at 25 °C and waste vegetable oil at two temperature values.

Fuel	Viscosity (mPa s)
B0 (Standard Diesel No. 2)	3.168555
B20	3.88231
B40	4.379905
B80	6.080945
B100	9.636337

Table 2 – Fuel densities measured using precision hydrometers at 25 °C.

Fuel	Density (kg m^{-3})
Standard Diesel No. 2	815
Waste Vegetable Oil-Derived Biofuel	876

2.3. Surface tension

Although surface tension was not measured for diesel or biofuel, it is reported in the literature [18] that the variation of surface tension for biodiesel fuels is 5% average. Therefore, it has little influence on atomization characteristics based on the type of biofuel used. However, the viscosities of biodiesel fuels may vary as much as 100% according to the comparison of 15 biofuels. Thus, viscosity measurements were necessary and reported above.

2.4. Heating value

The Calorimeter is furnished with oxygen filling connection, six fuel capsules, digital thermometer, fuse wire and support stands for the bomb head and calorimeter cover. The ignition unit provides low voltage electrical current to fire the oxygen bomb.

The measurements are done based on ASTM D240 standard test method. Results are shown in Table 3 for standard diesel and biofuel. Heating value of diesel fuel is slightly higher than biofuel.

3. Engine performance and emissions

3.1. Engine specifications and test procedure

Two four-cycle, direct injection diesel engine generators were used for engine tests. Table 4 shows specifications of the engines.

Commercially available diesel fuel (Valero Diesel #2) was tested as a baseline fuel, denoted as blend B0. Biodiesel fuel derived from waste vegetable oil prepared using the common transesterification process was tested as a straight fuel, denoted as B100. Blends were prepared by mixing appropriate volumes of the aforementioned diesel and biodiesel fuels which were subsequently tested.

The test engines included a Yanmar YDG-5500 generator with an L100 air-cooled single-cylinder engine, and a Kubota GL-7000 generator with a Z482 liquid-cooled two-cylinder engine. A sequence of loads was applied to the engines by using two Holmes 1000/1500 W electric heaters, and one

Table 3 – Heating values of standard diesel, waste vegetable oil and biofuel.

Fuel	Heating Value (MJ kg^{-1})
Standard Diesel No. 2	44.8
Waste Vegetable Oil-Derived Biodiesel	40.3