Performance and Emission Analysis of Direct Injection Diesel Engine Fuelled with Waste Cooking Oil Biodiesel-Diesel Blends

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ABSTRACT

Biodiesel is an alternative fuel that can be derived from renewable sources. It is a oxygenated, non-toxic, biodegradable and renewable that can be used in unmodified diesel engine. High cost of raw material is the main obstacle to biodiesel production. Waste cooking oil (WCO) may be a low cost feedstock for biodiesel production. In this study, the engine performance and emission of a diesel engine using three different biodiesel diesel blends were studied and compared with petroleum diesel. The test result shows that there is a slight decrease in brake thermal efficiency and increase in specific fuel consumption for all the blended fuels when compared to that of diesel fuel. The reduction in carbon monoxide, unburned hydrocarbon and slight increase in oxides of nitrogen emission were observed for all the blended fuels when compared to diesel fuel. Waste cooking oil methyl esters and its blends with diesel fuel can be used as an alternative fuel for diesel in direct injection diesel engines without any significant engine modification.

Keywords: ***Waste cooking oil, biodiesel, performance, emission,***

1. INTRODUCTION

Diesel engines are the most efficient prime movers widely used in transportation, agriculture and industry. Biodiesel is an alternative fuel that can be derived from vegetable oils, animal fats and used waste cooking oil including triglycerides, Suresh Kumar *et al.* [1]. Biodiesels can be used as fuel at varying concentrations with petroleum based diesel with little or no modification in existing diesel engines, Sanjib and Anju [2], Heywood [3]. It is produced from raw vegetable oil by a chemical process, which removes glycerol from the oil. However, a major barrier in the commercialization of biodiesel production from vegetable oil is its high manufacturing cost, which is due to the higher cost of virgin vegetable oil. Waste cooking oil, which is much less expensive than pure vegetable oil, is a promising alternative to vegetable oil for biodiesel production.

Restaurant waste oils and rendered animal fats are less expensive than food-grade canola and soybean oil, Canackci and Gerpen [4].The quantity of waste cooking oil generated per year by any country is huge. The disposal of waste cooking oil is problematic, because disposal methods may contaminate environmental water, Kulkarni and Dalai [5].The production of biodiesel from waste cooking oil is one of the better ways to utilize it efficiently and economically. Waste cooking oils and animal fats are attractive feed stocks for biodiesel production because they are two or three times cheaper than refined vegetable oils and are available in abundantly to fulfil the market demand for biodiesel production Chattha *et al.* [6].Properties of biodiesel such as oxygen content, cetane number, viscosity, density and heat value are greatly dependent on the sources (soybean, rapeseed or animal fats) of biodiesel, USEPA [7], Wu *et al.* [8]. Many investigations have shown that using biodiesel in diesel engines can reduce hydrocarbon (HC), carbon monoxide (CO) and particulate matter (PM) emissions, but nitrogen oxides (NOx) emission may increase, Nagaraj and Prabhu Kumar [9], Banapurmatha *et al.* [10], Ulusoy *et al.* [11]. The oxygen content of biodiesel is an important factor in the NOx formation, because it increases combustion temperature to maximum level due to excess hydrocarbon oxidation and increase NO_x formation, Raheman and Ghadge [12], Fernando *et al.* [13]. This paper aims to investigate the engine performances (brake thermal efficiency, fuel consumption) and emissions (unburned hydrocarbon, carbon monoxide and nitrogen oxides) of a diesel engine using three different biodiesels diesel blends and compared to that of petroleum diesel.

2. MATERIALS AND METHOD

2.1. TEST FUEL

Biodiesel produced from waste cooking oil (WCO) was used in the present investigation. Waste cooking oil was collected from the local restaurants and Waste cooking oil methyl ester was produce by single step transesterification process to reduce viscosity of the oil. Waste cooking oil was filtered using 15 μm filter to remove solid impurities. 10 gm KOH (acted as catalyst) was fully dissolved in 200 ml methanol. 1 litre of WCO was heated and the mixture of KOH and methanol was added to it at a temperature of 60^{o} C. The reaction was taking place about 1 hour and waste cooking oil methyl ester (WCOME) was produced. Biodiesel was separated from glycerol, washed three times with warm water to remove impurities and heated up to 120^{o} C to evaporated dissolve water and catalyst. Standard diesel was used as reference fuel. The properties of diesel and biodiesel were shown in the table 1. Table 2 shows the fuel blends used in the test.

Table 1 Test fuel properties.

Properties	**Diesel**	**WCOME**
Density at 40^{0}C (kg/m^3)	807.3	876.08
Specific gravity at 15.58 ^{o}C	0.825	0.893
Flash point (^{o}C)	160	53
Kinematic Viscosity at 40^{o}C (mm^2/s)	3.658	1.81
Calorific value (kJ/kg)	39767	42347
Cetane index	50.54	47

Source: Utlu and Kocak [16]

Table 2: Fuel blends used in the test

Blends	Composition
D100	100% Diesel Fuel
B10	10% Biodiesel + 90% Diesel
B20	20% Biodiesel + 80% Diesel
B30	30% Biodiesel + 70% Diesel

2.2. EXPERIMENTAL SETUP

Engine performance and exhaust emission tests were run on a commercial single cylinder, four-stroke, naturally aspirated, water-cooled direct injection compression ignition engine. The schematic view of the experimental setup is shown in figure 1. The detailed technical specifications of the engine are given in Table 3. The engine is connected to dynamometer running at a constant speed of 1500 rpm. The fuel flows to the engine directly measured from the glass burette by operating individual valves provided and three way stop cock. AVL 444 Di-gas analyzer used for measuring the exhaust gas emissions from internal combustion engines

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Table.3: Specifications of the direct injection diesel engine

Particulars	Specification
Make and model	Kirloskar, AV1
Method of cooling	Water cooled
Number of	One
Number of strokes	Four
Rated power output	3.7 kW(5HP)
Rated speed	1500 rpm
Fuel injection	Direct injection
Bore, Stroke	80 mm, 110 mm
Compression ratio	17.5:1
Fuel injection	23° Btdc
Loading device	Eddy current

2.3. TEST PROCEDURE

The fuels used in this study are standard diesel and biodiesel diesel blends. The experiments are carried out by using standard diesel as the base line fuel standard diesel (denoted as D100), 10% biodiesel + 90% diesel (denoted as B10), 20% biodiesel + 80% diesel (denoted as B20), 30% biodiesel + 70% diesel (denoted as B15). The study was carried out at different loading conditions of 20% (0.75kW), 40% (1.5kW), 60% (2.25kW), 80% (3.0kW) and 100% (3.7kW). The fuels used in this study include standard diesel, and three biodiesel-diesels blends B10, B20. B30. Before running the engine with new fuel, it is allowed to run for sufficient time to consume the remaining part of fuel from the previous experiment. The engine is started initially with standard diesel and warmed to obtain its base parameters. Then, the same tests are performed with neat biodiesel and its ethanol blends. When the engine reaches the stabilized working condition, parameters like fuel consumption and load are measured. Fuel consumption was measured with a burette (20 ml volume) and a stopwatch. The performance parameters of biodiesel diesel blends (B10, B20, and B30) were determined in comparison with baseline. Similarly exhaust emissions like carbon monoxide (CO), unburned hydrocarbon (HC), and nitrogen oxides (NOx) are measured using a non-dispersive infra-red analyzer (Make: AVL-444 Di-gas analyzer).

3. RESULTS AND DISCUSSIONS

3.1. ENGINE PERFORMANCE PARAMETER

The effects of WCO biodiesel addition with diesel on engine performance parameters such as brake thermal efficiency and specific fuel consumption for various blends at different loading conditions are studied in detail.

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3.1.1. BRAKE THERMAL EFFICIENCY

From Figure 1, it is observed that the brake thermal efficiency (BTE) is low at low load and increases with increase of load for all blends of fuel, Raheman and Phadatare,[13]. The brake thermal efficiency is high for B10 blends at high load condition when compared with other blends of fuel and is very close to diesel. The brake thermal efficiency is the lowest for B30 blends at high load condition when compared with other blends of fuel and diesel fuel. Hence at high load for the B10 blend of methyl ester, the performance of the engine is good. Diesel shows highest brake thermal efficiency which is 34.56% and B30 blends shows lowest value of brake thermal efficiency which is 31.28% at full load condition.

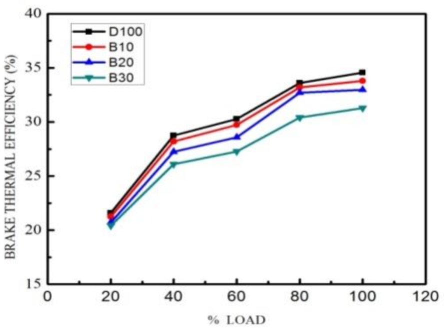

Fig. 1: Variation of BTE with % load

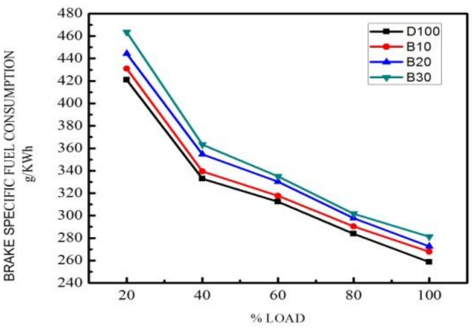

Fig. 2: Variation of BSFC with % load

3.1.2. BRAKE SPECIFIC FUEL CONSUMPTION

The Figure 2 shows that the waste cooking oil methyl ester has higher brake specific fuel consumption (BSFC) compared to diesel. This is due to the low calorific value and high density of WCOME compared with diesel fuel, Suresh *et al*. [15]. It was observed that B10 blend is having lower brake specific fuel consumption closer with diesel. However brake specific fuel consumption was higher for all the other blends. The brake specific fuel consumption decreases with the increasing loads. Diesel shows lowest brake specific fuel consumption which is 281.11 g/KWh and B30 blends shows highest value of brake specific fuel consumption which is 258.56 g/KWh at full load condition.

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3.2. EMISSION PARAMETERS

Emission characteristics are improved for biodiesel compared to conventional diesel except oxides of nitrogen, which is slightly higher than diesel. In this section the variation of CO, HC and NOx emission with percentage of load are presented.

3.2.1. CARBON MONOXIDE EMISSIONS

Figure 3 shows the variation of Carbon Monoxide Emissions (CO) with percentage of load. It is seen that CO emissions for all the biodiesel blends are lower than that of diesel. The CO emission initially decreases and drops extremely low level at 60% load; thereafter it increases rapidly with the increasing load. The CO emissions for all biodiesel blends are lower than petroleum diesel. This is due to the presence of excess oxygen in the WCO biodiesel resulting better combustion. Diesel shows highest CO emissions which is 0.383% volume and B30 blends shows lowest value of CO emissions which is 0.305% volume at full load condition.

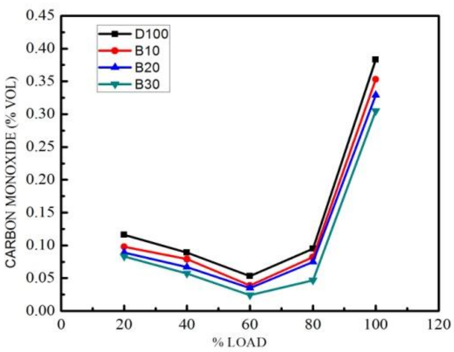

Fig. 3: Variation of CO emissions with % load

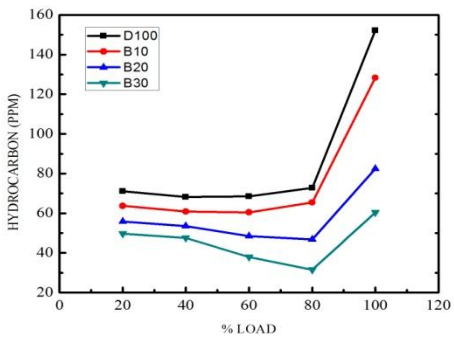

Fig. 4: Variation of HC emission with % load

3.2.2. HYDROCARBON EMISSION

Figure 4 explains that the variation of Hydrocarbon (HC) emission with load for diesel fuel, biodiesel and its blends. It is clear from Figure 6 that there is an increase in HC emissions for all test fuels as load increases. This is due to fuel- rich mixtures at higher loads. . However, at full load, diesel had the highest HC emission. With the addition of biodiesel in the blend which reduces unburned hydrocarbon considerably. This is due to presence of oxygen in biodiesel resulting better combustion. Diesel shows highest HC emission which is 152 ppm and B30 blends shows lowest value of HC emission which is 60 ppm at full load condition.

3.2.3. OXIDES OF NITROGEN EMISSION

Figure 5 shows the variation of Nitrogen oxides (NO_x) emission with load for diesel fuel, biodiesel and its blends. The NOx emission for all blends increases with load. The NO_x emission for and the blends of WCOME are slightly higher than diesel fuel for all loading conditions. Diesel shows lowest NO_x emission which is 1209 ppm and B30 blends shows highest value of NO_x emission which is 1311 ppm at full load condition.

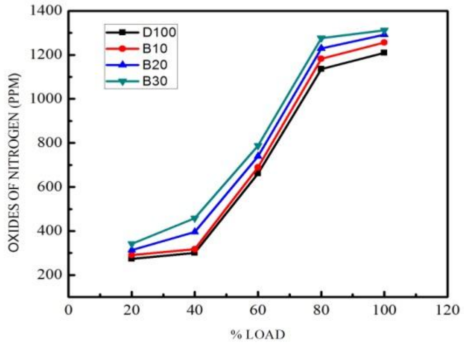

Fig. 5: Variation of NO_x emission with % load

4. CONCLUSIONS

Based on the experimental study, the conclusions are summarized as follows:

- BTE increases with an increase in engine load. For biodiesel blends the BTE are lower than that of diesel fuel. BTE of B10 blend is very close to standard diesel and BTE of B30 blend is the lowest among all tested fuel.
- The BSFC decreased with an increase in engine load. For biodiesel blends the BSFC are higher than that of diesel fuel.
- For all biodiesel blends, it is found that CO and HC emissions were lower than that of pure diesel.
- The NOx emission is higher than diesel fuel for all modes of test fuels.
- The methyl esters of waste cooking oil and its blends can be used as an alternative fuel in diesel engines without any engine modifications.

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