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Performance, emissions and combustion characteristics of a diesel engine fuelled with waste vegetable oil added with diethyl ether as an additive biodiesel at different injection pressure

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ABSTRACT

Petroleum based fuels have not only resulted in the rapid depletion of conventional energy sources but have also caused severe air pollution. As one of most promising renewable and clean alternative fuel, biodiesel has been widely studied in recent years for CI engines. This study investigates performance, emissions and combustion characteristics of a diesel engine fuelled with waste vegetable oil added with diethyl ether as an additive biodiesel. The experiments performed on a single-cylinder direct injection, 4-stroke, air cooled system running with diesel (D100) and diesel/biodiesel blends containing 10% (B10), 20% (B20) and 30%B(30) biodiesel fuels. The experiments conducted at two different injection pressures 200 & 240 bar. Brake thermal efficiency of biodiesel was greater than the diesel at various load condition. Brake thermal efficiency of B20 at 240 bar was 23.40 % higher as compared to different blends and diesel at full load condition. The results of the experiment showed that BSFC of 240bar was greater than 200bar, and the fuel consumption of the B20 at 240bar was 16.48% lower at full load condition. As per the result, CO and CO_2 emission for the biodiesel were reduced, and HC emission was higher when compared to diesel at different load conditions. NO_x emission for B10 at 200bar was 35.71% lowest as compared to diesel and biodiesel at various load condition.

1. INTRODUCTION

Depletion of fossil fuels and environmental problems like pollution have encouraged the need to find alternatives to petroleum fuels like mineral diesel, which plays a vital role in the industrial and transportation sector of every country in the world. Biomass-based fuels such as vegetable and non-vegetable oils and their derivatives are the potential solution at an international level to this major crisis. This environmentally friendly, non-toxic and reproducible resource could be produced at large scale in rural areas and could provide clean, efficient and useful energy in rural and urban sector. The carbon emissions (CO_2 and CO) which are exhausted during the combustion of these oils are the ones, which are absorbed by the plants from the atmosphere; therefore, the combustion of vegetable and non-vegetable oils or its derivatives does not increase the global balance of CO_2 and does not harm the environment. It has already proved that emissions from these fuels are far less harmful and have small greenhouse gas potential compared to petroleum fuels. Straight vegetable oils can use but on long-term usage, this leads to many operational problems in engines. Three major problems of using vegetable oils which adversely affect the performance of the engine are poor volatility, high viscosity and polyunsaturated character of vegetable oils (Agarwal AK 2007, Peterson CL 1991 & 1983, Vellguth, 1983). The high viscosity of vegetable oils causes inefficient pumping and sprays formation with large droplets. Therefore, fuel and air are not properly mixed, and combustion remains incomplete in the engine. The low volatility of vegetable oils and their ability to polymerize (due to unsaturation) causes the formation of undesirable carbon deposits in the injector coking, combustion chamber, and piston ring sticking issues. There are different studies related to engine tests of biodiesel fuel blends.

2. MATERIALS AND METHODS

Biodiesel blend preparation: The trans-esterification reaction was carried out by mixing of the diethyl ether and the KOH in a flask. The mix diethyl ether/KOH is heated to 50°C (in a water bath) and stirred by a magnet at 800 rpm (constant speed), until, the catalyst completely dissolved in the ether. 200 ml of waste vegetable oil was heated up to 60°C. The solution ether-KOH and waste vegetable oil have mixed. The container is introduced in a water bath at 50°C and stirred at 500 rpm. The reaction performed for 60 minutes. The final solution poured into a separation funnel. The top layer is the biodiesel, and the bottom darker layer is the by-product, glycerol. Removal the glycerol from the biodiesel, and measure the glycerol. The biodiesel is washed with 5 % wet H_2SO_4 (50ml) to neutralize the residue catalyst measurement of the amount of produced biodiesel.

Experimental setup and testing: The test has performed on a single-cylinder, naturally aspirated, four-stroke, and direct injection, water cooled diesel engine. The test was conducted at various loads resulting in variation of speed. The schematic diagram of the diesel engine experimental setup has been given below in Fig. 1. The detailed engine description has shown in table 1. The performance and emissions characteristics of the diesel engine running with samples of biodiesel blends have compared with pure diesel fuel. The flow rate of air has measured with Orifice and manometer. Combustion pressure and crank angle were measured using necessary instruments provided on the engine as PΘ vs PV diagrams. Smoke opacity during steady state and free acceleration mode has measured with a smoke meter (AVL 437).

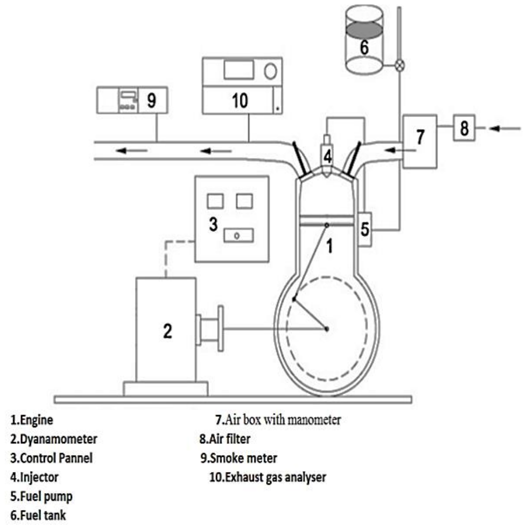


Fig.1.Schematic representation of Experimental setup and testing

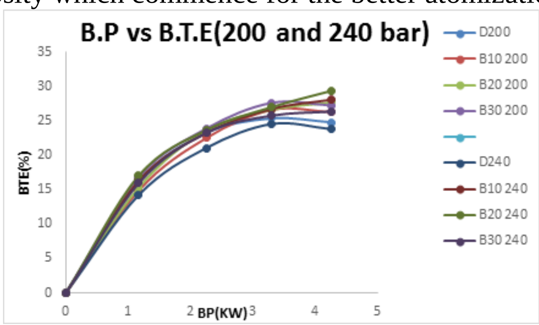
Table.1.Specification of the experimental setup

Product		Specification
Engine	Model	Make Kirloskar, Model TV1
	Type	1 cylinder
	Strokes	4 Stroke
	Cooling system	Water cooling
	Power	power 5.2 kW at 1500 rpm
	Dimension	Stroke 110 mm, bore 87.5 mm. 661 cc, CR 17.5
Dynamometer		eddy current
Data acquisition device		NI USB-6210, 16-bit, 250kS/s.
Crank angle sensor	.	Resolution 1, Speed 5500 RPM with Top Dead Center pulse.
Piezo powering unit		Make-Cuadra, Model AX-409
Piezo sensor		Range 5000 PSI, with low noise cable
Temperature sensor		PT100, and Thermocouple, K Type
Load indicator		Digital, Range 0-50 Kg, Supply 230VAC
Load sensor		Load cell, type strain gauge, range 0-50 Kg
Fuel flow transmitter		DP Transmitter, Range 0-500 mm WC
Air flow transmitter		Pressure transmitter, Range (-) 250 mm WC

3. RESULT AND DISCUSSION

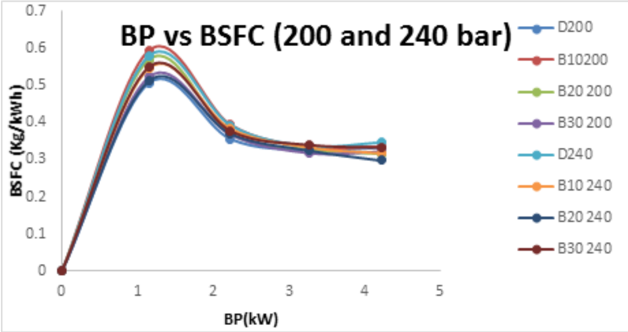
Performance:

BP vs. BTE: The engine was run at different blends of biodiesel at two different pressures (200 and 240 bars) as seen in the graph. As the BP increases the BTE of the fuel also increases. As seen in the graph 1 that B20 at 240 had the highest BTE as compared to diesel and other fuels at different injection pressures. The maximum BTE (23.40%) was found at 240 bar. The lowest BTE was found to be of diesel at 240 bar. The reason may be due to the higher injection pressure and viscosity which commence for the better atomization at full load condition.



Graph.1.BTE vs. BP

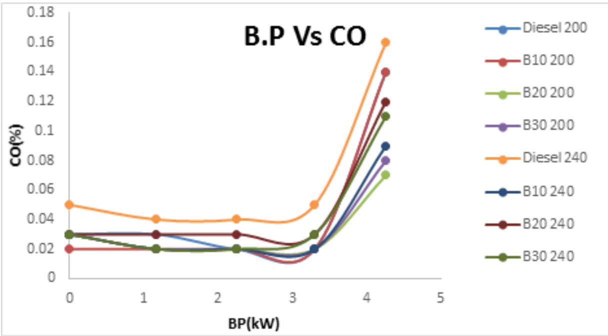
BSFC vs BP: Diesel and different biodiesel blends have tested at different pressures (200 and 240 bar), and the graph has drawn for the BSFC vs. BP. An increase in the pressure decreases the BSFC for some of the blends. Maximum BSFC (16.48%) was found to be of B20, which was at 240 bar. Biodiesel was showing lower BSFC as compared to diesel (240 bar) at full load condition. The reason may be due to increasing in pressure which results in proper mixing of the fuel at full load. Thus, due to increase in pressure, there is the reduction in the size of the fuel droplets which enhances for better atomization.



Graph.2.BSFC vs. BP

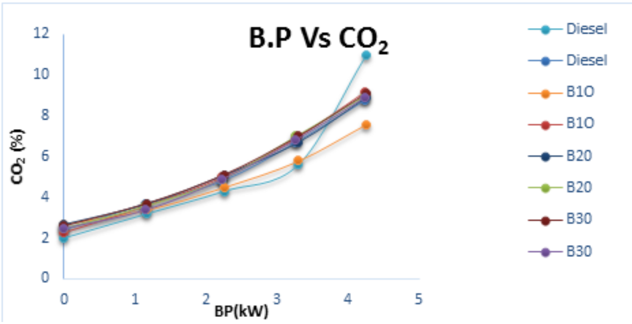
Emission:

CO vs. BP: As brake power increases the CO emission is almost constant, but there is a drastic increase in the emission at full load condition as seen in the graph. Diesel (240 bar) is showing the highest emission at maximum load condition whereas B20 was showing 56.25% reduction for 200bar at full load condition. Possibly a result of better spray atomization and uniform mixture formation which leads to the reduction of the CO emission.



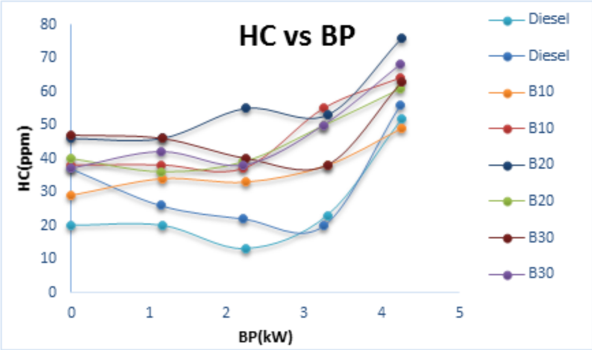
Graph.3.CO vs. BP

CO_2 vs. BP: A BP increases CO_2 emission increases. As at lower loads the emission values are similar for diesel and biodiesel at different pressures (200 and 240 bar). As seen in the graph Diesel (240 bar) is having the highest emission at full load condition as there was 31% decrease in the emission for B10 at 200 bar.



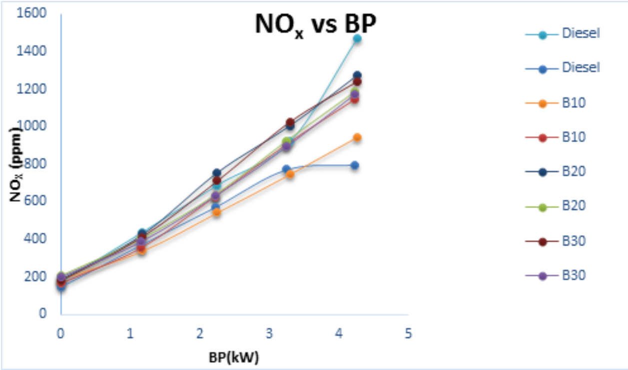
Graph.4.CO2 vs. BP

HC vs. BP: The graph shows a drastic increase at full load condition. The results show that B10 at 200 bar pressure shows 35.52% reduction at full load condition. Biodiesel has the higher HC emission as compared to diesel (200 and 240 bar). The increase in the emission is due to lack of oxygen resulting in the emission of the HC.



Graph.5.HC vs. BP

NO_X vs. BP: As seen from the graph at initial load there is the linear increase in the NO_x emission. Diesel (200 bar) is showing the lowest NO_x emission whereas diesel (240 bar) is the greatest at full load condition. 35.71% of reduction found for B10 (200 bar). These may be due to combined effect of fuel spray characteristics deterioration because of higher fuel viscosity and higher fuel density and differences in the ignition quality due to the differences in the chemical structure of mineral diesel and biodiesel.



Graph.6.NOX vs. BP

4. CONCLUSION

Different fuel injection pressure has experimented in the present paper, which shows that increasing the pressure the spray characteristics and atomization improves. B20 at 240 bar was showing 23.40% increase in BTE at full load condition. This was due to the increase of the injection pressure from 200 to 240 bar.Biodiesel is showing lower BSFC as compared to diesel ar240 bar 16.48% of reduction has found for the B20 blend at 240 bar pressure at full load condition.

Diesel (240 bar) is showing the highest emission at full load condition whereas B20 was showing 56.25% reduction for 200 bar at full load condition. There was 31% decrease in the CO_2 emission for B10 at 200 bar. The results indicate that B10 at 200 bar pressure shows 35.52% reduction at full load condition. Diesel (200 bar) is showing the lowest NO_x emission whereas diesel (240 bar) is showing the largest at full load condition whereas 35.71% of reduction was found for B10 (200 bar) as compared to other biodiesel. The experimental investigation showed that use of 20% Waste vegetable oil at 240 bar improves the performance of the engine whereas 10% Waste vegetable oil at 200 bar reduces the emission, so Waste vegetable oil can be considered as one of the alternative fuel for the long-term process.

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