Experimental investigations to study the effect of butanol and pentanol addition in a jatropha oil methyl ester fuelled compression ignition engine

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ABSTRACT

Research for getting alternate fuels for CI (Compression Ignition) engines is the subject of importance today. Blending of alcohol with biodiesel improves the engine performance and reduces the emissions. This article concentrates on the presentation of results of an experiment conducted on CI engine using Jatropha oil methyl ester blended with butanol and pentanol in the ratio of 70:30 by volume. Experiments are carried out using a single cylinder, 4 stroke, direct injection, water cooled diesel engine at five loads between no load to full load at a constant speed of 1500rpm. In the present work, standard diesel, neat jatropha oil biodiesel, jatropha oil biodiesel (70%) butanol (30%) (J70B30) and Jatropha oil biodiesel (70%) pentanol (30%) (J70P30) fuels are tested. The experimental test results showed that smoke opacity, nitrogen oxides emissions decreases while the carbon monoxide and hydrocarbon emissions increases with blended fuels. Also, there is an increase in the brake thermal efficiency and brake specific fuel consumption with alcohol blending.

KEY WORDS: Biodiesel, Diesel engine, Butanol, Pentanol.

1. INTRODUCTION

The energy needs of the world are increasing rapidly. The alternatives for internal combustion engines are, Biofuels such as alcohols and biodiesel. In particular, replacement for petroleum diesel fuel is biodiesel, because it is renewable, non toxic and can significantly reduce exhaust emissions. Biodiesel, butanol and pentanol can be produced from feedstock's that are generally considered to be renewable. Biodiesel has long been used as fuel for diesel engines. In many studies it has been reported that using biodiesel in engines can reduce hydrocarbon (HC), carbon monoxide (CO) and particulate matter (PM) emissions, but NOx emissions may increase slightly. Most important factor in the formation of NO_x by the combustion of biodiesel ids the oxygen content in it, because oxygen content only determines the efficiency of combustion of the biodiesel.

Vegetable oils having the advantage of freely mixing with alcohols, and in existing diesel engines these blends can be used. It is also a simple process. Blending of vegetable oils with alcohol results in significant improvement in their physical properties. The viscosity and density are considerably reduced. The volatility is also improved. Results obtained from the experiments on a diesel engine using a blend of vegetable oil and alcohol showed improved brake thermal efficiency and reduced exhaust smoke emissions than neat vegetable oils. However, the water presence in alcohol can reduce the quantity of alcohol that can be blended. High quantities lead to separation. Ethanol is high oxygen content of 34% by weight and low cost oxygenate. For significant reduction of particulate matter (PM) emissions for motor vehicles, ethanol can be used in diesel fuel. Compared to other bio resources, Jatropha curcas oil is interest for its certain advantages, especially in developing regions. Jatropha oil has a high cetane number, which is very close to diesel. This makes it an ideal alternative fuel as compared to other vegetable oils

2. EXPERIMENTAL SETUP AND TEST FUELS

The engine used for the test was a Kirloskar (TV1), single cylinder, four stroke, direct injection, water cooled and naturally aspirated compression ignition engine with 5.2 kW of power at the rated speed of 1500 rpm. The specifications of the test engine are given in Table 1. The engine was connected to an eddy current dynamometer and suitable arrangements were made to acquire all the controlling parameters.

The fuels used in this study include standard diesel fuel, biodiesel, biodiesel-butanol and biodiesel-pentanol blends. The blended fuel contains 30% by volume of butanol and 30% by volume of pentanol identified as J70B30 and J70P30 respectively. It was found that there is no phase separation or stability problems when biodiesel is blended with butanol and separately with pentanol. Hence there is no need for surfactant to be used. The major properties of the fuel are shown in table-2.

Experiments were conducted with diesel, biodiesel, J70B30 and J70P30 blends from no load to full load at a constant speed of 1500rpm.

Table.1. Specifications of test engine

Make and model	Kirloskar, TV1
No. of cylinder	1
Cycle	87.5mm
Bore	87.5mm
stroke -	110 mm
Displacement volume	661 cm^3
Compression ratio	17.5:
Combustion chamber	Hemispherical
Rated power	5.2 kW @ 1500 rpm
Injection timing	23^0 BTDC

Table.2. Properties of Diesel, Biodiesel, Butanol and Pentanol

Fuel	Diesel	Biodiesel	Butanol	Pentanol
Heating value (kJ/kg)	42500	39512	33120	34940
Density (Kg/m^3)	840	880	810	815
Flash point (^0C)	70	126	37	51
Viscosity (cst)	2.95	4.57	2.23	4
Cetane number	45	52	17	20
Oxygen content		15	21.59	18.15
Latent heat of vaporization (kJ/kg)	270		585	305

3. RESULTS AND DISCUSSION

Brake Thermal Efficiency: Fig. 1 shows the comparison of the brake thermal efficiency with engine brake power for the tested fuels. It can be observed that brake thermal efficiency is 35.02% at full load for J70P30, while those of diesel, J70B30 and jatropha oil biodiesel are 32.4%, 34.7% and 28.03% respectively. The brake thermal efficiency of both J70B30 and J70P30 blend was higher compared to diesel and neat jatropha oil biodiesel. This may be explained by a better combustion due to the presence of oxygen, which involves higher combustion efficiency and a reduction of heat losses due to the lower boiling point of butanol and pentanol compared to diesel fuel. Neat biodiesel have the lowest brake thermal efficiency compared with other fuels. This may be due to the lower heating value and inferior combustion of biodiesel.

Brake Specific Energy Consumption: The variation of brake specific energy consumption with brake power is shown in Fig. 2. The brake specific energy consumption of the engine with biodiesel operation at full load is 13 MJ/kWh which is higher compared to 12.17 MJ/kWh in diesel operation. The increase in brake specific energy consumption of engine fuelled by biodiesel is due to low volatility, high density and viscosity, which affect the mixture formation of the fuel. The specific energy consumption is lowest for both biodiesel-butanol and biodiesel-pentanol blends.

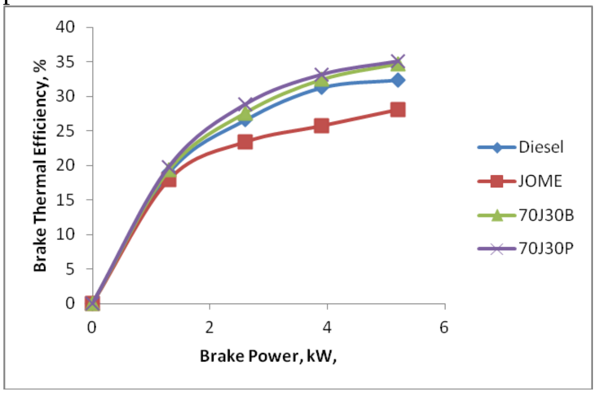

Fig.1. Variation of brake thermal efficiency with brake power

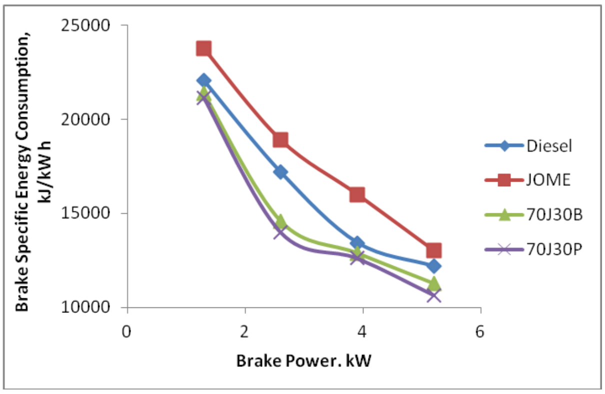

Fig.2. Variation of brake specific energy consumption with brake power

Exhaust Gas Temperature: Fig.3. shows the effect of biodiesel-butanol and biodiesel pentanol blends on exhaust gas temperature at constant engine speed and various engine loads. It was observed that exhaust gas temperature reduces for both J70B30 and J70P30 blends. This may be attributed to the lower energy content and latent heat of evaporation of the alcohol in the blends. Biodiesel-alcohol blends supplies more oxygen to the combustion chamber and hence increases the combustion chamber temperature. However, the higher latent heat of alcohol tends to reduce the in cylinder temperature. In general, exhaust gas temperatures are similar at low loads and there is no significant difference at the no load as seen in Fig.3. At full load, neat biodiesel show higher exhaust gas temperature of 448ºC than standard diesel fuel 408ºC due to slower combustion of biodiesel. At full load, the exhaust exhaust gas temperature of J70B30 and J70P30 blends are 390ºC and 361ºC respectively.

Nitric Oxide Emissions: As seen in Fig.4, the NO emissions are higher with neat biodiesel with 1741 ppm and for diesel it is 1510 ppm at maximum load. B80M20 blends produce 463 ppm and B80E20 blends emits 612 ppm of NO at full load. The reason for the reduction is due to higher latent heat of vaporization of alcohols, the cylinder gas temperature is reduced. It is also observed that biodiesel leads to higher NO levels as compared to diesel. This is mainly due to the oxygen content of Jatropha oil. The oxides of nitrogen in the exhaust emissions contain nitric oxide (NO) and nitrogen dioxide (NO_2). The formation of NOx is highly dependent on in-cylinder temperatures, the oxygen concentration, and residence time for the reaction to take place.

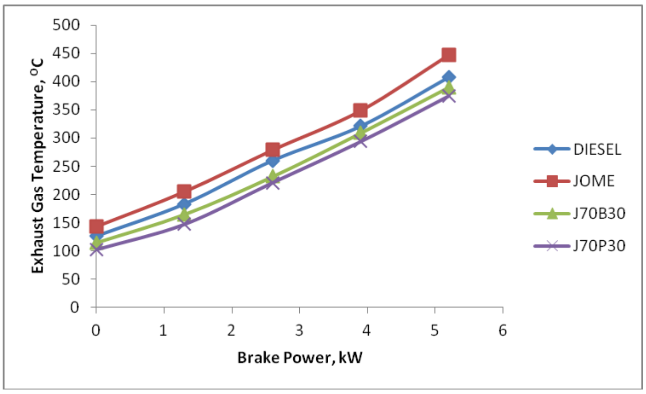

Fig.3. Variation of exhaust gas temperature with brake power

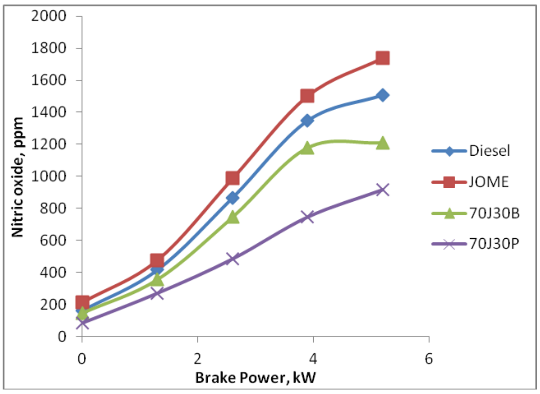

Fig.4. Variation of nitric oxide with brake power

Smoke Opacity: The variation of smoke opacity is illustrated in Fig.5. It can be observed that the smoke opacity increases with the increase of engine load, which is especially significant at high engine load. This is because that more fuel is required to achieve higher power output at high engine load and hence more fuel (and hence more carbon) is available for particulate formation while excess air ratio decreases leading to less oxygen available for soot oxidation. Decrease in smoke is observed with biodiesel, biodiesel-butanol and biodiesel-pentanol blends compared to diesel. This is due to the presence of oxygen in biodiesel and alcohol which promotes soot oxidation. At full load, smoke opacity decreases by 32% and 13% for J70P30 and J70B30 respectively, compared with neat diesel fuel.

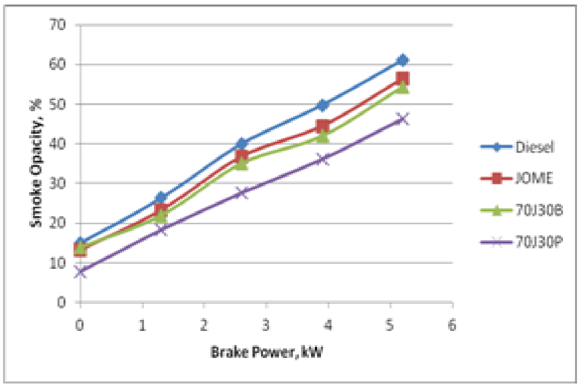

Fig.5. Variation of smoke opacity with brake power

Carbon monoxide Emissions: CO emission is toxic and an intermediate product in the combustion of a hydro carbon fuel, so it results from incomplete combustion. Emission of CO is, therefore, greatly dependent on the air–fuel ratio relative to the Stoichiometric proportions. Fig.6 shows the CO emissions for standard diesel, biodiesel, biodiesel-butanol and biodiesel-pentanol blends. It is shown that biodiesel-alcohol blends result in higher CO emissions than standard diesel and biodiesel at loads lower than 75%, due to higher vaporization energy requirements and hydrogen bonding of alcohols. At full load, CO emissions increase for diesel than biodiesel and biodiesel-alcohol blends. Butaanol has a higher heat of vaporization than pentanol; Butanol would produce higher CO emissions than pentanol under the same engine operating conditions

Hydrocarbon Emissions: Fig.7 shows hydrocarbon emissions for diesel, biodiesel and biodiesel-alcohol blends. The biodiesel records the lowest HC emissions compared with all other fuels. For Biodiesel-alcohol blends HC emission increases due to the cooling effect of alcohol. However at full load there is no significant change in HC emissions for all fuels.

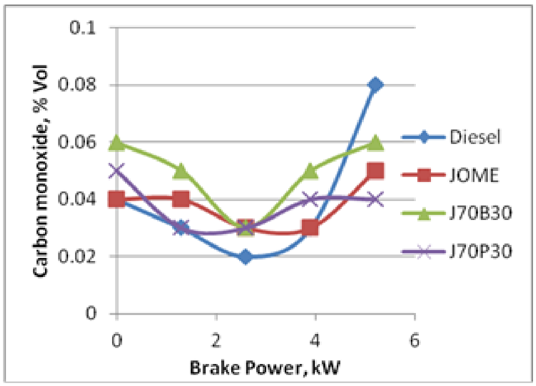

Fig.6. Variation of carbon monoxide with brake power

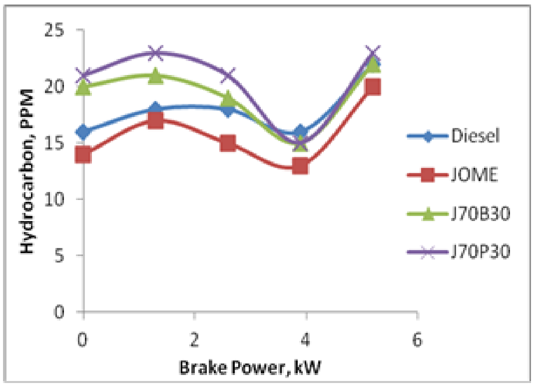

Fig.7. Variation of hydrocarbon with brake power

4. CONCLUSION

A direct injection compression ignition engine was fuelled with butanol/biodiesel fuel and pentanol/biodiesel fuel blend and engine performance tests were compared with the use of neat diesel fuel. From this field trial, it may be concluded:

The existence of oxygen in the molecular structure of butanol and pentanol offsets its reduced calorific value, showing better combustion and brake thermal efficiency compared with diesel and biodiesel. As regard to brake specific energy consumption, pentanol blends exhibit slightly better behaviour than butanol blends, biodiesel and neat diesel fuel.

Significant reduction in NO_x and smoke were observed with both butanol and pentanol blends.

Butanol and pentanol exhibit values of some of the main fuel properties (calorific value and Cetane number) closer to those of diesel fuel,compared to lower order alcohols (Methanol and ethanol). This may explain the better diesel engine behavior when higher alcohol blends are used instead of lower alcohol blends. Although, better performance may be expected if the engine is modified to fit butanol and pentanol properties.

30% Butanol/biodiesel fuel blend and 30% pentanol/biodiesel fuel blend may replace the use of 100% diesel fuel on diesel engines (without any modification and without significant loss of performance) if long-term diesel engine tests provide satisfactory results.

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