Effect of Oxygen Enrichment of Intake Air on the Performance and Emission of Single Cylinder CI Engine Fueled with Cardanol Blends

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ABSTRACT

In this study, the effect of intake air enrichment on the performance and emission characteristics of a single-cylinder direct-injection diesel engine fueled with non edible oil namely Cardanol—diesel-methanol blend (B20M10) are investigated. With increase of intake air oxygen concentration, CO and HC decreased while brake thermal efficiency and NO_x considerably increased. The maximum Brake Thermal Efficiency of 33.98% is obtained for B20M10 with 7% oxygen enrichment of intake air. Maximum NO_x emission 20% is obtained for B20M10 with 7% oxygen enrichment for the full load condition. Decreases of 20% and 14.5% in CO emission are obtained for B20M10, over B20M10 with 7% oxygen enrichment, where as 76.8% and 74% decrease in hydrocarbon emission is obtained over B20M10 without oxygen enrichment.

Keywords: Cardanol, Emission, Methanol, Oxygen enrichment, Performance

INTRODUCTION

Today's world has been affected with an energy crisis due to twin problems such as petro fuel depletion and environmental degradation. Biodiesel is becoming an alternative fuel for diesel engines. Many investigators have reported that biodiesel can replace the conventional petro diesel which is fast depleting. The biodiesel is derived from plant and animal sources such as Pongamia, Jatropa, Linseed oil, Mahua oil, waste cooking oil, rubber seed oil, animal fat, fish oil etc. The use of biodiesel will minimize the environmental pollution. Bio-diesel has the potential to reduce the level of pollution and the level of global warming [1-3]. Also from the research review it shows that it is possible to blend some of the vegetable oils with conventional fuels to produce eco friendly blends. Out of many such oils cashew nut shell liquid (CSNL) is one which is a reddish brown viscous liquid, which is extracted from honey comb structure of the shell of cashew nut obtained from cashew tree. Major CNSL producing countries are Tanzania, India, Sri Lanka, Mozambique, Kenya, Madagascar, Thailand, Malaysia, Nigeria, Indonesia, Senegal and Angola [4].

Bio Fuel from CNSL

Cashew nut shell liquid (CNSL) is one of the sources of naturally occurring phenols. It is obtained from the shell of a cashew nut. About 30-35% CNSL is present in the shell, which amounts to approximately 67% of the nut. CNSL is traditionally obtained as a by-product during the process of removing the cashew kernel from the nut. The processes used are mainly hot-oil and roasting in which the CNSL oozes out from the shell. Cashew (Anacardium occidentale L.) nut shell liquid (CNSL) contains cardol, methyl-cardol and mainly cardanol (decarboxylated anacardic acid), a meta-substituted n-long chain (C15) unsaturated alkylphenol [5]. The physical properties of CNSL are comparatively similar to that of Diesel. There are two commercial methods used in cashew nut processing industries by which CNSL is extracted, (i) mechanical method and (ii) hot extraction method. The hot extraction method recovers 50% of CNSL [6] and due to heat, the Anacardic acid is converted into cardanol. This oil is known as technical CNSL and it is a unique natural source for unsaturated long chain phenols [4]. CNSL extracted by mechanical method extracted CNSL is called natural CNSL. The main constituents of technical and natural CSNL are Cardanol, Methyl—Cardol and Cardol. Cardanol is a naturally occurring phenol manufactured from CNSL. It is a mono hydroxyl phenol having a long hydrocarbon chain in the Meta position. Many researchers have reported the application of CNSL based fuel blends in diesel engines [7-9]. Mallikappa et al. [9] have conducted an investigation on performance and emission characteristics of a four-stroke double cylinder CI cylinder engine with cardanol biofuel volumetric blends like 0, 10, 15, 20%, and 25%. The brake thermal efficiency obtained for Cardanol biofuel blends was less than that of diesel. The NO_x emissions increases with increased proportion of blends and also with higher EGT (exhaust gas temperature).

In recent years, many researchers have conducted experiments on oxygen enrichment of intake air in the diesel engine and proved that smoke emissions from the engine could be reduced when oxygen composition of intake air is increased [10-12].The research results of various investigators reported that the oxygen-enriched combustion in diesel engines shows significant reductions in smoke emissions, higher peak cylinder pressure, increased power output and significantly shortened ignition delay [13-16]. Byun et al. [17] conducted experiments on the effect of oxygen enriched air obtained by gas separation membranes from the emission gas of diesel engines. He experimented with small size (632cc—single cylinder) four stroke diesel engine. He concluded with the results that when the oxygen enriched air was used for the diesel engines, the smoke density was decreased remarkably. But, unfortunately, NO_x increased with the increase of oxygen concentration mainly due to the high supply of oxygen molecules per cycle. In the present study the B20M10 (20% cardanol, 10% Methanol and 70% diesel) was used as fuel and the intake air oxygen enriched with 3, 5 and 7 percentage by weight. The performance and emission characteristics were compared with base line B20M10 fuel blend.

EXPERIMENTAL SETUP

The engine tests were conducted on a computerized single cylinder four-stroke diesel engine test rig as shown in Figure 1. The specification of diesel engine used for the experiments is given in Table 1. It is directly coupled to an eddy current dynamometer. Test rig was provided with necessary equipment and instruments for combustion pressure and crank angle measurements. These signals are interfaced to computer through an analog to digital converter (ADC) card PCI-1050 which was mounted on the motherboard of the computer. The engine intake system was equipped with oxygen supply arrangements to vary the oxygen composition in the intake air. The oxygen was stored in the cylinder and supplied to the engine intake manifold through the surge tank. The oxygen flow was regulated with the help of oxygen mass flow meter. In the present study base fuel B20M10 was supplied to the engine through the injector and 3%, 5% and 7% oxygen was supplied to the intake air. The engine exhaust emissions were measured by AVL 437 C Smokemeter and AVL Digas 444 analyzer.

Table 1. Test Engine Specifications

Engine type	Four-stroke, single cylinder, water cooled CI engine
Make	Kirloskar
Model & BHP	TV1 & 5.2kW@ 1,500 RPM
Compression Ratio	17.5:1
Dynamometer Type	Eddy Current, with loading unit
Load Measurement	Strain Gauge Load cell
Interfacing	ADC card- PCI 1050

RESULTS AND DISCUSSION

A wide range of experiments were carried out at different load conditions to examine the effect of oxygen enrichment of intake air with Cardanol Methanol diesel blend (B20M10) on the performance parameter like brake thermal efficiency (BTE) and also an analysis is carried out on the emission parameters like NO_x, CO, HC and smoke. The tests have been carried out for 3, 5 and 7% by weight of intake air oxygen enrichment at 0%, 25%, 50%, 75%, and full load conditions.

Brake Thermal Efficiency (BTE)

The variation of BTE for various loads and oxygen proportions is shown in Figure 2. As expected, the BTE increased with increase in load for all the cases and maximum BTE was obtained for 75% load condition. An increased BTE was observed as the percentage of oxygen in the intake air was increased. The maximum BTE of 33.98% was obtained for B20M10 with 7% oxygen enrichment, where as 33.84% BTE obtained for B20M10 without intake air enrichment at 75% load. At the same operating condition, 33.87% and 33.94% BTE were obtained for B20M10 fuel blend with 3% and 5% oxygen enrichment. The excess oxygen available in the intake air could increase combustion rate and there by increased brake thermal efficiency was obtained.

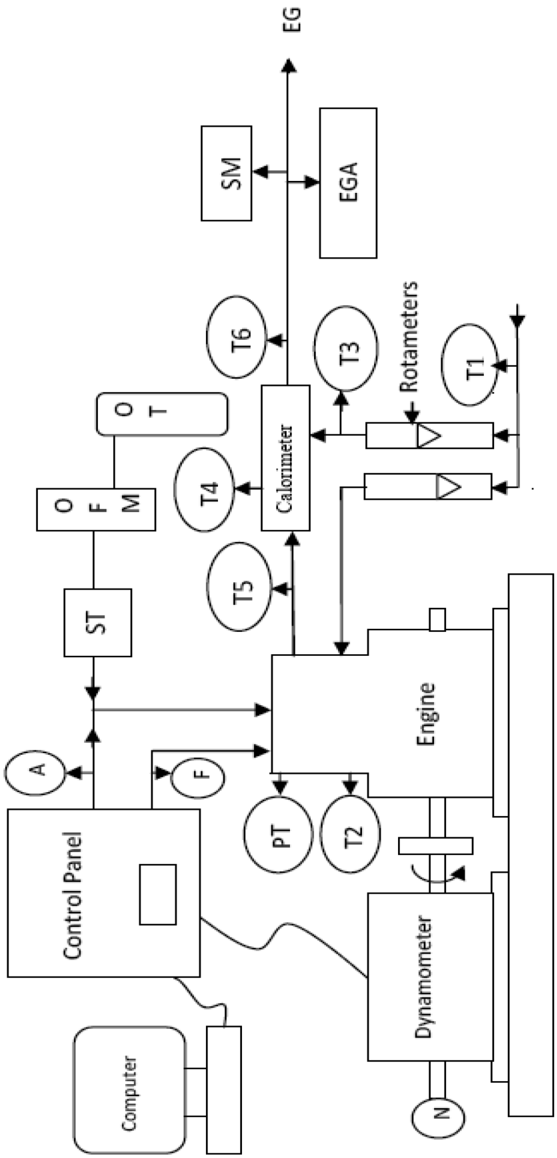

Figure 1. Schematic diagram of the experimental test rig
(A-Air flow, F—fuel flow, PT—pressure Transducer, OT—Oxygen Tank, OFM—Oxygen flow meter, SM—Smoke meter, EGA—Exhaust gas analyzer, EG—Exhaust gas, T1 to T6—Temperature terminal points, N—RPM decoder)

NO_x Emission

The NO_x emission increases with load due to higher temperature developed inside the engine during combustion. The NO_x emission of the tested fuels at different load is shown in Figure 3. At full load condition the increment in the NO_x emission was 3.4%, 8% and 20% with 3%, 5% and 7% oxygen enrichment respectively when compared to B20M10. This increase in NO_x emission because of the increase in oxygen content in the intake air cause complete combustion of fuel droplets thereby maximum heat released.

CO Emission

It is observed from the Figure 4 that CO emission is lower for B20M10 with 7% oxygen enrichment for all load conditions compared to other blends. The decrease in CO emission was 14% and 3.2% with 3% oxygen enrichment, 16% and 6.4%while with 5% oxygen enrichment 20% and 14.5% with 7% oxygen enrichment obtained at 75% and 100% of full load respectively when compared to B20M10 alone. This is because of the oxygen enrichment of intake air increases the possibility of formation of CO_2 instead of CO.

Hydrocarbon (HC) Emission

The variation of HC emission at different loads for different percentage of oxygen enrichment is shown in Figure 5. It is observed that B20M10 with 7% oxygen enrichment has lower hydrocarbon emission compared to other fuel conditions at 75% load and at full load. 76.8%% and 74% decrease in hydrocarbon emission was observed over B20M10 without oxygen enrichment at 75% and full load conditions respec-

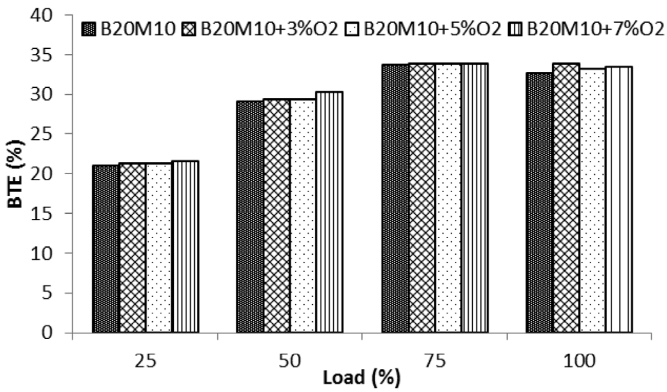

Figure 2. Variation of BTE for oxygen enrichment percentage

tively. 68.6% and 66% decrease in hydrocarbon emission was observed for B20M10 with 5% oxygen enrichment and 64.8% and 59% lower HC emission obtained for B20M10 with 3% oxygen enrichment over B20M10 without oxygen enrichment at 75% and full load conditions respectively. As the percentage of intake air oxygen enrichment increased the complete combustion of fuel is achieved so the hydrocarbon present in the exhaust gas will be minimum.

CONCLUSION

From the above findings it can be concluded that B20M10 blend with 7% oxygen enrichment of intake air gives improved performance and emission characteristics over 3% and 5% oxygen enrichment. It is recommended that 7% oxygen enrichment of intake air is the best oxygen composition for the CI engine combustion. The maximum BTE value of 33.98% is obtained for B20M10 with 7% oxygen enrichment of intake air. Maximum NO_x emission 20% is obtained for B20M10 with 7% oxygen enrichment for the full load condition. 20% and 14.5% decrease in CO emission are obtained for B20M10 over B20M10 with 7% oxygen enrichment where as 76.8% and 74% decrease in hydrocarbon emission is obtained over B20M10 without oxygen enrichment.

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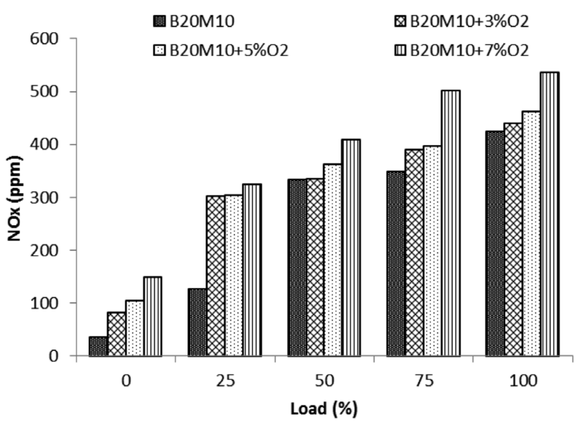

Figure 3. Variation of nitrogen oxides for oxygen enrichment percentage

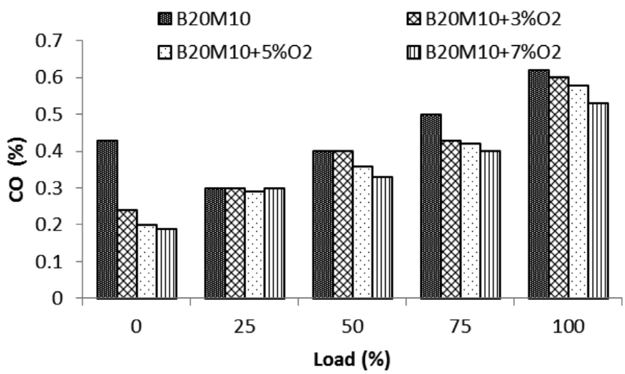

Figure 4. Variation of carbon monoxide for oxygen enrichment percentage

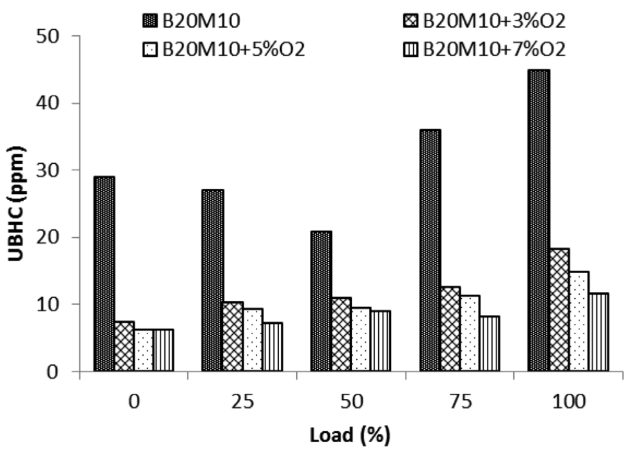

Figure 5. Variation of UBHC for oxygen enrichment percentage

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