Experimental Investigation on CRDI engine using butanol-biodiesel-diesel blends as fuel

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Abstract. In this research work an experimental investigation of butanol-biodisel-diesel blends on combustion, performance and emission characteristics of a direct injection (DI) diesel engine is carried out. The blends are prepared at different proportions and fuel properties such as calorific value, viscosity, flash point and fire point, cloud point, pour point of butanol (B), biodiesel (B), diesel (D), biodiesel-diesel (BD) blends and butanol-biodiesel-diesel (BBD) blends are determined. The engine test is conducted at different speed and load. From the results obtained for fuel properties we can observe that the flash, fire and pour point, viscosity and density are decreasing by increasing the percentage of butanol in BBD blends. It is also observed that the performance parameters such as brake thermal efficiency (BTE) and exhaust gas temperature increases with increase in the proportion of butanol in BBD blend. However, the brake specific fuel consumption (BFSC) decreases with increase in the proportion of butanol in BBD blend. The increase of butanol in BBD blends also influence to increase on emission characteristic such as carbon monoxide (CO), hydrocarbon (HC) and oxides of nitrogen (NO_x).
Keywords: CRDI engine, ED3R Esterification, Butanol, Biodiesel, BBD blends, Emission characteristics.

INTRODUCTION

Energy crisis as well as sharp escalation in adverse environmental conditions made the technologies to direct themselves towards the use of renewable energy resource to produce chemical that appeared to be an alternative to non-renewable energy resource and are non-polluting. Bio-derived fuels are being considered to replace or supplement conventional distilled petroleum fuel. Biodiesel has become more attractive because of its low polluting nature and it is a renewable energy source as fossil fuel is leading to exhaust shortly. Areerat Chotwichien et.al.,[1] found that the use of butanol in diesel could solve the problem of fuel instability at low temperature because of its higher solubility in diesel fuel. Benjamin R. Wigg et.al.,[2] established that the unburnt hydrocarbon (UBHC) and NO_X emission of neat butanol were increase than gasoline and ethanol. They also found that CO emission decreases when the amount of butanol in gasoline increase.

D.B. Hulwan et.al.,[3] concluded that the blend prepared on diesel, ethanol and biodiesel on volume basis, the smoke and CO emissions are reduced at all the speeds and loads and the NO_X, CO_2 and UBHC emissions are increased. Vinod kotebavi et.al.,[13] revealed in their experimental results that CO and HC emissions reduced with increasing the waste cooking oil percentage in the blends because of high oxygen content in the oil. Edward Antwi et.al.,[4] experimentally studied the performance characteristic of CI engine with diesel and different proportions of biodiesel blend. They found that the BSFC, BTE and BP did not changed significantly by using biodiesel in place of diesel.

Substituting biodiesel with diesel the BSFC, BTE and brake power did not differ from that obtained with diesel. F.Halek et.al.,[5] examined the diesel engine operated on biodiesel- fatty acid methyl ester (FAME) and concluded that the engine when operated on FAME fuel have lower emissions of CO, HC, particulate matter and air toxics then when operated on diesel fuel. G. Venkata Subbaiah et.al.,[6] conducted an experiment on direct injection diesel engine with diesel fuel, rice bran oil biodiesel, a blend of diesel and rice bran oil biodiesel and three blends of diesel-biodiesel-ethanol over the entire range of load on the engine. The experimental results showed that the BTE increased and CO, sound, UBHC and smoke were lower than that of the diesel fuel with the diesel-biodiesel-ethanol blends. H S Farkade et.al.,[7] investigated the role of oxygen on the basis of oxygen percentage in the blend of three different alcohols such as methanol, ethanol and butanol. They found that the presence of oxygen gives more desirable combustion resulting into low emission of CO and HC. J. Dernotte et.al.,[8] experimentally conducted a test using butanol-gasoline blends in spark ignition engine to quantify the influence of butanol addition on the emission of UBHC, CO and NO_X. M. Prabhabar et.al.,[9] studied the performance parameters like BSFC, BTE and emission parameters like CO, HC,NO_X and smoke on diesel engine using the blend of diesel and pongamia methyl ester oil. Shashi Kumar Jain et.al.,[10] discussed the technological disadvantages such as cold starting, clogging and storage associated with biodiesel in diesel engine and proposed a requirement of some modifications in injection timing and fuel pump when the engine operates at 100% biodiesel. Vinod kotebhavi et.al.,[11] performed an emission test on diesel engine using waste cooking oil and diesel blends and found that the emissions of HC and CO dicreases by increasing the biodiesel content in the blends. Ravi shanker shukla et al.,[12] conducted an experiment on diesel engine fueled with diesel-plastic oil blends and concluded that CO and HC decreases at higher blends, however NO_X and exhaust gas temperature increases slightly. The above all literatures concluded that the biofuels are the environmental friendly source to reduce dependence on fossil fuel and to reduce the air pollution. Butanol has higher energy content and butanol-biodiesel blends do not seperate in the presence of water. Butanol can be blended with biodiesel in any percentage, all the way up to 100%. These routes the present study to investigate the properties, performance and emission profiles of diesel engine operated with butanol-biodiesel-diesel blends with different proportions.

METHODOLOGY AND SPECIFICATIONS

A four stroke CRDI liquid cooled diesel engine was used for conducting the experiments. Specifications of the engine are shown in Table1. Stirring through magnetic stirring plate, butanol, biodiesel and diesel were blended together. The blends were prepared on the volume basis such as B2B48D50, B10B40D50, B12B38D50, B16B34D50 and B30B20D50 (e.g. B10B40D50 consists of 10% butanol, 40% biodiesel and 50% diesel by volume). Using ED3R Esterification method, the biodiesel was prepared from vegetable oil. Adiabatic oxygen type bomb calorimeter for calorific value measurement; Hindustan IP15 & 219 ASTM-D 2500 type pour point analyzer for determining the pour point; Red Wood viscometer for determining the viscosity and flash point was determined by using Pensky Marten closed type flash point analyzer. Exhaust gas temperature was found using Chromelelumel thermocouple and AVL DIGAS 444D gas analyzer was used to measure HC, CO, CO_2, O_2 and NO_X emissions. Smoke opacity of the test engine was evaluated using AVL 437 C smoke meter.

Engine Type	CRDI Diesel engine
Capacity	1248cc
Bore	74 mm
Stroke	75.5 mm
Power	75ps@4000rpm
Torque	190Nm@2000rpm
Compression Ratio	17.6:1

Table 1: Engine specifications

RESULTS AND DISCUSSION

Fuel properties

The chemical and fuel properties of diesel, biodiesel and butanol are determined. We observed that butanol is having very much less values of all the properties compared to biodiesel and diesel samples. The flash point and fire point of BBD blend decreases as the percentage of butanol increases which in turn biodiesel percentage decreases and it can be seen from the Fig.1. Fig.2 shows the variation of viscosity of acid oil, butanol, biodiesel and diesel fuel. As longer the carbon-carbon chain, the more viscous the fuel is and because of this feature diesel fuel is more viscous than any other oils. The calorific value of biodiesel is generally lower than mineral diesel and it can be seen from Fig.3.

As lower the calorific value, lesser the power produce and higher the fuel consumed. As seen in Fig.4, acid oil is a denser fuel than any other fuel and since butanol is a lighter alcohol, it shows lesser density. Fig.5, shows the variation of density at different temperature for different composition of BD and BBD blends. The density of BBD is lesser when compared to other BD blends because it consists of an alcohol.

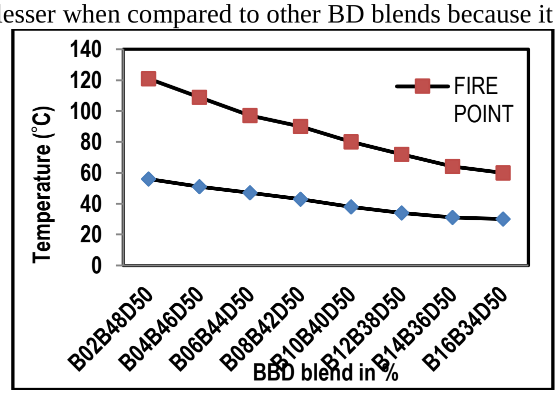


Fig.1

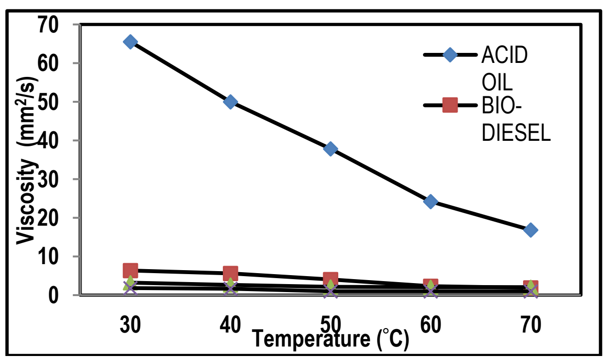
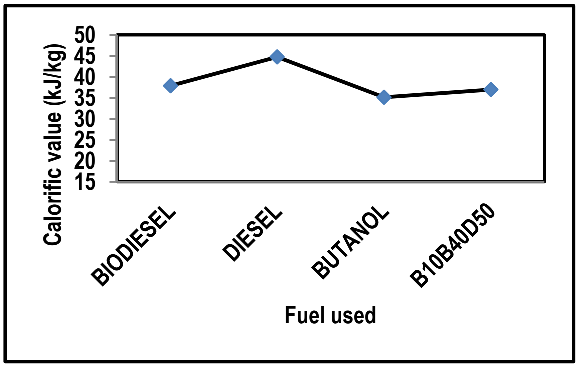


Fig.2

Figure 1: Variation of Flash and fire point with BBD blends

Figure 2: Variation of kinematic viscosity for different fuel used



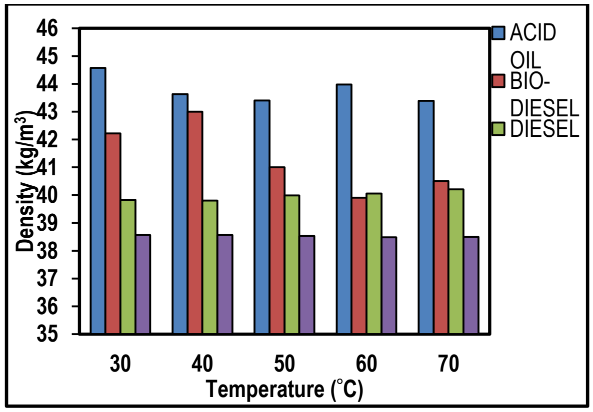
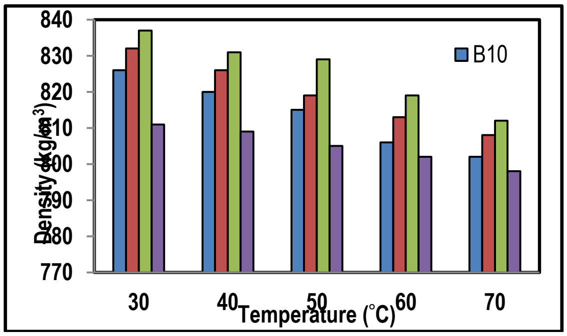


Fig.3 Fig.4

Figure 3: Variation of Calorific value for different fuel used.

Figure 4: Variation of density at different temperature for different fuel used.



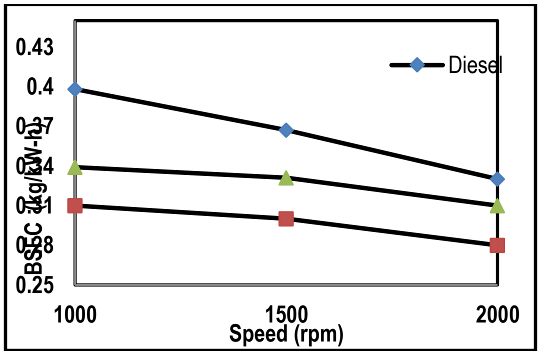


Fig.5 Fig.6

Figure 5: Variation of density at different temperature for different biodiesel-diesel blends.

Figure 6: Variation of BSFC with speed.

ENGINE PERFORMANCE

Brake specific fuel consumption

Fig.6 shows the variation of BSFC with speed for B30B20D50, B10B40D50 and diesel fuel. BFSC decreases with increasing speed. As the speed increases, BSFC decreases for both diesel and BBD blends [27]. BFSC decreases with increase in the proportion of butanol in BBD blend i.e. BBD blend B30B20D50 which has maximum butanol of 30%, shows the minimum value of BSFC at all speed.

Brake thermal efficiency

The variation of BTE with speed for diesel and B30B20D50, B10B40D50 blends is shown in Fig.7. BTE attains a maximum value when the blend fuel has maximum percentage of butanol. BTE is maximum for B30B20D50 of 34.21%, whereas the diesel and B10B40D50 have a BTE of 25.66% and 29.27% respectively.

Exhaust gas temperature

Fig.8 depicts the variation of exhaust gas temperature with speed. As speed increases, to obtain the required power the exhaust temperature also increases by burning more fuel. It can be seen from figure8 that for the fuel blends B30B20D50 and B10B40D50, the exhaust gas temperature varies from 158^{O}C to 249^{O}C and 163^{O}C to 254^{O}C respectively whereas in next diesel it is from 152^{O}C to 243^{O}C. It is seen that the fuel blends have higher exhaust gas temperature due to its higher heat release rate and near complete combustion then when compared to neat diesel.

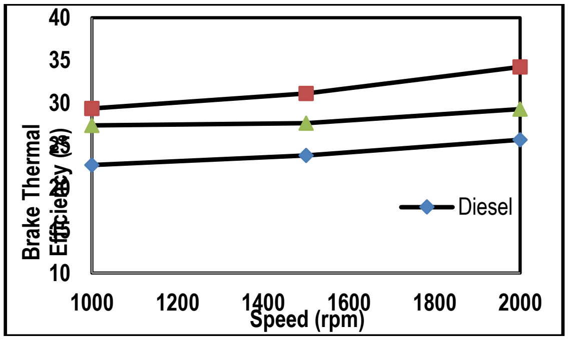


Fig.7

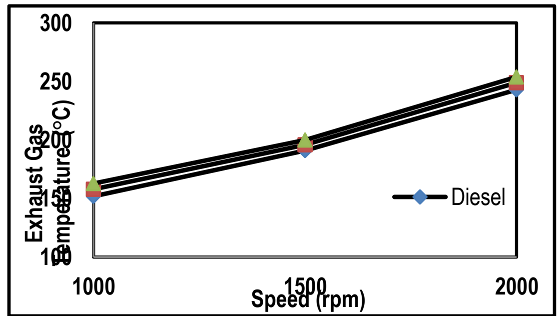


Fig.8

Figure 7: Variation of Brake thermal efficiency with speed
Figure 8: Variation of exhaust gas temperature with speed

Emission characteristic

Carbon monoxide

The variation of carbon monoxide with speed is depicted in Fig.9. At higher speed, the CO emission of B30B20D50 is less than B10B40D50 and as previously mentioned, from the literature that BBD blend reduce the amount of CO emission with increasing butanol concentration in BBD blend.

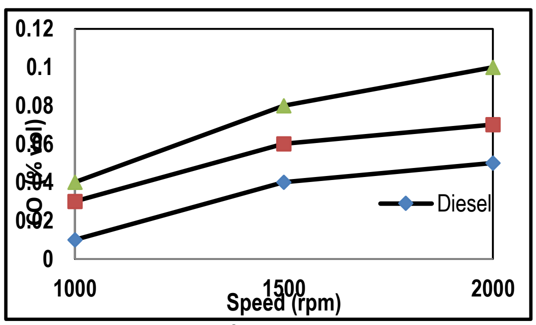


Figure 9: Variation of carbon monoxide with speed.

Hydrocarbon

The variation of hydrocarbons with speed for tested fuels is shown in Fig.10. Unburned hydrocarbon varies from 11ppm to 6ppm at variable speed for diesel. In the case of B30B20D50 blend it varies from 15ppm to 9ppm and for B10B40D50 it is 18ppm to 12ppm at the same operating condition. From the experimental results, it can be noticed that the concentration of the hydrocarbon of B30B20D50 and B10B40D50 blends is marginally higher as compare to diesel. The reason behind increased unburned hydrocarbon is may be due to insufficient oxygen content.

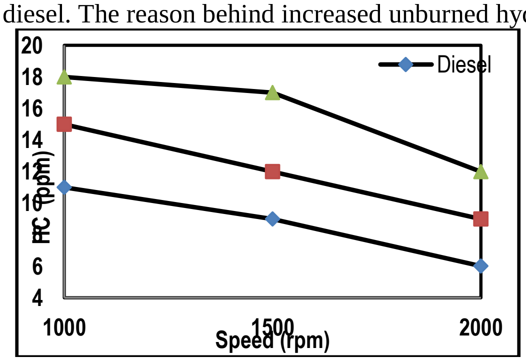


Figure 10: Variation of hydrocarbon with speed.

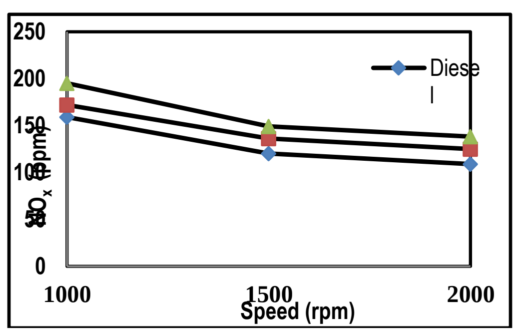


Figure 11: Variation of oxides of nitrogen with speed

Oxides of nitrogen

Fig.11 shows the comparison of oxides of nitrogen with speed. It can be noticed that the NOx emission decreases with increasing speed. NOx varies from 159ppm to 101ppm for diesel and from 172ppm to 125ppm for B30B20D50 blend and for B10B40D50 it varies from 195ppm to 138ppm. The reason for increased NOx is due to the higher heat release rate and higher combustion temperature. Thus it is seen from the Figure11 that when the percentage of butanol increased from 10 to 30 in BBD blend, there occurred a reduction in NO_X emission of about 12%.

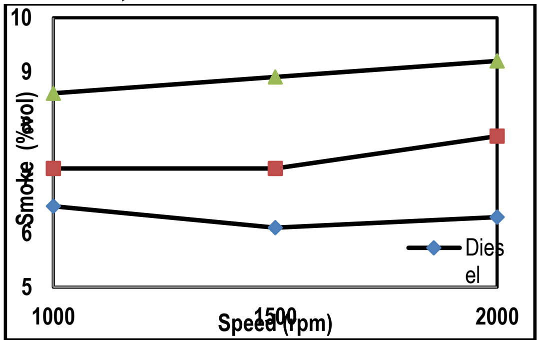


Figure 12: Variation of smoke with speed

Smoke opacity

Smoke is nothing but solid soot particles suspended in exhaust gas. Fig.12 shows the variation of smoke with speed. Smoke varies from 6.5 to 6.3 for diesel whereas in B30B20D50 blend it varies from 7.2 to 7.8. It can be noticed that the smoke level for B30B20D50 blend is low as compare to B10B40D50. The reason for lower smoke may be better and complete combustion of fuel due to the oxygen present in the B30B20D50 blend. As most of the other authors reported, the smoke opacity values decrease with the addition of butanol to diesel or biodiesel fuel.

CONCLUSION

Emission characteristic and engine performance experiments were conducted on a four-cylinder, four-stroke, common rail direct injection diesel engine. The effects of butanol and biodiesel addition in diesel on physical and fuel properties, BFSC, BTE, exhaust gas temperature, emission of CO, NOX and HC and smoke opacity were investigated. As compared to neat diesel, BBD blends increased BTE, exhaust gas temperature, CO emissions, and HC emissions and NOx emissions while decreasing the BFSC. Lower concentration of butanol in the BBD blends as compared to higher concentration of butanol, increased BSFC, CO emission, HC emission, NOx emissions and smoke opacity while decreasing the BTE. When compared to neat diesel fuel, the lower and higher concentration of butanol in BBD blends fuel has no significant changes in the exhaust gas temperature. The exception being the case of BSFC, which decreased when butanol was added to biodiesel, and according to the literature, increases when butanol is added to biodiesel.

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