Emission Characteristics of Jatropha - Dimethyl Ether Fuel Blends on A DI Diesel Engine

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Abstract— In this study, Biodiesel -Dimethyl Ether (BDE) was tested in a 4-cylinder direct-injection diesel engine to investigate the performance and emission characteristics of the engine under five engine loads at the maximum torque .The engine speed was maintained at 1500 rpm. Here the jatropha oil is used as a non edible oil to produce the biodiesel. The dimethyl ether is used as an additive to enhance the engine combustion. The BDE 5 (biodiesel 95% and dimethyl ether 5%), BDE 10 (biodiesel 90% and dimethyl ether 10%) and BDE 15(biodiesel 85% and dimethyl ether 15%) were tested in the engine. The results indicate that when compared with neat jatropha, the engine performance increased and emission level decreased with adding the diethyl ether with methyl ester of jatropha oil. In comparison with neat jatropha, the BDE10 blends have 10% higher brake thermal efficiency (BTE) .The experimental results showed that the CO, HC and NOx emission is decreased for all BDE blends. The brakes specific fuel consumption (BSFC) decreased for all BDE blends compared to neat jatropha oil.

Index Terms— Dimethyl Ether, Biodiesel, methyl ester of jatropha

1 INTRODUCTION

THE demand for energy around the world is increasing, specifically the demand for petroleum fuels. World energy consumption is expected to increase to 180,000 GWh/year by 2020 [1]. Facing the increasing consumption of petroleum fuels and the increasingly stringent emission regulations, biofuels, such as ethanol and biodiesel, have been explored to reduce fuel consumption and engine emissions. Biodiesel is an alternative diesel fuel consisting of alkyl monoesters of fatty acids derived from vegetable oil or animal fats. Because of its reproducibility, nontoxicity, and sulfur-free property, a considerable amount of recent research has focused on the use of biodiesel on diesel engines. Furthermore, due to its similar physical properties to diesel fuel, there is no need to modify the engine when the engine is fueled with its blends [2],[3]. In comparison with conventional diesel fuels, the fuel-borne oxygen in biodiesel may promote more complete combustion and thus reduce particulate matter (PM), carbon monoxide (CO) and total hydrocarbons (THC) in compression ignition (CI) engine, while increase nitrogen oxides (NOx)[4]. The same trends are obtained in the review paper published by Lapuerta et al.[5] . Thus, the higher NOx emission arising from the use of biodiesel might be considered as an obstacle of biodiesel application. However, there are also opposite trends of NOx emission in the literature. The results of Rakopoulos et al.[6] showed a slight decrease in NOx emission. Ethanol, with a high oxygen content of 35%, has been used in compression ignition engine as ethanol-diesel blends. Lapuerta et al.[7] studied the emissions of diesel-bioethanol blends in a diesel engine and concluded that the use of ethanol-diesel blends provided a significant reduction on PM emissions, with no substantial increase in other gaseous emissions (NOx,HC,CO).

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Ahmed [8] compared a 10% ethanol-diesel blend and a 15% ethanol-diesel blend with baseline diesel fuel when applied to a compression ignition engine. They found 27% and 41% reduction in PM respectively for 10% and 15% ethanol-diesel blends, while an increase of 4% and 5% in NOx respectively for 10% and 15% ethanol-diesel blends. Moreover, the use of ethanol-diesel blends has some disadvantages; for instance, an additive is required for ensuring good mixing of the two fuels and the blended fuel has poor lubricity. Biodiesel could be served as a good additive in stabilizing ethanol in diesel blends. Kwanchareon et al.[9] studied the solubility and emission characteristics of diesel-biodiesel-ethanol blends. They found that CO and HC reduced significantly at high engine load, whereas NOx increased, when compared with those of diesel fuel. Ren et al.[10] and hansen et al.[11] showed that the drop in combustion temperature due to the higher heat of evaporation could suppress NOx emissions and concluded that ethanol could act as an effective NOx emissions reducing additive. Lebedevas et al.[12] reported that CO and NOx emissions decreased from 10% to 12% for every 10% increase of ethanol blended with rapeseed oil methyl esters. Bhale et al.[13] studied the performance and emissions on Mahua biodiesel blended with ethanol. In their study, they found reduction of CO and NO emissions using 20% blended fuel but an increase in HC emission. However, there is lack of detailed data on performance and emission of additive like dimethyl ether with neat biodiesel (B100) produced from jatropha oil. Thus, the aim of this study is to investigate the performance and emissions of a diesel engine operating on biodiesel - dimethyl ether blends, using biodiesel produced from jatropha oil, and to compare these results with those obtained from neat biodiesel.

2 PRODUCTION OF BIODIESEL

Researchers have proved that oils and fats can be converted in to biodiesel by transesterification process [14],[15],[16]. Biodiesel is an alternative fuel, which has a correlation with sustainable development, energy conservation and environmental preservation. Biodiesel is biodegradable, non-toxic and essentially free from sulphur. In this work the Methyl ester of jatropha oil is produced by the Transesterification process. Esterification of jatropha oil is composed of heating of oil, addition of KOH and methyl alcohol, stirring of mixture, separation of glycerol, washing with distilled water and heating for removal of water. This process produces uniform quality of the alkyl esters and reduces viscosity and increases cetane number. In a transesterification reaction, the following parameters should be taken into account: water in the reagents, molar ratio of reagents, concentration of free fatty acids in oils, temperature, the reaction time, types of alcohol, and types of catalysts. In this research work the dimethyl ether is used with biodiesel of jatropha oil. They are mixed and stirred in the magnetic stirrer for proper mixing. This mixture was kept under investigation for more than 24 hours to see the separation of fuels. It was confirmed that there is no separation of dimethyl ether and biodiesel taking place. The dimethyl ether is blended with the biodiesel in the proportion of 5%, 10% and 15% by volume which is called as BDE5, BDE10 and BDE15. The addition of dimethyl ether to biodiesel changes the physicochemical properties of the blends. By using dimethyl ether, the density, kinematic viscosity, low calorific value and aromatics fractions of the blends decrease. Simultaneously, H/C ratio and oxygen content of the blends are enhanced, which has some favorable effects on the ignition and combustion of the blends. The main purpose of blending dimethyl ether with biodiesel, as a solvent additive, is to research the possibility to use blended fuels with high percentages of biodiesel an unmodified diesel engine.

3 TEST ENGINE AND FUEL PROPERTIES

The experiments were carried out on a naturally aspirated, water-cooled, 4-cylinder, direct-injection diesel engine. The specifications of the engine are shown in Table 1. The major properties of the fuels are shown in Table 2. In Table 2 the lower heating values of biodiesel were determined with bomb calorimeter. The densities of the three fuels were measured at 20 °C. Other properties of the fuels were obtained either from the literature or from fuel specifications.

Table 1. Engine specifications

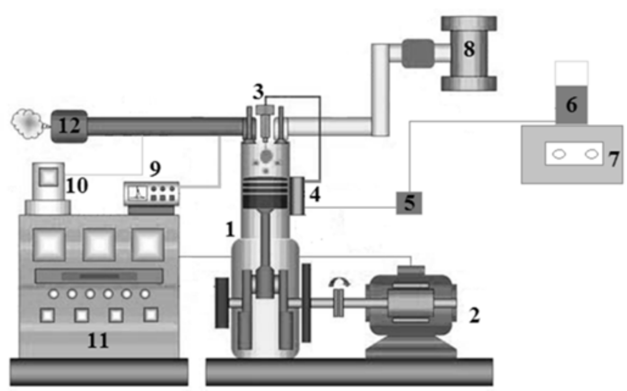
Type	:	Vertical, water cooled, Four stroke
Make	:	KIRLOSKAR AV-1
Number of cylinder	:	One
Bore	:	87.5 mm
Stroke	:	110 mm
Displacement Volume	:	661 CC
Compression ratio	:	17.5:1
Maximum power	:	3.7 kW
Speed	:	1500 rpm
Dynamometer	:	Eddy current dynamometer
Injection opening angle	:	23° b TDC

Table 2. Fuel properties

Properties	Diesel	Methyl ester of Jatropha oil	Dimethyl Ether
Density at (g/cc)	0.8/0.84	0.880	0.197
Kinematic Viscosity @ 40 °C (cSt)	2.0 to 4.5	4.36	1.84
Calorific value (kJ/kg)	42000	41000	28882
Flash Point (°C)	80	138	-41
Fire Point (°C)	86	136	13
Ash content (%)	0.01 to 0.1	0.01	---

4 EXPERIMENTAL PROCEDURE

The experimental setup is shown in Fig.1. The engine was connected to an eddy current dynamometer, and a control system was used for adjusting its speed and torque. The engine was run at a constant speed of 1500 rpm. The NOx ,CO and HC emission were measured with non-dispersive infrared analyzers (NDIR) (Make: HORIBA make Gas Analyser). The gas analyzers were calibrated with standard gases and zero gas periodically. Experiments were conducted at the engine speed of 1500 rpm and at five engine loads. At each engine operating mode, experiments were carried out for the biodiesel (B100), biodiesel-dimethyl ether (BDE) namely BDE5, BDE10 ,



1. KirloskarAV1Engine 2.Eddycurrent dynamometer
3. Injector 4. Fuel pump 5. Fuel filter 6.Fuel tank
7. Weighing balance 8.Air stabilizing tank
9.HORIBA-gasanalyzer 10. Smoke meter
11. Dynamometer control 12. Exhaust pipe

Figure 1. Experimental setup

BDE15 respectively. In this study, the diesel engine was not modified during all the tests. Before each test, the engine was allowed to operate with the new fuel for twenty minutes to clean the fuel system which is used in the previous running. The data were recorded continuously for 5 min to reduce experimental uncertainties, and average values were presented.

5 RESULTS AND DISCUSSION

The performance and emission characteristics for the various load conditions for different fuels are analyzed and the results are presented in the following sections.

5.1 Performance and Emission Parameters

5.1.1 Brake Thermal Efficiency

The variation of brake thermal efficiency (BTE) with respect to load for different additives proportion of dimethyl ether with jatropha biodiesel were considered for the present analysis and presented in Fig.2. In all cases, brake thermal efficiency has the tendency to increase with increase in applied load. This is due to the reduction in heat loss and increase in power developed with increase in load. The thermal efficiency of all blends of biodiesel-dimethyl ether (BDE) is higher than that of neat jatropha oil (B100). This is due to better mixture formation as a result of high volatility, lower viscosity and lower density of BDE blended fuels. The BTE of BDE5, BDE10 and BDE15 blends gives the higher efficiency compared to neat biodiesel .This is because of addition of more additives of dimethyl ether decrease the viscosity of mixture and improve the atomization and hence better combustion takes place. It is observed from the figure that BTE of BDE5, BDE10, and BDE 15 is 6%, 10%, and 3% higher than that of neat jatropha at full load (3.7 kW).

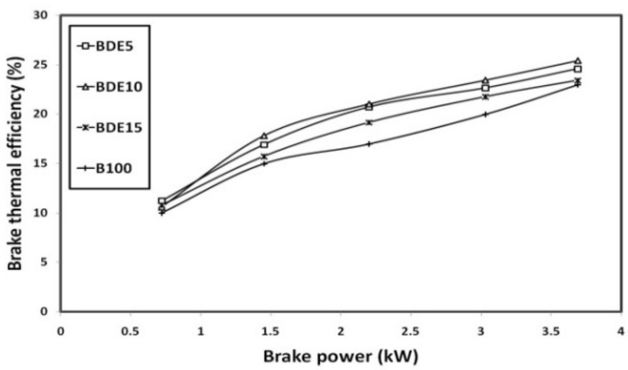


Figure 2. Comparison of Brake thermal efficiency

5.1.2 Brake Specific Fuel Consumption

The variation of brake specific fuel consumption (BSFC) with load for different fuels is presented in Fig.3. For all fuels tested, BSFC is found to decrease with increase in the load. Increased BSFC is found with all BDE blends are due to the faster burning rates and more heat release rate [17]. The BSFC of jatropha -dimethyl ether blends are higher than that of neat biodiesel for all loads. This is proved from the graph that the BDE blends gives more fuel consumption compared to neat jatropha oil (B100). BSFC for BDE5, BDE10 and BDE15 are 8%, 12% and 17% higher than that of neat jatropha. The increase of BSFC is mainly due to the lower calorific values of biodiesel and dimethyl ether compared with that of neat jatropha. The specific fuel consumption of the higher percentage of blends increases as compared to that of neat biodiesel.

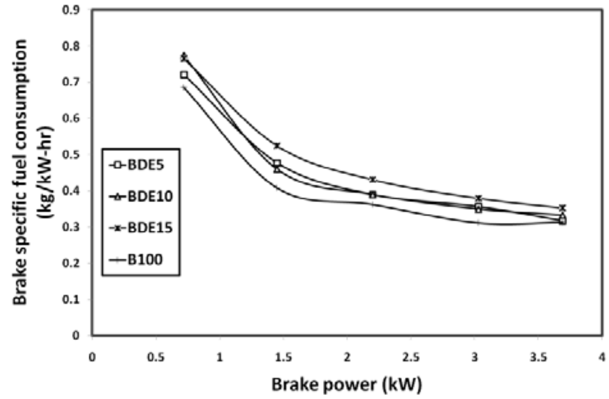


Figure 3. Comparison of brake specific fuel consumption

5.1.3 Hydrocarbon Emission

The variation of HC emissions are shown in Fig.4. Compared with neat jatropha oil, the BDE blends gives lower HC emissions. The higher oxygen content of biodiesel leads to better combustion, resulting in lower HC. The HC emissions for jatropha oil are 34 ppm, while for BDE5, BDE10 and BDE15 are 19 ppm, 25ppm and 27 ppm respectively, at full load. Therefore the percentage of reduction in HC is 42%.36% and 26% for BDE5, BDE10 and BDE15 respectively. The higher oxygen content in biodiesel and addition of diethyl ether results in lower HC emission for BDE blends. For BDE5, the amount of diethyl ether could increase the oxygen content and reduce the viscosity and density of the blended fuel, leading to improved spray and atomization, better combustion and hence lower HC emissions. But for higher blends namely BDE10 and BDE15 the percentage of HC reduction was low ,because of poor combustion of higher blends.

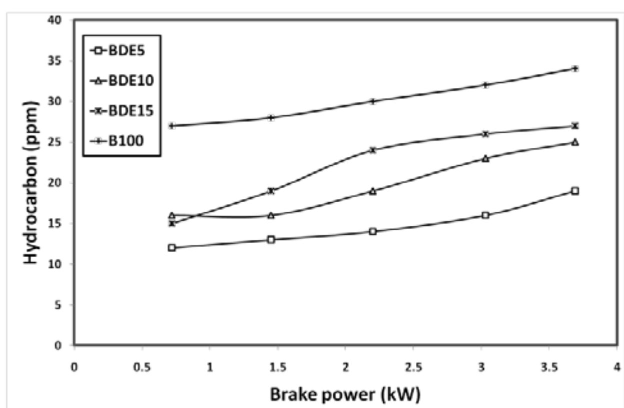


Figure 4. Comparison of HC emission

5.1.4 Carbon Monoxide Emission

The Fig.5 shows that the CO emission of BDE5, BDE10 and BDE15 fuel is lower than that of neat jatropha oil at all loads. This is because of the higher oxygen content of biodiesel, which could improve the combustion process [18]. The CO emissions increase as the air fuel ratio becomes greater than the stoichiometric value. With increasing jatropha dimethyl ether percentage, CO emission level increases. The reductions of CO for BDE5, BDE10 and BDE15 is 67%, 51% and 35% respectively at full load, compared to neat jatropha oil. This can be explained by the enrichment of oxygen owing to the diethyl ether and biodiesel addition, in which an increase in the proportion of oxygen will promote the further oxidation of CO during the engine exhaust process.

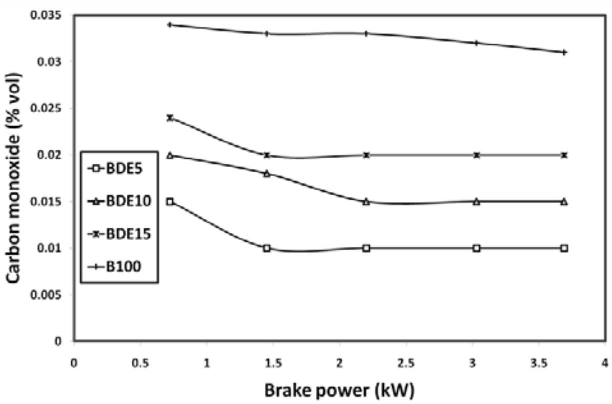


Figure 5. Comparison of CO emission

5.1.5 Exhaust Gas Temperature

The exhaust gas temperatures were increased for all the fuels with the increase of applied load [19]. It is seen that the exhaust temperature of dimethyl ether with biodiesel is increased because of enhanced combustion, compare to neat jatropha oil. In Fig. 6, BDE blends gives the higher temperature distribution at each load compared to neat jatropha oil. The main reason is the improved combustion of BDE blends , due addition of dimethyl ether with biodiesel. Another reason may be the shortened combustion period of BDE blends with increased flame velocity. The minimum exhaust gas temperature was obtained for neat jatropha oil.

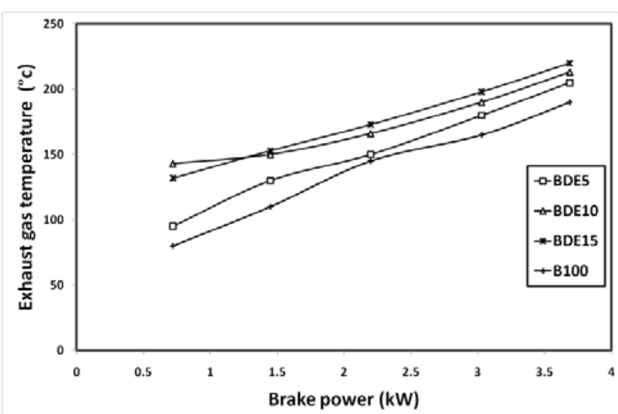


Figure 6. Comparison of exhaust gas temperature

5.1.6 Oxides of Nitrogen Emission

The NOx emissions are shown in Fig. 7. The NOx emissions increase with increase in the engine load. Compared with the neat jatropha oil, the NOx emissions for BDE15 decreased by 15% at full load. In addition, with increase of dimethyl ether quantity with biodiesel, the NOx emission also increase. The thermal mechanism dominates the formation of NOx in biodiesel combustion [1]. Thus the major factors affecting NOx formation are combustion temperature, local oxygen concentration and residence time in the high temperature zone. For the BDE blends, the cooling effect of dimethyl ether associated with its lower calorific value and higher latent heat of evaporation could reduce the combustion temperature and hence reduce the NOx emissions. The percentage of reduction of NOx for BDE5, BDE10 and BDE15 is 17%, 28%, and 35 % at full load compare to neat jatropha oil.

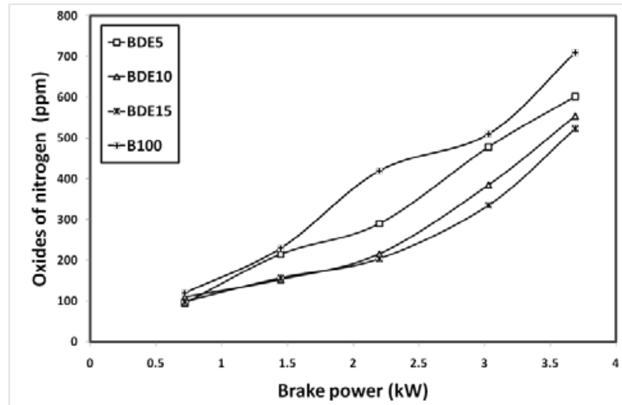


Figure 7. Comparison of oxides of nitrogen

6 CONCULSION

Based on the experimental results the performance and emissions characteristics of diesel engine using BDE and neat jatropha oil have been analysed and presented as follows. The brake thermal efficiency is increased with blends of jatropha dimethyl ether (BDE5, BDE10 and BDE15) compared to neat jatropha oil operation. The BTE of BDE5, BDE10, and BDE 15 was 6%, 10%, and 3% higher than that of neat jatropha at full load (3.7 kW). The Brake specific fuel consumption is increased in the case of jatropha -dimethyl ether blends compared to neat jatropha oil. Brake specific fuel consumption for BDE 5, BDE10 and BDE15 are 8%, 12% and 17% higher than that of neat jatropha oil. The CO and HC emissions were reduced with the use BDE fuels, compared to neat jatropha oil for all load condition. The percentage of reduction in HC is 42%.36% and 26% for BDE5, BDE10 and BDE15 respectively. The reductions of CO for BDE5, BDE10 and BDE15 is 67%, 51% and 35% respectively at full load, compared to neat jatropha oil. The exhaust gas temperature was increased for BDE fuels at all loads compared to neat jatropha oil. The NOx emission was decreased with addition of dimethyl ether. The percentage of reduction of NOx for BDE5, BDE10 and BDE15 is 17%, 28%, and 35% at full load compare to neat jatropha oil. On the whole it was concluded that the jatropha -dimethyl ether blends can be used as alternative fuels in diesel engine. The addition of dimethyl ether with jatropha biodiesel improved the engine performance and decreased the emission level.

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