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BIODIESEL BIO-OIL EMULSIONS AS ALTERNATIVE FUEL FOR DIESEL ENGINE

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ABSTRACT

Biofuels obtained from renewable resources, such as agriculture residues, woody biomass, sugars crops, and vegetable oils, are attracted because of their effect on the atmosphere is more carbon-neutral and they are less toxic in the environment. Alcohols, biodiesel, biogas are the most common biofuels used today. Bio-oil is a fuel derived from pyrolysis of biomass source. Recently biofuels and their emulsions are listed as promising alternative fuels for diesel engines. This article reports an experimental study on the use of biodiesel and bio-oil emulsions as fuels in a compression ignition(CI) engine. Emulsions were prepared by using two different types of surfactants. Comparison on engine performance and emission between the emulsified fuels, diesel and Jatropha methyl ester (JME) are discussed in this paper. The experimental results indicate that the biodiesel bio-oil emulsions enhance the combustion efficiency with improved engine performance and lower tailpipe emissions as compared to neat fuels.

Keywords: Bio-oil, Biodiesel, Emulsion, Diesel Engine, Emissions.

1. INTRODUCTION

Diesel engines find applications in the transport and agricultural sectors owing to their higher thermal efficiency, high power to weight ratio, high fuel economy and simple design. However, the pollutants particularly the NO_x and smoke generated by the operation of diesel engines contribute to the green house effect, produce acid rains, destroy the ozone layer and affect the human respiratory system. Depletion of petroleum reserves as well as concern over emission problems has now compelled us to widen our search for alternative fuels. Biodiesel is derived from animal fat, vegetable oil or waste cooking oil results in a substantial reduction of CO, CO_2, particulate emissions, poly-aromatic hydrocarbons (PAH), nitrated poly-aromatic hydrocarbons (n-PAH) and oxides of sulphur (SO_x) emissions than fossil fuels but increase in oxides of nitrogen (NO_x) emissions. It is composed of mono alkyl esters of fatty acids. These chemicals have a low flash point, a high heating value as well as density and viscosity comparable to those petroleum derived diesel. Additional advantages are better lubricity, excellent biodegradability, superior combustion efficiency and low toxicity [1]. However, it has certain demerits such as poor cold flow properties, oxidation stability and higher NO_x formation when it is used as fuel in diesel engine. The availability of feedstock for biodiesel is also found to be less in India as on today. Therefore biodiesel can be replaced with some other possible biofuel.

Wood pyrolysis oil (WPO) is a free flowing dark -brown organic liquid accompanied by a strong acid smell. The oil comprises of different size molecules which are derived from depolymerization and fragmentation reaction of three biomass building blocks: cellulose, hemicellulose and lignin [2]. It has high oxygen content and moisture content but a poor volatility, high viscosity, corrosiveness and cold flow properties which limit their uses as just additives in transportation fuel rather than being used as transportation fuels themselves. WPO cannot be made to mix directly with diesel due to poor miscibility, different surface tension and hydroscopic characteristic [3].

The application of an emulsification technique has been considered to be one of the possible approaches to reduce the production of diesel engine pollutants, as well as the rate of fuel consumption [4]. Various researches are made to make emulsions with WPO with diesel to overcome the miscibility problem. However, in this issue we have tried to replace a certain percentage of biodiesel (Jatropha methyl ester indicated as JME) with WPO, it can improve the economic prospects of biodiesel. For this purpose surfactants namely Span -80 and Tween-80 were used, which will reduce the difference in surface tension between JME and WPO. In this investigation, the performance and emission characteristics of a single cylinder, four stroke, air-cooled, direct injection diesel engine was studied with the emulsions made with WPO and JME and the results were compared with diesel and presented in this paper.

2. MATERIALS AND METHODS

2.1 Production and fuel properties of WPO

The WPO used in this investigation was produced from the pine wood feed stock by pyrolysis process. The experimental setup and the steps involved in the production of WPO were described by the authors in their earlier work [5].The measured properties of WPO is compared with diesel fuel and given in Table 1.

Table 1: Comparison of WPO with diesel and JME

Properties	ASTM method	Diesel	WPO	JME
Specific gravity at 15 °C	D 4052	0.83	1.15	0.88
Net calorific value (MJ/kg)	D 4809	43.8	20.58	39.1
Flash point (°C)	D 93	50	98	118
Fire point (^{o} C)	D 93	56	108	126
Pour point (°C)	D 97	-6	2	-1
Carbon residue (%)	D 4530	0.1	12.85	-
Kinematic viscosity at 40 °C (cSt)	D 445	2.58	25.3	4.6
Cetane number	D 613	50	27	55
Moisture content (wt %)	-	0.025	15-30	-
Carbon (%)	D3178	86.5	49.1	77.1
Hydrogen (%)	D 3178	13.2	6.2	11.81
Nitrogen (%)	D 3179	Nil	3.0	0.119
Sulphur (%)	D 3177	0.3	0.05	0.001
Oxygen (%)	E 385	Nil	41.65	10.97

2.2 Emulsification of WPO and JME

In this investigation, four different type of emulsions were prepared, two by adding a single surfactant Span-80 and remaining two by adding a mixed surfactant (Span-80 and Tween-80) 2% by volume to emulsify WPO with JME. Two emulsions prepared by taking 10%, 15% by volume of WPO with 90%, 85% by volume of JME using a single surfactant were denoted as JOE10 and JOE15. Whereas, another two emulsions prepared by using mixed surfactant were denoted as Y2JOE10 and Y2JOE15. The resultant mixture was stirred with the help of a mechanical stirrer for about 30 minutes. The emulsion produced was observed visually by about eight hours and found that the emulsions made were found to be stable.

2.3 Experimental Setup

Fig.1 shows the photographic view of the experimental setup. Technical specifications of the engine were given in Table 2.

Fig.1. Photographic view of the experimental setup

Table 2: Specifications of the test engine

Make/Model	Kirloskar TAF 1
Brake power [kW]	4.4
Rated speed [rpm]	1500
Bore [mm]	87.5
Stroke [mm]	110
Compression Ratio	17.5:1
Nozzle Opening Pressure [bar]	200
Injection Timing [^{o}CA]	23

The engine was coupled to an alternator to provide the loading. A control panel located near the engine helps to operate the alternator to provide the load to the engine by a load switch. The exhaust gas temperature was measured with the help of a temperature thermocouple fitted on the exhaust pipe. Fuel was admitted from fuel tank to the engine through a fuel filter and fuel pump. The fuel consumption was measured with the help of a burette and a fuel sensor. Air enters to an air filter and then to air box. Air intake was measured by air flow sensor that was fitted in the air box. A speed sensor was connected near the flywheel of engine to measure the speed. The exhaust pipe had a provision to access the probes of an AVL444 exhaust gas analyser that measures unburnt hydrocarbon (HC), carbon monoxide (CO) and nitric oxide (NO) emissions. HC and NO emissions were measured in ppm and CO is measured in percentage. The gas analyser is capable of measuring only NO emissions. An AVL437C diesel smoke meter was used to measure the smoke density of the engine exhaust. The specifications and accuracy of gas analyser and smoke meter used are given in Table 3. Initially the engine was operated with neat JME for obtaining reference data. The performance and emission parameters were evaluated. Then, the engine was allowed to run with the emulsions made with JOE10, JOE15, Y2JOE10, Y2JOE15.. The test was conducted three times consecutively and the repeatability of the results was coincided more than 97%. The results were compared with diesel fueled and Jatropha fueled operations.

Table 3: Specifications and accuracy of the gas analyser and smoke meter

Instrument	Make/Model	Range	Accuracy
Gas analyser	AVL444	NO-0-5000 ppm	±50ppm
		HC-0-20000 ppm	±10ppm
		CO-0-10%	0.03%
Smoke meter	AVL437C	0-100%	±1 %

3. RESULTS AND DISCUSSION

3.1 Performance parameters

The variation of brake thermal efficiency and specific fuel consumption with brake power is given in Fig.2. Thermal efficiency is the ratio between the power output and the energy introduced through fuel injection, the latter being the product of the injected fuel mass flow rate and the lower heating value.

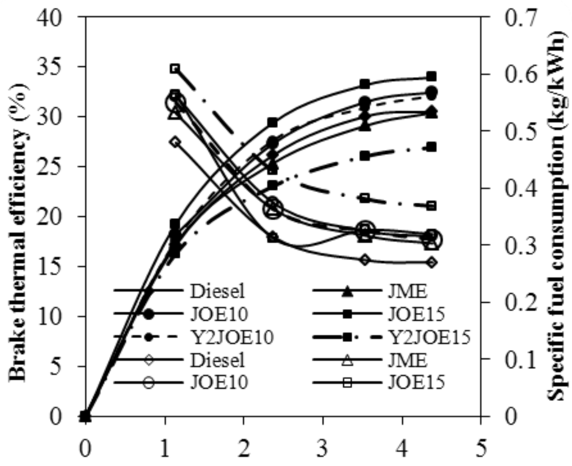

Fig. 2. Variation brake thermal efficiency and SFC with brake power

It is observed from the figure that the brake thermal efficiency of the JOE10 and JOE15 emulsions are 6.5% and 11.3% percentage higher than diesel fuel at full load. In the case of Y2JOE10 emulsion, the efficiency is higher by 5.3% compared to that of diesel fuel. Also the Y2JOE15 emulsion experienced a drop in the thermal efficiency by 11.6%. The increase in brake thermal efficiency of JOE10, JOE15 and Y2JOE10 are due to the improvement of the combustion process on account of increased oxygen content in the fuels [6]. In the case of Y2JOE15 emulsions, the drop in the thermal efficiency may be due to lower calorific values of the emulsions and poor mixture formation.

Brake specific fuel consumption is the ratio between mass of fuel consumption and brake power. The BSFC of diesel, JME, JOE10, JOE15, Y2JOE10 and Y2JOE15 at full load are 0.269, 0.302, 0.315, 0.319, 0.31 and 0.368 kg/kWh respectively. Also it can be observed that the BSFC values of JME and its different emulsions with WPO are higher than that of diesel fuel operation. This is because of the combined effects of lower heating value and the higher fuel flow rate due to high density of the JME and its emulsions with WPO [7].

3.2 Emission parameters

3.2.1 HC emissions

Figure 3 depicts the variation of HC emissions with brake power.

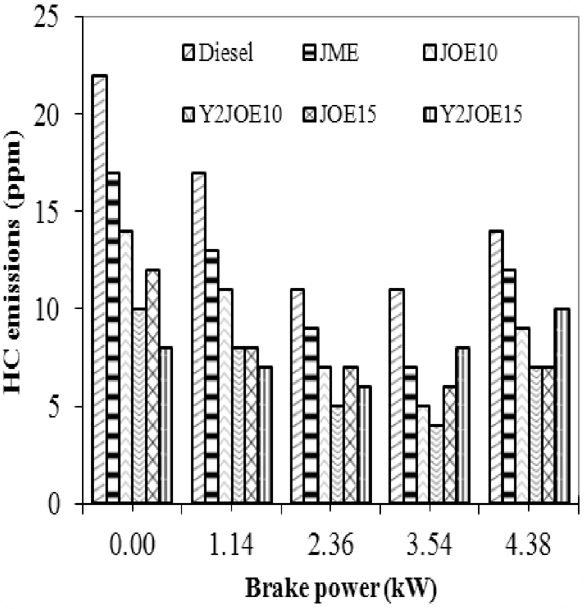

Fig.3. Variation of HC emissions with brake power

The HC emissions of JME are found to be lower than that of diesel fuel since, the higher oxygen content of the JME leads to more complete burning than diesel fuel. For the JME-WPO emulsions, HC emissions were found to be lower than that of JME. At full load condition, the HC emissions of JME, JOE10, JOE15, Y2JOE10 and Y2JOE15 are lower by 14.2%, 35.7%, 50%, 50% and 28% than that of diesel fuel. When comparing JOE15 and Y2JOE15 emulsions, higher HC emission is noticed with Y2JOE15 emulsion at full load. This may be due to higher fuel air ratios and poor mixing of fuel with air.

3.2.2 CO emissions

The variation of CO emissions with brake power is given in Fig.4. The combustion temperature in the engine cylinder significantly influences the oxidization rate of CO emission. Higher combustion temperature accelerates the oxidization rate of CO to form CO_2, and thus results in less CO in the exhaust gases of the engine [8].

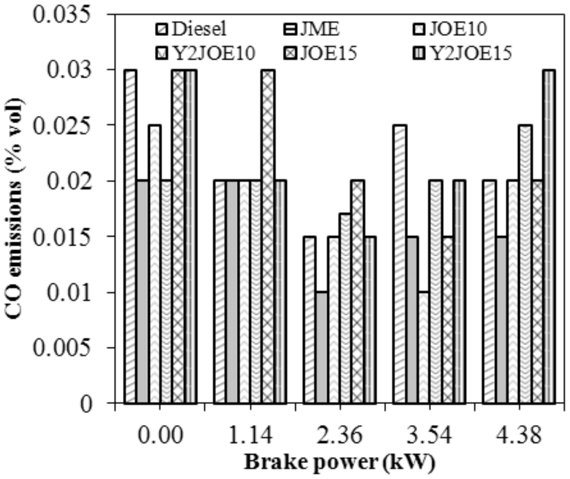

Fig.4. Variation of CO emissions with brake power

It is observed that the CO emission of JME is lower than that of diesel fuel due to the oxygen content present in the fuel, which makes the combustion complete. The CO emissions are found to be higher by 25% and 50% in the case of Y2JOE10 and Y2JOE15 emulsions compared to that of diesel, JOE10 and JOE15 emulsions. This may be due to reduction in oxidation time for converting CO into CO_2.

3.2.3 NO emissions

The variation of nitric oxide (NO) emissions with brake power is presented in Fig.5. NO is formed by chain reactions involving nitrogen and oxygen in the air. These reactions are highly temperature dependent. Since diesel engines always operate with excess air, NO emissions are found to be higher than SI engines. Also NO emissions are mainly a function of gas temperature. It can be observed from the figure that the NO emissions of the JME operation are higher compared to JME-WPO emulsions as well as diesel operation. The presence of oxygen molecule in biodiesel causes an increase in combustion gas temperature resulting in a marginal increase in NO emissions [9]. The NO emissions of JME, JOE10, Y2JOE10 and Y2JOE15 are higher by 12.8%, 2%, 3% and 1.5% than that of diesel fuel at full load. In the case of JOE15 emulsion the NO emissions are lower by 3% compared to that of diesel fuel. It can be observed that the NO emissions are lower with addition of WPO in JME compared to that of JME operation.

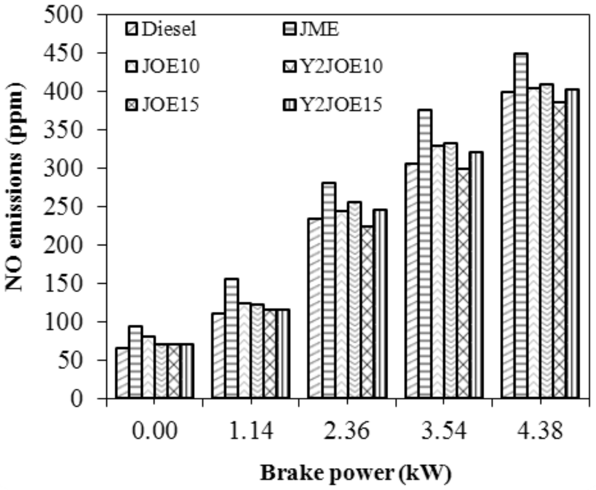

Fig.5. Variation of NO emissions with brake power

This may be due to the water content present in the WPO which may reduce the combustion temperature [10].

3.2.4 Smoke density

In diesel engine smoke formation generally occurs in the fuel rich zone at high temperature, particularly within the core region of fuel spray. Fig. 6 depicts the variation of smoke density with brake power.

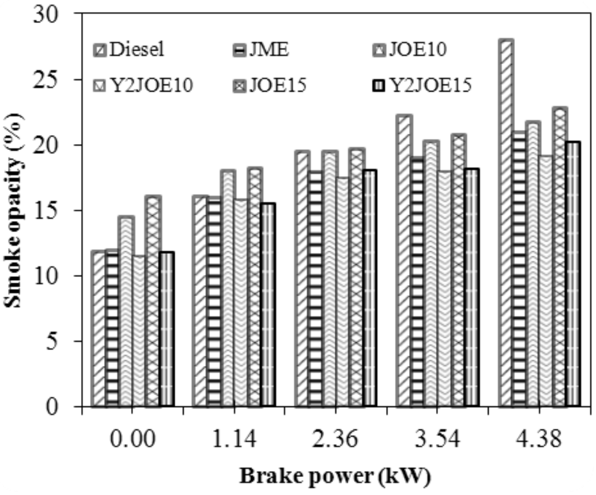

Fig.6. Variation of smoke opacity with brake power

It can be viewed from the figure that the smoke density of JME, JOE10, JOE15, Y2JOE10 and Y2JOE15 are lower by 25%, 22.1%, 18%, 31.7% and 27.8% respectively than that of diesel fuel at full load. The significant reduction in smoke emission may be due to the presence of oxygen in JME and JME-WPO emulsions [11]. Compared to JOE10 and JOE15, the Y2JOE10 and Y2JOE15 experience more reduction in smoke density.

4. CONCLUSIONS

The performance and emission characteristics of a single cylinder, 4-stroke, direct injection diesel engine using four different JME-WPO emulsions were investigated and compared with the neat diesel and JME operations. It is observed brake thermal efficiency of the JOE10, JOE15 and Y2JOE10 emulsions are 6.5%, 11.3% and 5.3% higher than diesel fuel at full load. For Y2JOE15 emulsions the thermal efficiency drops by 11.6%. The BSFC values of JME and all JME-WPO emulsions are higher than diesel fuel operation. JME and JME-WPO emulsions emit lower HC emissions to the environment. When comparing JOE15 and Y2JOE15 emulsions, higher HC and CO emissions are experienced by Y2JOE15 emulsions at full load. The NO emissions of JME-WPO emulsions exhibit declining trend with WPO addition. In the case of JOE15 emulsion the NO emissions are lower by 3% compared to that of diesel fuel. Smoke density of JME and JME-WPO emulsions are found to be lower than diesel fuel operation. Compared to JOE10 and JOE15, the Y2JOE10 and Y2JOE15 experience more reduction in smoke density.

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NOMENCLATURE

WPO	Wood Pyrolysis Oil
KME	Karanja Methyl Ester
JME	Jatropha Methyl Ester
JOE	Jatropha Oil Emulsion
HC	Hydrocarbons
CO	Carbon monoxide
NO	Nitric oxide
CO_2	Carbon-di-oxide

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