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Experimental Investigations on Diesel engine using Methyl esters of Jatropha oil and fish oil

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Abstract. The aim of the study is to use fish oil methyl ester (FME) and Jatropha oil methyl ester (JME) as a substitute for diesel in compression ignition engine.Experiments were conducted when the engine was fuelled with Diesel, Fish oil methyl ester and Jatropha oil methyl ester. The experiment covered a range of loads. An AVL smoke meter was used to measure the smoke density in HSU (Hatridge Smoke Unit). The exhaust emissions were measured using exhaust gas analyzer. High volume sampler was employed to measure the particulate matter in exhaust.The performance of the engine was evaluated in terms of brake specific fuel consumption, brake thermal efficiency. The combustion characteristics of the engine were studied in terms of cylinder pressure with respect to crank angle. The emissions of the engine were studied in terms of concentration of CO, NOx, particulate matter and smoke density.The results obtained for Fish oil methyl ester, Jatropha oil methyl ester, were compared with the results of diesel. Bio-diesel, which can be used as an alternate diesel fuel, is made from vegetable oil and animal fats. It is renewable, non-toxic and possesses low emission profiles.

1. Introduction

Fluctuations in the fuel price and limited number of oil reserves are the causes of for the arise of alternative fuel technology. In the current context, India is producing only 30% of petroleum fuels requirement. The rest 70% is being imported1. Biodiesel is a form of diesel fuel manufactured from vegetable oils and animal fats. It is safe, biodegradable and produces less air pollutants than petroleum-based diesel. Biodiesel is a liquid fuel made up of fatty acid alkyl esters, fatty acid methyl esters (or) long-chain mono alkyl esters. Like conventional diesel, biodiesel is used in compression-ignition engines. Any fatty acid source may be used to prepare biodiesel. Thus, any animal or plant lipid should be a ready substrate for the production of biodiesel. The use of edible vegetable oils and animal fats for biodiesel production has recently been of great concern because they compete with food materials.

There are several countries has already started to substitute biodiesel for the conventional diesel. India is also one among them. So many plant sources are available to get oil from it for the production of Biodiesel. Some of them are Jatropha, Maize, Soybean, UCO (used cooking oil), Cotton seed and Rape seed. Biodiesel- the substitute has the fuel properties very close to the conventional Diesel. There are literatures which reported that the output power for biodiesel is almost equal to diesel. But the Specific fuel consumption for biodiesel is higher than diesel. This is due to its lower heating value [2]. Transesterification is one the popular techniques used to convert the oil in to biodiesel, it also enhance the properties of plant oils to meet the requirements of a diesel engine [3,11].

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Jatropha oil is having promising career as a biodiesel source. Tests were already conducted on the CI engines running with Jatropha oil blends with Diesel. While using as dual fuel mode with Diesel it has recorded brake thermal efficiency very closer to pure Diesel as well less smoke [4]. Most research on biodiesel has focused on using plant based oils as feed stocks. There has been much less works on converting animal-based oils into biodiesel [5]. One potential source of oil is fish oil. A large amount of fish by-products are generated from the fishing industry. Some of these products are converted into fish meal and oil, but approximately 60% are not utilized [6,9]. The oil contained in the discarded fish parts can be extracted and better converted in to fish oil methyl ester (Biodiesel) by transesterification process [7].

2. Experimental Setup and Methodology

The work used crude fish oil extracted from the lipid content present in the soap stock of discarded parts of different marine fish. The soap stock was treated by series of processes, i) cooking it thoroughly in boiling water, ii) squeezing it and iii) centrifugally separating the product. The crude fish oil of the marine fish was brown and contains many impurities, such as water, fish residue and saline compounds. To remove these impurities the lipids was refined by a set of pre-treatment processes. These processes included the absorption of the fish residue by active clay, winterizing at 4°C for 2 hrs, centrifuging for 10 min at 3000 rpm to remove the solid impurities, washing with water by 5 vol. % distilled water for 15 min, and heating to 105°C for 30 min [6,7]. The refined fish oil then used to produce biodiesel.

Table 1. Fuel properties

Properties	Diesel	Fish oil methyl ester	Jatropha oil methyl ester
Kinematic viscosity at 40°C (Cst)	3.52	4.96	5.4
Density at 15°C (kg/m^3)	830	850	870
Flash point (°C)	49	162	169
Cetane number	50	51	53
Calorific value (kJ/kg)	43000	37800	38450
Total sulphur (% by mass)	0.01	0.05	Nil
Distillation (% by volume)	-	90 at 333°C	90 at 330°C
Ash (% by mass)	0.01	Nil	0.03
Oil ester (biodiesel) %	-	89.96	90.69
Carbon residue	0.1	0.47	0.35

The refined fish oil was transesterified with methyl alcohol to produce biodiesel. Sodium methoxide was prepared by mixing 25% (by volume of oil) of pure methanol and 6.25g (Per liter of oil) of sodium hydroxide (NaOH). The sodium methoxide, which played a role of enhancing the transesterification process was poured in to a reaction vessel and mixed with the refined fish oil. To prevent the methanol from being vaporized by the reactant mixture, the reacting temperature was fixed at 60ºC, which is just below the boiling point of methanol at 63ºC [8]. The mixing was done for 50 to 60 minutes. Then the mixture was poured in to a separating funnel and it was allowed to rest for 12 hours. The glycerin was formed at the bottom and the methyl ester at the top. Methyl ester was separated from the glycerin which is called biodiesel [10]. Finally, it was washed and dried to remove the excess alcohol. The properties of the tested fuel are presented in Table 1.

A vertical water cooled single cylinder four stroke, direct injection diesel engine was used for this study. The engine was coupled with eddy current dynamometer for load measurement. The smoke density was measured using AVL smoke meter. Exhaust emissions were measured using exhaust gas analyzer. Particulate matter was measured using high volume sampler. Experiments were conducted with pure diesel, fish oil methyl ester (FME) and Jatropha oil methyl ester (JME). The experiment covered a range of loads.

3. Results and Discussion

The Combustion, performance and emission parameters of the engine with the considered biodiesel blends are analyzed here. The results of Fish oil and Jatropha oil biodiesel blends are compared with the results of diesel.

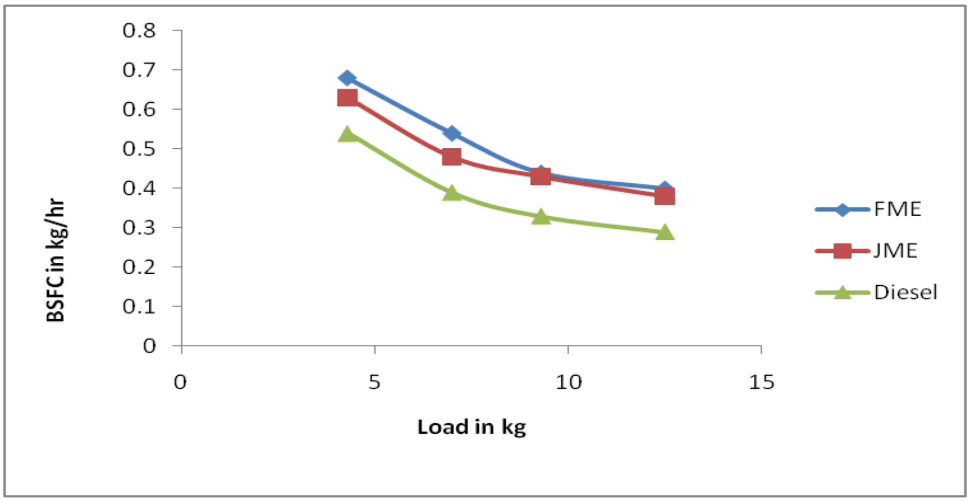

Figure 1. Load Vs BSFC

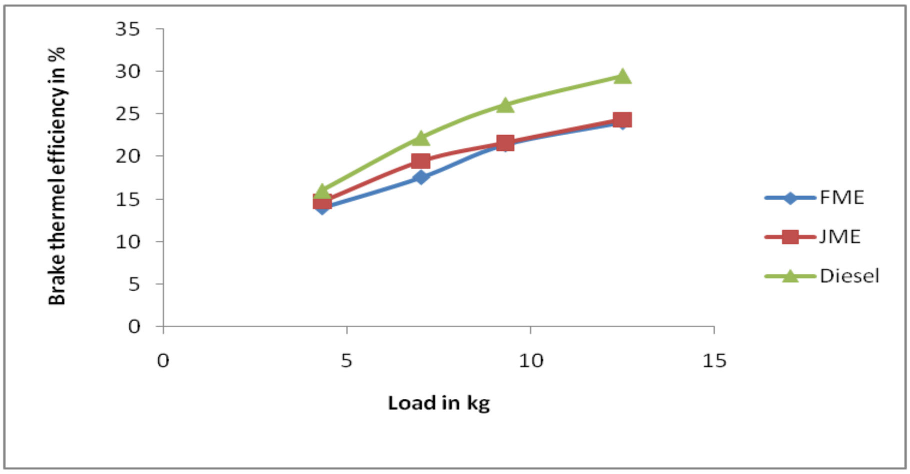

Figure 2. Load Vs Brake Thermal Efficiency

3.1. Brake specific fuel consumption

Brake specific fuel consumption of the engine is defined as the ratio between mass of fuel consumed to produce one unit of brake power for one hour. The BSFC results for the tested fuels are presented in the figure 1. For all the tested fuels the BSFC values decrease with increase in the engine load. The differences between the values of BSFC for FME and JME are small. The minimum BSFC values calculated are 0.29 kg/kW hr, 0.38 kg/kW hr and 0.40 kg/kW hr for Diesel, JME and FME respectively. The higher BSFC values of the FME and JME indicates their lower calorific value and the higher fuel flow rate due to high density. More quantity of fuel is consumed to maintain the engine speed constant.

3.2. Brake thermal efficiency

BrakeThermal efficiency of the engine is defined as the ratio between the power output and heat energy supplied through fuel injection. The BTE results for the tested fuels are presented in the figure 2. For all the tested fuels the BTE values increase with increase in the engine load. The brake thermal efficiency values are higher for pure diesel compared to JME and FME at all loads. At higher loads the brake thermal efficiency values of JME and FME are almost equal. The brake thermal efficiency values at full load are 29.55%, 24.37 % and 24.04 % for pure diesel, JME and FME respectively. The low brake thermal efficiency values of methyl esters are due to their low calorific value and increase in fuel consumption.

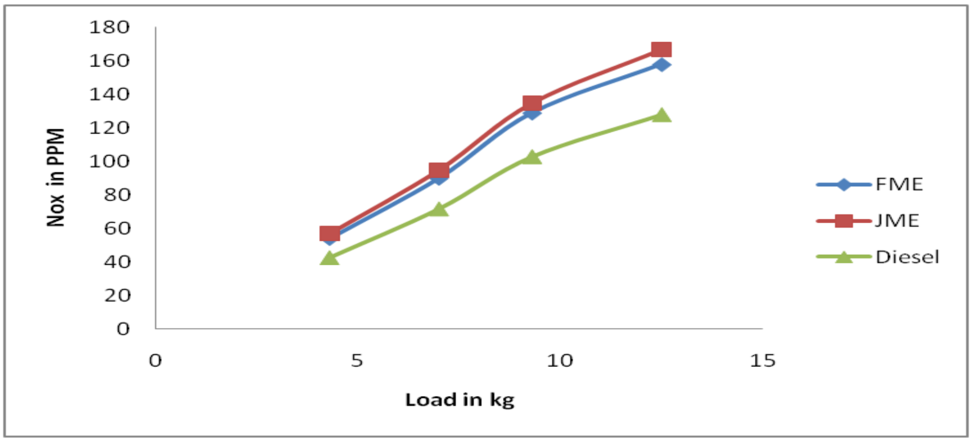

Figure 3. Load Vs NO_x

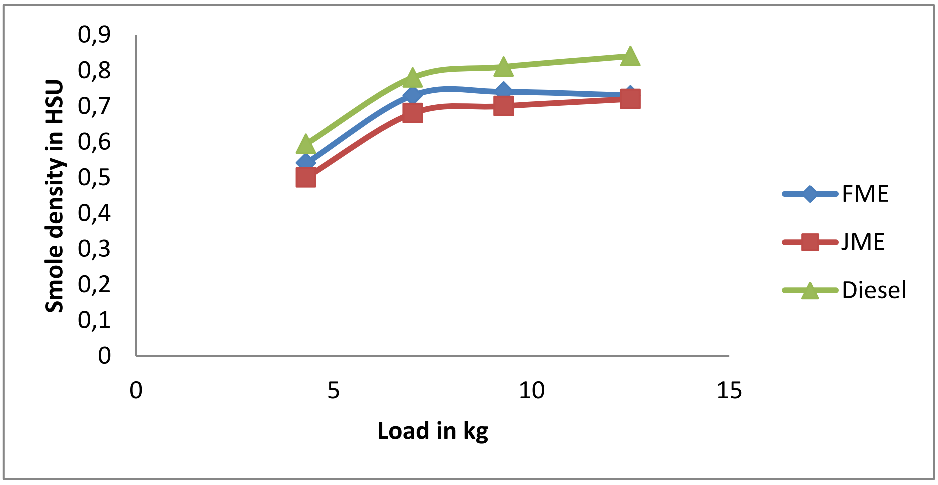

Figure 4. Load Vs Smoke Density

3.3. NO_x emission

The formation of NO_x is mainly dependent upon the availability of oxygen during combustion and flame temperature. Figure 3. Indicates the variation of NO_X emission with load for the tested fuels. It is clear from the figure that the NO_x emission value decreases in the order of Diesel, FME and JME. It is observed that FME shows 25% higher value of NO_x emissions when compared with diesel. It is observed that JME shows around 30-32% higher value of NO_x emissions when compared with diesel. The nitrogen oxide emission increases with increase in loads due to the increase in cylinder gas temperature.

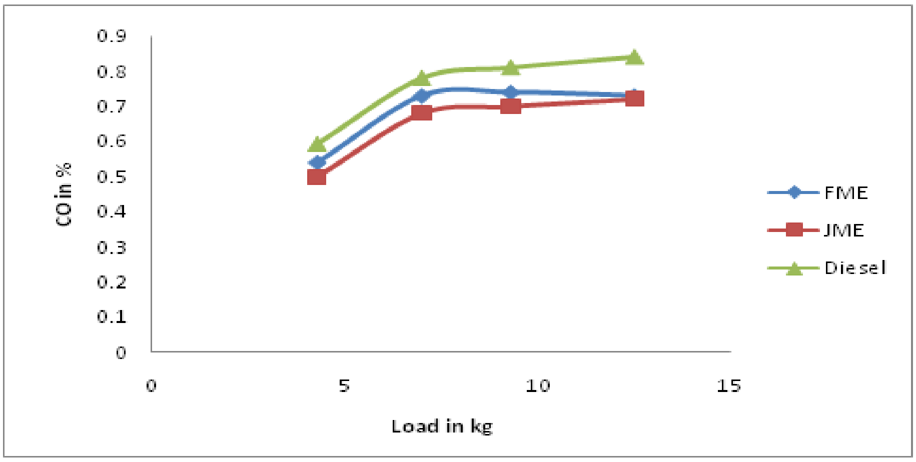

Figure 5. Load Vs Carbon monoxide

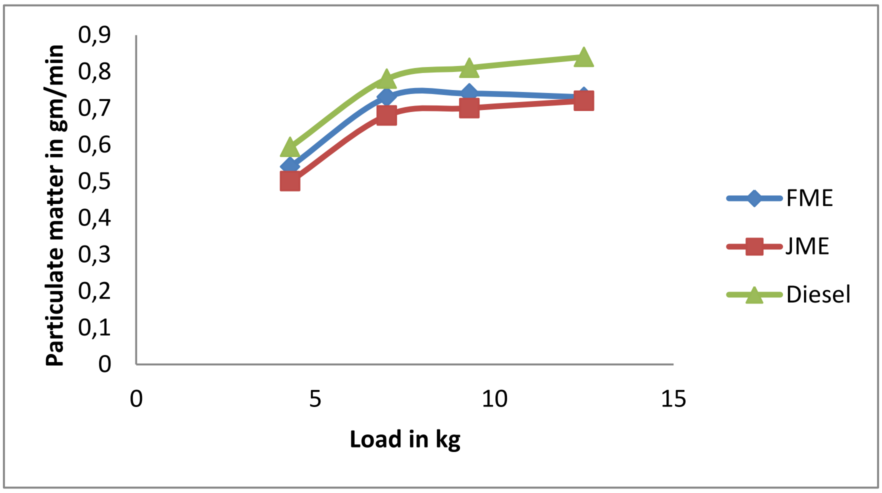

Figure 6; Load Vs Particulate matter

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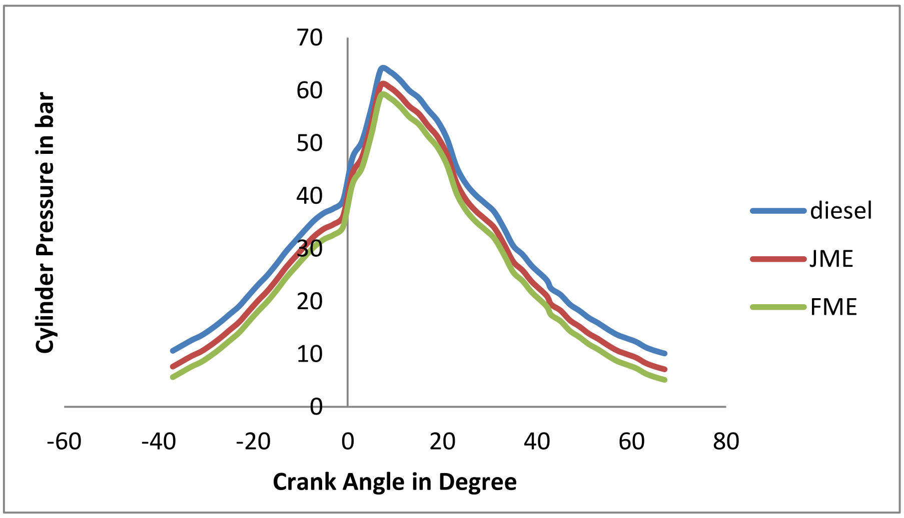

Figure 7. Crank angle Vs Cylinder Pressure

3.4. Smoke density

The formation of smoke is primarily resulted from the incomplete burning of the hydrocarbon fuel and partially reacted carbon content in the liquid fuel. Figure 4 shows the variation of smoke density with load for various test fuels. It is observed that FME shows 18% lower value of smoke density when compared with diesel. It is observed that JME shows 25% lower value of smoke density when compared with diesel. This may be due to improved combustion characteristics of methyl esters. The smoke density is found to be higher for FME compared with JME. The reason may be due to its larger quantity of carbon residue compared with JME.

3.5. CO emission

Figure 5 shows the variation of CO emission with load for various test fuels.CO is predominantly formed due to the lack of oxygen. Since methyl esters are oxygenated fuels, it lead to better combustion of fuel resulting in decrease in CO emission. It is found that the burning of FME and JME produced fewer CO emissions than the diesel. The CO emission is found to be lower for JME and its blends compared to other two fuels. It is found that FME shows 60% reduction and JME shows 65% reduction when compared with diesel at all loads.

3.6. Particulate matter

Brake Particulate emissions are as a result of incomplete combustion. It was clear from the figure 6 that the Particulate matter emissions decrease in the order of Diesel, FME and JME. It is observed that FME shows around 8-10% lower value of particulate matter emission when compared with diesel. It is observed that JME shows around 14% lower value of particulate matter emission when compared with diesel. Since methyl esters are oxygenated fuels, they promote better combustion and result in reduction of particulate matter emissions.

3.7. Pressure variation with crank angle

The pressure variation in the cycle is important in the analysis of the performance characteristics of any fuel. Figure 7 shows the variation of cylinder pressure with crank angle for various fuels at rated load. Similar trends are observed for other loads also. JME and FME exhibit slightly lower pressure at all crank angles compared to diesel. The peak pressure values are 64 bars for diesel, 61 for JME, 59 bars for FME.

4. Conclusion

From the above analysis it can be concluded that fish oil methyl ester produce lower smoke, CO, Particulate matter emissions compared to diesel but slightly higher compared to Jatropha oil methyl ester. The NOx emissions of fish oil methyl ester are higher than diesel and lower than Jatropha oil methyl ester. The fish oil methyl ester is having satisfactory performance and combustion characteristics which are comparable with diesel and Jatropha oil methyl ester.

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