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PERFORMANCE STUDIES ON DIESEL ENGINE USING BLENDS OF COCONUT DE-OILED CAKE AND METHYL ESTERS OF JATROPHA

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ABSTRACT
Increasing environmental concern, depleting oil and natural resources are the driving forces in promoting biodiesel as an alternate fuel. Vegetable oils are considered as good alternatives to diesel as their properties are comparable to diesel and at present biodiesel are commercially produced from vegetable oils by esterification processes. Since most of these oils are edible, its cost restricts the usage. The de-oiled cakes after crushing the seeds contain around 2% of oil with less fatty materials has been considered in this study, by complementing with diesel fuel. The fuel is prepared by adding dry coconut de-oiled cake (Coc) powder at 15 percent by weight with diesel, and methyl esters of Jatropha (MEJ), while Jatropha seeds which are transesterified and blended with diesel in 15% percent. Experimental results reveal that the fuel has the potential in reducing the smoke levels, carbon monoxide, unburnt hydrocarbon emissions simultaneously along with a marginal increase in brake thermal efficiency and oxides of nitrogen.
Keywords: Biodiesel, Coconut De-Oiled Cake, Methyl Esters of Jatropha, Emission Study, Diesel Engine

INTRODUCTION

The petroleum based diesel fuel needs to be substituted with alternate fuel to meet the energy demands in the future for developing countries.[1] The fossil fuels are depleting drastically which increases the demand in the international market that affects the economy of the developing countries like India.[2] Thus, an alternate energy source to be identified to overcome the problems with the petroleum based diesel fuel. One such energy source is fuel derived from vegetable oil that is bio diesel. Many biodiesels in the form of esters are being experimented to suit the diesel engine without any major engine modification. Pure coconut oil usage in diesel engine shows lesser smoke, carbon monoxide (CO), hydrocarbon (HC) emissions compared to diesel fuel since it has oxygen molecules which result in enhanced oxidation.[3] With pure coconut oil and diesel fuel blends in an automotive DI diesel engine increase in brake power and net heat release rate with a reduction in emissions such as HC, CO, NOx, smoke are reported for coconut oil in the fuel blend.[4] The increase in brake power is expected due to larger fuel droplets and oxygen content in coconut oil, which contribute to better combustion.[5] When the coconut oil in the fuel is increased above 20% decrease in performance was reported which is attributed to lower calorific value, with a reduction in emissions.[6,7] Even though the coconut oil gives a significant reduction in emission, it is edible oil based fuel thus cost of the oil restricts its use as a fuel for replacing diesel. The Coconut De-Oiled Cake (Coc) was investigated by a couple of authors in a variable speed DI diesel engine and their results show that emissions are lowest for Coc compared to diesel.[8,9] The fuel can be categorized as oxygenated fuel since it has oxygen molecules and this oxygen can enhance the oxidation during the combustion resulting in lesser CO, HC and smoke emission.[10,11] The de-oiled cakes contains oxygen with very minimum fatty substances, and hence in this work, a fuel is produced by adding 15% of de-oiled cake with diesel.[12,13]

Biodiesel derived from the trans-esterification of fats and oils is a possible fuel for diesel engines, Methyl Esters of Jatropha (MEJ) is derived through transesterification process.[14,15] Properties of this fuel are comparable to that of diesel and can be used directly to run the existing diesel engines or as a blend with crude oil diesel.[16] Biodiesel is renewable, biodegradable and non-toxic, with diesel it increases fuel lubricity and operates in compression ignition engines with little or no modification[17]. In the present work, non-edible coconut de oiled cake and the methyl ester of Jatropha blends with diesel were compared for the performance and emission characteristics. Experimental investigations have been carried out to examine performance and emissions of 15% MEJ blend and 15% de-oiled coconut cake blends with diesel in comparison to sole diesel fuel.

EXPERIMENTAL

The major problems in the direct use of vegetable oil as fuel in the diesel engine are fuel filter plugging, choking of injector nozzles, sticking of piston rings and crankcase oil dilution. The kinematic viscosity of the vegetable oil is generally higher than diesel fuel and can be brought down by various techniques such as preheating, blending, emulsification and transesterification. The de-oiled cake of edible and non-edible oils is now used as cattle feed and manure which is a good oxidizer having less fat and will be dissolved in diesel up to some extent. The de oiled cake was dried and pulverized and the fuel was prepared by adding a known amount of pulverized de oiled cake with a known amount of diesel and the blend can settle for 5 to 7 days to get a completely dissolved blend. The sediments are filtered and the fuel is used in a diesel engine without any engine modification. The properties of the diesel fuel, coconut oil, coconut oil blends and Coc blends were measured and given in Table-1 and 2.

Table-1: Properties of Coconut De-Oiled Cake (Coc) Blends

Properties	Diesel	Limits as per IS 15607-2005 ASTM D6751	Coconut De-Oiled Cake Blend (15%)	MEJ Blend (15%)
Kinematic Viscosity at 40°C (cSt)	3.366	1.9-6.0	4.2	4.5
Calorific value (kJ/Kg)	42,000	-	40,055	39,640
Density (kg/m³)	830	860-900	872	882
Calculated Cetane Index	50	-	53	54
Flash Point (°C)	54	120 min	154	160

The experiment was conducted on Kirloskar, four strokes, single cylinder, air cooled diesel engine. The rated power of the engine was 5.2 kW at 1500 rpm. The engine was operated at a constant speed of 1500 rpm and standard injection pressure of 200 bar pressure. Experiments were conducted with different blends of diesel with coconut de-oiled cake powder (Coc) and Methyl Esters of Jatropha (MEJ) ranging from 15% by weight to sole fuel. Readings were taken, when the engine was operated at a constant speed of 1500 rpm for all loads. The performance of the engine was evaluated in terms of brake thermal efficiency, specific fuel consumption from the above parameters. The combustion characteristics like cylinder pressure and heat release rate were noted for different blends.

Table-2: Comparison of the Fatty Acid Composition (wt %) of Coconut De-Oiled Cake (Coc) and Methyl Esters of Jatropha (MEJ)

Types of Fatty Acids	Chemical Structure	Type	MEJ	Coc
Palmitic Acid	C16:0	S	15.30	12.6
Stearic Acid	C18:0	S	9.60	3.99
Oleic Acid	C18:1	US	40.60	10.54
Linoleic Acid	C18:2	US	33.40	2.58

Linolenic Acid	C18:3	US	0.30	0.01
Arachidic Acid	C20:0	S	-	0.2
Saturated Fatty Acids (S)	C14-C18	-	25.60	86.75
Unsaturated Fatty Acids (US)	C18:1,2,3	-	74.30	13.25

RESULTS AND DISCUSSION

Carbon monoxide emissions

Figure-1 shows that the variation of Carbon monoxide (CO) emission with the load. Formation of CO is due to insufficiency oxygen and time in the combustion chamber during the combustion process. In general, the CO emissions are low for diesel engines as they operated with lean mixtures.
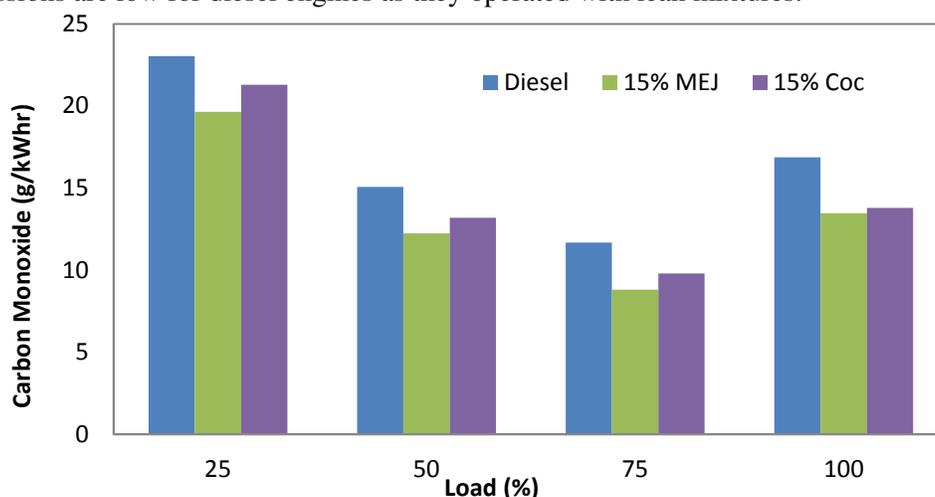
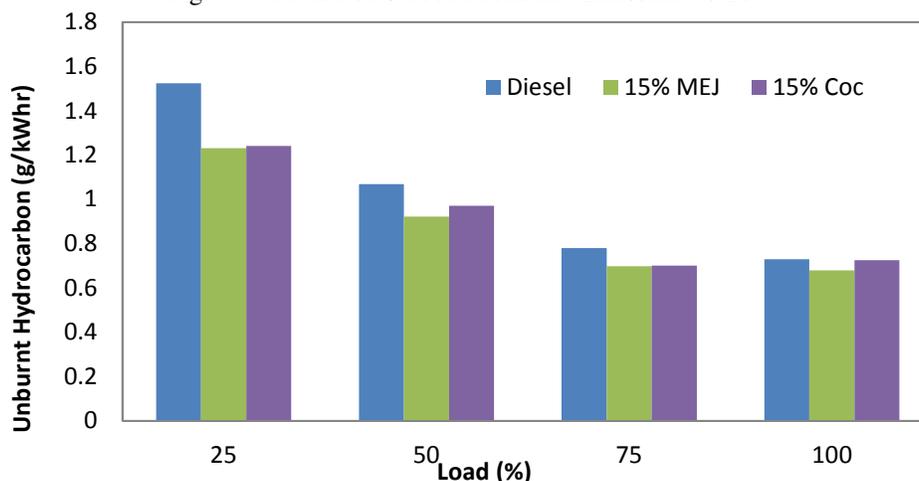Fig.-1: Variation of Carbon Monoxide Emission Vs Load

Fig.-2: Variation of Unburnt Hydrocarbon Emission Vs Load

It is observed that both 15% MEJ and 15% Coc blends show lower CO compared to diesel at all the loads. The CO emission varies from 19.64 g/kWh at 25% of load to 13.47 g/kWh for 15% MEJ blends at full load while 15% Coc CO emission varies from 21.3 g/kWh to 13.8 g/kWh. Diesel fuel shows higher CO emission which varies from 23.04 g/kWh at 25% of load to 16.87 g/kWh at full load. Due to the intrinsic oxygen content in MEJ and Coc, the oxygen available for oxidation of CO is more compared to diesel which results in reduced CO emission.

1045

Unburnt hydrocarbon emissions
The emissions of UBHC, CO and NOx are measured using AVL five gas analyzer and converted to g/kWh. The variation of Unburnt Hydrocarbons (UBHC) with the load for 15% MEJ and 15% Coc compared with that of diesel is shown in Fig.-2. It is observed that UBHC emissions decrease as the load increases for all the fuels tested. The oxygen surrounding the fuel droplets would take the relatively larger time to assist the combustion of fuel droplets; there is a reduction in UBHC emissions for all loads. It can be observed that Coc blends show marginally higher UBHC emissions compared to MEJ.
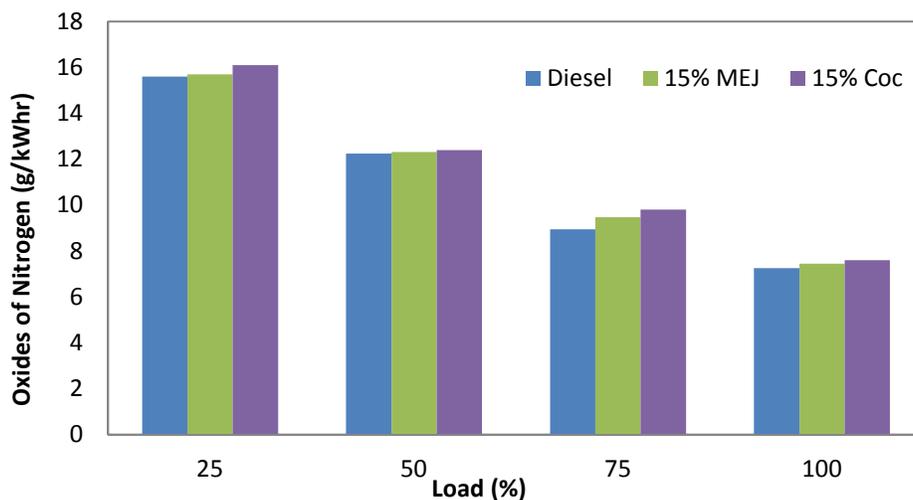

Fig.-3: Variation of Oxides of Nitrogen Emission Vs Load

Oxides of nitrogen emissions
Oxides of nitrogen (NO_x) consist of nitric oxide (NO) and nitrogen dioxide (NO_2). Nitric oxide is predominant in the oxides of nitrogen produced inside the engine cylinder. The variation of NO_x emission with the load for these fuels tested is shown in Fig.-3. A gradual increase in the emission of NO_x is observed at all loads except at 25% load. As methyl esters and Coc are oxygenated fuels their use results in higher combustion temperature and higher NO_x emission at higher loads[18]. The NO_x emission varies from 15.095 g/kWh at 25% of load to 7.454 g/kWh for 15% MEJ blend at full load. NO_x emission varies from 15.4 g/kWh to 7.6 g/kWh for 15% Coc. Diesel fuel show higher NO_x emissions which vary from 15.6 g/kWh at 25% of load to 7.25 g/kWh at full load. Coc blends show higher values of NO_x emissions compared to MEJ blends.

Smoke emissions
Diesel particulate matter consists higher agglomerated solid carbonaceous material, ash, volatile organic and sulfur compounds resulting from incomplete combustion of hydrocarbons present in the fuel. The increase in smoke emissions for diesel fuel is also due to higher boiling point and thermal stability of aromatic hydrocarbons present in it. It can be observed that smoke emission increase with an increase in power output for all the fuels due to lower air fuel ratio at higher loads as shown in Fig.-4. The smoke emissions at full load for diesel, 15% MEJ and 15% Coc are 166 mg/m³, 123 g/m³ and 150 g/m³ respectively.
Figure-5 shows the variation of cylinder pressure with crank angle at rated power output for diesel, 15% MEJ and 15% Coc oil respectively. In-cylinder peak pressure is higher for 15% MEJ and 15% Coc compared to diesel. The cylinder pressures at all the crank angles are higher for both the blends compared to diesel due to their higher cetane number and shorter ignition delay compared to diesel. Hence, combustion starts early in the case of methyl ester blend and results in higher cylinder pressure. Methyl esters are oxygenated fuels and their higher oxygen content results in better combustion and higher cylinder

pressure. It is observed that both the methyl ester blends show marginally higher in-cylinder pressure during the expansion stroke due to the late burning of higher fatty acid components present in them.
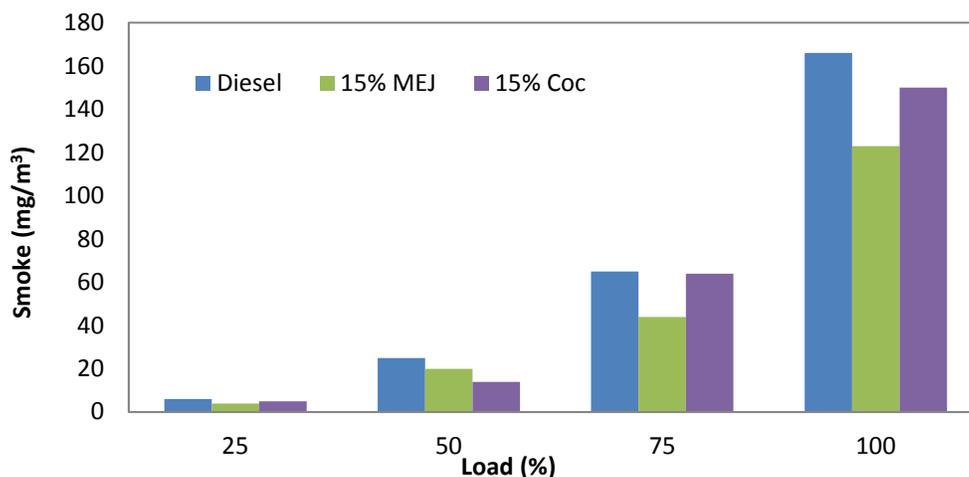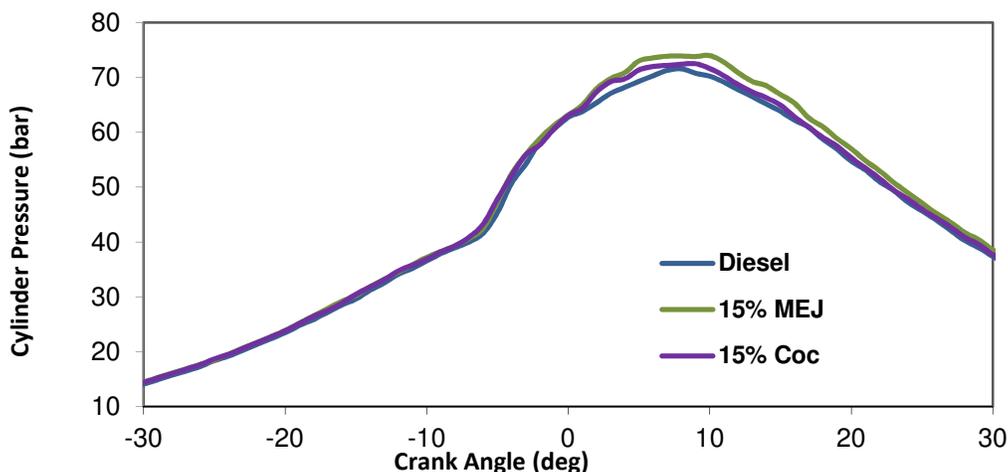

Fig.-4: Variation of Smoke Vs Load

Fig.-5: Variation of Cylinder Pressure Vs Crank Angle

The ignition delay is usually defined as the period from the start of injection to the start of combustion as shown in Fig.-6. Start of injection is given by the engine manufacturer as 23.4° bTDC (Static injection timing). The start of combustion is the point at which the heat release rate curve starts rising from zero determined from cylinder pressure data. The start of combustion is determined from the AVL indimodule. At rated power output, the ignition delay of diesel, 15% MEJ and 15% Coc is determined to be 15.8, 14.86 and 15.54 °CA respectively. The marginally lower ignition delays for both the methyl ester blends compared to diesel are due to their higher cetane index. The calculated cetane index values for diesel, 15% MEJ and 15% Coc are 50, 54 and 53 respectively.

Heat release rate
The heat release rate is used to identify the start of combustion, the fraction of fuel burned in the premixed mode and differences in combustion rates of fuel[19]. Fig.-7 shows the variation of heat release rate with crank angle at rated power for a diesel, 15% MEJ and 15% Coc methyl esters. It can be observed that prior to the start of combustion the heat release rate is negative for all the fuels tested as the fuel injected absorbs heat for vaporization. It is also observed that the peak heat release rates for MEJ and Coc blends are lower

than that of diesel. The peak heat release rates at rated power output for diesel, 15% MEJ and 15% Coc are 77.5, 66.5 and 70.5 J/°CA respectively.
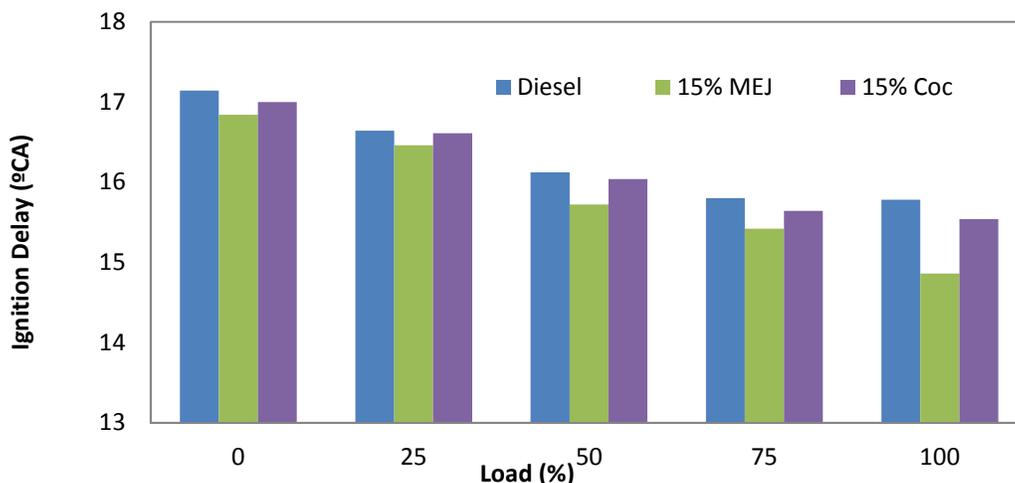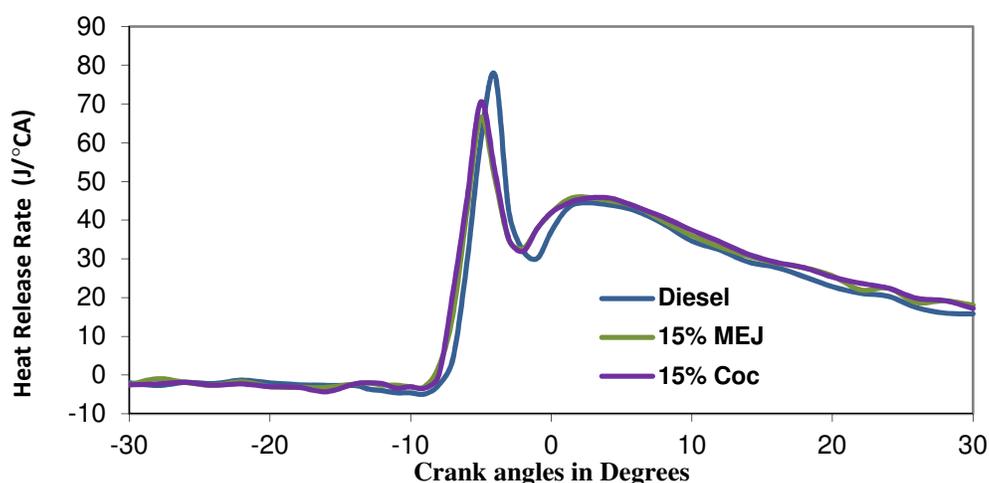

Fig.-6: Variation of Ignition Delay Vs Load

Fig.-7: Variation of Heat Release Rate Vs Crank Angles

CONCLUSION

The major conclusions drawn from the experiments were the oxides of nitrogen (NOx) increases with a load for all blends. The smoke levels are considerably reduced in de-oiled cake blends. CO emission is considerably reduced at high loads. Specific fuel consumption increases in MEJ and Coc blends, brake thermal efficiency decreases marginally. The MEJ blends show better performance and emission reduction than Coc and Diesel. The MEJ and Coc oils have higher viscosity compared to diesel. Hence, better lubricity than diesel fuel which will reduce the need for lubricity additives being added to diesel fuel. overall, it is concluded that de-oiled cake powders may be used as an oxygenated additive with diesel to improve the performance and emissions of a diesel engine.

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S. Sendilvelan and K. Bhaskar

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