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Effect of Madhuca Indica Biodiesel Blends on Performance and Emission Parameters in a Single Cylinder Direct Injection Compression Ignition Engine

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Abstract

Increasing atmospheric pollution and gradual depletion of conventional fuels have resulted in hunting of alternative sources of fuels. Transesterified fuels have gained prominence due to their environmental friendly nature and engine hardware compatibility. In the current study, Madhuca indica biodiesel derived from non-edible feedstock was blended with diesel and used as fuel. The fuel properties and blend properties were found within the specification standards. Experimental investigations were carried out in Kirloskar 240 PE, single cylinder, and direct injection CI engine. Performance parameters like BSEC, BTE, EGT and Exhaust emissions such as UBHC, CO, NO_x and Smoke density were evaluated to ensure the suitability of MOME blends. B20 blend was found to be a favorable alternative for CI engine due to increased BTE, reduced BSEC at higher loads and lower CO, UBHC, Smoke emissions over the entire operating range.

Keywords: Compression Ignition Engine, Madhuca indica biodiesel blends, Performance, Emissions.

Introduction

Alternative fuels have attained more significance in the recent years and abundant researches have been carried out to replace conventional fuels. Fuel energy crisis and increasing need of Petroleum diesel fuels have primarily paved way for the application of biofuels. Increased exhaust emissions of conventional fuels contribute to environmental pollution and global warming. The property of transesterified biodiesel blends like viscosity, Specific gravity, Calorific value and cetane index were found very similar to that of diesel and has proved effective for application to CI engines [1,2]. Biodiesel extraction from non-edible sources have become the need of the hour in order to solve the problem of food crisis. Biofuels can be extracted from non-edible oils like jatropha, neem, Karanja, Mahua etc. India has more potential of extracting biofuel from non-edible oil based trees and Mahua trees are found more in tribal and waste lands[13,16].The role of diesel engines have been indispensable in the fields of heavy load vehicles and industrial gensets and it is essential to use biodiesel blends providing better performance and reduced emissions. Performance and emission characteristics of CI engine were recorded using blends of Mahua biodiesel ranging from B20 to B100 at various loads.B20 and B40 blends showed higher BTE compared to other blends at higher loads. BTE of B20 blend was 4% higher than diesel at full load which would have been attributed due to improved combustion. BSFC increased with increase of load and BSFC of B20 was slightly lower than diesel at 75% and 100% loads and at other loads, BSFC was almost similar. Increase in NOx emission with blends was not much significant but CO and smoke emission reduction with increasing proportions of blends were phenomenal.CO emission reduction was observed around 12% to 80% with increase of blends and smoke emission showed a maximum increase of about 42% with the blends [8]. Combustion and emission characteristics were evaluated with Rice bran oil Methyl ester blends on CI engine which resulted in reduced ignition delay with increasing proportion of blends. BTE for diesel and 20% RBME was found almost similar at all loads. Exhaust gas temperature steadily increased with increasing blends at all loads. UBHC emissions steadily increased with increase of load and nearly 8 to 10 % of UBHC reduction was noticed for every increasing blend proportion. More reduction of Co emissions were observed at full load between diesel and B20 blend. Rubber seed oil Methyl ester B10 blend showed nearly 10% increase BTE than diesel which would have been due to increased lubricating properties of methyl ester. BTE was low for higher blends due to reduced calorific value of the blends.10% blend showed the least BSFC which would have been due to effective combustion.CO

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emission showed a drastic reduction for all blends and it increased with increasing load. Low smoke density was observed with 20% blend increasing proportion of blends caused increase in smoke values [7].In the present study, two stage transesterification process was carried out from the expelled mahua oil to obtain Mahua oil Methyl esters. The Physio chemical properties analyzed were found within ASTM standards and GC/MS, FTIR tests proved the conformity of Biodiesel. Properties of the blends tested were also within the specifications. Performance and emission characteristics were carried out on a Single cylinder, four stroke CI engine for diesel, B10, B15 and B20 blends. Performance and emission parameters were analyzed revealing effective blend meeting reduced emissions and better performance.

Materials and methods

Production and Characterization of MOME

Mahua oil was extracted from the seeds by the expeller process. Per Kg of Mahua seed yielded nearly 350 ml of oil. Using titration technique, The FFA content of mahua oil was found to be high around 18% by titration technique. Acid esterification process was carried out where 5% of concentrated Sulphuric acid and methanol were added and reduced the FFA content to less than 2%. The base catalyzed transesterification was carried out using sodium meth oxide solution and almost 90% yield of biodiesel was obtained at optimized methanol to oil molar ratio of 1:6 at 65°C. Characterization of Mahua oil biodiesel was carried out using Gas chromatography Mass spectrometry and Fourier transform Infrared techniques. GC/MS test shown in Table 1 revealed the existence of Pentadecanoic acid, Margaric Acid, Nonadecylic acid, Palmitic acid and Decanedioic acids in significant quantities. FT IR analysis confirmed the presence of fatty acid methyl esters where strong signal was identified between wave numbers 1500 cm^{-1} to 2000 cm^{-1}. The presence of alcohols with OH and CO stretch, group of carboxylic acid compounds and Aliphatic chloro and fluoro compounds were also present. Biodiesel blends were prepared on volume basis and the properties of B10, B15 and B20 were tested and compared with ASTM biodiesel standards and straight diesel. The properties like Density, Kinematic viscosity, Flash point, Calorific value, ash content etc were found within ASTM standards as seen from Table 2. Properties like Density, viscosity, flash point and fire point show an increasing trend with increase of blend percentage and calorific values decreases with increasing blends.

Table 1: Composition of Fatty Acid methyl ester in Mahua biodiesel

S.No	Name of the Acid	Chemical
1	Pentadecanoic acid	$C_{15}H_{30}O_2$
2	Margaric Acid	$C_{17}H_{34}O_2$
3	Nonadecylic acid	$C_{19}H_{36}O_2$
4	Palmitic acid	$C_{16}H_{32}O_2S$
5	Decanedioic acid	$C_{19}H_{24}NO_4$

Table 2: Fuel Properties of MOME blends in comparison with ASTM D6751biodiesel and Straight Diesel

Fuel Properties	ASTM D6751 Biodiesel	Straight diesel [a]	MOME 10 %	MOME 15%	Mome 20%
Density at 15°C (Kg/m³)	860-900	839	841	842	844
Kinematic viscosity at 40°c(mm^2/s)	860-900	3.18	2.95	2.98	3.12
Calorific value (MJ/Kg)	1.9-6.0	44.8	42.9	42.6	42.5
Flash point (°c)	……….	68	76	81	92
Fire point (°c)	min 130	103	86	88	102
Carbon residue(%)	min 145	0.1	0.02	0.02	0.03
Acid value, mg KOH	<0.8	0.35	0.37	0.39	0.40
Cetane index	……….	51	56	56	56

[a] Raheman et.al(2007)

Experimentation

Tests were carried out on single cylinder, water cooled Kirloskar 240PE engine as shown in Fig 1.The power rating of the engine is 3.5kW at speed of 1500 rpm. The engine operates at compression ratio of 18:1 and is coupled to eddy current dynamometer of SAJ make.

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Dynamometer is fitted with load cell sensor and rpm sensor. Static injection timing was set as 23°BTDC and the engine parameters are shown in the Table 3. Engine is also equipped with K type thermocouple for temperature measurement and piezoelectric sensors for pressure measurement. Emission parameters like NO_x, CO and HC can be measured using Crypton 290 analyzer which employs Non dispersive Infra red technique. The emission analyzer is coupled to Computer and emission values can be noted. Smoke density can be measured using Bosch smoke meter.

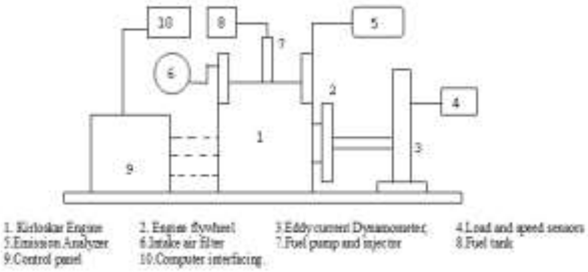

Fig 1. Experimental layout

Table 3:Technical specifications of Engine set up

Engine Parameters	Specifications
Make & model	Kirloskar/240PE
Number of cylinders	Single
Bore/Stroke	87.5mm/110mm
Rated Power	3.5kW @ 1500 rpm
Capacity(cc)	661
Compression ratio	18:1
Load indicator	Digital, range (0to50Kg)
Loading	Eddy current Dynamometer
Temperature Sensor	RTD,PT 100,K type thermocouple
Injection Timing	23° BTDC

Result and discussions

Variation in Brake thermal efficiency

Brake Thermal efficiency steadily increased with increase in load for all the blends tested as shown in the fig 2 which could be due to the possibility of heat loss reduction and increase of power with increasing load [11]. Maximum Brake thermal efficiency was observed for B20 blend at full load of 32.9% which was about 4.6% greater than diesel.B15 blend also exhibited increase in BTE at higher loads of about 2.6% higher than diesel. Biodiesel blends generally improve the thermal efficiency of the engine which could be due to additional lubricity of biodiesel and oxygen content of blends enabling better combustion.

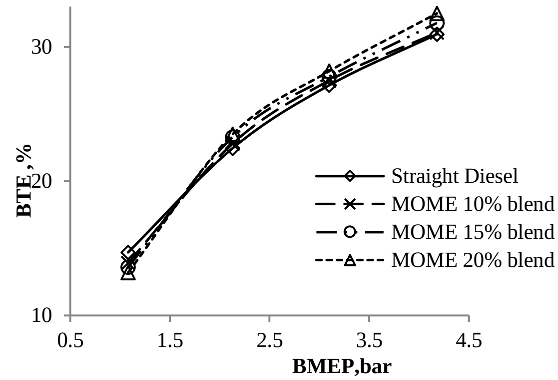

Fig 2. Comparison of Brake Thermal Efficiency for Diesel and MOME blends

Variation in Brake Specific energy consumption

Brake specific energy consumption variation with respect to load is seen in Fig 3 where brake specific energy consumption decreased with increase of load which may be due to lower heat loss at higher loads lower percentage increase of fuel required to run the engine. Lower loads shown increase of BSEC with increasing blend percentage.

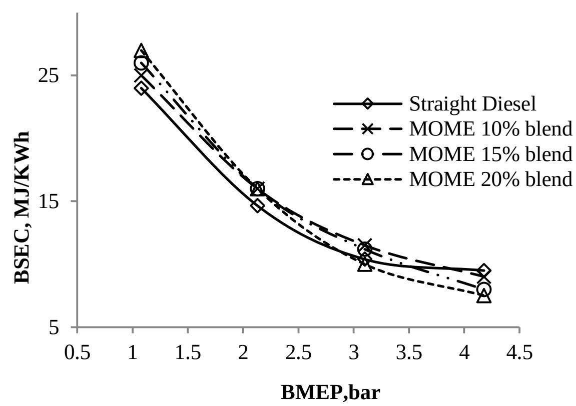

Fig 3. Comparison of Brake specific energy consumption for Diesel and MOME blends

At 75% and 100% loads, Brake specific energy consumption reduced with increasing proportion of blends. At full load condition, B20 blend showed more reduction of brake specific energy consumption compared to diesel which could be due to efficient combustion at higher loads.

Variation in Exhaust gas Temperature

Exhaust gas temperature increased with increase in load for all the blend proportions. The exhaust gas temperature also increased with increasing proportion

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of blends as shown in Fig 4.Exhaust gas temperature of diesel was 6.5% less than that of B20 blend at full load condition and exhaust gas temperature of B10 and B15 was 1.5% and 2% higher than diesel. Higher oxygen content of Biodiesel blends would have resulted in increased Exhaust gas temperature.

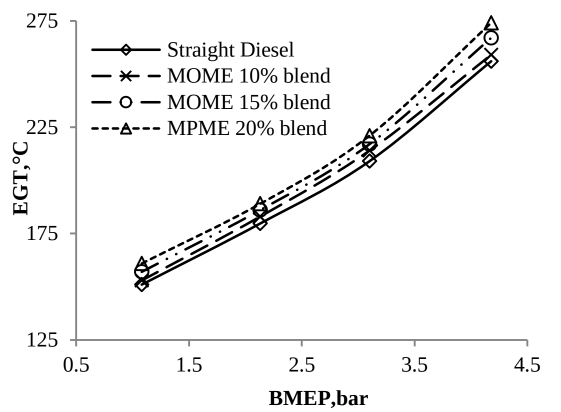

Fig 4. Comparison of Exhaust gas Temperature for Diesel and MOME blends

Variation in Unburnt Hydrocarbons

Hydrocarbon emissions are generally due to incomplete combustion or due to under mixing or over mixing of fuel and air[7].UBHC emissions generally decrease with increasing load as seen from Fig 5. which may be due to sufficient amount of oxygen in the mixture at increasing loads reducing the HC emissions in spite of rich mixture. Hydrocarbon emissions reduced with increasing proportion of biodiesel blends. At no load UBHC emissions reduced by almost 25% for B20 blends compared to that of diesel and at full load condition the reduction of UBHC for B20 were about 30% to that of diesel. The mean reduction of UBHC emission was about 22% for B20 to that of diesel.

Variation in Carbon Monoxide

Carbon monoxide emissions are generally high at higher loads. The variation of Carbon Monoxide emission with respect to load can be seen from the Fig 6 where carbon monoxide emission increases with increasing load conditions which may be due to decreased air-fuel ratio at increasing loads.CO emission of diesel is more than biodiesel blends at all loads. B20 blends exhibited least CC emission compared to other blends. About 25% reduction of CO emission was observed between diesel and B20 blend and 21% reduction of CO emission was observed for B15 blend at full load condition.

Variation in Oxides of Nitrogen

NO_x emission is an important parameter regarding Diesel engine emissions. Oxides of nitrogen formation are high when peak combustion temperatures are high. NOx emissions generally increase with increase of load which also could be seen from Fig 7 which could be due to increasing temperature of the combustion chamber. NO_x emissions also steadily increased with increasing proportion of blends due to better combustion and increased exhaust temperature of the blends. B20 blend showed high NO_x emission compared to other blends. About 5.7 % increase in NOx emission was found for B20 blend and about 3.5% of higher NO_x emission for B10 blend was observed at full load condition compared to that of diesel.

Variation in Smoke density

Smoke density was observed low for biodiesel blends at all loads compared to diesel which could be due to better combustion of blends.

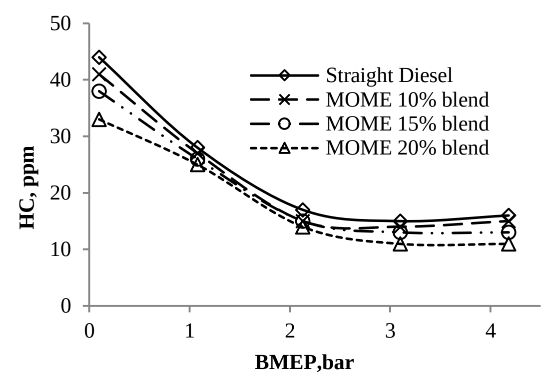

Fig 5. Comparison of UBHC emissions for Diesel and MOME blends

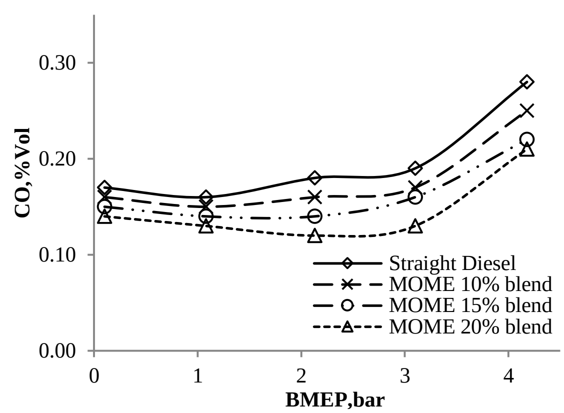

Fig 6. Comparison of CO emissions for Diesel and MOME blends

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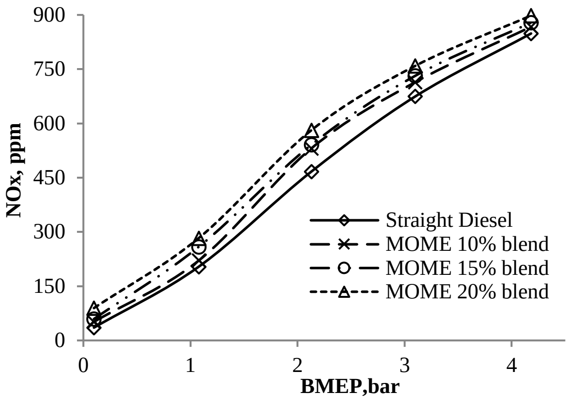

Fig 7. Comparison of NOx emissions for Diesel and MOME blends

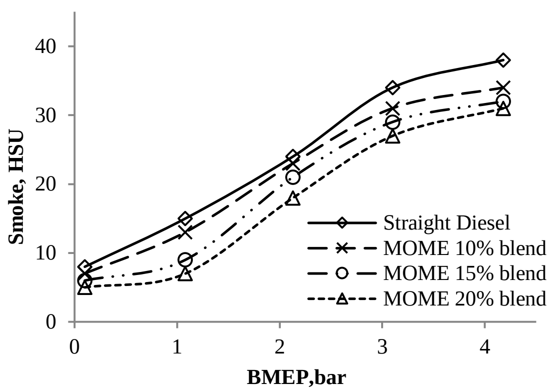

Fig 8. Comparison of Smoke density for Diesel and MOME blends

Variation of smoke with respect to loads for all blends can be referred from Fig 8 where B15 and B20 blends emitted lower smoke compared to diesel and B10 blend. At full load condition about 18.4 % and 15.6% reduction of smoke density was observed for B20 and B10 blend compared to diesel.

Conclusion

Influence of Mahua biodiesel blends on the performance and emission characteristics of diesel engine were analyzed in this study. B20 blend shown improved brake thermal efficiency at higher loads compared to other blends which was about 4.5% higher than diesel. The Brake specific energy consumption of blends were lower than diesel at higher loads and at full load condition, BSEC for B20 blend was lower than other blends. The exhaust gas temperature steadily increased with load and blends which also denoted steady increase in NO_x emission for increasing loads and blends. Carbon monoxide emissions, unburnt hydrocarbon emissions and smoke density decreased with increase of blends and B15 and B20 blends shown good reduction of above emissions. The current experimental research conclude the feasibility of MOME B20 blend as an effective fuel for CI engines without any engine modification and reduction in emissions is ensured.

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Nomenclature and Abbreviations	
BTE	Brake Thermal efficiency
BSEC	Brake specific energy consumption
CI	Compression ignition
HSU	Hartidge smoke unit
ASTM	American Society of Testing Materials
EGT	Exhaust gas temperature
MOME	Mahua oil Methyl ester
UBHC	Unburnt Hydrocarbons
bTDC	Before Top dead centre
NOx	Oxides of Nitrogen
CO	Carbon monoxide
GC/MS	Gas chromatography/ Mass spectrometry
FT-IR	Fourier Transform Infrared

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