Effect of Using Transesterified Vegitable Oil as Fuel on Performance and Emmission in CI Engine – (Experimental Investigation)

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Abstract

There is an increasing interest in many countries to search for suitable alternative fuels that are environment friendly. Although straight vegetable oils can be used in diesel engines, their high viscosities, low volatilities and poor cold flow properties have led to the investigation of various derivatives. The rapid depletion in world petroleum reserves and uncertainty in petroleum supply due to political and economic reasons along with the sharp escalation in the petroleum prices have simulated the search for alternatives to petroleum based fuels especially diesel and gasoline. Vegetable oil due to their properties being close to diesel fuel may be a promising alternative for diesel engines. In this study, Mahua oil (Madhuca Indica seed oil) is trans esterified with methanol using sodium hydroxide as catalyst to obtain mahua oil methyl ester(MOME) and effect of injector nozzle opening pressure(IOP) on the performance and emission characteristics of the direct injection(DI), CI engine was studied.

The engine tests were conducted on a single cylinder, naturally aspirated, water cooled, diesel engine. The engine performance with MOME bio diesel was compared with neat diesel operation. From the engine tests, it is observed that the higher IOP of 200 bar results in better BTE and lower smoke, CO and HC emissions as compared to other IOPs. But there was slight increase in the NOx emission at this IOP. From the present work it is concluded that the biodiesel derived from MO can be used as a renewable and alternative fuel for the CI engine with higher IOP.

Keywords:- *MOME, Madhu oil, indica seed oil, etc..*

1. Introduction

The growing concern due to environmental pollution caused by the conventional fossil fuels and the realization that they are non-renewable have led to search for more environment friendly and renewable fuels. Among various options investigated for diesel fuel, biodiesel obtained from vegetable oils has been recognized world over as one of the strong contenders for reductions in exhaust emissions. Several countries including India have already begun substituting the conventional diesel by a certain amount of biodiesel. Since, India is not self-sufficient in edible oil production, hence, some non-edible oil seeds available in the country are required to be tapped for biodiesel production. In the light of the above facts, present study is to investigate the suitability of mahua biodiesel as a substitute for diesel.

Moreover, the combustion of these fuels has polluted the environment. Renewable fuels, such as vegetable oils and alcohols, are an alternative. Hence, it is necessary to reduce the viscosity of vegetable oil more approximate to that of diesel. The solution to the problems has been approached in several ways, such as preheating the oils, blending them with diesel, thermal cracking and transesterification. Mahua oil is best one compare with other biodiesels. This oil is widely available in India and neighbouring countries.

Property	**Mahua oil**	**Mahua biodiesel**	**Diesel**	**Biodiesel standards**	
Density at 15 °C	915	883	846	—	860–900
Viscosity at 40 °C	27.63	4.85	2.68	1.9–6.0	3.5–5.0
Flash point	212	126	56	>130	>120
Water content	1.6	0.04	0.02	<0.03	<0.05
Ash content	0.90	0.01	0.01	<0.02	<0.02
Carbon residue	0.43	0.01	0.01	—	<0.3
Calorific value	35.61	36.91	42.91	—	—

2. Composition of mahua oil

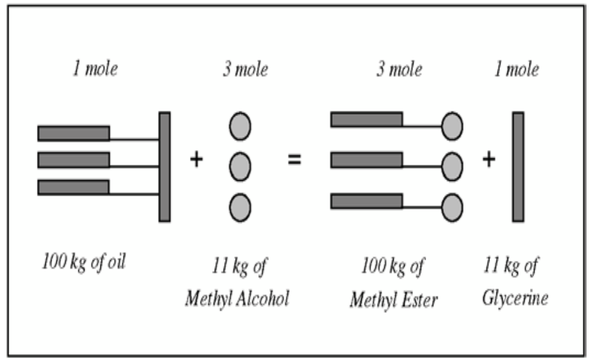
The basic composition of any vegetable oil is triglyceride, which is the ester of three fatty acids and one glycerol. The fatty acid composition of mahua oil is given in below.

Fatty Acid Profile of Mahua oil

Fatty acid	Formula	Structure	wt%
Palmitic	$C_{16}H_{32}O_2$	16:0	16.0–28.2
Stearic	$C_{18}H_{36}O_2$	18:0	20.0–25.1
Arachidic	$C_{20}H_{40}O_2$	20:0	0.0–3.3
Oleic	$C_{18}H_{34}O_2$	18:1	41.0–51.0
Linoleic	$C_{18}H_{32}O_2$	18:2	8.9–13.7

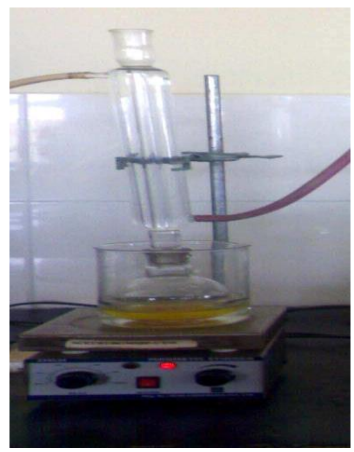
3. Transesterification Process:

Round bottom flask equipment with mechanical stirrer, thermometer and condenser with guard tube to prevent moisture entering into the system. On cooling of Mahua oil (crude grade) will added .Two layers are observed clearly on cooling. The top layer is biodiesel and the bottom denser layer is glycerin. The top layer was neutralized by diluted acetic acid and washed with distilled water. The process of converting vegetable oil into biodiesel fuel iscalled transesterification Chemically, Transesterification means taking a triglyceride molecule, or a complex fatty acid, neutralizing the free fatty acids, removing the glycerin, and creating an alcohol ester. This is accomplished by mixing methanol with sodium hydroxide to make sodium methoxide. This liquid is then mixed into the vegetable oil. After the mixture has settled, Glycerin is left on the bottom and methyl esters, or biodiesel is left on top and is washed and filtered.



4. Experimental setup

In the present work, biodiesel was prepared from MO by transesterification using methanol and sodium hydroxide.



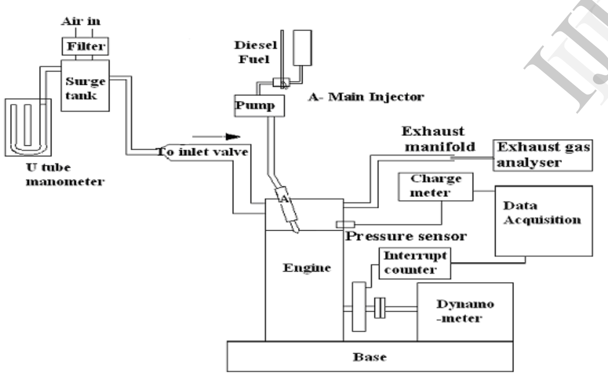
The transesterification reactions were performed in a round bottom vessel of 500 mL in volume. First, the vessel reactor was filled with 210 mL of MO. Then, measured amount of the methanolic sodium hydroxide, which was prepared by dissolving 2 grams of sodium hydroxide in 85 mL of methanol, was added to the reactor. For refluxing purpose, a vertical water-cooled condenser was placed on the top portion of the vessel and the reactor was immersed in a constant-temperature water bath. The temperature of the water bath was maintained at 60 ° C and agitation was provided with a magnetic stirrer during the reaction. This reaction was carried out for two hours. After the transesterification, the condenser was removed and the products were heated, to remove excess methanol. After heating, the products were shifted to 500 ml separator funnel. The top layer containing esters were washed

Biodiesel production from vegetable oils by supercritical methanol:

Transesterification of vegetable oils in supercritical methanol are carried out without using any catalyst. Methyl esters of vegetable oils or biodiesels have several outstanding advantages among other new-renewable and clean engine fuel alternatives and can be used in any diesel engine without modification. Biodiesel has become more attractive because of its environmental benefits. The cost of biodiesel, however, is the main obstacle to commercialization. With cooking oils as raw material, viability of a continuous transesterification process and recovery of high quality glycerol as a biodiesel by-product are primary options to be considered to lower the cost of biodiesel. Supercritical methanol has a high potential for both transesterification of triglycerides and methyl esterification of free fatty acids to methyl esters for diesel fuel substitute.

5. EXPERIMENTAL SET UP

The compression ignition engine used for the study of Kirloskar, single cylinder, four stroke, constant speed, vertical, air cooled, direct injection are given below. .



SPECIFICATION OF TEST ENGINE:

Make and model	**Kirloskar, TAF-1**
General details	**4-stroke, compression ignition, constant speed,, AIR cooled, direct injection**
Number of cylinders	**One**
Bore	**87 .5 mm**
Stroke	**110 mm**
Compression ratio	**17.5: 1**
Rated output	**4.4 kW at 1500 rpm**
Rated speed	**1500 rpm**

6. Combustion equation for MOME:

C18H36O2 +26O2 + 97.76N2 □ 18CO2 + 18 H2O + 97.76N2

BLEND RATIO FOR DIESEL AND MOME:

<u>For B100 (MOME)</u>

$C_{18}H_{36}O_2 + 26O_2 + 97.76N_2 \rightarrow 18CO_2 + 18\ H_2O + 97.76N_2$

Air Fuel ratio (mass): 12.56:1

Air Fuel ratio (molar): 117.75:1

<u>For 100% (DIESEL)</u>

$C_{10}H_{22} + 15.4O_2 + 47.4N_2 \rightarrow 10CO_2 + 11\ H_2O + 47.4N_2$

Air Fuel ratio (mass): 15.1:1

Air Fuel ratio (molar): 80.25:1

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7. PERFORMANCE AND EMISSIONS ANALYSIS:

Diesel fuel

Speed	Load		Power	Fuel consumption		BSFC	Thermal eff	NOx	HC	CO	Smoke
rpm	%	Nm	kW	10 cc in se	kg/hr	g/kW-h	%	ppm	ppm	%	%
1500	25	6	0.92	63.4	0.48	521.9	16.1%	308	23	0.08	10
1500	50	12	1.85	49.2	0.62	336.3	24.9%	509	37	0.09	13
1500	75	18	2.77	36.0	0.85	306.4	27.3%	610	68	0.14	32
1500	100	24	3.70	30.0	1.02	275.8	30.4%	950	99	0.2	50

MOME 180 bar IOP

Speed	Load		Power	Fuel consumption		BSFC	Thermal eff	NOx	HC	CO	Smoke
rpm	%	Nm	kW	10 cc in se	kg/hr	g/kW-h	%	ppm	ppm	%	%
1500	25	6	0.92	53.1	0.60	647.4	15.1%	411	21	0.03	8
1500	50	12	1.85	42	0.76	409.2	23.8%	558	23	0.08	10
1500	75	18	2.77	30.5	1.04	375.7	26.0%	710	50	0.09	24
1500	100	24	3.70	24.1	1.32	356.6	27.4%	986	58	0.17	44

MOME 200 bar IOP

Speed	Load		Power	Fuel consumption		BSFC	Thermal eff	NOx	HC	CO	Smoke
rpm	%	Nm	kW	10 cc in se	kg/hr	g/kW-h	%	ppm	ppm	%	%
1500	25	6	0.92	52.14	0.61	659.3	14.8%	399	20	0.02	8.2
1500	50	12	1.85	43	0.74	399.7	24.4%	518	22	0.03	9.5
1500	75	18	2.77	31.2	1.02	367.3	26.6%	726	42	0.08	22
1500	100	24	3.70	26.6	1.20	323.1	30.2%	1015	48	0.11	42

MOME 220 bar IOP

Speed	Load		Power	Fuel consumption		BSFC	Thermal eff	NOx	HC	CO	Smoke
rpm	%	Nm	kW	10 cc in se	kg/hr	g/kW-h	%	ppm	ppm	%	%
1500	25	6	0.92	51.5	0.62	667.5	14.6%	390	24	0.04	8.5
1500	50	12	1.85	41.2	0.77	417.2	23.4%	600	28	0.1	9
1500	75	18	2.77	31.2	1.02	367.3	26.6%	717	42	0.08	22.5
1500	100	24	3.70	26.6	1.20	323.1	30.2%	1028	50	0.14	41

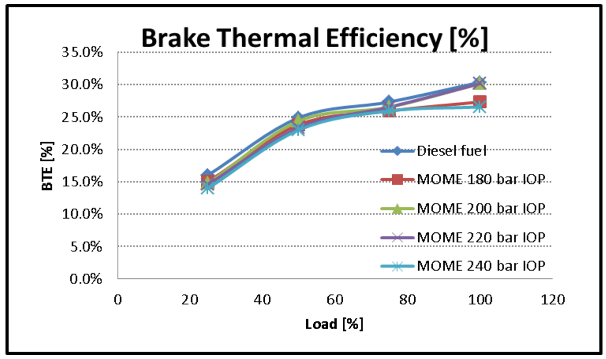
MOME 240 bar IOP

Speed	Load		Power	Fuel consumption		BSFC	Thermal eff	NOx	HC	CO	Smoke
rpm	%	Nm	kW	10 cc in se	kg/hr	g/kW-h	%	ppm	ppm	%	%
1500	25	6	0.92	49.4	0.64	695.9	14.0%	390	32	0.05	9
1500	50	12	1.85	40.6	0.78	423.3	23.0%	528	38	0.14	10.5
1500	75	18	2.77	30.5	1.04	375.7	26.0%	698	52	0.13	25
1500	100	24	3.70	23.4	1.36	367.3	26.6%	967	68	0.16	45

8. Engine Performance Analysis:

The engine was running smoothly, when MOME was used as sole fuel. The engine performance and emissions at different IOPs were analyzed and discussed below. Figure shows the effect of IOPs on the performance and emissions of the diesel engine at different loads.

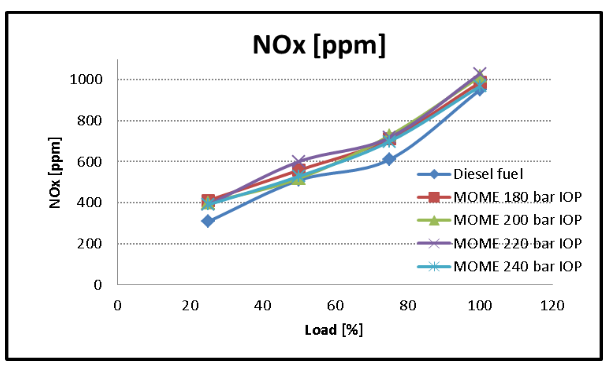
Effect of IOP on Brake thermal efficiency -Brake thermal efficiency (BTE) is defined as the ratio of brake power to the heat supplied. Figure 4 shows the variation of brake thermal efficiency with different loads at various IOPs.



From the figure, it is observed that the IOP of 200 bar results in higher BTE as compared to other IOPs except at 25% load. But there is a small difference in BTE of 200 and 220 bars at 75 and 100% load. In engines, as The load increases, the fuel consumption also increases to produce more amount of power required for taking up the load. At low load, the fuel consumption is less and at high load, fuel consumption is high. At full load, the IOP of 200 and 220 bar results in higher BTE as compared to other IOPs. This is due to the better atomization and spray formation of large quantity of fuel. It is observed that the higher injection pressure increase the BTE of the biodiesel operated diesel engine. At 25% load, the IOP of 180 bar results in higher BTE. The BTE of the engine with MOME is slightly lower than the diesel. This is due to slightly higher viscosity and lower volatility of the MOME.

Oxides of Nitrogen Emission (NOx):

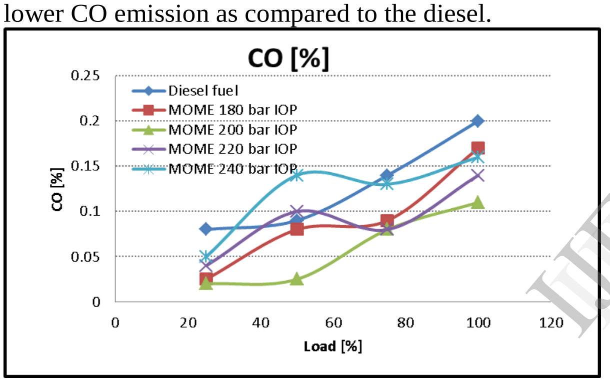
Figure shows the variation of oxides of nitrogen (NOx) emission with load. The NOx emission depends on the combustion temperature. If the combustion temperature increases, then the NOx emission also increases. From the figure, it is observed that the MOME results in higher NOx emission due to slow combustion of slightly viscous and low volatile MOME.



From the figure, it is observed that the IOP of 200 and 220 bar results in higher Nox emission. This is due to the better atomization and combustion of the MOME, which results in higher combustion temperature and hence higher Nox emission. It is observed that the higher injection pressure results in higher Nox emission.

Carbon monoxide (CO):

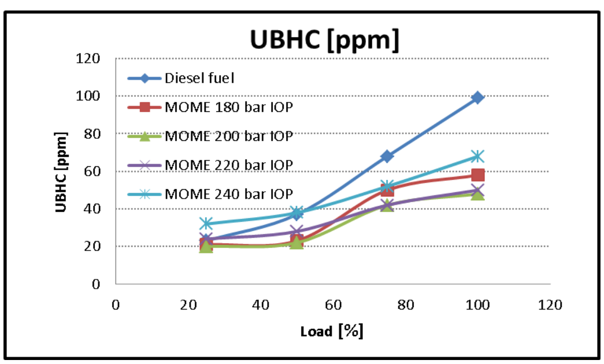
Figure shows the variation of carbon monoxide (CO) emission with load. From this figure, we can see that the lower IOP of 180 bar results in higher CO emissions as compared to 200 bars. This is due to the lower injection pressure, which results in larger fuel droplets and poor mixing of air and fuel. This results in higher products of incomplete combustion (CO). But higher IOP of 200 bar results in better combustion and hence lower CO emission. The IOP of 240 bar results in slightly higher CO emission as compared to IOP of 200 bar. The engine operation with MOME results in lower CO emission as compared to the diesel.



This is due to the presence of oxygen in the molecular structure of the MOME, which results in better combustion and reduces the CO emission.

Unburnt Hydrocarbon:

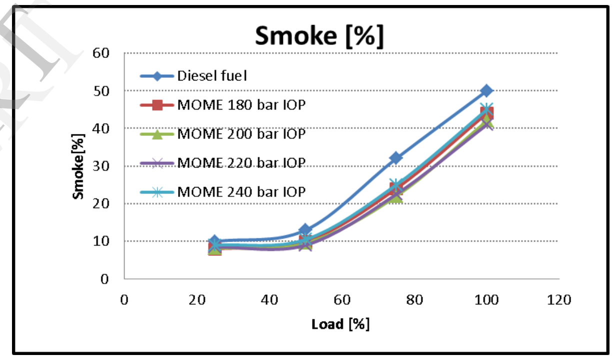
Figure shows the variation of unburnt Hydro Carbon (UBHC) emission with load. From the figure it is observed that the lower and higher IOP pressure results in higher UBHC emission.



The ignition delay period of the fuel at lower IOP is high. This results in sudden combustion of the fuel, which results in higher UBHC emission. Among the IOPs, the IOP of 200 bar results in lower UBHC emission. But at 75 and 100% of full load, the difference in UBHC of 200 and 220 bar is negligible. The engine emits lower UBHC emission with the MOME as compared to the diesel. At low loads, there is small difference in the UBHC of MOME and diesel, but at higher loads, the difference is high.

Smoke Opacity:

Figure shows the variation of smoke emission with load. From the figure it is observed that the IOP of 200 and 220 bar results in lower smoke emission as compared to other IOPs. This may be due to the increase in the fraction of fuel burned in the premixed burning phase and the decrease in the fraction of fuel burned in diffusive combustion phase, as well as the improvement of the diffusive combustion. Compared to the diesel, the MOME produces less emission due to the presence of oxygen in its molecules. This reduces the formation of smoke.



9. CONCLUSION

The non-edible and underutilized MO was converted into biodiesel by transesterification. The fuel properties of MOB are better than MO and close to the diesel. The diesel engine works smoothly with the MOB. The IOP of 200 bar results in higher thermal efficiency and lower CO, HC and smoke emission in most of the load conditions. But this IOP results in higher NOx emission. The higher injection pressure results in better atomization spray formation and penetration of the MOME, which results in better combustion. The cost of the MO is more than the diesel, but the cost of MOME is higher than the diesel. From the experimental results, it is concluded that MOME can be used as standalone fuel in the diesel engine with higher IOP with a slight increase in NOx emission. Use of non-edible oil for biodiesel production will reduce the dependence of edible oil for biodiesel production. The plantation and cultivation of mahua trees in degraded land may improve the rural economy and for sustainable development.

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