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Performance and Emissions Analysis of Compression Ignition Engine Using Mesua Ferrea Linn Methyle Ester and Diesel

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Abstract—*Biodiesel, an alternative diesel fuel, is made from renewable biological sources such as vegetable oils and animal fats. It is biodegradable and non-toxic. It has a low emission profiles and so it is environmentally beneficial. In this study, Mesua ferrea linn (MFL)seed oil was used as a feedstock for biodiesel production. The biodiesel so obtained from MFL seed oil have been characterized and found that the fuel properties were within the standards limits defined by ASTM. In order to determine the potential of the biodiesel as a fuel, performance evaluation of the engine and emission studies were done using different blends in a standard diesel engine set up. From performance point of view B20 blend was found to be identical result with diesel fuel. With the increase of the engine speed, HC, CO and NOx emissions were found to be decreased. From the emissions point of view B30,B40 and B50 blends were found to be suitable blends, because they had a very less emissions then the other fuel samples.*

1. INTRODUCTION

Now a day, fossil fuels are the one of most demanded energy sources all over the world. It fulfills the energy needs in the sectors like transportation, industry, agricultural equipments etc.The continuous increase in worldwide demand and also the increasing the price of these fuels day by day is a great concern in the present days because of limited resources and limited reserves of these fuels. A developing country like India mainly depends on imported large quantity of fuels due to lack of fossil fuel reserves and it has a great impact on economy. Also the combustion of fossil fuels in internal combustion engines emits various harmful emissions like carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxide (NOx) ,unburned HCs etc which have continuously effect on entire environment [1]. To minimize the above difficulties there is a great demand of alternative fossil fuels. Biodiesel has become more concentrated recently because of its environmental benefits and the fact that it is made from renewable resources. Biodiesel refers to a vegetable oil or animal fat-based diesel fuel consisting of alkyl (methyl, propyl, or ethyl) esters obtained by chemical reaction of the vegetable oil or animal fat with an alcohol. More than 350 oil-bearing crops have been identified, among which mainly jatropha, sunflower, safflower, soybean, cottonseed, rapeseed, and peanut oils are considered to be a potential alternative fuels for diesel engines. As India is deficient in edible oils, non-edible oils become the primary choice for biodiesel[2].

The major problem associated with the use of pure vegetable oils as fuels for diesel engines is the high-fuel viscosity in compression ignition. The vegetable oils were all extremely viscous, with viscosities ranging 10–20 times greater than Diesel fuel. Dilution, micro-emulsification, pyrolysis, and transesterification are the four techniques applied to solve the problems encountered with the high fuel viscosity [3]. Among these, the transesterification is the commonly used commercial process to produce clean and environmental friendly fuel. Transterification is a process of producing biodiesel. Here vegetable oil react with alcohol in the presence of catalyst like NaOH, KOH etc, which produce Biodiesel and Glycerin. Glycerin can be easily separated from the final product and Biodiesel can be obtain. Biodiesel can also be used in its pure form (B100), but may require certain engine modifications to avoid maintenance and performance problems. [4]. There are mainly two methods of transterification process for production of biodiesel. Those are based catalyst transterification and acid catalyst transterification. Base-catalyzed transesterification, however, has some limitations among which are that it is sensitive to FFA content of the feedstock oils. A high FFA content (> 1 % w/w) will lead to soap formation which reduces catalyst efficiency, causes an increase in viscosity, leads to gel formation and makes the separation of glycerol difficult. Also, the oils used in transesterification should be substantially anhydrous (0.06 % w/w). The presence of water gives rise to hydrolysis of some of the produced ester, with consequent soap formation.There is a limitation of base-catalyzed transesterification is its sensitivity to the purity of the reactants, especially to moisture and FFA content. Acid catalyst transesterification of triglycerides is usually catalyzed by inorganic acids such as sulfuric acid, hydrochloric acid, phosphoric acid and sulfonated organic acids[5].The biodiesel, when mixed with petro diesel up to 20% requires very little or no modification internal combustion engine and it helps substantial reduction in the emission of unburned hydro-carbon by 30%, carbon monoxide by 20% and particulate matters by 25% with no sulphur [6]. Blending with diesel helps to bring down the values of properties of biodiesel such as specific gravity, viscosity, and carbonresidue to acceptable ranges and would improve the atomization process during combustion[7].Also, researchers had found that biodiesel has identical combustion properties with petro diesel, including combustion energy and cetane ratings[8].

In this study Mesua ferrea L seed oil was used as a feedstock for biodiesel production. *Mesua ferrea* L. (MFL) is a timber plant that grows naturally in the northeastern parts of the Himalayan regions of India and in Srilanka. The oil seed contains 55–57 wt.% nonedible, reddish-brown-colored oil (the shelled kernel contains > 75 wt.% oil), which had been traditionally used as fuels [2].***Mesua ferrea*** is also known as medicinal plant, it is widely used in indigenous systems of medicine for the treatment of fever, dyspepsia and renal diseases. Its stamens are **used** for treating bleeding piles [9].

2. MATERIALS AND METHODOLOGY:

Materials:

The Mesua Ferria linn seeds were collected from Sivasagar district, Assam, India. All the seeds were collected during the month of August- September, 2010. The oils were mechanically extracted from the seeds using a screw press in the mechanical expeller and then settled until impurities were precipitated. All chemicals used in the experiments such as methanol, sodium and potassium hydroxides, H_2SO_4 etc were procured from local suppliers.

Methodology:

The acid value of the Mesua Ferria linn seeds oils was found to be considerably high so pretreatment was necessary prior to the transesterification reaction. Because of high FFA(Free Fatty Acid) of the oil, both steps (acid and based catalyst tranterification) of the biodiesel production process were carried out in a 500 ml two necked round-bottomed flask equipped with a reflux condenser . The reaction flask was placed on the plate of a magnetic stirrer (400 rpm). The temperature was maintained at around 60^0C .

Acid catalyzed esterification (Pretreatment): A 500 ml two necked round bottom flask was used as a reactor. The oil was poured into the flask and heated. The solution of conc. H_2SO_4 acid (1.0 or 2.0% based on the oil weight) in methanol was added to the flask. The molar ratios of methanol to FFA of the oil was maintained at 6:1 and the reaction was carried out for 3 hours from the start at 60 ○C. The final reaction mixture was poured into a separating funnel. The lower layer (oily phase) was separated, dried and used for further processing by the Based catalyzed Transesterification .

Based catalyzed Transesterification: The acid pretreated oil was poured into the reaction flask and heated. The solution of NaOH in methanol (1% based on the oil weight) was thermostated at 60°C and then added with the pretreated oil. The molar ratio of methanol-to-pretreated oil was 6:1. The reaction mixture was stirred by a magnetic stirrer. Heating and stirring were continued at atmospheric pressure. After the reaction, the product was allowed to settle under gravity in the separating funnel where it was separated into two layers. The upper layer consisted of methyl esters, residual methanol and catalyst, and impurities, whereas the lower layer contained a mixture of glycerol, excess of methanol, catalyst and impurities. The glycerin layer was drawn off and the methyl ester layer was then washed gently with hot distilled water at 60°C. The wet biodiesel was then dried at 100°C in the oven . Finally, the methyl ester content in the biodiesel product was determined.

3. RESULTS AND DISCUSSION:

3.1 Feedstock and biodiesel analysis:

High acid value of 16.6 was obtained from the Mesua ferria linn seed oil, which indicates that the feedstock must undergo two stage transesterification in order to produce biodiesel. GC-MS analysis (table 1) was carried out to obtain the fatty acid compositions for feedstock employed.

Table 1: Major Fatty acid composition

Fatty acid	Retention time	Chemical formula	% weight
Palmitic acid	10.35	$C_{16}H_{32}O_2$	15.50
Stearic acid	8.76	$C_{18}H_{36}O_2$	16.64
Linoleic acid	14.48	$C_{18}H_{32}O_2$	17.38
Oleic acid	18.45	$C_{18}H_{34}O_2$	47.84

3.2 Fuel characteristics of Biodiesel from the mixture of different seeds oil :

The prepared Mesua ferria linn oil methyl ester (MFLOME) was mixed with pure diesel in five different proportions i.e., 10%,20%,30%,40% and 50% to prepare its blends. It was named as B10,B20,B30,B40 and B50 respectively. All the blends were sent to Quality Control Division of Numoligarh Refinary Limmited (NRL), Assam,India to determine their properties by using standard test methods. The fuel properties of biodiesels and diesel are summarized in table 2.

Table 2: Fuel properties of biodiesel and diesel obtained from NRL, Assam, India

Parameters	Unit	Diesel	B10	B20	B30	B40	B50	Biodiesel
Density@ 15°C	gm/cc	0.852	0.857	0.864	0.850	0.855	0.854	0.874
S- Content	% wt	0.0165	0.0256	0.0051	0.0095	0.0075	0.0060	0.0033
Viscosity @ 40°C	cst	2.781	4.01	4.11	3.11	3.75	4.23	6.2
Flash Point	°C	49	62	72	91	98	>110	>110
Pour Point	°C	0	2	2	4	4	4	3

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Calorific value	kJ/g	45.01	44.6	44.4	42.97	42.25	41.80	40.11
Cetane number		46	-	-	-	-	-	54
Carbon residue	% wt	0.011	0.018	0.021	0.035	0.44	0.058	0.088
Cloud Point	°C	-18	-3	3	4	4	4	5
Ash content	% wt	0.0185	0.0168	0.0163	0.0158	0.0147	0.0141	0.0141

3.3 Specification of the Engine Setup :

Product: Engine test setup 4 cylinder, 4 stroke, Diesel Engine (computerized)

Product code: 228

Engine: Make Telco, Model Tata Indica, Type 4 Cylinder, 4 Stroke, Diesel water cooled ,Power 39 kW at 5000 rpm, Torque 85 Nm at 2500 rpm ,stroke 79.5 mm, bore 75 mm, 1405 cc, Dynamometer: Type eddy current, water cooled, with loading unit.

3.4 Performance Evaluation of the Engine:

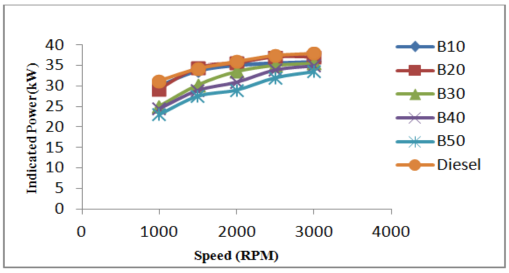

Fig. 1: Indicated power vs Speed

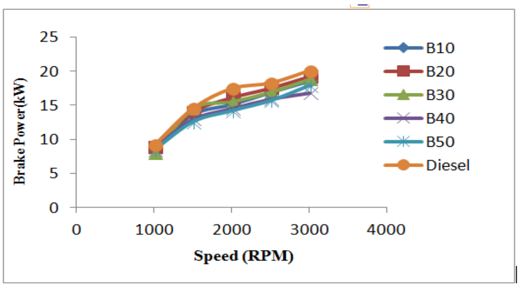

Fig. 2: Brake power vs Speed

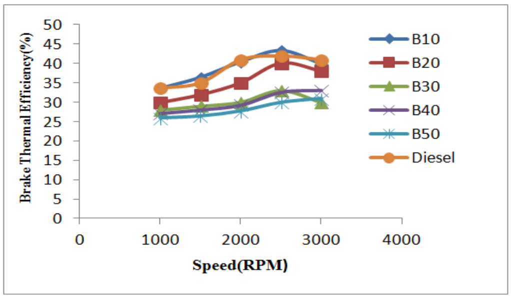

Fig. 3: Brake thermal efficiency vs speed

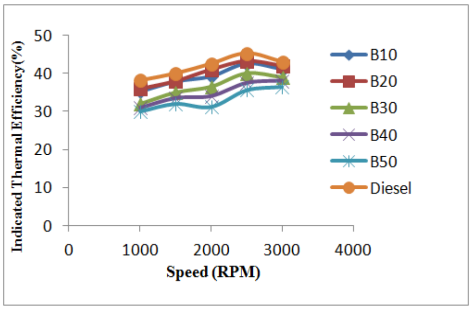

Fig. 4: Indicated thermal efficiency vs speed

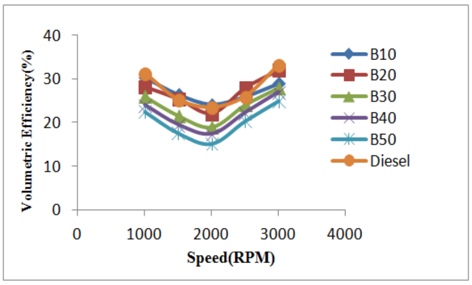

Fig. 5: Volumetric Efficiency vs speed

The indicated power increased linearly with the increased of engine speed for the all fuel samples B10, B20, B30, B40,B50 and petroleum diesel. From the Fig. 2 it was seen that B20 shows identical performance with diesel at all the engine speeds. From Fig. 3, maximum brake power values were obtained at high speed for all blend fuels and diesel fuel . There were no noticeable differences in the measured engine power output between diesel fuel and the blends fuels at lower speeds. However, at higher engine speeds, a slight decreasing in power output of the engine was obtained with B30, B40 and B50, according to diesel fuel. This is due to low calorific value of blend fuels. From fig.4 and fig.5 ,Brake thermal efficiency and indicated thermal efficiency increased linearly with increased of speeds for all the fuel samples. B10 and B20 were found to be identical with diesel fuel. Other samples had lower efficiency. This might be due to lower specific heat of blended fuel. In terms of volumetric efficiency B20 blend was found to be identical with diesel fuel at all the engine speeds. It might be due to better mixing of air-fuel mixture inside the cylinder for B20 blend.

3.5 Emissons analysis of the engine:

Exhaust emissions like CO_2, CO, HC and NOx were measured with the help of a exhaust gas analyzer and the results were analyzed with the speeds.

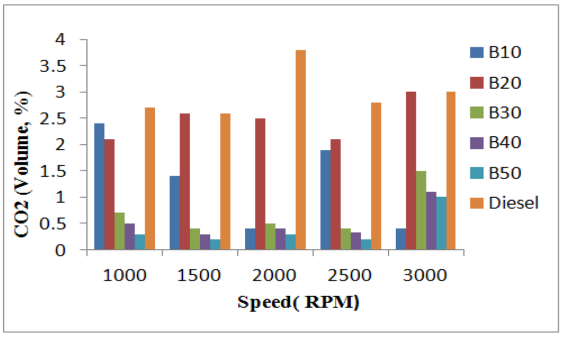

Fig. 6: CO_2 Emissions

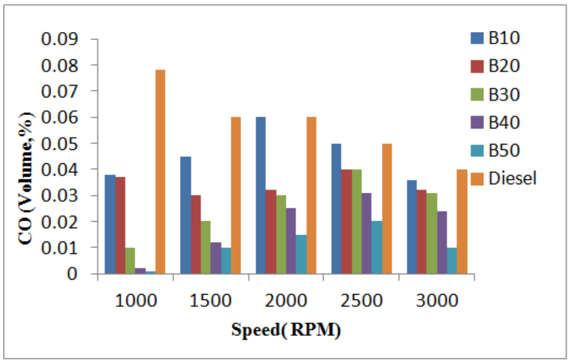

Fig. 7: CO Emissions

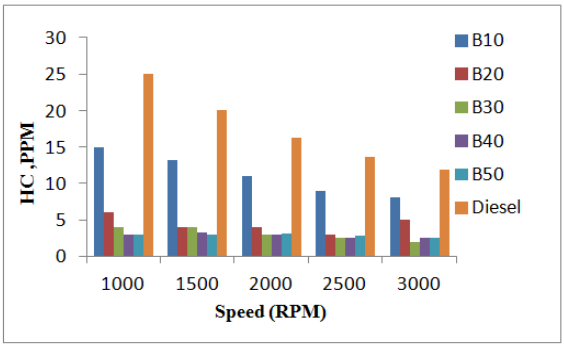

Fig. 8: HC Emissions

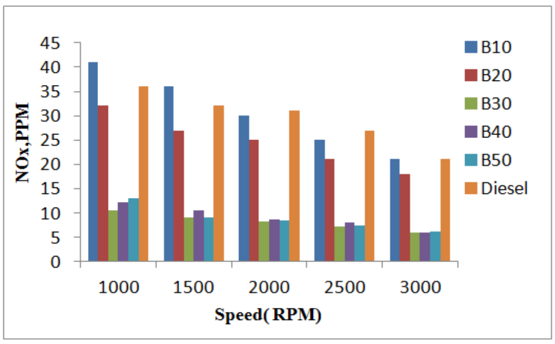

Fig. 10: NOx Emissions

From the Fig.7, CO_2 emission was found to be increased for the blends B10,B20 and B30 but its emission level was lower than the diesel fuel. Higher CO_2 emissions is a indication of the complete combustion of fuel. That means the higher value of exhaust gas temperature. Hence higher percentage of biodiesel blends showed the lower emissions because of the reason of incomplete combustion of fuel. From Fig.8 it was observed at all the speeds diesel fuel showed higher CO emissions then the other fuel samples and B30, B40, B50 blends showed lower CO emissions then the other fuel samples.i.e, higher percentage of biodiesel blends lower the CO emissions. This could be due to higher O_2 concentration in the air–fuel mixture, which can improve combustion and enhance further CO oxidation. From pollution point of view, all blends were found to be much superior than the petroleum diesel. HC emissions were shown in the Fig.9 for different blending with different speeds. It was observed from the figure that HC emission was found to be lower than diesel fuel. And also B30,B40 and B50 showed the lower emissions of HC at all the speeds that is the higher the biodiesel percentage in biodiesel–diesel blends, the lower the HC emissions. This might be due to the fact that the higher O_2 concentration in the air–fuel mixture can help enhance oxidation of unburned hydrocarbons.

Emissions of NOx are shown in the Fig.10 for different blending with different speeds. From the figure it seens that with the increase of the speeds NOx emissions decreases for all blends and diesel. This might be attributed to the shorter residence time/ignition delay available for NOx formation at higher speeds[10]. Again B30, B40 and B50 showed the lower NOx emissions at all the speed. It might be due to light load operation at this stages and with these blends. At light load operations, the engine runs at a very lean state. Extra O_2 in biodiesel in this case does not help to produce higher NOx, because the mixture is already very lean[11].

4. CONCLUSION:

In this work attempt has been done to produce biodiesel from Mesua ferrea linn seed oil. The properties of produced biodiesel were found to be within the standard limits defined by ASTM. In order to determine the potential of the biodiesel as a fuel, engine performance evaluation and emission analysis were studied. Different biodiesel blends were prepared and studied using a standard diesel engine set up. From the performance point of view, B20 blend showed the identical result with diesel fuel and from emissions point of view B30,B40 and B50 can be considered as a suitable blends, because it has a very less emissions then the other fuel samples at different speeds.From the result of present study, Mesua ferrea linn seed oil can be used as a feeds stock for biodiesel production. But two step of biodiesel production process should be carried out, because of high acid value of the oil. The neat biodiesel produced from the mixture by transterification process do not meet all the required fuel characteristics as per ASTM standards for petro-diesel. Hence

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each of these biodiesel needs to be blended with the petroleum diesel to achieve the required specification.

For commercial production of biodiesels from non-edible plant oils in large scale, plantation of tree in waste land and roadside should be taken up.

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