Performance Evaluation of Diesel Engine Fueled with Jatropha Methyl Ester Blends along with Sunflower Oil

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Abstract: ***Sunflower oil is used for domestic purpose such as cooking oil. This Sunflower oil is blended with jatopha oil and converted into biodiesel using a process known as transesterification process. In this process oil reacts with a monohydric alcohol in presence of a catalyst to produce a biodiesel of monoalkyl ester. In the present work diesel engine using methyl-ester of Jatropha and Sunflower oil as fuel was evaluated for its performance and exhaust emissions. The fuel's performance is analyzed for Jatropha and Sunflower oil, blends of these oils and diesel as baseline at varying loads. The variations in the loads were analyzed to observe its influence on the engine performance with different fuels. Experimental results show that diesel engine gives poor performance than the Sunflower oil and its blends with diesel. For Jatropha and Sunflower biodiesel and its blended fuels the exhaust gas temperature increased with increase in power and amount of biodiesel. However, diesel blends showed reasonable efficiency, lower smoke, CO and HC.***

Keywords: Calorific value, Glycerin, Catalyst, Transesterification

1. Introduction

The demand for energy is increasing in the world as the population goes on increasing. The reason for energy demand is the limited amount of fossil fuels. The use of fossil fuels causes emission and pollution which is harmful to the environment. It necessitates searching an alternative for the fossil fuels. Biodiesel is one of the most trusted alternative fuels which can be utilized as a fuel for automotive engines, because their fuel properties are much closer to diesel fuel. The two important properties, the cetane number and calorific value. These two properties of biodiesel are similar to diesel fuel, so I.C. engines can be operated on biodiesel. In I.C. engine the thermal energy is produced by burning the fuel in engine cylinder. For the combustion in I.C. engine a proper air-fuel mixture is required which mainly depends on the nature of fuel and its introduction into the combustion chamber. To have maximum heat energy during the stroke it is necessary that the combustion process should take as less time as possible. If the time for combustion process lasts long then deposits gets formed and are combined with other combustion products. This may cause wear, corrosion of cylinder, piston and piston rings. To avoid this and to satisfy the requirement of engine the biodiesel from non edible sources like Jatropha, Mahua, and Neem etc. can be used which meets the above engine performance requirements. Bio diesel is most often blended with others in ratios of 5% (referred as B5), 10% (B10), and pure biodiesel 100% (B100) which can also be used in many applications. It is found that there is no significant change in the thermal efficiency while using biodiesel up to B20, but when pure biodiesel B100 is used there is slight decrease in thermal efficiency. The objective of this study is to develop alternative fuel for I.C. engines from non edible oil sources like Jatropha along with Sunflower oil and to test it on I.C. engines for its potential as a substitute for diesel fuel.

Production of Bio-Diesel

The process of production of biodiesel involves a chemical reaction in which vegetable oil or animal fat reacts with an alcohol such as methanol or ethanol and forms a new alcohol called glycerol or glycerin. The process is termed as Transesterification and is the process of exchanging the organic group 'ester' with the organic group 'alcohol' according a mechanism called as alcoholysis.

Oil + alcohol + catalyst → Biodiesel + glycerin

In other words transesterification is the process in which the biodiesel is being produced. This conversion process of bio diesel through transesterification is shown in Fig. 1.

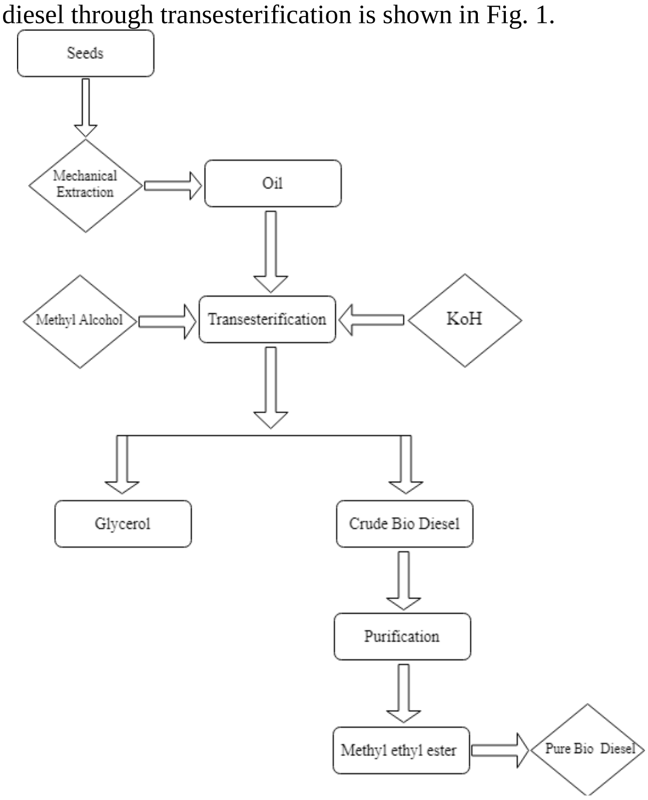

Figure 1: Production process of Bio-Diesel

It is very important to note that unmodified vegetable oil is not a Bio-Diesel because of its high viscosity and low volatility. So this unmodified vegetable oil needs modification which is done by the chemical reaction. Before converting the oil into biodiesel it is necessary that the contaminants must be filtered out. The reaction converts the oil or fat into the compounds that are closer to the hydrocarbons found in diesel fuel. In this process oils and fats react with methanol or ethanol with a byproduct of glycerin or glycerol. The particular chemical reaction has a catalyst which helps to speed up the reaction. The catalyst is prepared by mixing methanol with a strong base such as potassium hydroxide or sodium hydroxide. This biodiesel is also known as methyl alcohol and sometimes wood alcohol. The reaction steps involved in the transesterification process are indicated as follows. [4]

Triglyceride + ROH ⟶ Diglyceride + RCOOR1
Diglyceride + ROH⟶ Mono glyceride + RCOOR2
Mono glyceride + ROH ⟶ Glycerol + RCOOR

In the first reaction the triglycerides react with an alcohol and produce diglyceride along with fatty acid methyl ester. Then in the second reaction diglyceride reacts with alcohol to form monoglyceride and fatty acid methyl ester. As now the monoglyceride is formed it reacts with alcohol group and produces glycerol and a byproduct of fatty acid methyl ester molecule. This reaction requires 1 mol. of triglycerides and 3 mol. of alcohol. This alcohol can be used in the more quantity as it can increase the yields of esters. The different aspects such as type of catalyst, alcohol – oil molar ratio, temperature, purity of reactants (as it contains water), has an impact on transesterification process.

Steps involved in the production of biodiesel

1) Process requirement
   - Preheating of oil at a temperature of 50^0 c
   - Pressure required is 1 atm.
2) Titration
   - This is the first stage of production process which determines how much catalyst is needed to neutralize the fatty acids in the used oil. This process decides the amount of potassium hydroxide that has to be used in the reaction.
   - Dissolve 1000 mg of potassium hydroxide (KOH) in 1000 ml of distilled water (H2O)
   - Dissolve 1 ml of oil in 10 ml of alcohol.
   - Keep adding potassium hydroxide (KOH) in the burette until and unless the color of the solution changes.
   - Record this quantity of KOH which has changed the color of the solution.
3) Mixing and heating
   - The catalyst prepared by the titration process is mixed with the oil. This mixture is mixed very well by using stirrer until it becomes identical and uniform.
   - If the mixture has some residues then heat the mixture and allow it to become uniform.
4) Settling
   - The mixture is now allowed to cool down. In this cooling process the mixture will get settle so the biofuel will float on top and the glycerin will be at the bottom.
   - The reaction breaks the solution in several layers having oil, alcohol, catalyst in different layers.
   - The top most layers are of ester, the middle layer will be of soap and bottom layer is of glycerin.
5) Separation
   - The formed biofuel is found on the top and the heavier glycerin is at the bottom.
   - The glycerin can be easily separated by allowing it to drain out.
6) Washing
   - After the separation of biofuel must be washed with hot water to remove the in reacted methanol and other residual by products.
7) Filtration
   - This process involves worming of liquid so that the food particles will be able to remove and the oil is filtered.
8) Removal of water
   - The biofuel has some amount of water content so it is necessary to remove the water from the biofuel as it reduces the rate of reaction.
   - The water is removed by boiling the water at 500

These are the steps involved in the production process of biodiesel. As the oil goes through all these processes it is converted into the biodiesel.

A mixture of saturated and unsaturated fatty acids forms the composition of fatty acid from vegetable oil. Fatty acids are classified according to the number of unsaturated bonds as monounsaturated and polyunsaturated fatty acids. Vegetable oils have specific fatty acid distribution and it depends on the plant source.

Table 1: Fatty acid composition of Jatropha oil and Sunflower oil

Fatty acid	Formula	Structure	Net percent for Jatropha oil [2]	Net percent for Sunflower oil [8]
Lauric acid	$C_{12}H_{24}O_2$	C_{12}	-	0.0 – 0.02
Palmitic acid	$C_{16}H_{32}O_2$	C_{16}	14.1 – 15.3	4.20 – 6.86
Stearic acid	$C_{18}H_{38}O_2$	C_{18}	3.7 – 9.8	2.06 – 4.90
Oleic acid	$C_{18}H_{34}O_2$	$C_{18.1}$	34.30 – 45.8	17.52 – 87.54
Linoleic acid	$C_{18}H_{32}O_2$	$C_{18.2}$	29.0 – 44.2	3.66 – 67.90
Linolenic acid	$C_{18}H_{30}O_2$	$C_{18.3}$	0 – 0.3	0.109 – 0.262
Arachidice acid	$C_{20}H_{40}O_2$	C_{20}	0 – 0.3	0.166 – 0.333
Behenic acid	$C_{22}H_{44}O_2$	C_{22}	0 – 0.2	0.517 – 0.935
Saturated acid	-	-	21.1	9.4
Unsaturated acid	-	-	78.9	28.3

The fatty acid composition of Jatropha oil and Sunflower oil is shown in table 1. This states that both the oils are mainly composed of unsaturated fatty acid. Due to this the biodiesel is unstable in its fuel characteristics.

Table 2: Fuel properties of Diesel, Jatropha oil and Sunflower oil

Fuel properties	Diesel	Jatropha oil	Sunflower oil	Equipment/method
Density at 25^0 C	830	884	919.21 [7]	Gravimetric method
Viscosity (cSt, @30^0 C)	2.7	4.4	28.74 [7]	Digital viscometer
Flash point ^{0}C	46	173	188	Pensky martens apparatus
Calorific value (kJ/Kg)	45843	40105 [1]	39480	Bomb calorimeter

Engine

The engine used is a four stroke engine. The engine is connected to hydraulic / eddy current type dynamometer to obtain signals which are interfaced with computer through engine indicator for Pθ, PV plots and engine indicated power. Provision is made to measure air temperature, fuel temperature, exhaust temperature, cooling water temperatures and load measurements. Digital indication is provided for temperature measurements. The Pθ diagram, PV plot and performance curves are obtained at various operating points.

Table 3: Engine specifications

Engine	Single cylinder, 4 stroke, water cooled, diesel, rated power 5.2 KW, speed 1500rpm, bore 87.5mm, stroke 110mm, compression ratio 17.5, Capacity 661 cc.
Dynamometer	Hydraulic or eddy current type
Pezos sensor	Range 1000 PSI, make PCB USA
Crank angle sensor	Resolution 1 deg, speed 5000RPM with TDC marker pulse
Software	For pressure crank angle and PV plots, IP and IMEP calculations, data logging, Printing
Fuel tank	10 lit. with graduated glass fuel metering column
Air box	With orifice meter and manometer
Rota meter	For water flow measurements
Overall size	2.0 m L x 2.5m W x 1.5m H
Temperature indicator	Digital, PT- 100 type temperature sensors (6 points)
Calorimeter	Pipe in pipe type, with rotameter

Test Procedure

The experiments were carried out by using various blends of Jatropha oil and Sunflower oil with additives like Methyl ester of 10% and 1% Ethanol and Diesel at different load conditions on the engine.

a) The fuel level and oil levels were checked.
b) Cooling of water is supplied to the engine.
c) The electrical power is supplied to the panel so the engine can run idly at uniform engine speed of 1500 rpm.
d) The inlet and exhaust temperatures of air are recorded by using thermometer.
e) Required readings were recorded at no load condition such as manometer, time required for the intake of 10cc gas, emission and time taken for cooling engine.
f) The engine is now loaded in the increasing percentage, and the readings were taken at respective load.
g) This experiment is repeated for different loads and different blends of fuels.
h) The engine performance test was conducted for all bends separately and performance parameters reading and emission readings were taken.

2. Performance Analysis

Brake thermal efficiency

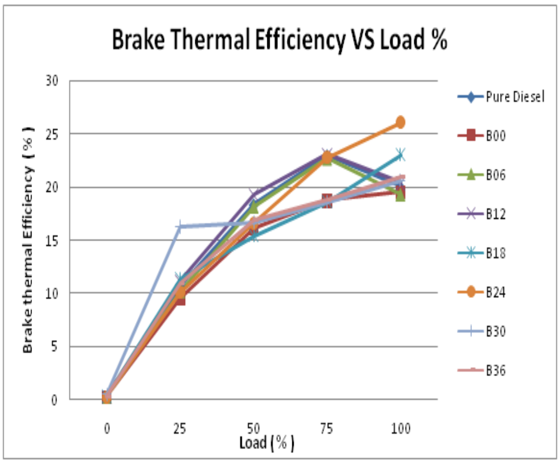

Figure 2: Brake thermal efficiency vs. Load percent

This graph shows the effect of load on the brake thermal efficiency. The thermal efficiency of the blend B24 is high at full load condition where as at no load condition the thermal efficiency of blend B30 is also high. At no load condition the blend B00 has very low thermal efficiency where the blend B06 has also very low efficiency at full load condition. At no load condition the brake thermal efficiency of the blend B12 is very close to the efficiency of diesel.

Mechanical Efficiency

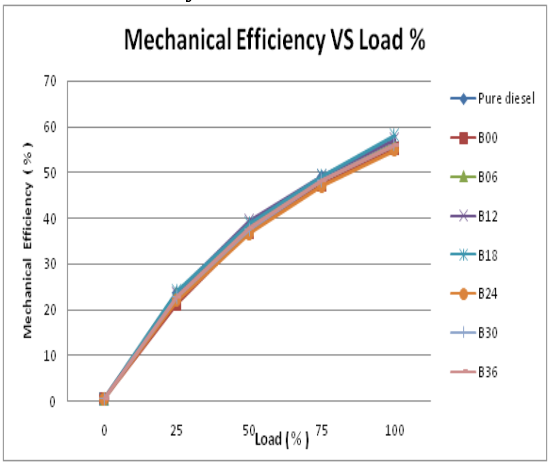

Figure 3: Mechanical efficiency vs. Load Percent

The influence of load on the mechanical efficiency is shown in this graph. The higher mechanical efficiency for no load condition and full load condition is for blend B18. And lower mechanical efficiency at no load condition and full load condition is for blend B00 and B24 respectively when compared to other blends.

Brake specific fuel consumption

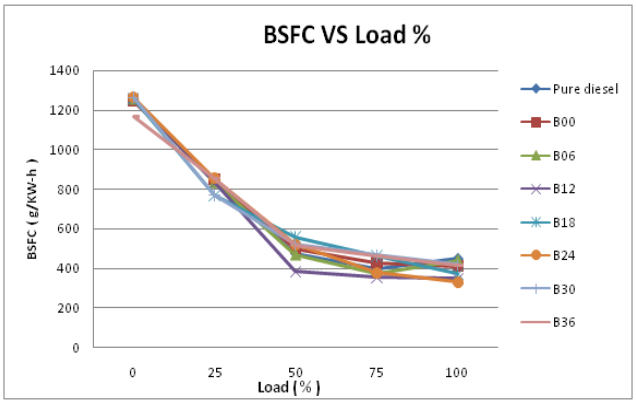

Figure 4: Brake specific fuel consumption vs. Load percent

This particular graph explains the relation between the brake specific fuel consumption and the load applied to the engine. At no load condition the fuel consumption of blend B00 is less compared to the diesel and the blend B30 has the higher fuel consumption compared with other blends. The blend B06 has the fuel consumption nearly equal to the pure diesel. When seen at full load condition the blend B30 has less consumption and the blend B06 has more consumption as compared to other blends and diesel.

Emission analysis

Bio diesel can be used in any conventional unmodified diesel engine and can have equal performance as petroleum diesel. The biodiesel used have lower viscosities than the diesel oil. This biodiesel ensure better atomization of the fuel in the combustion chamber that leads in the reduction of emissions and increased lubricity. The emissions of unburned hydrocarbon, carbon monoxide and nitrous oxide were measured by a multi fuel gas analyzer. The analyzer detects the content of HC and CO. it works according to the principle of selective absorption of each gas radiation within infrared field.

Specifications of Multi fuel gas analyzer

Model: AVL Detest gas 1000
Response time: 10 seconds
Gas flow rate range: 60 – 140 LPH
Warm time: 120 seconds
Dimensions (L×B×H): 270×85×320

Table 4: Emission result of Hydrocarbon (HC) with respect to load percent

Blend / Load Percent	B00	B06	B12	B18	B24	B30	B36	Pure Diesel
00	41.65	30.97	26.33	30.28	33.4	16.36	30.88	32.35
25	32.26	34.93	33.58	31.8	33	23.5	32.44	31.20
50	34.44	32.66	28.88	32.7	36.85	29.92	38.7	34.85
75	35.33	42.05	41.66	40.41	48.33	35.5	55.12	47.17
100	54.56	54.48	49	44.75	58.18	64.9	69.33	56.11

At no load condition the blend B30 has very much less emission of HC compared to others and when seen at full load condition the blend B12 has less percent of HC emission. For a lower compression the higher blended mixture gives more HC emission.

Table 5: Emission result of Carbon monoxide (CO) with respect to load percent

Blend / Load Percent	B00	B06	B12	B18	B24	B30	B36	Pure Diesel
00	0.318	0.58	0.18	0.21	0.22	0.27	0.26	0.24
25	0.295	0.47	0.49	0.45	0.237	0.26	0.26	0.250
50	0.317	0.6	0.8	0.33	0.231	0.23	0.2	0.255
75	0.327	0.37	0.39	0.38	0.416	0.48	0.29	0.517
100	0.949	1.04	1.43	0.61	1.03	1.18	0.75	1.06

The CO emissions are reduced by increasing the percentage of biodiesel. It is clear from the table that at no load condition the blend B12 has less emission and full load condition the blend B18 has less percent of emission of CO. this is due the lower temperature in the combustion chamber. As the load on engine goes on increasing the temperature of combustion chamber increases and hence CO emission increases.

3. Conclusion

The present study deals with the production of biodiesel from Jatropha blends along with Sunflower oil. Biodiesel is a promising fuel for compression ignition engines, which has characteristics very close to diesel fuel. The comparison of fuel properties and characteristics of biodiesel with the diesel fuel indicates that biodiesel fuel is quite similar in nature to diesel fuel. However Biodiesel has high viscosity which indicates the higher octane value that is useful for the normal combustion of fuel due to normal combustion.

Along with high viscosity Biodiesel has high density and low volatility Affects mixture formation and high density gives higher energy efficiency.

The result show that the fuel consumption of Biodiesel fuel is near about same with pure diesel fuel. All the blends Jatropha Biodiesel along with Sunflower oil shows brake Specific fuel consumption close to diesel. As the concentration of blends increase it improves the brake thermal efficiency.

It is observed that the emission is reduced by using biodiesel comparable to the diesel level. Biodiesel blends give better emission result.

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