Experimental Investigation of Performance and Emission Characteristics of DI Diesel Engine using Pumpkin Seed Oil as an Alternate Fuel

Abstract

Currently, alternate fuels are being investigated in detail for application in compression ignition (CI) engines resulting in exciting potential opportunities to increase energy security and reduce gas emissions. Biodiesel is one of the alternative fuels which is renewable and environmentally friendly and can be used in diesel engines with little or no modification. The objective of this study is to investigate the effects of biodiesel and biodiesel blends on the performance and emission characteristics of a CI engine. The experimental work was carried out on a four cylinder, four stroke, direct injection (DI) and turbocharged diesel engine by using biodiesel made form vegetable oil as a pumpkin seed oil and comparing them to normal diesel. The blended fuels used in the analyses are B20, B60 and B100. The engine was operated under various loads. Based on the measured parameters, detailed analyses were carried out on major regulated emissions such as NOx, CO, CO2, O2 and HC. It has been seen that the biodiesel types (sources) do result in significant differences in emissions.

Keywords: Vegetable oil, Biodiesel, Diesel engine, Performance, Emission

I. INTRODUCTION

In the current energy scene of fossil fuel, renewable energy sources such as biodiesel, bio-ethanol, bio-methane and biomass from wastes or hydrogen have become the subjects of great interest. These fuels contribute to the reduction of dependence on fossil fuels. In addition, energy sources such as these could partially replace the use of those fuels which are responsible for environmental pollution and may be scarce in the future. For these reasons they are known as—alternative fuel.

Pumpkin is a popular vegetable of rainy season crop in India. The pumpkin belongs to—cucurbita pepo family and is grown extensively during monsoon season and summer season throughout India, for immature and tender fruits. India is the second largest country producing pumpkin in the world wide after china. Pumpkins are consumed in daily cooking and also use in sweets preparations. A report indicated the oil content of pumpkin seed is remarkably high (45%). The carbohydrate content is between 4% and 5%. The fatty acid profile show that is composed linoleic (43-55%), oleic (27-38%), palmitic (13.3%) and stearic (8.0%) acids. The oil was chemically converted via an alkaline Tran’s esterification with methanol and methyl esters with a yield nearly 97.5% of wt.

II. LITERATURE SURVEY

[1] Ashok Kumar Yadav et al. States that the production, performance and emission characteristics of methyl esters of Oleander, Kusum and Bitter Groundnut oil in a transportation diesel engine were studied. Oleander oil methyl esters (OOME), Kusum oil methyl esters (KOME) and bitter Groundnut Oil Methyl Esters (BGOME) were prepared by Trans esterification process. The effects of three methyl esters on engine performance and exhaust emissions were examined at different engine speed and full load condition. Experimental results showed that the brake thermal efficiency of OOME is found higher and brake specific fuel consumption lower compared to KOME and BGOME. BGOME shows less emissions compared to OOME and KOME. In short,
it may be concluded from the experimental investigations that biodiesel from different non-edible oils (Oleander, Kusum, and Bitter Groundnut) can become an alternative source of fuel in future. The NOx emissions were slightly more than that of diesel. Overall engine operation with all three biodiesels (OOME, KOME, and BGOME) was smooth. All tested biodiesels (OOME, KOME, and BGOME) exhibited reduced brake thermal efficiency and exhaust emissions (CO and HC and smoke opacity) except NOx. The engine could be operated with these biodiesels without major modifications.

[2] Basavaraji M. Shrigiri et al. states that the performance, emission and combustion characteristics of a diesel engine are investigated using two methyl esters: One obtained from cotton seed oil and other from neem kernel oil. These two oils are transesterified using methanol and alkaline catalyst to produce the cotton seed oil methyl ester (CSOME) and neem kernel oil methyl ester (NKOME) respectively. From these experimental investigations they have been carried out on a CI engine using CSOME, NKOME and diesel. The LHR engine using CSOME and NKOME is analysed and compared with that of diesel fuel in normal engine. Compared with cotton seed oil methyl ester (CSOME) operation, neem kernel oil methyl ester (NKOME) resulted in better performance characteristics in LHR engine. However, compared with diesel in normal engine, the performance of the LHR engine with methyl esters is observed to be lower. The brake thermal efficiency values of CSOME and NKOME in LHR engine are lower than that of diesel fuel in normal engine. The above comparative study indicates the possibility of using the methyl esters in LHR engine. The performance, emission and combustion analysis show the suitability of using cot-ton seed and neem kernel oil methyl esters as good alternative fuels in LHR engine.

[3] Duple Sinha et al. states that the production of fatty acid methyl esters from waste cotton seed oil through trans-esterification was reported. The GC—MS analysis of WCCO oil was studied and the major fatty acids were found to be palmitic acid (27.76%) and linoleic acid (42.84%). The molecular weight of the oil was 881.039 g/mol. A maximum yield of 92% biodiesel was reported when the reaction temperature, time, methanol/oil ratio and catalyst loading rate were 60°C, 50 min, 12:1 and 3% (wt.%), respectively. The calcined egg shell catalyst was prepared and characterized. Partial purification of the fatty acid methyl esters was proposed for increasing the purity of the biodiesel and better engine performance. The flash point and the fire point of the bio diesel were found to be 128°C and 136°C, respectively. The Brake thermal efficiency of WCCO B10 biodiesel was 26.04% for maximum load, specific fuel consumption for diesel was 0.32 kg/kwh what maximum load. The use of biodiesel blends showed a reduction of carbon monoxide and hydrocarbon emissions and a marginal increase in nitrogen oxides (NOx) emissions improved emission characteristics. The Brake Thermal Efficiency of the Diesel was 28% at full load (100%). The specific fuel consumption of biodiesel fuel blends (B10, B20) were 0.34kg/kwh respectively. The biodiesel blends B10 and B20 with improved emission characteristics hydro carbon and carbon emissions and also could become a choice for conventional diesel fuel.

### III. MATERIAL AND METHOD

Biodiesel is the ester of vegetable oils produced through a process called Trans esterification. Trans esterification is a chemical reaction which occurs between triglyceride and methyl alcohol in the presence of potassium hydroxide (KOH). It consists of a sequence of three consecutive reactions where triglycerides are converted to diglycerides; diglycerides are converted to monoglycerides followed by the conversion of monoglycerides to glycerol. In each step an ester is produced and thus three ester molecules are produced from one molecule of triglyceride.

Biodiesel is produced from vegetable oils or animal fats and an alcohol, through a trans-esterification reaction. This chemical reaction converts an ester into a mixture of esters of the fatty acids that makes up the oil. Biodiesel is obtained from the purification of the mixture of fatty acid methyl esters (FAME). A catalyst is used to accelerate the reaction. According to the catalyst used, trans-esterification can be basic, acidic or enzymatic, the former being the most frequently used.

#### Table – 1

<table>
<thead>
<tr>
<th>Properties of Biodiesel</th>
<th>B-100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinematic viscosity @40°C in CST</td>
<td>4.335 centi strokes</td>
</tr>
<tr>
<td>Absolute viscosity</td>
<td>3.8017 g/cc</td>
</tr>
<tr>
<td>Flash point</td>
<td>125°C</td>
</tr>
<tr>
<td>Fire point</td>
<td>140°C</td>
</tr>
<tr>
<td>Gross calorific value kJ/kg</td>
<td>34502.45 kJ/kg</td>
</tr>
<tr>
<td>Density @15°C in gm/cc</td>
<td>878 kg/cc</td>
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</tbody>
</table>

### IV. STAGES OF BIODIESEL PRODUCTION PROCESS


Refined corn oil, palm oil, waste cooking cotton seed and rice bran oils were esterified by the Trans esterification method. Trans esterification is otherwise known as alcoholises. It is the reaction of fat or oil with alcohol to yield esters and glycerine. Trans esterification of selected oils was carried out by heating the oil. In this process, alcohol combines with triglyceride molecule from acid to form glycerol and ester.
The glycerol is then removed by density separations. Simple alcohols are used for Trans esterification and this process is usually carried out with a basic catalyst (NaOH, KOH) in the complete absence of water. Trans esterification decreases the viscosity of oil, making it similar to diesel fuel in characteristics. A catalyst is used to improve the reaction rate and yield. Trans esterification of triglycerides using alcohol is shown in Figure 4.2. The —catalytic Trans esterification‖ process is the reaction of a triglyceride (fat/oil) with an alcohol in the presence of acidic, alkaline or lipase as catalyst to form mono alkyl ester (i.e. Biodiesel) and glycerol. Alkaline catalysed Trans esterification is the fastest and require simple setup.

V. EXPERIMENTAL SETUP

The experiments are conducted for variable loads like 0.2, 1.37, 2.67, 3.88, and 5.09 KW at rated speed, with injection pressure of 210 bar and cooling water exit temperature at 65°C. Three blends of all types of vegetable oils such as 10%, 20% and 30% are used in this experimentation. The vegetable oils and their blends with diesel are heated externally to a required temperature as stated earlier before injecting into the test cylinder. The engine was sufficiently warmed up and stabilized before taking all the readings. All the observations recorded were replicated thrice to get a reasonable value. The performance parameters such as Brake Thermal Efficiency(η_B.Th.), Brake Specific Fuel Consumption(bsfc), Exhaust Gas Temperature(EGT) and Volumetric efficiency(η_Vol.) Emission parameters such as Carbon Monoxide (CO), Carbon Dioxide (CO₂), Hydro carbon (HC) (HC), Nitrogen Oxides (NOx) and Smoke are evaluated. These performance and emission parameters of oils are compared to those of pure diesel.

A. Engine

The Engine chosen to carry out experimentation is a single cylinder, four stroke, vertical, water cooled, direct injection computerized Kirloskar make CI Engine. This engine can withstand higher pressures encountered and also is used extensively in agriculture and industrial sectors. Therefore this engine is selected for carrying experiments.

B. Dynamometer

The engine has a DC electrical dynamometer to measure its output. The dynamometer is calibrated statistically before use. The dynamometer is reversible i.e., it works as monitoring as well as an absorbing device. Load is controlled by changing the field current. Eddy-Current Dynamometer's theory is based on Eddy-Current (Fleming's right hand law). The construction of eddy-current dynamometer has a notched disc (rotor) which is driven by a prime mover(such as engine, etc.) and magnetic poles(stators) are located outside with a gap. The coil which excites the magnetic pole is wound in circumferential direction.

C. Smoke Meter

Smoke measurement is made using an AVL 437C Smoke Meter shown in fig 6.4. The measurement is based on the principle of light absorption by particle. Photo electronic smoke detection is based on the principle of optical detection. It is also known as the "scattered" light principle. An alarm condition occurs when smoke particles enter the light path and a part of the light is "scattered" by reflection and refraction onto a sensor.

D. Exhaust Gas Analyzer

All emissions like Carbon monoxide, Carbon dioxide, Un-Burnt Hydrocarbons, Nitrogen oxide and unused oxygen are found in 5 gas emission analyser of model —5G -10 , PLANET EQUIPMENT is used. In this cable one end is connected to the inlet of the analyser and the other end is connected at the end of the exhaust gas outlet. The broadband infrared radiation produced by the light source passes through a chamber filled with gas, generally methane or carbon dioxide. This gas absorbs radiation of a known wavelength and this absorption is a measure of the concentration of the gas. There is a narrow bandwidth optical filter at the end of the chamber to remove all other wavelengths before it is measured with a pyro-electric detector.

<table>
<thead>
<tr>
<th>Company and Model</th>
<th>Kirloskar oil Engine, SV1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Single cylinder, 4-Stroke, diesel engine</td>
</tr>
<tr>
<td>Bore</td>
<td>87.5mm</td>
</tr>
<tr>
<td>Stroke</td>
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<tr>
<td>Rpm</td>
<td>1800rpm</td>
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<tr>
<td>Rated power</td>
<td>8 HP</td>
</tr>
<tr>
<td>Type of cooling</td>
<td>Water cooled</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>16.5:1</td>
</tr>
</tbody>
</table>
VI. ENGINE PERFORMANCE

A. Brake Thermal Efficiency

It is defined as brake power of heat engine as a function of the thermal input from the fuel. It’s used to evaluate how well an engine converts the heat from fuel to mechanical energy.

Shows the variation of Brake Thermal Efficiency with Brake power output for pumpkin seed oil and its blends with Diesel in the test engine. Brake thermal Efficiency blends of pumpkin seed oil is comparatively very high to that of Diesel. B60 and B100 are showing high results regarding $\eta_{BTH}$ and B20 is closer enough to diesel.

B. BRAKE SPECIFIC FUEL CONSUMPTION

It is a measure of the fuel efficiency of any prime mover that burns fuel and produces rotational, or shaft power. It is typically used for comparing the IC engine with the shaft output it is rate of fuel consumption divided by the power produced. Shows the variation of brake specific fuel consumption with

Brake power output for pumpkin seed oil and its blends in the test engine. B100 is higher than the other blends and B20 is closer to the diesel.

![Fig. 1: Brake power VS Brake thermal efficiency](image1)

![Fig. 2: Brake power VS Brake fuel consumption](image2)
VII. EMISSION PARAMETER

A. Carbon Monoxide:
Shows the variation of Carbon monoxide emissions with Brake power output for pumpkin seed oil and its blends with Diesel in the test engine. CO emission for blends of pumpkin seed oil is compared with diesel at all loads. At low loads B100 is high and B60, B20 is lower than the diesel. After 50% of load B100 start decrease, at peak load B20 is high emission

![Fig. 3: Brake Power VS Carbon Dioxide](image)

B. Carbon Dioxide
Shows the variation of Carbon Dioxide emission with Brake power output for pumpkin seed oil and its blends with Diesel in the test engine. B60 and diesel are comparatively close, B100 are low emission than other blends

![Fig. 4: Brake Power VS Carbon Dioxide](image)

C. Hydrocarbons
Shows the variation of hydro carbon emission with Brake power output for pumpkin seed oil and its blends with Diesel in the test engine. At low load B100 is higher and B20 is lower, after peak load B100 is lower emission. Diesel is higher emission than the other blend
**D. Nitrogen Oxides**

Shows the variation of Nitrogen Oxide emission with Brake power output for pumpkin seed oil and its blends with Diesel in the test engine. When applying load, B20 is higher than diesel and B100 averagely emits low NOx than the other blends, but differ at peak load.

**VIII. CONCLUSION**

- Filtered Pumpkin seed oil (biodiesel) can be substitute of diesel because the properties like calorific value, density and viscosity are very much comparable with diesel.
- Variation of brake specific fuel consumption with Brake power output for pumpkin seed oil and its blends in the test engine. B100 is higher than the other blends and B20 is closer to the diesel.
- Brake thermal efficiency of the engine is slightly increased for Methyl Esters of oils compared to diesel.
- Compare to neem oil methyl ester (NOME) and waste cotton oil methyl ester (WCOME), Brake thermal efficiency is increased in Pumpkin seed oil methyl ester (PSOME).
- Emission parameters of engine such as CO, CO2, HC and smoke for Methyl Esters of all respective oils are decreased compared to diesel, but NOx is increased at all loads. This is the result of complete combustion of the fuel.
- Methyl Esters produced from Pumpkin seed oil is proved technically feasible and used as alternative to diesel.
REFERENCE

[1] Performance and emission characteristics of a transportation diesel engine operated with non-edible vegetable oils biodiesel Ashok Kumar Yadav et al.