Performance, Emission and Combustion Characteristics of Multicylinder Diesel Engine Operating on Rice Bran Biodiesel

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Abstract— Continuous rise in the conventional fuel prices and shortage of its supply have increased the interest in the field of the alternative sources for petroleum fuels. Biodiesel is one such alternative source which provides advantage of pollution control. In the present work, experimentation is carried out to study the performance, emission and combustion characteristics of Rice-Bran biodiesel and diesel. In this experiment a multi cylinder, four stroke, naturally aspirated, direct injection, water cooled, eddy current dynamometer, TATA Indica V2 diesel engine is used at variable speed condition. Crude oil is converted into biodiesel and characterization has been done. The experiment is conducted at variable speed condition. The engine performance parameters studied were brake power, brake specific fuel consumption, brake thermal efficiency. The emission characteristics studied were CO, CO₂, UBHC, mean gas temperature, exhaust gas temperature and smoke opacity. The combustion characteristics studied were cylinder pressure, mass fraction burned, net heat release rate, cumulative heat release rate and rate of pressure rise. These results are compared to those of pure diesel. These results are again compared to the corresponding results of the diesel. From the graph it has been observed that, there is a reduction in performance, combustion characteristics and emission characteristics compared to the diesel. This is mainly due to lower calorific value, higher viscosity, lower mean gas temperature and delayed combustion process. The present experimental results show that Rice-Bran biodiesel can be used as an alternative fuel in diesel engine.

Keywords: Biodiesel, Rice bran biodiesel, Diesel, Alternate fuel, Transesterification, Performance, Emission, Combustion

I. INTRODUCTION

The economic progress of a country will be decided by the amount of fuel consumption per capita. India is one of the fastest growing economies in the world. The development objectives focus on economic growth, equity and human well being. Energy is a critical input for socio-economic development. The energy strategy of a country aims at efficiency and security and to provide access which being environment friendly and achievement of an optimum mix of primary resources for energy generation. The main source of energy is fossil fuels. It will continue to play a dominant role in the energy scenario in our country in the next few decades. However, conventional or fossil fuel resources are limited, non-renewable, polluting and therefore, need to be used prudently. On the other hand, renewable energy resources are indigenous, non-polluting and virtually inexhaustible. India is endowed with abundant renewable energy resources. Therefore, their use should be encouraged in every possible way. The availability of petroleum is also uncertain in future. Fast depletion of fossil fuels is demanding research work to find alternative fuels. Petro-based oil meets about 95% of the requirement for transportation fuels, and the demand has been steadily rising. The domestic crude oil is able to meet only about 23% of the demand, while the rest is met from imported crude. India’s energy security would remain vulnerable until alternative fuels to substitute/supplement petro-based fuels are developed based on indigenously produced renewable feedstock. The idea of using vegetable oils as a fuel for diesel engines is not a new one. Rudolph Diesel used peanut oil to fuel in his engine at Paris Exposition of 1900. However, despite the technical feasibility, vegetable oil as fuel could not get acceptance, as they were more expensive than petroleum fuels. Later the various factors as stated earlier, created renewed interest of researchers in vegetable oil as substitute fuel for diesel engines.

It is from the study by Venkata Subbaiah G et al [1] conducted experiments to extract bio diesel from rice bran oil as an additive in diesel ethanol blends for diesel engines. The experiments were aimed to investigate the performance and exhaust emission characteristics of a direct injection (DI) diesel engine when fuelled with conventional diesel fuel, rice bran oil bio diesel, a blend of diesel and rice bran oil bio diesel and three blends of diesel bio diesel ethanol over the entire range of load on the engine. The experimental results showed that the maximum brake thermal efficiency of 28.2% was observed with the blend B10 E15. The exhaust gas temperature of the blend B10 E15 was slightly lower than that of diesel fuel throughout the range of the load on the engine. The CO emissions of the bio diesel and all the other fuel blends were lower than that of the diesel fuel. The hydro carbon emissions increased with the increase of ethanol percentage in diesel bio diesel ethanol blends, but lower than those of the diesel at higher loads on the engine. The NOx emissions of the bio diesel and all the other fuel blends were low at lower loads and high at higher loads compared with the diesel fuel. The CO₂ emissions of the bio diesel and all the other fuel blends were higher than that of the diesel fuel. The smoke from the blend B10 E15 was lower than the diesel fuel.

In another study it is reported that O.D.Hebbal, et, al [2]-(2006), conducted experiment on performance characteristics of a diesel engine with Deccan hemp oil, they concluded that

- Performance and emission characteristics of 50% blend are better than other blends, followed by 25% blend. The maximum efficiency of 50% blend is well comparable with diesel. However smoke, unburnt HC, and CO emissions are respectively...
51.74%, 71.42% and 33.3% higher as compared with diesel. The performance characteristics of 25% blend is well comparable with 50% blend.

- The maximum brake thermal efficiency, minimum BSFC and BSEC of neat deccan hemp oil are respectively 1.61% lower, 0.05 kg/kW h higher and 867.11 kJ/kW h higher compared with diesel.

- Smoke, unburnt HC and CO emissions at maximum load for neat deccan hemp compared with diesel are higher by 3.08 Bosch No., 1.0 vol.%, and 50 ppm, respectively.

- Performance of deccan hemp oil is validated as results are in well comparison with results of jatropha and pongamia oils.

Senthil kumar M et al [3] investigated the use of untreated Rice-Bran oil and methanol in dual fuel mode of operation. They chosen Rice-Bran oil as pilot fuel and methanol was inducted as a primary fuel. Methanol was inducted through a carburettor. They conducted the tests on an AVI direct injection diesel engine at 1500 rpm and at full load. The primary objective of their study was to improve the performance of engine with Rice-Bran oil by inducting different quantities of methanol. The conclusions drawn from their studies are brake thermal efficiency was increased in the dual fuel mode when both Rice-Bran oil and diesel were used as pilot fuels. The maximum brake thermal efficiency was 30.6% with Rice-Bran oil and 32.8% with diesel oil. Smoke density was drastically reduced in dual fuel mode compared to pure Rice-Bran oil operation. Hydrocarbon and carbon monoxide emissions were higher in the dual fuel mode with both fuels. Heat release patterns in the case of neat Rice-Bran oil operation showed a smaller premixed combustion phase and larger diffusion combustion phase as compared to diesel operation. The phases were not distinguishable in the dual fuel mode.

The present work aims to investigate the variation of performance, emission and combustion characteristics of multi (four) cylinder diesel engine at different engine speeds. The present investigations are planned after a thorough review of literature in this field. The combinations of Rice bran biodiesel, along with pure diesel are taken for the experimental analysis.

In this article fuel properties, engine performance, emission and combustion characteristics of neat rice bran biodiesel and diesel will be investigated experimentally at variable speeds. Initially engine is operated by pure diesel at half (50%) load and at variable speeds ranging from 1500 to 4000 rpm, for this the performance, emission and combustion characteristics are recorded. These characteristics curves are then compared with the engine operated on neat rice bran biodiesel. The experimental setup for the study is arranged in the following manner.

II. EXPERIMENTATION

A. Characteristics for vegetable oil as fuel

For a vegetable to be used as a fuel in diesel engine, it should possess some of the characteristics which are given below.

- Higher viscosity and density will affect injection system and lower viscosity and density will lead to internal pump leakages thereby affecting engine performance, so it should be in acceptable level.

- Lower calorific value will cause ignition delay while starting, so it should be high i.e., nearer to diesel.

- Pour point and cloud point should be below the freezing point of the oil so that cold starting of the engine will be easy.

- Flash point should be high, so that it is much safer to handle and store.

- To avoid corrosion and residue formation on the engine parts, sulphur, carbon residue and ash content should be low.

- For short ignition delay period, the ignition quality should be high.

- Cetane number should be high i.e., it should be in the range of 40 to 60.

- Aniline point should be greater than 21°C, so that it can blended with diesel easily.

B. Biodiesel production from rice bran oil

Widely used and accepted process to reduce the viscosity of triglycerides is transesterification of vegetable oils, triglycerides react with alcohol in the presence of a strong acid or base, producing a mixture of fatty acid alkyl esters and glycerol. In transesterification which is a popular conditioning of vegetable oil of present practice, one ester is converted into another. The reaction is catalyzed by either acid or base involving reaction with an alcohol, typically methanol if a bio-fuel is the desired product. This section deals with steps involved in the preparation of Biodiesel from untreated vegetable oils. A stoichiometric material balance yields the following simplified equation.

\[ \text{Oil} + \text{Alcohol} \rightarrow \text{Esters} + \text{Glycerol} \]

![Fig. 2.1: Transesterification reaction](image)

Transesterification procedure- In organic chemistry, transesterification is the process of exchanging the organic group \( R^+ \) of an ester with the organic group \( R^- \) of an alcohol. These reactions are often catalyzed by the addition of an acid or base catalyst. Transesterification is otherwise known as alcoholysis. It is the reaction of fat or oil with an alcohol to form esters and glycerin. A catalyst is used to improve the reaction rate and yield. Among the alcohols, methanol and ethanol are used commercially because of their low cost and their physical and chemical advantages. They quickly react with tri-glycerides and NaOH and are easily dissolved in them. To complete a transesterification process, 3:1 molar ratio of alcohol is needed. In transesterification which is a popular conditioning of vegetable oil of present practice, one ester is
converted into another. Widely used and accepted process to reduce the viscosity of triglycerides is transesterification of vegetable oils, as shown in Fig 2.1 triglycerides react with alcohol in the presence of a strong acid or base, producing a mixture of fatty acid alkyl esters and glycerol.

Fig.2.2 shows the experimental setup of transesterification process

- Measure 500 ml of oil with the help of suitable measuring flask and transfer it to large Mason jar. As shown in Fig 2.2
- Measure 100 ml of methanol with the help of suitable measuring flask and transfer it to a small jar.
- Measure the calculated amount of NaOH with the help of suitable measuring device and transfer it to a small jar.
- Dissolve the NaOH completely and carefully with the methanol.
- Transfer the Sodium methoxide solution into the large Mason jar containing sample oil.
- Close the lid on the Mason jar and make it airtight and use suitable heating equipment.
- Stir the mixture vigorously.
- After the reaction is completed, the mixture is allowed to settle for around 15 to 20 hours.

Two major products like glycerin and biodiesel are obtained after the settling.
- As the glycerin phase is much heavier than the biodiesel phase, both of them are gravity separated.
- Bio-diesel and glycerin can be separated either by pouring Bio-diesel out from the top or by draining out glycerin from the bottom of the container.
- The separated biodiesel is then gently washed with warm water for 2 or 3 times to remove residual catalyst or soaps.
- Then drying of Biodiesel is carried out by using a container with large opening or by bubbling the air through the Bio-diesel. Drying can also be done by using fan to move air around the container or by increasing the temperature of air to remove the water vapour from the Bio-diesel.
- Finally the biodiesel obtained from the biofuel can be used in replace of Diesel. The separated diesel, biodiesel, and glycerol is shown in Fig 2.3.

(1)Thermometer (2)Mason jar (3)Heating coil (4)Thermostat (5)Magnetic stirrer (6)Temperature control knob (7)Magnetic rotor

Fig. 2.3: Separation process of rice bran biodiesel.

C. Properties of fuels used

Table 2.1 shows the values of different properties such as density, kinematic viscosity, flash point, fire point and calorific value of diesel and neat rice bran biodiesel.

<table>
<thead>
<tr>
<th>Sl.n</th>
<th>characteristic</th>
<th>Diesel</th>
<th>Ricebran biodiesel</th>
<th>Apparatus used</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Density (kg/m³)</td>
<td>831</td>
<td>872</td>
<td>Hydrometer</td>
</tr>
<tr>
<td>2</td>
<td>Calorific value (kJ/kg)</td>
<td>44585</td>
<td>39638</td>
<td>Bomb calorimeter</td>
</tr>
<tr>
<td>3</td>
<td>Viscosity at 40°C (cst)</td>
<td>3.21</td>
<td>4.81</td>
<td>Redwood viscosity</td>
</tr>
<tr>
<td>4</td>
<td>Flash point (°C)</td>
<td>51</td>
<td>168</td>
<td>Abel’s apparatus</td>
</tr>
<tr>
<td>5</td>
<td>Fire point (°C)</td>
<td>57</td>
<td>175</td>
<td>Abel’s apparatus</td>
</tr>
</tbody>
</table>

Table 2.1: Properties of Rice Brain methyl ester

1) Density

Fig 2.4 shows the hydrometer setup. Density is defined as the ratio of the mass of fluid to its volume. It is denoted by the symbol \( \rho \) (rho). The SI unit is given by kg/m³. Density of diesel is 831 kg/m³.
2) **Calorific value**

The total quantity of heat liberated by complete burning of unit mass of fuel. The calorific value of a substance is the amount of energy released when the substance is burned completely to a final state and has released all of its energy. It is determined by bomb calorimeter as shown in Fig 2.5 and its SI unit is $\frac{kJ}{kg}$. The calorific value of diesel is found that $44,585 \frac{kJ}{kg}$ and rice bran biodiesel is $39,638 \frac{kJ}{kg}$.

3) **Kinematic viscosity**

The resistance offered to flow of a fluid under gravity. The kinematic viscosity is a basic design specification for the fuel injectors used in diesel engines. At too high a viscosity the injectors do not perform properly. Its SI unit is centistokes (cst). Kinematic viscosity determined by the instrument called Redwood viscometer as shown in Fig 2.6. The value of kinematic viscosity is found that 3.21 cst for diesel and 4.81 for rice bran biodiesel.

4) **Flash and fire point**

Flash point of the fuel is defined as the temperature at which fuel gives off vapour to just ignite in air. Fire point of the fuel is defined as the temperature at which fuel will ignite continuously when exposed to a flame or spark. The flash point of biodiesel is higher than the petroleum based fuel. Flash point of biodiesel blends is dependent on the flash point of the base diesel fuel used and increase with percentage of biodiesel in the blend. Thus in storage, biodiesel and its blends are safer than conventional diesel. Its SI unit is °C. Determined by the instrument called Ables flash and fire point apparatus as shown in Fig 2.7. The value of flash and fire point of diesel found that 51 °C and 57 °C respectively and Jrice bran biodiesel is 168 °C and 175 °C respectively.

### III. EXPERIMENTAL SETUP

#### A. Dynamometer

The eddy current dynamometer shown in Fig 3.1 is connected to the engine which is used to control the load on the engine. It consists of a stator on which number of electromagnets is fitted and a rotor disc is made of copper or steel and coupled to the output shaft of the engine. When the rotor rotates eddy currents are produced in the stator due to magnetic flux set up by the passage of field current in the electromagnets. These eddy currents oppose the rotor motion, thus loading the engine. These eddy currents are dissipated in producing heat so that this type of dynamometer also requires some cooling arrangement. The torque is measured with the help of moment arm. The load is controlled by regulating the current in the electromagnets. The technical specification of the dynamometer is given in table 3.1.

<table>
<thead>
<tr>
<th></th>
<th>Model</th>
<th>AG-80</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Type</td>
<td>Eddy Current Dynamometer</td>
</tr>
</tbody>
</table>
The following are the main advantages of eddy current dynamometer:

- High horse power per unit weight of dynamometer.
- They offer the highest ratio of constant horse power speed range (up to 5:1)
- Level of field excitation is below one percent of total horse power being handled by dynamometer, thus, easy to control the programme.
- Development of eddy current is smooth, hence the torque is also smooth and continuous at all conditions.
- Relatively higher torque under low speed conditions.
- No natural limit to size, either small or large.

### B. Engine

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Component</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Engine</td>
<td>Tata Indica V2, 4 Cylinder, 4 Stroke, water cooled, Power 39kW at 5000 rpm, Torque 80 NM at 2500 rpm, stroke 79.5mm, bore 75mm, 1405 cc, CR 22</td>
</tr>
<tr>
<td>2</td>
<td>Dynamometer</td>
<td>eddy current, water cooled</td>
</tr>
<tr>
<td>3</td>
<td>Temperature</td>
<td>eddy current, water cooled</td>
</tr>
<tr>
<td>4</td>
<td>Piezo sensor</td>
<td>Range 5000 PSI</td>
</tr>
<tr>
<td>5</td>
<td>Air box</td>
<td>M S fabricated with orifice meter and manometer</td>
</tr>
<tr>
<td>6</td>
<td>Load indicator</td>
<td>Digital, Range 0-50 Kg, Supply 230VAC</td>
</tr>
<tr>
<td>7</td>
<td>Engine</td>
<td>Input Piezo sensor, crank angle</td>
</tr>
</tbody>
</table>

### C. Exhaust emission testing machine

The engine chosen to carry out the experimentation on multi (four) cylinder, four stroke, vertical, water cooled, computerised TATA make Indica V2 diesel engine at variable speed condition. Fig 3.2 photograph taken from the IC engine laboratory, PDA College of Engineering shows engine connected with controlling unit. Table 3.2 shows the specification TATA Indica V2 engine.

Fig 3.3 shows exhaust testing machine. The emission test is done with AVL DITEST MDS 480 exhaust gas analyser 1000 modules. The product has additional features to save a vehicle and customer database, radio connected measuring chamber up to the option of designing the protocols individually. Due to the robust and intuitive application of the device, the tester can be used to get sophisticated and accurate emission measurements. This provides information motivation and modification. The computer is interfaced with engine through ‘IC engine soft’ software and ‘automation and measurement’ used to control the entire engine readings.
D. Experimental procedure
For getting the base line data of engine first the experimentation is performed with diesel and then with biodiesel.

- Fill the diesel in fuel tank
- Start the water supply. Set cooling water for engine at 650 LPH and calorimeter flow at 150 LPH.
- Also ensure adequate water flow rate for dynamometer cooling and piezo sensor cooling.
- Check for all electrical connections. Start electric supply to the computer through the UPS.
- Open the lab view based engine performance analysis software package “engine soft” for on screen performance evaluation.
- Supply the diesel to engine by opening the valve provided at the burette.
- Set the value of calorific value and specific gravity of the fuel through the configure option in the software.
- Select run option of the software. Start the engine and let it run for few minutes under no load condition.
- Choose log option of the software. Turn on fuel supply knob. After one minute the display changes to input mode then enter the value of water flows in cooling jacket and calorimeter and then the file name (applicable only for the first reading) for the software. The first reading for the engine gets logged for the no load condition. Turn the fuel knob back to regular position.
- Repeat the experiment for different engine speeds.
- All the performance readings will be displayed on the monitor.
- Switch on the AVL Dismoke 480 and exhaust gas analyser1000 machine.
- Using AVL Dismoke 480 and exhaust gas analyser1000 value of CO, CO₂, NOₓ, UBHC and smoke opacity has to be recorded.
- Now clear the diesel present in the engine and use neat biodiesel as a fuel, repeat the same procedure.
- At the end of the experiment bring the engine to no load condition and turn off the engine and computer so as to stop the experiment.
- After few minutes turn off the water supply.

IV. RESULTS
A. Introduction
The experiment is conducted on TATA Indica V2 multi cylinder, direct ignition diesel engine. The experiment is carried out to obtain performance, emission and combustion characteristics of multi-cylinder diesel engine using ricebran biodiesel (B100) and diesel (D100) at different speeds.

Variation of Brake power with speed is shown in Fig 4.1. at variable speed. It is evident from graph that the brake power increases proportionally to engine speed in the range of 2000 to 4000 rpm. BP of biodiesel is initially low compared to that of diesel but as speed of engine increases BP of ricebran biodiesel consistently increases at high Speed (rpm)
Between speed of 3000 to 4000 rpm the variation of torque with speed remain almost constant. Torque obtained for the biodiesel is less as compare to the diesel. The maximum torque recorded for biodiesel is 37.83N-m and diesel is 37.81N-m. Torque generation for biodiesel is low mainly due to higher viscosity and lower calorific value of biodiesel. Since the experiment was conducted at constant load, no much variation of torque is seen with speed.

![Graph showing variation of brake thermal efficiency (BTE) with speed](image)

Fig. 4.3: Variation of brake thermal efficiency with speed.

The Fig 4.3 shows comparison of brake thermal efficiency Vs speed for biodiesel of rice bran in comparison to diesel respectively. The maximum value of BTE for the biodiesel and pure diesel is between 2000 to 3000 rpm. For the biodiesel the variation of BTE is lower as compared to pure diesel. The maximum thermal efficiency is achieved by diesel is around 26.74% at 2500 rpm which is slightly high compared to biodiesel. The BTE is almost constant between rpm range of 2500 to 4000 rpm, and it decreases sharply with further increase in rpm. Rice bran biodiesel exhibits comparatively somewhat equal efficiency for all speed range than pure diesel.

Variation of specific fuel consumption with speed is shown in Fig 4.4. It is evident from graph that SFC of biodiesel is slightly more compared to that of diesel this is because of lower calorific value of biodiesel. At the beginning specific fuel consumption is more and becomes mere constant with increase in speed. And also Biodiesel consumption is more because of higher viscosity which produces improper air fuel mixture and hence poor combustion. Higher viscosity of biodiesel lowers the maximum temperature. So consumption of biodiesel is more for same power output.

![Graph showing variation of specific fuel consumption (SFC) with speed](image)

Fig. 4.4: Variation of specific fuel consumption with speed.

C. Emission characteristics of multi cylinder diesel engine.

Variation of carbon monoxide with speed is shown in Fig 4.5. As speed increases, carbon monoxide emission seems to be constant at high speed condition. At maximum speed of 4000 rpm carbon monoxide recorded for biodiesel is 0.03 % volume and for diesel it is 0.04 % volume. Initially carbon monoxide emission is high since engine is at idling condition due to poor combustion. Biodiesel gives less carbon monoxide compared to diesel with increase in speed. Since biodiesel contains intrinsic oxygen, it gives additional oxygen for the combustion which leads to better combustion of biodiesel.

![Graph showing variation of carbon monoxide with speed](image)

Fig. 4.5: Variation of carbon monoxide with Speed.

Variation of carbon dioxide with speed is shown in Fig 4.6. Carbon dioxide increases with speed of engine for both biodiesel and diesel. Carbon dioxide emission for biodiesel is less compared to diesel with increase in speed. Even though biodiesel gives additional oxygen for complete combustion, because of lower calorific value of biodiesel, that is carbon molecule percentage in biodiesel is less as compared to diesel per unit volume leads to lower CO\textsubscript{2} emission.

![Graph showing variation of carbon dioxide with speed](image)

Fig. 4.6: Variation of carbon dioxide with Speed.

Variation of unburnt hydrocarbon with speed is shown in Fig 4.7. At the idling condition unburnt hydrocarbon percentage is more in exhaust due to poor combustion results. As speed of the engine increases percentage of unburnt hydrocarbon decreases. Biodiesel recorded slightly high value of unburnt hydrocarbon compared to diesel, this is due to the fact that the rice bran contains starch which offers incomplete combustion. Hence biodiesel produces some what equal proportionate of unburnt hydrocarbon percentage in the emission compared to diesel.

![Graph showing variation of unburnt hydrocarbon (UBHC) with speed](image)

Fig. 4.7: Variation of unburnt hydrocarbon with Speed.

Variation of smoke with speed is shown in Fig 4.8. To understand the pollution aspect of biodiesel the variation of smoke with brake power and speed is studied. Smoke value is lower for B100 compared to D100 because of intrinsic oxygen present in the biodiesel which gives additional oxygen, which in turn leads to better combustion. Lower CO, CO\textsubscript{2} and UBHC also supports the lesser smoke value of B100.
Performance, Emission and Combustion Characteristics of Multicylinder Diesel Engine Operating on Rice Bran Biodiesel

D. Combustion characteristics of multicylinder diesel engine

Fig. 4.10: Variation of cylinder pressure with crank angle

Variation of mass fraction burnt with crank angle

Variation of mass fraction burnt with crank angle is shown in Fig. 4.11. Biodiesel starts burning at 30 degree before top dead center and continues up to 14 degree after top dead center. Diesel starts burning at 30 degree before top dead center and continues up to 30 degree after top dead center. From the graph it is observed that diesel combustion prolongs for longer time, but biodiesel combustion completes near the top dead center only. Burning of the mass fraction of biodiesel is not continuous due to improper atomization, distinct rate of reaction leads to non uniform combustion. Major combustion of the biodiesel completes at 14 degree CA and diesel completes at 30 degree CA. Lower maximum cylinder gas temperature leads to poor chemical dissociation of biodiesel gives abnormal combustion which in turn reduces poor mass fraction burning.

The variation of net heat release rate with crank angle

The variation of net heat release rate with crank angle is shown in Fig. 4.12. The net heat release rate is more for biodiesel at 676 degree crank angle only as compared to the diesel fuel. In the later stage of combustion of biodiesel there is a distinct net heat release rate can be observed. This is due to lower calorific value, low mean gas temperature.
and high viscosity leads to improper mass fraction burnt and rate of reaction.

- The blends of rice bran oil with petro diesel will be compatible with diesel oil at higher load from the perspective of engine performance.
- Physical and chemical properties test revealed that the rice bran oil methyl ester have almost similar physical and chemical properties of diesel oil, except the viscosity which is slightly higher that of specified range for petro diesel fuel. Both the blends are suitable as fuel for C I engines without any engine modification.
- Brake specific fuel consumption was found to have minimum for neat diesel as compared to biodiesel. However at lower compression ratios biodiesel has minimum specific fuel consumption. The brake thermal efficiency was found to increase with increase in speed and there is no large difference in the brake thermal efficiency of biodiesel and neat diesel.
- Biodiesel have more heat release rate than neat diesel at initial stages compared to neat diesel and biodiesel have large negative heat release rate due to cooling effect of the liquid fuel injected into the cylinder.
- The result of this work showed B100 which is pure biodiesel gives better performance compared to diesel in some aspects so it can be used effectively in diesel engine for higher performance without any modifications.
- NOx emission is found to be minimum for biodiesel compared to diesel.
- CO emission is more for diesel compared rice bran biodiesel, Smoke opacity of biodiesel blends is found to be lesser than diesel. This is due to heavier molecules of hydrocarbons in vegetable oils.
- Unburnt hydrocarbon emission of diesel is found to maximum than biodiesel. This is due to oxygen content in the biodiesel.
- A general conclusion from this work is that, biodiesel can be used safely without any modifications in the engine.

REFERENCES


