Experimental Investigations on Performance, Emission and Combustion Characteristics of Multi Cylinder Diesel Engine Operating on JOME and Diesel at Very Low Load

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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 Jatropha oil methyl ester(JOME) and diesel. In this experiment a multi cylinder, four stroke, naturally aspired, direct injection, water cooled, eddy current dynamometer, TATA Indica V2 diesel engine is used at very low load condition. Crude oil is converted into biodiesel and characterization have been done. The experiment is conducted at low load condition. The engine performance parameters studied were brake power, brake specific fuel consumption, brake thermal efficiency. The emission characteristics studied are CO, CO_2, UBHC, mean gas temperature, exhaust gas temperature and smoke opacity. The combustion characteristics studied are 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 compare 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 Jatropha biodiesel can be used as an alternative fuel in diesel engine.

Keywords— Biodiesel; JOME; Diesel; Alternative fuel; Transesterification; Performance; Emission; Combustion

I. INTRODUCTION

For the social development, economic growth and welfare of human being of any country, the energy is critical input factor. Fossil fuels are the major source for the energy demand since from their exploration. India with high rate of economic growth and increase in population has an energy demand of 3.5% of world commercial energy demand and ranks sixth. The highest proved oil reservoirs including non conventional oil deposits are in Venezuela (20% of global reserves), Saudi Arabia (18% of global reserves), Canada (13% of global reserves) and Iran (9% global reserves). This inequality of petroleum reservoirs creates the dependency of other countries on the above mentioned countries. Political imbalances in these countries have the ability to shake the economy of dependant countries. The environmental impact of petroleum is often negative because its emission is toxic to all most all kinds of living beings. The possibility of climate change exists due to the effect of green house gases emitted from the petroleum based products. An increased emission product creates the health related problems on living beings. To overcome this problem usage of biodiesel is the best solution, since the properties of these esters are comparable to that of diesel. But the production of biodiesel trend is originating recently to fulfill the energy demand and lots of data are required for the engine modification for optimum operation. In the whole world biodiesel production, Indian contribution is only 1.5% till today. The planning commission of India has launched a bio-fuel project in 200 districts from 18 states in India. It has recommended two plant species, viz. Jatropha (Jatropha curcas) and Karnaja (Pongamia pinnata) for biodiesel production. Indian government has also started lot of programs like “National Mission on Biodiesel”, “National Mission on Jatropha” etc to grow Jatropha and Pongamia in unused areas through aid from the government sectors and there by planned to enhance the production of biodiesel and its usage.

The substitution of diesel oil by renewable fuels produced by the country generates higher foreign exchange savings, even for the major oil exporting countries. Therefore developing countries can use this kind of projects not only to solve their ecological problems, but also to increase their economy. In view of the several advantages, biofuels have potential to replace petroleum based fuels in the long run. In the recent years, systematic efforts have been made by several researchers to use the various vegetable oils as fuel in the compression ignition engines. The viscosity of vegetable oil is about ten times higher than that of diesel. The commonly employed method to reduce the viscosity of vegetable oils is transesterification.

It is from the study by Dipak Patil et.al;[11] has conducted experiment on performance characteristics and analysis of Jatropha oil on multi-cylinder turbocharger compression ignition engine. According to the investigation he found that, it was observed that JBD20 shows less indicated 39.8% and brake thermal efficiency of 26.9% and 0.429 kg/kW-hr specific fuel consumption against diesel which are comparable. JBD20 is more suitable blend of Jatropha oil.

In another study it is reported that Agarwal D et.al;[13] conducted experiment on performance evaluation of multi-cylinder diesel engine using biodiesel from Pongamia oil and concluded that the performance evaluation of engine has found that BSFC for B30 in case of Pongamia biodiesel is 0.489 kg/kW-hr at peak load which is 5% higher than 0.412 kg/kW-hr of diesel. Maximum brake thermal efficiency of 26.7%, which is 6.6% lower compare to that of diesel value 28.6% Hence B30 is the better blend that gives the comparable result with diesel.

Gvidonas Labeckas et.al;[15] conducted experiment on influence of fuel additives on performance of direct-injection diesel engine and exhaust emissions when operating on Shale oil and concluded that the brake specific fuel consumption at low loads and speeds of 1400–2000 rpm reduces by 18.3 to 11.0% due to the application of the Marisol FT. The additive SO-2E proved to produce nearly the same effect. The total NO_x emission from the fully loaded diesel engine fuelled with the treated Shale oil reduces by 29.1% (SO-2E) and 23.0% (Marisol FT). It is important that the lower NO_x is obtained due to reducing both harmful pollutants, NO and NO_2. The CO emission at rated power increases by 16.3% (SO-2E) and 48.0% (Marisol FT), whereas the smoke opacity of the exhausts increases by 35% and 70% respectively.

The present work aims to investigate the variations of performance, emission and combustion characteristics of multi (four) cylinder diesel engine at different loads and speeds. The present investigations are planned after a thorough review of literature in this field. The combinations of Jatropha biodiesel, along with diesel are taken for the experimental analysis. In this article, the fuel properties, engine performance and emissions and combustion characteristics of the neat biodiesel and diesel will be investigated experimentally at variable load and speed. The engine will be operated once with fixed load and variable speed. At the second time engine will be operated with fixed speed and variable load. The engine gives 39 kW at 5000 rpm. In the beginning 75% of load will be fixed i.e. 29.25 kW and later speed variation of 1000, 1500, 2000, 2500 and 3000 rpm will be done. In the second step experiment will be conducted for varying load of 20%, 40%, 60% and 80% at a fixed speed of 2500 rpm. For the above mentioned experimental setup performance and emission characteristics will be recorded.

II. Experimentation

During the Jatropha oil is converted into biodiesel process it is necessary to find FFA, which gives the information about process conversion. Since the Jatropha oil FFA was around 12 primarily esterification process and later transesterification process should be performed.

2.1 Esterification process

Esterification is the reaction of an acid with an alcohol in the presence of a catalyst to form an ester. The equation 2.1shows esterification process

$$\mathrm{RCOOH} + \mathrm{R^1OH} \longrightarrow \mathrm{RCOOR^1} + \mathrm{H_2O}$$

Eqn 2.1 Esterification process

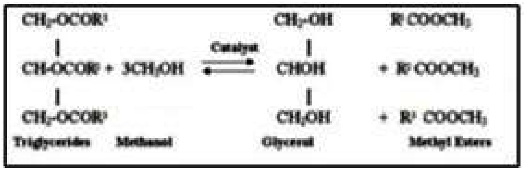
Generally, acid catalyst like sulphuric acid is employed. Esterification is a reversible reaction. Thus water produced must be removed to drive the reaction to the right to obtain a higher ester yield.

- **Process details**
- **Filtering:** Oil is filtered to remove solid particles. The oil is required to be warm up a bit first to get it to run freely, 35 ^{o}C should be enough. Cartridge filter is used for the same.
- **Removing the water:** The oil is heated to remove water content, otherwise this can slow down the reaction and cause saponification.
- **Heating and mixing:** Oil is preheated to 50°C to 60°C (< 65°C). Sodium methoxide solution is added to oil and heat the solution until reaction completes. This separates the methyl esters form the glycerine.
- **Settling and separation:** The mixture is allowed to settle and cool for at least 8 hours, preferably longer in a separating funnel. It is observed that there are two distinct layers formed. The semi-liquid glycerine has a dark brown colour at bottom and biodiesel is honey coloured at top. Separate the gycerine from biodiesel.
- **Washing and drying:** Water washing is done to remove any moisture and emulsion. After heating, the mixture is once again transferred to the separating funnel where in again the water with any emulsion formed settled at the bottom. The upper layer is pure methyl ester i.e. biodiesel, ready for the use in diesel engine.

2.2 Transesterification process

Transesterification reaction is the reaction of a fat or oil with an alcohol to form esters and glycerol. This reaction is also called alcoholysis.. A catalyst is usually used to improve the reaction rate and yield. Because the reaction is reversible, excess alcohol is used to shift the equilibrium to the products side. It can quickly react with triglycerides and sodium hydroxide (NaOH) which is used as the catalyst is easily dissolved in it. To complete a transesterification stoichiometrically, a 3:1 molar ratio of alcohol to triglycerides is needed. In practice, the ratio needs to be higher to drive the equilibrium to a maximum ester yield.

The reaction can be catalyzed by alkalis, acids, or enzymes. The alkalis include sodium hydroxide (NaOH), Potassium hydroxide (KOH). Alkali - catalyzed transesterification is always with R_1, R_2 and R_3 are long chain hydrocarbons which may be the same or the different for an alkali-catalyzed transesterification, the glycerides. The triglycerides can be purified by saponification (known as alkali treating) and then transesterified using an alkali catalyst. The transesterification reaction is shown in equation 2.2



$$\begin{array}{llcll} CH_2\text{-}OCOR^1 & & & CH_2\text{-}OH & R^1COOCH_3 \\ CH\text{-}OCOR^2 & +\ 3CH_3OH & \overset{\text{Catalyst}}{\rightleftharpoons} & CHOH & +\ R^2COOCH_3 \\ CH_2\text{-}OCOR^3 & & & CH_2OH & +\ R^3COOCH_3 \\ \text{Triglycerides} & \text{Methanol} & & \text{Glycerol} & \text{Methyl Esters} \end{array}$$

Equation 2.2 Chemical reaction of biodiesel

- **Parameters affecting on transesterification reaction system**

The transesterification is essentially a heterogeneous liquid-liquid system whether the catalyst is used or not. As a result, the reactor used must have intense level of turbulence to promote mass transfer. This can be achieved with the help of a mechanically agitated contactor or a static mixer. The process parameters affecting biodiesel production are discussed below.

- **Catalyst**: Transesterification is catalyzed by acidic or basic catalyst. For instance, H_2SO_4, HCl are the acidic catalysts while NaOH or sodium methoxide ($NaOCH_3$) are basic catalysts.
  The enzymes such as lipase have been also reported as catalyst for transesterification/esterification. The most popular catalyst is sodium methoxide. However, NaOH was also found to be suitable.
- **Feedstock:** The quality of feedstock plays important role. The free fatty acids (FFA) present in non-edible oil would destroy the basic catalysts and soap formation would take place. Thus, non-edible oil needs prior processing to remove FFA or one has to use acidic catalysts. The oil used must have as low moisture content as possible (moisture < 0.1%) so as to avoid hydrolysis of catalysts and triglycerides also.
- **Temperature:** The transesterification reaction precedes best under atmospheric pressure at reflux temperature of about 64°C in the case of FAME and could be higher in the case of FAEE.
- **The product recovery**: The reactor contents are thoroughly washed at the end to remove catalyst (caustic), methanol and glycerol. The residual methanol and water could be distilled out from Biodiesel to meet the desired specifications.

3.2 Properties of fuels used

- **Density**

Fig 2.1 shows the hydrometer setup. Density is defined as the ratio of the mass of fluid to its volume. It is denoted by the symbol ρ (rho). The SI unit is given by kg/m^3. Density of diesel is 828 kJ/kg and density of Jatropha biodiesel is 864 kJ/kg.

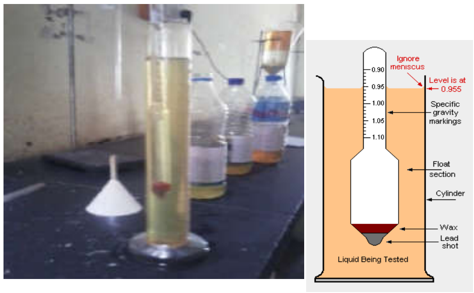


Fig 2.1 Hydrometer

- **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 2.2 and its SI unit in kJ/kg. The calorific value of diesel is found that 42,600 kJ/kg and Jatropha biodiesel is 40,800 kJ/kg.

Fig 2.2 Bomb calorimeter

- **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. Kinematic viscosity determined by the instrument called Redwood viscometer as shown in fig 2.3 The value of kinematic viscosity is found that 4.6 cst for diesel and 5.81 for Jatropha biodiesel.

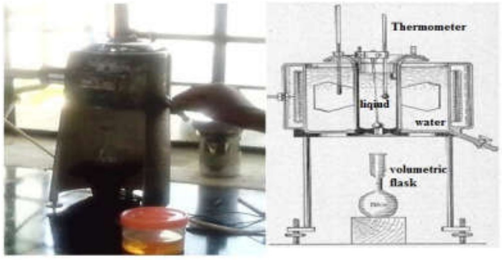


Fig 2.3 Redwood viscometer

- **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. Determined by the instrument called Ables flash and fire point apparatus as shown in fig 2.4 The value of flash and fire point of diesel found that 51 ^{o}C and 57 ^{o}C respectively and Jatropha biodiesel is 160 ^{o}C and 175 ^{o}C respectively.

Fig 2.4 Ables flash and fire point apparatus

Table 3.1 shows the values of different properties such as density, kinematic viscosity, flash point, fire point and calorific value of diesel and neat Jatropha biodiesel.

III EXPERIMENTAL SETUP

3.1 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.

Fig 3.1 Eddy current dynamometer

Table 3.2 Technical specification of dynamometer

1	Model	AG-80
2	Type	Eddy Current Dynamometer
3	Make	Saj Test Plant Private Ltd
4	Cooling System	Water cooled
5	Load Cell	Maywood load cell
6	Dynamometer arm length	210 mm

The following are the main advantages of eddy current dynamometers:

- 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.

3.2 Engine

The engine chosen to carry out the experimentation is multi (four) cylinder, four stroke, vertical, water cooled, computerised TATA make Indica V2 diesel engine. Fig 3.2 photograph taken from the IC engine laboratory, PDA College of Engineering shows engine connected with controlling unit. Table 3.3 shows the specification TATA Indica V2 engine.

Fig 3.2 Engine connected with dash board

Table 3.3 Technical specification of TATA Indica V2 engine

Sl.No	Component	Specifications
1	Engine	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
2	Dynamometer	eddy current, water cooled
3	Temperature	eddy current, water cooled
4	Piezo sensor	Range 5000 PSI
5	Air box	M S fabricated with orifice meter and manometer
6	Load indicator	Digital, Range 0-50 Kg, Supply 230VAC
7	Engine Indicator	Input Piezo sensor, crank angle sensor, Input Piezo sensor, Communication RS 232, Crank angle sensor
8	Software	IC Enginesoft, Measurement and Automation
9	Temperature Sensor	Type RTD, PT100 and Thermocouple Type K
10	Fuel flow transmitter	DP transmitter, Range 0-500 mm
11	Air flow transmitter	Pressure transmitter
12	Load sensor	Load cell, type strain gauge, Range 0-50 Kg

3.3 Exhaust emission testing machine

Fig 3.3 Exhaust gas analyser

The emission test is done with AVL DITEST MDS 480 exhaust gas analyser 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 sophisticate and accurate emission measurements. This provides information motivation and modification. The computer is interfaced with engine. The engine soft is the software used to control the entire engine readings.

3.4 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 load and speed.
- All the performance readings will be displayed on the monitor.
- Using AVL smoke meter and exhaust gas analyser CO, CO_2, NO_x, UBHC, smoke opacity will 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

4.1 Introduction

The experiment is conducted on TATA Indica V2 multi cylinder, direct ignition diesel engine to obtain performance, emission and combustion characteristics of multi-cylinder diesel engine using Jatropha biodiesel (J100) and diesel (D100) at low load condition i.e. up to 10% of maximum load.

4.2 Performance characteristics of multi cylinder diesel engine.

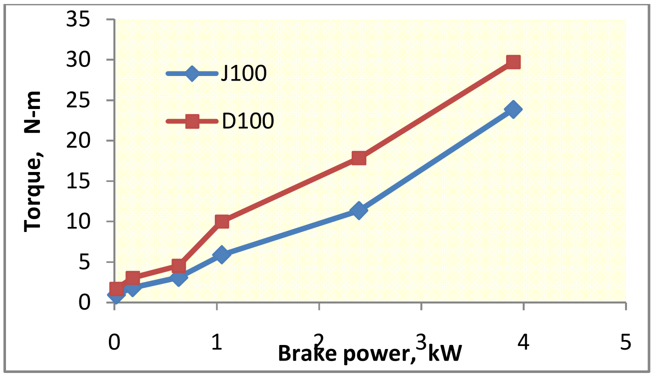


Fig 4.2.1 Variation of torque with brake power

Variation of torque with brake power is shown in fig 4.2.1 at low load condion. Torque obtained for the biodiesel is less as compare to the diesel. The maximum torque recorded for biodiesel is 23.6 N-m and diesel is 27.9 N-m at 3.9 kW brake power. Torque generation for biodiesel is low mainly due to higher viscosity.

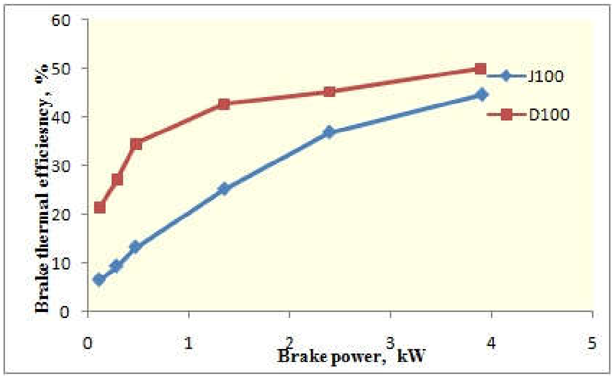


Fig 4.2.2 Variation of brake thermal efficiency with brake power

Variation of brake thermal efficiency with brake powers shown in fig 4.2.2. Brake thermal efficiency increases with increase in brake power for both biodiesel and diesel. Maximum brake thermal efficiency of 46% for biodiesel and 83.31% for diesel is obtained. Biodiesel yields lower brake thermal efficiency compare to diesel because of higher viscosity and lower mean gas temperature.

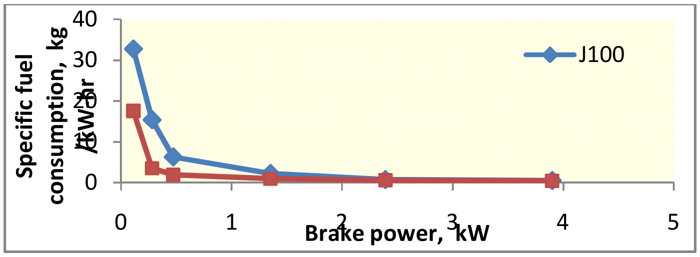


Fig 4.2.3 Variation of specific fuel consumption with brake power

Variation of specific fuel consumption with brake power is shown in fig 4.2.3. At the beginning specific fuel consumption is more and becomes constant with increase in brake power. In the idling condition specific fuel consumption of biodiesel is 32.76 kg/kW-hr at 0.11 kW and of diesel is 17.58 kg/kW-hr at 0.11 kW. 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.

4.3 Emission characteristics of multi cylinder diesel engine.

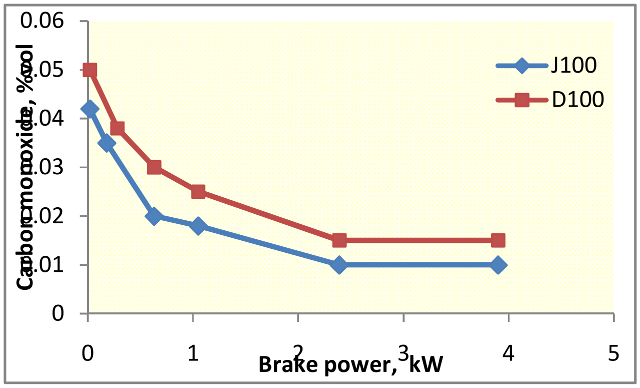


Fig 4.3.1 Variation of carbon monoxide with brake power

Variation of carbon monoxide with brake power is shown in fig 4.3.1. As brake power increases, carbon monoxide emission decreases at low load condition. At maximum power of 3.9 kW carbon monoxide recorded for biodiesel is 0.01 % volume and for diesel it is 0.015 % 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 brake power. Since biodiesel contains intrinsic oxygen, it gives additional oxygen for the combustion leads to better combustion of biodiesel compared to diesel.

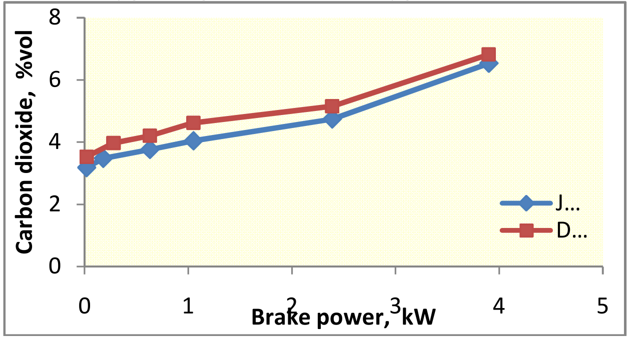


Fig 4.3.2 Variation of carbon dioxide with brake power

Variation of carbon dioxide with brake power is shown in fig 4.3.2. Carbon dioxide increases with brake power for both biodiesel and diesel. At 3.9 kW brake power, carbon dioxide value recorded for diesel is 6.82% volume and for biodiesel is 6.53% volume. Carbon dioxide emission for biodiesel is less compared to diesel with increase in brake power at lower load condition. 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_2 emission.

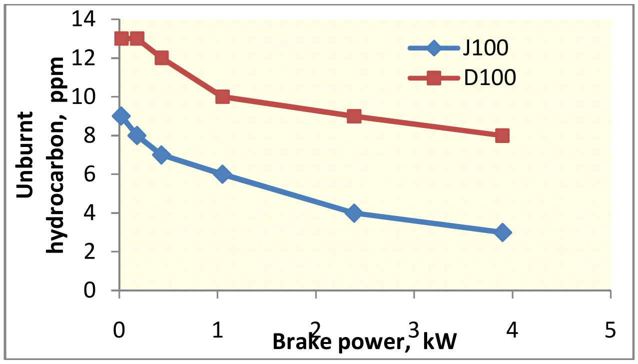


Fig 4.3.3 Variation of variation of unburnt hydrocarbon with brake power

Variation of unburnt hydrocarbon with brake power is shown in fig4.3.3. At the idling condition unburnt hydrocarbon percentage is more in exhaust due to poor combustion results. As the brake power increases percentage of unburnt hydrocarbon is decreases. At 3.9 kW brake power recorded for diesel is 8 ppm and the biodiesel is 3 ppm of unburnt hydrocarbon. Biodiesel recorded lower unburnt hydrocarbon compared to diesel, because of intrinsic oxygen present in the biodiesel gives additional oxygen to the combustion leads to better combustion. Hence biodiesel produces lower unburnt hydrocarbon percentage in the emission.

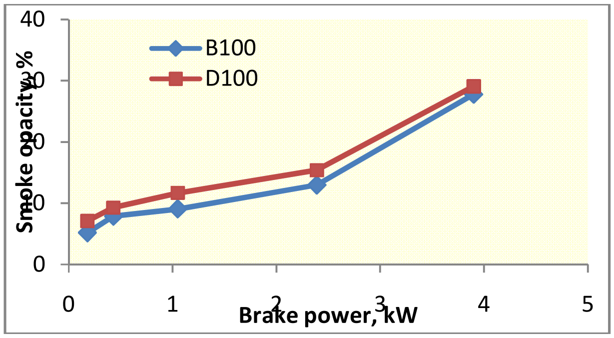


Fig 4.3.4 Variation of smoke opacity with brake power

Variation of smoke with brake power is shown in fig 4.3.4 at low load condition. To understand the pollution aspect of biodiesel the variation of smoke with brake power is studied. At 3.9 kW of brake power the value of smoke opacity recorded for is J100 27.8 % and for D100 is 29.1 %. Smoke value is lower for J100 compared to D100 because of intrinsic oxygen present in the biodiesel gives additional oxygen, leads to better combustion. Lower CO, CO_2 and UBHC also supports the lesser smoke value of J100.

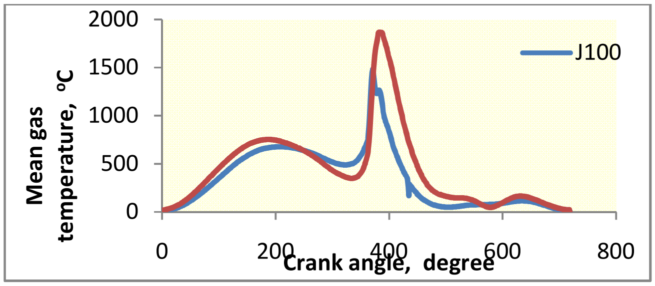


Fig 4.3.5 Variation of mean gas temperature with crank angle

Variation of mean gas temperature with crank angle is shown in fig 4.2.4 at low load condition i.e. at 10%. Maximum temperature noted for diesel is 1847.6 °C at 381 degree CA and for neat biodiesel is 1463 °C at 373 degree CA. Jatropha biodiesel having lower calorific value and lower Cetane number compare to D100. Along with that distinct rate of reaction of J100 leads to lower maximum mean gas temperature.

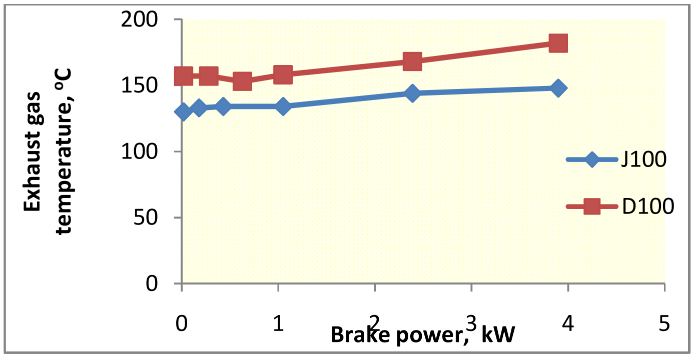


Fig 4.3.6 Variation of exhaust gas temperature with brake power

Variation of exhaust gas temperature with brake power is as shown in fig 4.2.5 at low load condition. Exhaust gas temperature increases with brake power. For 3.9 kW brake power values recorded for diesel is 182 °C and for biodiesel is 148 °C. The exhaust gas temperature of biodiesel is less compare to diesel because of lower mean gas temperature. Viscosity is also influences the exhaust gas temperature by affecting the rate of reaction.

4.4 Combustion characteristics of multi cylinder diesel engine.

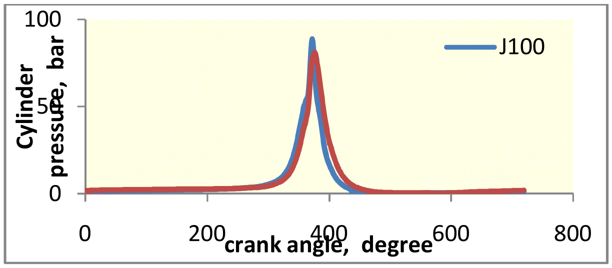


Fig 4.4.1 Variation of cylinder pressure with crank angle

Variation of cylinder pressure with crank angle is as shown in the fig 4.4.1. From the figure it is evident that maximum pressure rise is occurs for the Jatropha biodiesel and it is recorded as 90.3 bar. CI cylinder pressure is depends on fuel burning rate during the premixed burning phase, which in turn leads maximum cylinder gas pressure of 90.3 bar occurs at 371 degree CA for biodiesel and 82.3 bar at 376 degree for diesel. Maximum cylinder gas pressure is more for biodiesel, due to higher brake specific fuel consumption and intrinsic oxygen content in biodiesel.

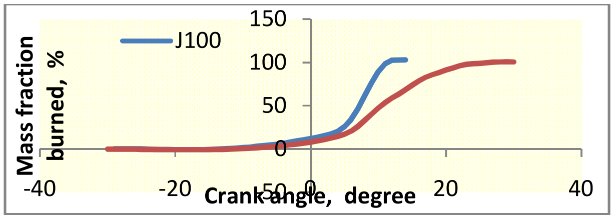


Fig 4.4.2 Variation of mass fraction burned with crank angle

Variation of mass fraction burnt with crank angle is shown in fig 4.4.2. 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.

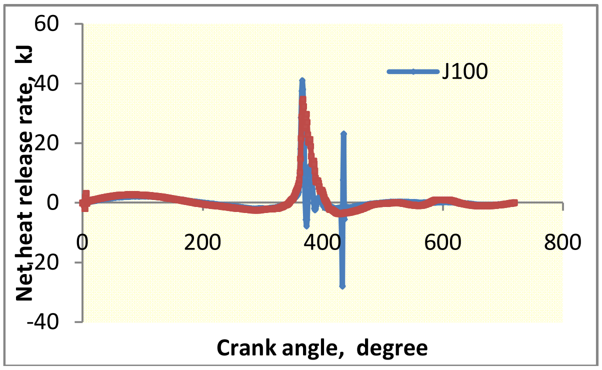


Fig 4.4.3 Variation of net heat release rate with crank angle

The variation of net heat release rate with crank angle is shown in fig 4.4.3. The net heat release rate is more for biodiesel at 366 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.

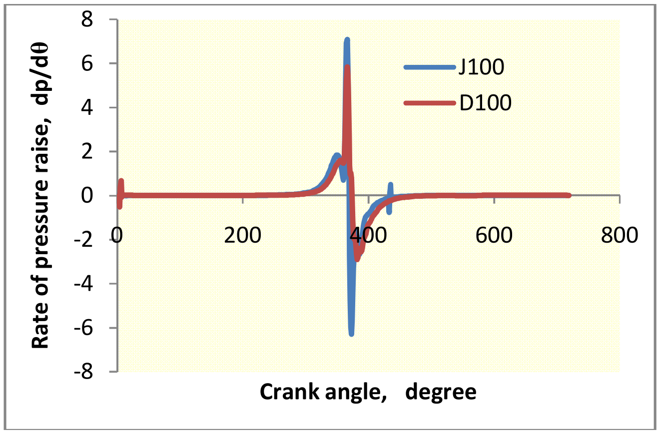


Fig 4.4.4 Variation of rate of pressure rise with crank angle

Variation of rate of pressure rise with crank angle shown in fig 4.4.4. The combustion starts in the pre ignition region where the rate of pressure raise increases slightly and then again decreases to a small extent. Near top dead center the rate of pressure rise is high for both biodiesel and diesel. The maximum rate of pressure rise recorded for biodiesel is 6.9 at 365 degree CA and for diesel are 5.84 at 366 degree crank angle. The pressure rise is distinct for biodiesel, this may be due to improper air fuel mixture, non uniform mass fraction burnt.

V. CONCLUSION

The purpose of this chapter is to summarize the preparation, characterization of biodiesel and the results of experiment has been carried out. The following section contains specific conclusions that have been drawn from the project work.
The conclusions of the project are as follows.

- Neat Jatropha oil is converted into biodiesel using transesterification process.
- Characterization of Jatropha biodiesel is carried out, the specific gravity and calorific value of biodiesel is less than that of diesel.
- Viscosity of the neat Jatropha oil is at higher values. However viscosity of biodiesel is well comparable with diesel.
- Engine is producing the desired brake power at different speed compared with that of diesel.
- Brake thermal efficiency of biodiesel is lower than diesel.
- In the load range of 0 to 2.2 kW specific fuel consumption of biodiesel is higher, as load increases biodiesel comparable with that of diesel.
- Mean gas temperature of combustion chamber for a complete cycle for burning of biodiesel is lower than that of diesel.
- Smoke, unburnt hydrocarbon, carbon monoxide, carbon dioxide emissions are a little lower than that of diesel due to low temperature of mean gas temperature.
- The mass burnt fraction for a Jatropha completes after 10 degree of top dead center. However that of diesel is prolonged 35 degree CA, which attributes to higher emission.
- Cumulative heat release rate and mean gas temperature has same trend of biodiesel and diesel.

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