ANALYSIS OF PERFORMANCE AND COMBUSTION CHARACTERISTICS OF DIESEL ENGINE OPERATING ON MULTI-BLEND BIODIESEL

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Abstract

As the fossil fuels are depleting at a very faster rate, there is a need to find out an alternative fuel to fulfil the energy demand of the world. Biodiesel is one of the best available sources to fulfil the energy demand of the world. The petroleum fuels play a very significant role in the development of industrial growth, transportation, agricultural sector and to meet many other basic human requirements. However, these fuels are limited and depleting day by day as the consumption is increasing very rapidly. Moreover, their use is alarming the environmental problems to society. Hence, there is a need of research for alternative fuels. There is a long list of trees, shrubs, and herbs available abundantly in India, which can be exploited for the production of biodiesel.In this present work combinations of jatropha biodiesel, Pongamia biodiesel, along with diesel (JPD) are taken for the experimental analysis. There was no evidence of any practical multi-blend biodiesel source engine. Experiments are conducted using a single cylinder direct-injection diesel engine with different loads at rated 1500 rpm. The brake thermal efficiency of JPD-2 has maximum 28.5% compares to pure diesel 27.5% at 4 kW brake power. Maximum specific fuel consumption is obtained in JPD-5 (0.77) compare to pure diesel at 1 kW brake power. The results which obtained are significantly comparable to pure diesel. The multi-blend biodiesels are suitable alternative fuel for diesel in stationary/agricultural diesel engines.

Keywords: Alternate fuel; diesel engine; performance; jatropha and Pongamia multi-blend biodiesel.

I. INTRODUCTION

The continuous rise in global prices of crude oil, increasing threat to environment due to exhaust emissions, the problem of global warming and the threat of supply fuel oil instabilities have adversely impacted the developing countries, more so to the petroleum importing countries like India. Major portion of today's energy demand in India is being met with fossil fuels. Hence it is high time that alternate fuels for engines should be derived from indigenous sources. As

India is an agricultural country, there is a wide scope for the production of vegetable oils from different oil seeds. The present work focused only on non-edible oils as fuel for engines, as the edible oils are in great demand and far too expensive. Vegetable oils are one such alternative source. Diesel engines have the advantages of better fuel economy, lower emissions of HC and CO. However, diesel engines suffered from high emissions of PM/smoke density and NOx, and there is inherent tradeoff between them from the point of view of long term energy security, it is necessary to develop alternative fuels with properties comparable to petroleum based fuels. The main commodity source for Bio-diesel in India can be non-edible oils obtained from plant species such as Jatrophacurcus (Ratanjyot), Pongamiapinnata (Karanja), Calophylluminophyllum (Nagchampa), Hevccabrasiliensis (Rubber), etc. The use of biodiesel in conventional diesel engines results in substantial reduction of un-burnt hydrocarbons, carbon monoxide and particular matters. India is one of the fastest developing countries with a stable economic growth, which multiplies the demand for transportation in many folds. Fuel consumption is directly proportionate to this demand. India depends mainly on imported fuels due to lack of fossil fuel reserves and it has a great impact on economy.

India has to look for an alternative to sustain the growth rate.. Recent studies and research have made it possible to extract bio-diesel at economical costs and quantities. The blend of Bio-diesel with fossil diesel has many benefits like reduction in emissions, increase in efficiency of engine, higher Cetane rating, lower engine wear, low fuel consumption, reduction in oil consumption etc. Biodiesel is defined as mono-alkyl esters of long chain fatty acids derived from vegetable oils or normal fats. The process of converting vegetable oils into Biodiesel is called Transesterification. Biodiesel can be made from a wide range of easily renewable plant oil sources and animal fats even waste oils thrown away by most restaurants. Combustion of vegetable oil produces negligible sulphurdioxide emissions and much less toxic emissions. Vegetable oil is biodegradeadable, safe to store and transport does not cause environmental or health problems [1].

II. MATERIALS AND METHOD

Based on the availability of biodiesel, the properties like calorific value, kinematic viscosity, flash point and fire point, Jatropha biodiesel and pongamia biodiesel is estimated in the table-2 selected for bio-fuel preparation and experimental analysis. Various blending combinations of multi-blend biodiesel i.e. JPD-1(Jatropha biodiesel 5% and Pongamia biodiesel5%, Diesel 90% by volume), JPD-2 (Jatropha biodiesel 10% and Pongamia biodiesel 10%, Diesel 80% by volume), JPD-3 (Jatropha biodiesel 20% and Pongamia biodiesel 20%, Diesel 60% by volume), JPD-4 (Jatropha biodiesel 30% and Pongamia biodiesel 30%, Diesel 40% by volume) , JPD-5 (Jatropha biodiesel 50% and Pongamia biodiesel 50%, Diesel 0% by volume), are prepared.

Table-1 Preparations of flue samples of multi-blend biodiesel along with diesel

Fuel samples	Jatropha Biodiesel (ml)	Pongamia Biodiesel (ml)	Pure Diesel (ml)	Quantity Obtained (liter)
JPD-1	50	50	900	01
JPD-2	100	100	800	01
JPD-3	200	200	600	01
JPD-4	300	300	400	01
JPD-5	500	500	NIL	01

Table-2 Estimated properties of multi-blends

Properties / Fuel samples	Fuel density Kg/m^3	Kinematic viscosity @ 40^0C in cSt	Flash point ^0C	Fire point ^0C	Calorific value kj/kg
Diesel	830	3.0	50	57	42680
JPD-1	835	3.3	54	64	42461
JPD-2	840	3.5	58	68	42243
JPD-3	850	3.8	64	74	41807
JPD-4	870	5.0	85	94	41370
JPD-5	880	6.5	153	163	40498
Apparatus used	Hydrometer	Water bath viscometer	Pensky-marten's	Pensky-marten's	Bomb calorimeter

III. EXPERIMENTATION

A. ENGINE COMPONENTS:

The various components of experimental set up are described below. Fig.1 shows line diagram of the experimental set up. The important components of the system are

(i) The engine

(ii) Dynamometer

Fig-1 Experimental set up

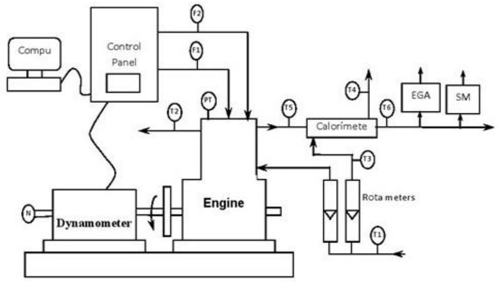

Table-3: Notations

PT	Pressure transducer
N	Rotary encoder
Wt	Weight
F1	Fuel flow
F2	Air flow
F3	Jacket water flow
F4	Calorimeter water flow
T1	Jacket water inlet temperature
T2	Jacket water outlet temperature
T3	Calorimeter water inlet temperature = T1
T4	Calorimeter water outlet temperature
T5	Exhaust gas to calorimeter temperature
T6	Exhaust gas from calorimeter temperature

Table-4 Engine Specifications

Manufacturer	Kirloskar oil engines Ltd, India
Model	TV-SR, naturally aspirated
Engine	Single cylinder, DI
Bore/stroke	87.5mm/110mm
C.R.	16.5:1
speed	1500r/min, constant
Rated power	5.2kw
Working cycle	four stroke
Injection pressure	200bar/23 def TDC
Type of sensor	Piezo electric
Response time	4 micro seconds
Crank angle sensor	1-degree crank angle
Resolution of 1 deg	360 deg with a resolution of 1deg

IV. RESULTS AND DISCUSSIONS

The experimental results obtained from the tests carried out on engine performance and combustion characteristics are presented in this section. The results which obtained are significantly comparable to pure diesel.

4.1 Variation of brake thermal efficiency with respect to brake power

Figure 4.1 shows the variation of brake thermal efficiency with brake power for various multi-blends of biodiesel are JPD-1,2,3,4,5 along with pure diesel respectively. Brake thermal efficiency is increasing with increasing brake power for all multi-blends of biodiesel and diesel. It may be due to reduction in heat loss and increase in power with increase in load.

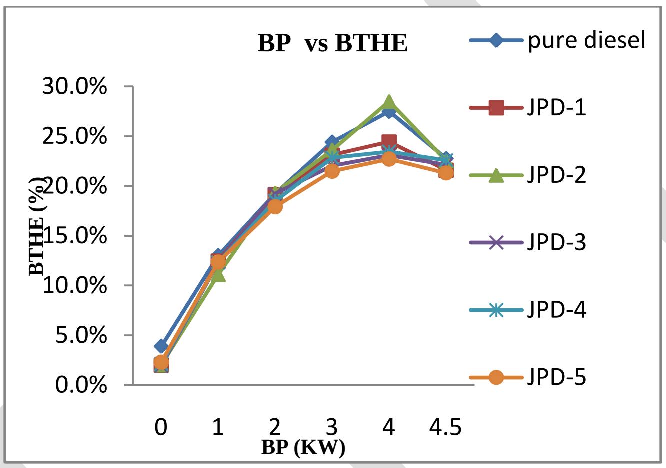

Figure 4.1 Variation of brake thermal efficiency with respect to brake power.

At rated power of 4kW almost all the multi-blends have higher efficiency than diesel in which JPD-2 have maximum thermal efficiency (28.5%) as compared to diesel (27.5%). It may be because of the presence of oxygen in biodiesel which enhance the combustion as compared to diesel and biodiesel is more lubricant than diesel that provides additional lubrication. Multi-blends of biodiesel have higher viscosity, density and lower calorific value than diesel. Higher viscosity leads to decreased atomization, fuel vaporization and combustion.

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4.2 Variation of specific fuel consumption with respect to brake power

The variation in SFC (specific fuel consumption) with brake power for different fuel samples of JPD-1,2,3,4,5 and pure diesel as shown in figure 4.2 The specific fuel consumption when using multi-blend biodiesel fuel is expected to increase as compared to the consumption of diesel fuel. SFC decreased sharply with increase in load for all fuel samples.

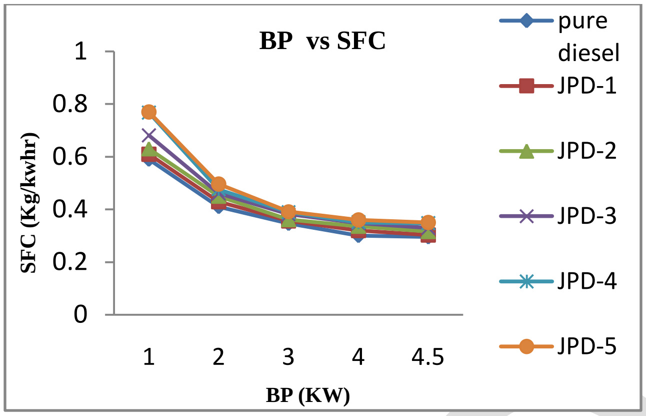


Figure 4.2 Variation of specific fuel consumption with respect to brake power

The main reason for this may be that the percent increase in fuel required to operate the engine is less than the percent increase in brake power due to relatively less portion of the heat losses at higher loads. As the SFC is calculated on weight basis, so higher densities resulted in higher values of SFC. Maximum SFC is obtained in JPD-5 (0.77) at 1 kW.

4.3 Variation of exhaust gas temperature with respect to brake power

The variation of exhaust gas temperature with brake power for different multi-blend biodiesels are shown figure 4.3. This graph shows that exhaust gas temperature of the fuel blends are higher than the diesel fuel and there is not much variation among multi-blends at all load conditions. In this case JPD-5 at 4.5 kW blends has the high exhaust gas temperature than other fuels. The exhaust gas temperature variation depends upon the flash point temperature and the viscosity of the fuel. The multi-blends biodiesel have higher flash point and viscosity than the diesel fuel and also lower volatility. So the multi-blends have higher exhaust gas temperature.

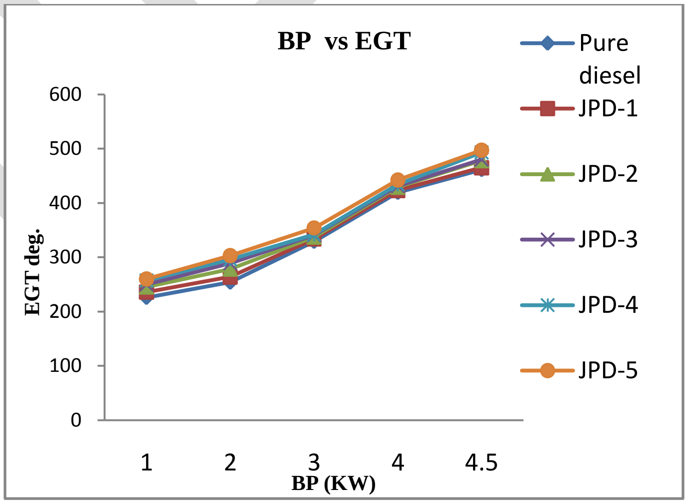


Figure 4.3 Variation of exhaust gas temperature with respect to brake power.

4.4 Variation of mechanical efficiency with respect to brake power

The variation of mechanical efficiency with brake power for pure diesel and multi-blend biodiesel are shown in figure 4.4 the mechanical efficiency of pure diesel is slightly higher than the multi-blend biodiesels. In this case the pure diesel and JPD-1 are almost nearer to each other. From the graph it is evident that as the percentage of multi-blend biodiesel increases in diesel the mechanical efficiency goes on decreasing. The mechanical efficiency of the engine is maximum at 4.5 kW pure diesel compare to other multi-blend biodiesel. This happens due to lower calorific value and higher viscosity of multi-blend biodiesel compared to pure diesel.

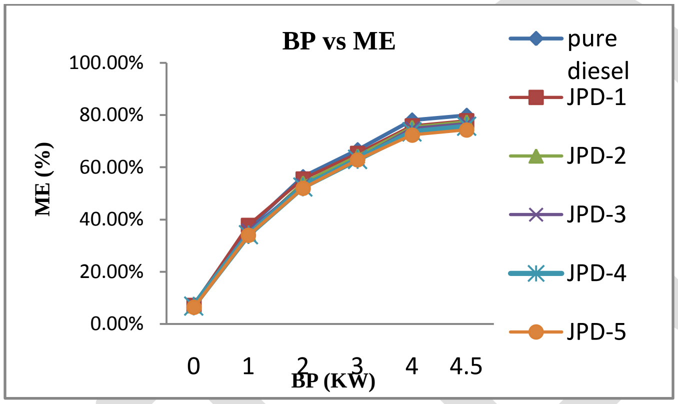


Figure 4.4 Variation of mechanical efficiency with respect to brake power

4.5 Variation of A/F ratio with respect to brake power

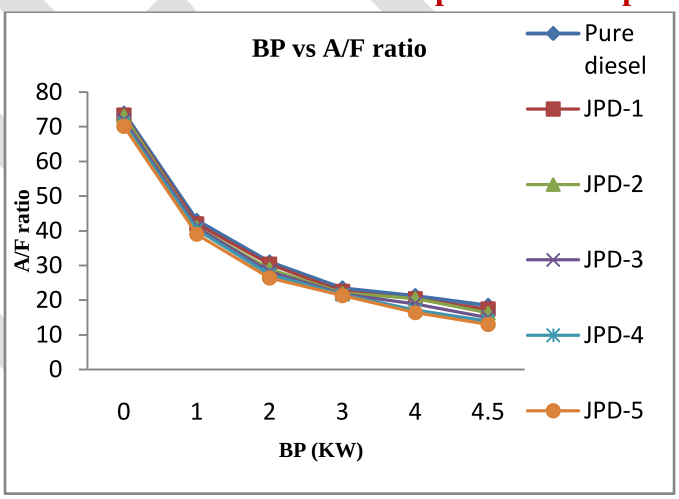


Figure 4.5 Variation of A/F ratio with respect to brake power

Figure 4.5 show the comparison of A/F ratio with respect to brake power for pure diesel and multi-blend biodiesel. From the graph it is observed that A/F ratio decrease with increase in brake power there is no change in initial brake power. Finally there is slightly variation in the range of 4 to 4.5 kW JPD-5 multi-blend biodiesel has lower A/F ratio compared to pure diesel it observed that 13. This happens air fuel mixing process is affected by the difficulty in atomization of multi-blend biodiesel due to its higher viscosity.

4.6 Variation of indicated thermal efficiency with respect to brake power

Figure 4.6 shows variation of indicated thermal efficiency with respect to brake power. From the graph it observed that the indicated thermal efficiency is maximum at average brake power in the range of 2-4 kW brake power. Pure diesel has higher indicated thermal efficiency compared with all multi-blend biodiesel. This is due to higher calorific value of diesel with lower viscosity. Maximum indicated thermal efficiency is obtained that 37.8% at 3kW.

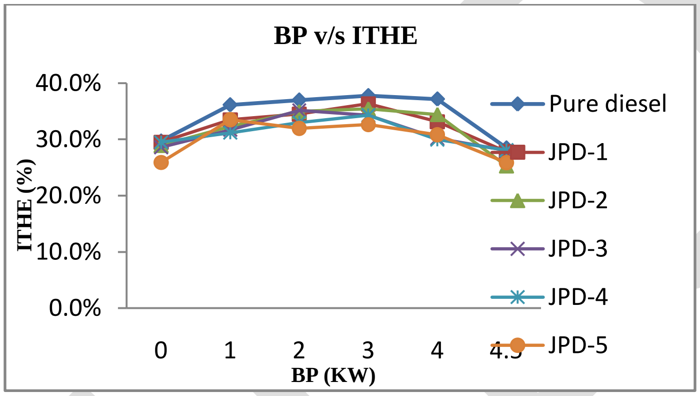


Figure 4.6 Variation of indicated thermal efficiency with respect to brake power

4.7 Variation of volumetric efficiency with respect to brake power

Figure 4.7 shows variation of volumetric efficiency with respect to brake power. From the graph it observed that the volumetric efficiency is slightly variation in the average brake power and almost constant. There is no much variation in the pure diesel compared to multi-blend biodiesel. From the graph pure diesel having least it observed that 83.5% at 4.5 kW. This is due to presence of oxygen during the combustion.

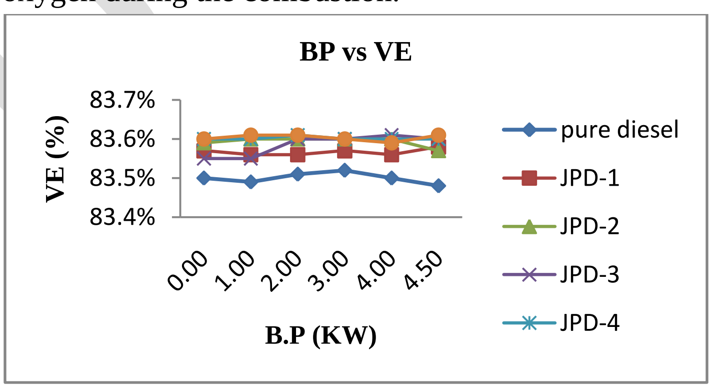


Figure 4.7 Variation of volumetric efficiency with respect to brake power

4.8 Variation of crank angle versus cylinder pressure

Figure 4.8 show the variation of crank angle versus cylinder pressure. In a CI engine, cylinder pressure depends on the fraction of fuel burned during the premixed burning phase. Cylinder pressure crank angle variation at maximum load with pure diesel and JPD-5 multi-blend biodiesel is given. Multi-blend biodiesel follows the trend, similar to pure diesel pressure diagram. Same trend is followed for other loads. The cylinder peak pressure is highest with JPD-5 followed by pure diesel. It is observed that the occurrence of peak pressure moves away with JPD-5 compared to pure diesel at crank angle 369^0C with cylinder pressure 46.22bar. This indicates that the ignition delay is longer with JPD-5 compared to pure diesel.

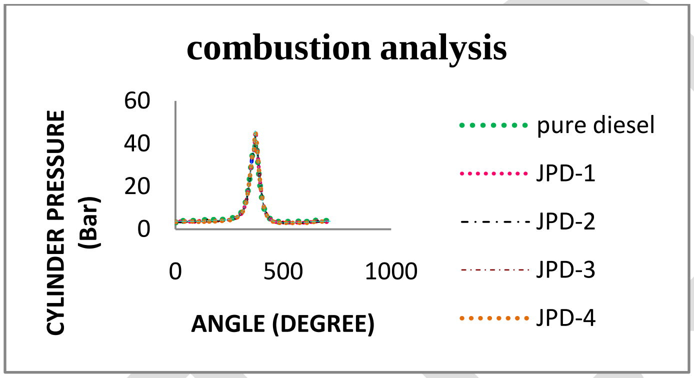
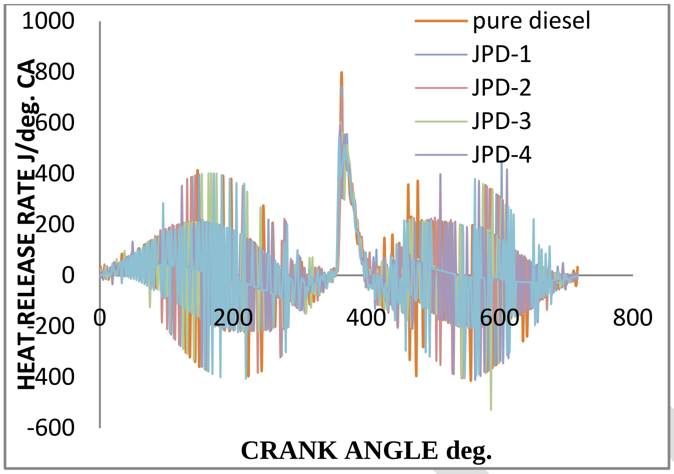


Figure 4.8 Variation of crank angle versus cylinder pressure

Longer ignition delay means more fuel is injected. Due to high viscosity, poor volatility, poor spray characteristics and lower heating value of JPD-5 leads to less fuel being prepared for rapid combustion result in lower peak pressure compared to pure diesel.

4.9 Variation of crank angle versus heat release rate

The combustion process in diesel engines is mainly divided into three phases. The first phase of combustion is called as ignition delay (ID), in which the tiny fuel droplets evaporates and mixes with high temperature (or high pressure) air. ID effects on rate of combustion. The delay period depends mainly on fuel Cetane number (CN), and temperature of the air. The ID is also influenced by the fuel temperature. The second phase of combustion is called as period of rapid combustion or premixed combustion. In this phase the air-fuel mixture undergoes rapid combustion, therefore the pressure rise is rapid and releases maximum heat flux. The third phase of combustion is called as period of controlled combustion. In this period, the fuel droplets injected during the second stage burns faster with reduced ID due to high temperature and pressure. In this third phase the pressure rise is controlled by the injection rate and the combustion is diffusive mode as shown in figure 4.9.



4.9 Variation of crank angle versus heat release rate

The estimated heat release rate with crank angle is represented in all the multi-blend the short premixed heat release period is noticed at the maximum rate of 4.5 kW. The heat release rate for all the tested fuel was less than that of diesel this may be attributed to low vaporization, high viscosity and low peak pressure of blends as compared to that of diesel. . It is computed based on static start of injection (23° bTDC) and start of combustion. Start of combustion is the point where change of slope in heat release rate is noticed. The ignition delay period was reduced with increase in load for all multi-blend biodiesel compared pure diesel. The maximum heat release rate of multi-blend biodiesel and their blends is lower than that of pure diesel. The maximum heat release of engine with pure diesel is higher about 5.87% than engine fueled with JPD-1 (multi-blend biodiesel) specifically at crank angle 363^0C with heat rate 793 J/degree CA for pure diesel. It was found that, premixed combustion in the case of multi-blends biodiesel fuel starts earlier than the diesel fuel and it may be due to excess oxygen available along with higher operating temperature in the fuel and the consequent reduction in delay period than that of pure diesel fuel. It may be expected that high surrounding temperature and oxygen availability of fuel itself (multi-blend biodiesel) reduce the delay period.

V.CONCLUSION

Based on the experimental work with multi-blend biodiesel, at maximum load, the following conclusions are drawn.

- The brake thermal efficiency of JPD-2 has maximum 28.5% compare to pure diesel 27.5% at 4 kW brake power due to the presence of oxygen in the molecular structure of multi-blend biodiesel intensifies the complete combustion phenomenon.
- The mechanical efficiency of pure diesel is slightly higher than the multi-blend biodiesels at 4.5 kW brake power due to lower calorific value of multi-blend biodiesel.

- The indicated thermal efficiency have maximum at average brake power in the range of 2-4 kW. Pure diesel has higher indicated thermal efficiency compared with other multi-blend biodiesel.
- The volumetric efficiency is slightly decreases in the average brake power and almost constant. There is no much variation in the pure diesel compared to multi-blend biodiesel.
- Maximum specific fuel consumption is obtained in JPD-5 (0.77) compare to pure diesel at 1 kW brake power.
- All multi-blends biodiesel have high exhaust gas temperature compare to pure diesel.
- There is slightly variation in the range of 4 to 4.5 kW brake power of JPD-5 has lower A/F ratio it observed that 13.
- Maximum cylinder peak pressure of JPD-5 is obtained 46.22 bar at 3690C CA (crank angle) compare to pure diesel.
- The maximum heat release of engine with pure diesel is higher about 5.87% than engine fueled with JPD-1 (multi-blend biodiesel).

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