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Effect of Injection Pressure on Ignition Delay and Combustion Duration of Diesel Engine with Biodiesel (Jatropha Oil) and Its Blends

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ABSTRACT : *This paper discusses the combustion characteristics of jatropha methyl ester (further biodiesel) in direct injection diesel engine with injection pressure range from 100 bar to 300 bar and variation of ambient air pressure from 5 bar to 25 bar. The experiments were carried out in a constant volume combustion chamber under conditions similar to the real engine condition using a single holepintle nozzle for the various blends i.e., B20 and B40 and the results were compared with the neat diesel. The combustion characteristics such as ignition delay and combustion duration were computed. The results showed that for all test fuels the reduction in ignition delay increases with the increase in injection pressure during all ambient air pressure. Analysis of combustion characteristics also shows that the combustion durations of JME were more than diesel fuel but with the increase in injection pressure from 100 to 300 bar leads to reduction in combustion duration.*

Keywords: *Jatropha, Biodiesel, Ignition Delay, Combustion Duration*

I. Introduction

Diesel engine has gained the name and fame in serving the society in many ways. Its main attractions are ruggedness in construction, simplicity in operation and ease of maintenance. The performance and emission characteristics of diesel engines depends on various factors like fuel quantity injected, fuel injection timing, fuel injection pressure, shape of combustion chamber, position and size of injection nozzle hole, fuel spray pattern, air swirl etc. The fuel injection system in a direct injection diesel engine is to achieve a high degree of atomization for better penetration of fuel in order to utilize the full air charge and to promote the evaporation in a very short time and to achieve higher combustion efficiency. The fuel injection pressure in a standard diesel engine is in the range of 200 to 1700 atm depending on the engine size and type of combustion system employed [1]. Due to the better fuel economy diesel engines have been widely used in automotive area. However, the limited reserve of fossil fuel and deteriorating environment have made scientists seek to alternative fuels for diesel while keeping the high efficiency of diesel engine. Since last decades researchers around the world have been trying to find new alternative fuels that are available, technically feasible, economically viable and environmentally acceptable [2]. One of the promising alternative fuel considered for diesel engine is “biodiesel”. With recent increases in petroleum prices and uncertainties concerning petroleum availability, there is renewed interest in vegetable oil fuels for Diesel engines. Biodiesel is non-explosive, biodegradable, non-flammable, renewable, non-toxic as well as environment friendly. It has similar properties with diesel fuel. Biodiesel is alky esters of fatty acids and can be obtained by employing the transesterification treatment of vegetable oils, animal fats, waste cooking oils. Vegetable oil can be obtained from both edible (palm oil, rapseed oil, coconut oil etc) and non-edible (jatropha, neem,jojobaetc) oil sources [3].

II. Literature Survey

Till today several biodiesel fuels for CI engines have been investigated. Most investigations show that the use of biodiesel results in lower emissions (except NO_x) and better combustion [4]. Pramanik (2003)has investigated the use of Jatropha oil blends with diesel fuel in direct injection diesel engine. It has been reported that 50 % of Jatropha oil blends can be substituted for diesel fuel in CI engine. It has been reported that the Jatropha oil exhibited higher specific fuel consumption and lower exhaust gas temperatures compared to diesel fuel.Szybist et al., (2007) have reported that the injection and ignition process can be altered significantly by biodiesels and their blends. An increase in the ignition delay period and combustion duration with both jatropha oil and its esters with lower heat release rates were noticed compared to diesel fuel. Tapan K. Gogoi ,ShovanaTalukdar, Debendra C. Baruah have analyzed the performance and combustion characteristics of 10%, 20%, 30% and 40% blending of Koroch Seed Oil Methyl Ester (KSOME) and Jatropha Methyl Ester (JME) with diesel as fuels in a diesel engine. They reported that the ignition delay was less and the combustion duration was more for the JME blends as compared to the KSOME blends. They have found that the ignition delay period for the KSOME and JME blends was less as compared to the diesel fuel. M.Senthil Kumar, A.Kerihuel,J.Bellettre and M.tazerouthave used preheated animal fat as fuel in single cylinder direct injection diesel engine developing a power output of 2.8 kW at 1500 rev/min. Experiments are conducted at the fuel inlet temperatures of 30, 40, 50, 60 and 70°C. They reported that animal fat at low temperature results in higher ignition delay and combustion duration than diesel. Preheated animal fat shows reduced ignition delay and combustion duration.

III. Biodiesel Production Processes for Combustion Study

3.1 Process flow chart

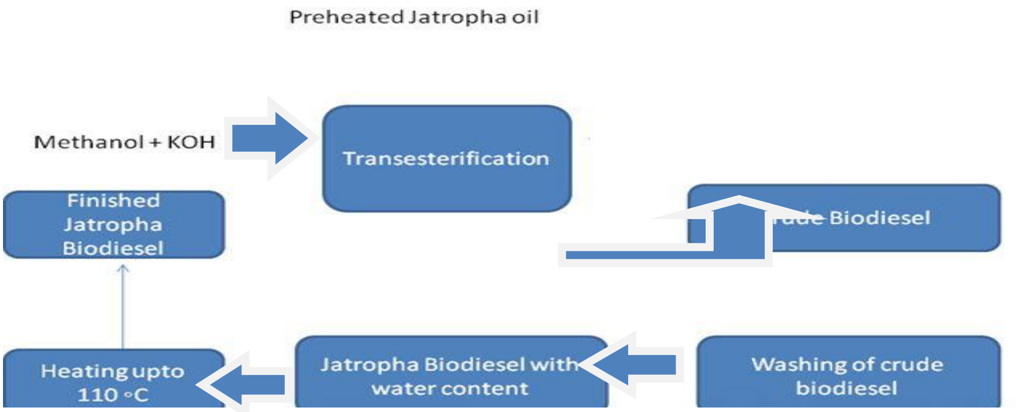


Figure1: Diagram of Jatropha Biodiesel Production (FFA less than 2.5%)

This experiment has been performed to evaluate performance of mechanical stirring method of biodiesel production in terms of yield (%) and time.

Experiment has been performed with the following steps:

1. Jatropha oil (4 Kg) is taken in a beaker and filtered it to remove impurities. The raw oil is heated up to 110 °C in order to remove water content of oil to avoid soap formation. This oil is allowed to cool up to 55 °C temperatures for the reaction to take place.
2. Now methanol (CH_3OH) is taken with a molar ratio of (1:6) and catalyst (KOH) is taken as (1%) by wt of oil. The mixture of methanol & KOH stirred until KOH dissolved into methanol.
3. Then Jatropha oil mixed in to the mixture of methanol & KOH.
4. Whole mixture stirred for 1 hr with the help of magnetic stirrer.
5. For better reaction, temperature of mixture kept into the range of 50 °C to 60 °C because methanol boiling point is 65 °C.
6. When reaction is completed the beaker is kept for the separation. Glycerol has higher sp- weight therefore it settles down at bottom. It will take 2 to 3 hrs.
7. After separation methyl ester (biodiesel) contains only catalyst KOH in form of impurity.
8. KOH harmful for diesel engine therefore it must be separate out into the biodiesel. Water washing process use for removing KOH in biodiesel. In the process water (at 55 °C) mixed in to separate methyl ester and left for settling down. KOH dissolved in to water and separated to biodiesel.
9. Excess water removed by heating the biodiesel up to 120 °C.

3.2 Description of Test Fuels:

The fuels used in this study include conventional diesel and blends of jatropha biodiesel. The blended fuels contain 20% and 40% by volume of jatropha biodiesel which are identified as B20 and B40 fuels. The biodiesel used in our experiments was produced from Jatropha oil. The major properties of the fuels are measured in petrochemical lab of the college. These properties are listed in the TABLE below. The properties with * are adopted from Sunil Kumar et.al [5].

Table I: Properties of Tested Fuels

Fuel	Viscosity, C.stokes at 40 ^{o}C	Lower heating value (MJ/kg) *	Flash Point (ºC) FP	Density (kg/l)ρ	Cetane Number *
Diesel	4.2	42	155	0.83	49
Jatropha biodiesel	5.2	34.2	185	0.88	51

IV. Experimental Apparatus and Procedure

The investigations on the combustion characteristics were conducted on a Direct Injection Constant Volume Combustion Chamber (DI-CVCC). Combustion Chamber in present study is stainless steel cylindrical tank having a 54.2 mm length, 95 mm diameter and 7.5 mm thickness. A pintle type nozzle is fitted on the head of the combustion chamber (right hand side). The combustion chamber used in present study is a closed type chamber so that the pressure developed inside the combustion chamber is very high as required in present study. The photo sensor is attached to the combustion chamber to detect the event of start of combustion, on the storage oscilloscope. The rise time of photo sensor for present study is 5µ sec. For detecting the event of combustion, the borosil glass window which the photo sensor is installed in front of it is attached on left hand side of combustion chamber. When fuel is injected into the combustion chamber with the help of fuel injection system, there is a pressure change takes place inside the fuel line. This pressure change is sensed by the piezo-electric crystal and display this signal on the screen of oscilloscope.Heating elements or coils act as a heater. One of them is fitted inside the combustion chamber so that hot surface combustion of fuel and air mixture takes place inside the chamber and other is fitted around the combustion chamber for increasing the surface temperature. Maximum temperature of heating coils for present study is 1400ºC. The oscilloscope used in present experimental setup is a digital storage two channel oscilloscope (RIGOL DS 1102, 100 MHz, 1GSa/s). On one channel it shows the fuel injection process and on the other channel it shows the combustion process. The ignition delay can easily be measured on the screen of oscilloscope by noting the difference between start of injection and start of combustion on adjusting the timescale and further it can be investigate to analyse the combustion duration.

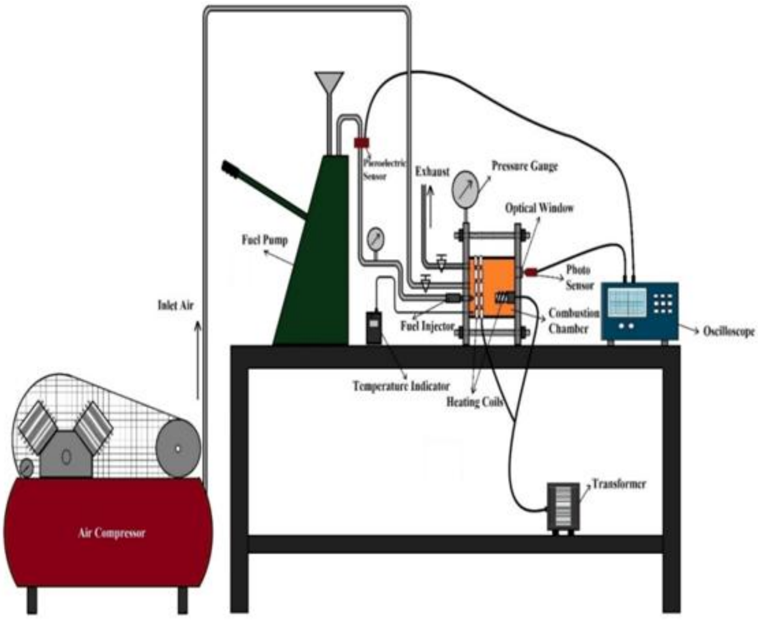
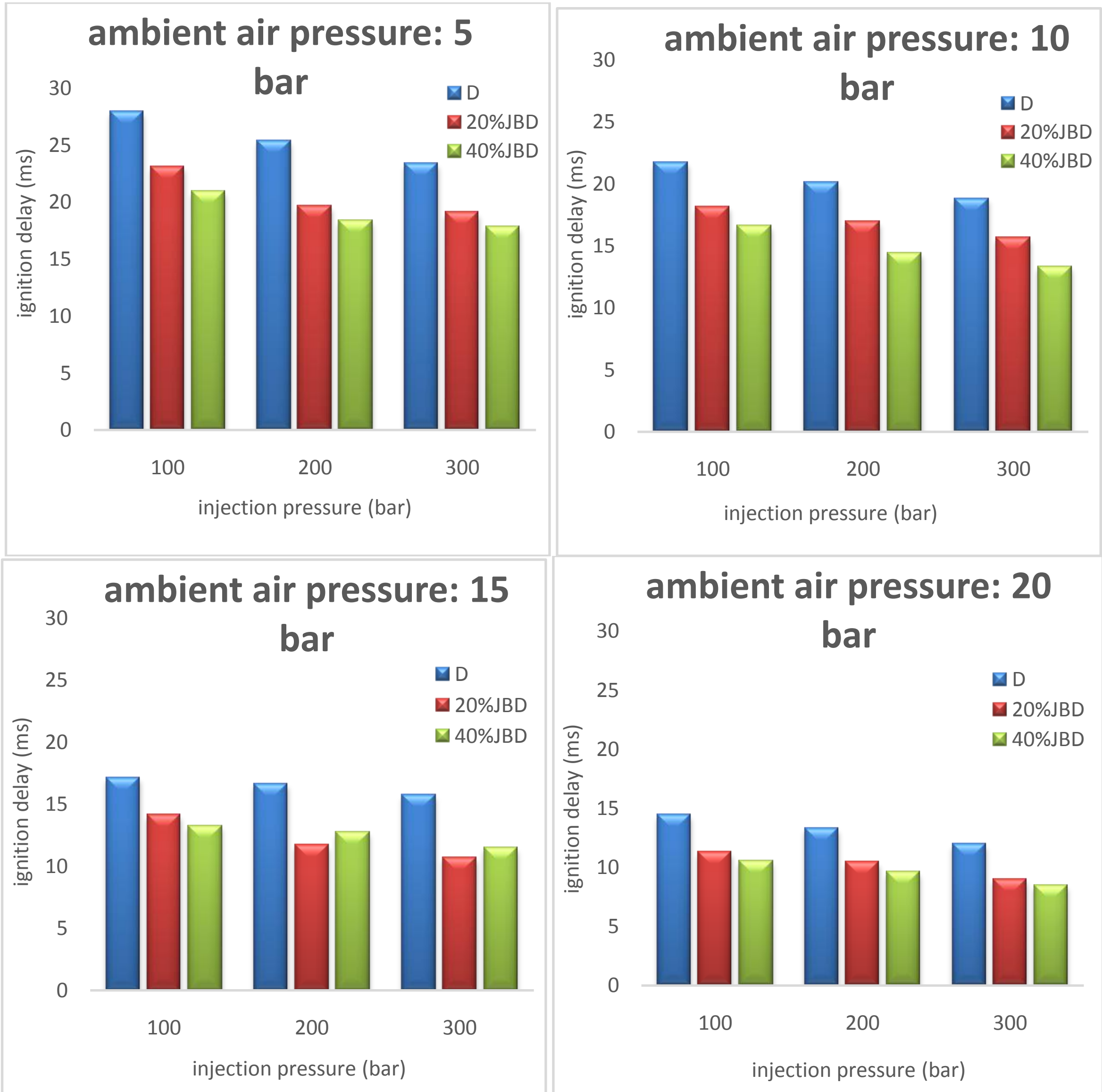


Figure2: Block Diagram of the Experimental Setup

V. Results and Discussion

5.1 Effect of Injection Pressure on Ignition Delay of Jatropha Biodiesel Blended Diesel in Different Ambient Air Pressure:

The variation of ignition delay period with different injection pressures for different cylinder pressures is plotted inFig.3. Ignition delay is the period between the start of fuel injection into the combustion chamber and the start of combustion. The effect of injection pressure ranging from 100 to 300MPa on the ignition characteristics of biodiesel fuel spray using direct injection system was investigated. Observations demonstrate that high-pressure injection affects engine ignition and combustion. An increase in injection pressure leads to reduced ignition delay time.When fuel injection pressure is low, fuel particle diameters will enlarge and ignition delay period during the combustion will increase. This situation leads to inefficient combustion in the engine. When the injection pressure is increased fuel particle diameters will become small. The mixing of fuel and air becomes better during ignition delay period. The ignition delay period of the tested fuels decreases with increasing cylinder pressure and fuel injection pressure. Among all the tested injection pressures, minimum ignition delay period of 6.32 ms is observed at 300 bar jatropha biodiesel operation and 27.92 ms is observed at 100 bar diesel operation. The reduction in ignition delay period of jatropha biodiesel is mainly due to higher cetanenumber . From Fig.3, it is observed that the increase in injection pressure from 100 to 300 bar leads to better atomization and proper mixing of fuel with air, there by reduction in ignition delay is achieved at all cylinder pressure . It can be observed from figure that the effect of cylinder pressure on ignition delay is more dominant than injection pressure. . If the injection pressure is too high ignition delay become shorter. So, possibilities of homogeneous mixing decrease and combustion efficiency falls down. Therefore, smoke is formed at exhaust of engine [6].



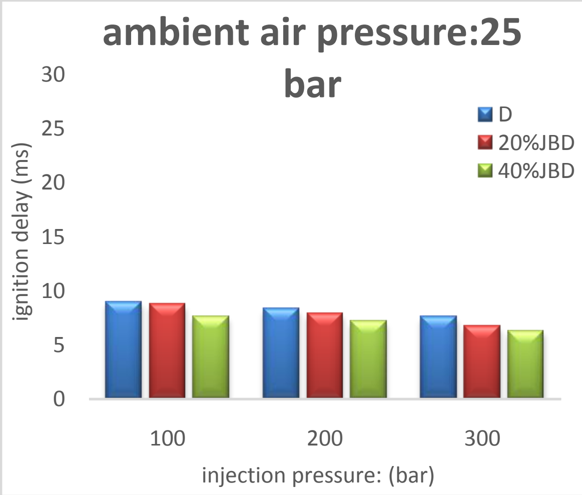
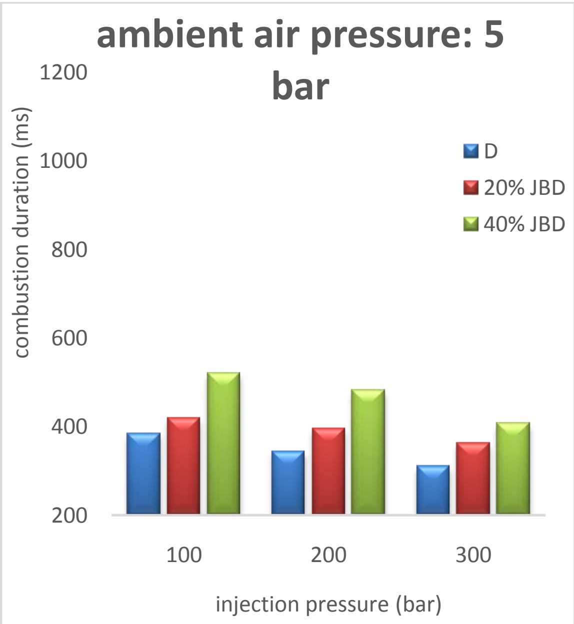
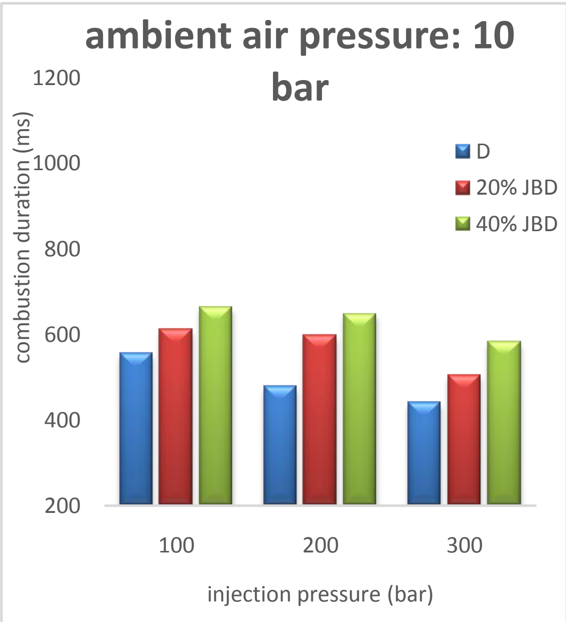


Figure 3:Variation of Ignition Delay of JBD Blends Diesel with Different Injection Pressure

5.2 Effect of Injection Pressure on Combustion Duration of Jatropha Biodiesel Blended Diesel in Different Ambient Air Pressure:

Observations demonstrate that injection pressure affects engine ignition and combustion. Combustion duration of a diesel engine can be defined as the time interval from the start of heat release to the end of heat release [7]. The fuel penetration distance become longer and the mixture formation of the fuel and air was improved when the combustion duration became shorter as the injection pressure became higher [8].Fig.4 shows the combustion duration for diesel and the various jatropha biodiesel blends(20% and 40%) with different cylinder pressure (5, 10, 15, 20 and 25 bar) and 100, 200 and 300 bar injection pressure respectively. It was seen that, the combustion durations of JBD were more than diesel fuel but with the increase in injection pressure from 100 to 300 bar leads to reduction in combustion duration. Higher combustion duration was obtained with JBD40at 100 bar injection pressure (1037 ms) compared to neat diesel fuel (310 ms at 300 bar injection pressure). This is may be due to the injection of more amount of JBD40 than diesel fuel. Higher duration of combustion with respect to JBD20 and JBD40 could be due to earlier start of combustion and relatively longer diffusion combustion for these blends.





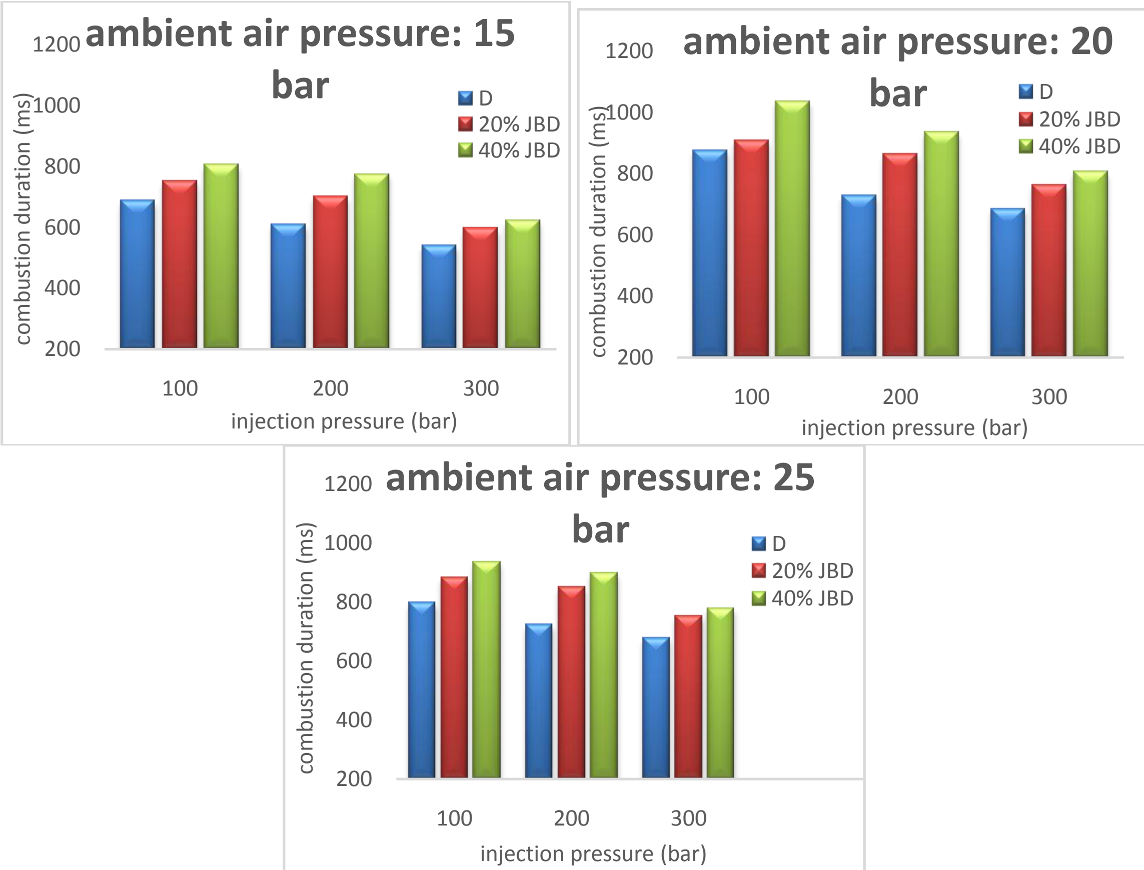


Figure 4:Variation of Combustion Duration of JBD Blends Diesel with Different Injection Pressure

VI. Conclusion

The purpose of the present work was to study experimentally the effect of injection pressure (100 to 300 bar) on combustion characteristics of jatropha biodiesel blended with diesel fuel (20% and 40%) in direct injection constant volume combustion chamber.

The conclusions drawn from the present study are the following points:

- Ignition delay decreases with the increase in injection pressure and ambient air pressure for all tested fuel.
- JBD has the shorter ignition delay which is prolonged with increasing biodiesel content in the blends.
- The combustion durations of JBD were more than diesel fuel but with the increase in injection pressure from 100 to 300 bar leads to reduction in combustion duration.

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