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An Experimental Measurement of Ignition Delay for Diesel Fuel Blends at Different Cylinder Pressures

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Abstract: **The key to efficient operation of a diesel engine is in the controlled ignition and combustion of the fuel. The ignition delay, can impact on power output, combustion efficiency, and engine maintenance. Measurement of ignition delay is an important aspect for the design of engines. An experimental study was done for the measurement of ignition delay characteristics for pure diesel oil and coconut oil-diesel fuel blends (50%:50%) at various ambient pressures (cylinder pressures) at a given hot surface temperature and injection pressure. An experimental set up fabricated for this purpose based on optical method for measurement of ignition delay. The ignition delay of fuel spray was measured by recording the time delay between the event of injection and the event of appearance of flame inside the combustion chamber by using digital storage Scope-Meter.**

Keywords: **Digital Storage Scope-Meter, Fuel Blends, Hot Surface Temperature, Ignition Delay,**

1. INTRODUCTION

The study of possible alternative liquid fuels derived from biomass is not a new topic. Although, during the last decade ethanol and biodiesel became the best-known liquid bio fuels, numerous studies examine different chemical structures as possible bio fuels and record their pros and cons. [1]

The ignition delay time can be defined as the period between the creation of a combustible mixture, as by injection of fuel into an oxidizing environment, and sustain and onset of the rapid reaction phase leading to the rise of temperature and pressure. The ignition delay times can also be indicated by either a fixed temperature increase or an evolution of certain species.

Masjuki et al (2001) performed dynamometer tests to evaluate the performance, emission and ignition delay characteristics of an indirect-diesel engine fuelled by blends of coconut oil and diesel fuel. Results showed that 10–30% coconut oil blends produced a slightly higher performance in terms of brake power than that of diesel. All the coconut oil blends produced lower exhaust emissions including polycyclic aromatic HC and particulate matter. [2]

Auto- ignition is the spontaneous combustion of a mixture of fuel and oxidizer in the absence of any ignition source. The ignition occurs after some period of mixing between the fuel and oxidizer occurs. It is the initiation of overall chemical reaction.

Geyeret et al (1984) conducted trials on a certified diesel fuel, cottonseed oil, sunflower seed oil, methyl ester of cotton seed oil, and methyl ester of sunflower seed oil. They compared the engine performance and emission characteristics and reported slight improvements in thermal efficiency and higher exhaust gas temperatures when operating on vegetable oils; equal or higher gas-phase emissions with vegetable oils; and significantly higher aldehyde emissions, including an increased percentage of formaldehyde. [3]

Wang et al (2006) evaluated the performance and gaseous emission characteristics of a diesel engine when fuelled with vegetable oil and its blends of 25%, 50%, and 75% of vegetable oil with ordinary diesel fuel separately. The engine was operated at a fixed speed of 1500 rpm, but at different loads .They reported that the basic engine performance, power output and fuel consumption are comparable to diesel when fuelled with vegetable oil and its blends. The emission of NOx from vegetable oil and its blends were lower than that of pure diesel fuel. [4]

1.1 Necessity to Reduce Ignition Delay:

Too short an ignition delay period does not normally create operational problems, but there is likely to be a loss of fuel efficiency. An extended ignition delay however can lead to poor running of the engine and, in the extreme, to damage of engine components. This is because with long ignition delay a relatively large amount of fuel droplets will have been injected and vaporized in the cylinder by the time ignition occurs. On igniting, this large amount of accumulated vapor will combust almost explosively leading to a sudden and abnormally high rate of pressure rise and a high cylinder pressure, beyond that for which the engine was designed or perhaps can tolerate in the longer term.

Reducing ignition delay is required to enable adequate control over the combustion process such that the combustion stability of the engine can be maintained; when fuel is injected in the combustion chamber it doesn't get ignited but rather requires a small but finite time to form a premixed combustible mixture for initiating the combustion process. Since during the ID fuel is still continue to be injected, therefore longer the ID, more will be the premixed burning and hence higher the peak of ROHR, leads to excessive NO_x formation because of highest possible flame temp. Hence if the emissions of NO_x are to be reduced, the ignition delay also needs to be reduced.

2. EXPERIMENTAL SET-UP AND TEST PROCEDURE

The aim of the present work is to study ignition delay characteristics for pure diesel oil and coconut oil-diesel fuel blends at various ambient pressures (cylinder pressure) at a given hot surface temperature (350^0C) and injection pressure (100 bar). Heating coils are used inside the combustion chamber to igniting the fuel because there is no any piston cylinder arrangement inside the combustion chamber. The fuel used in the present work is Pure Diesel and Vegetable Oil with Diesel.

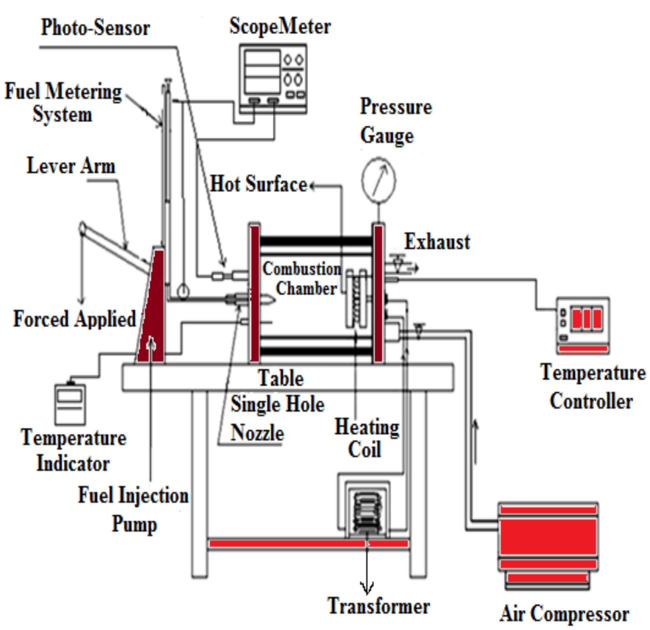

Fig. 1. Block Diagram for the Experimental Setup

TABLE 1: Specification of Combustion Chamber

Dimensions	Length = 14 cm Diameter = 90 mm
Material	Stainless Steel
Nozzle	Single Hole Nozzle
Temperature Controller	Universal Temperature Controller
1) Start of Injection 2) Start of Combustion	Piezo-electric Sensor Photo Sensor
Maximum Temperature	800°C
Maximum Pressure	500 bar

Fig. 2. digital storage Scope Meter (Injection and Combustion Pulses).

The oscilloscope used in present experimental set up is a Scope Meter oscilloscope. 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 Scope Meter by noting the difference between start of injection and start of combustion on adjusting the time scale. Scope Meter oscilloscope is shown in the following Fig. 2

TABLE 2: The parameters values used for measuring the Ignition Delay

Fuel used	Injection Pressure	Air Pressure (Cylinder Pressure)	Hot Surface Temperature
Pure Diesel	100-bar	10-bar, 15-bar, 20-bar, and 25-bar	350ºC
Vegetable oil 50% with Diesel 50%	100-bar	10-bar, 15-bar, 20-bar, and 25-bar	350ºC

The measurement of Ignition Delay is done by the Scope Meter and the values of parameters are fixed by Pressure gauges and Temperature controller. A Reciprocating axial flow Compressor is used for charging the Air in the combustion chamber.

Method of Taking Observations

1. After closing all valves the fuel is injected inside combustion chamber targeting the hot surface thus a flame is formed due to combustion of fuel at high pressure and high temperature. If there is no burning activity inside the combustion chamber, due to too low temperature of the hot surface, there is also no light intensity to sensor so the output of Scope Meter is zero.

2. Fuel injected into the combustion chamber through nozzle. The piezo-electric sensor, fitted in the fuel line, triggers signal in channel (I) of the Scope Meter which indicates the start of injection.

3. After the completion of ignition delay, the fuel ignites and a characteristic yellow flame is formed, which activates the optical sensor. After the completion of ignition delay, when the optical sensor detects the formation of the flame, the Scope Meter shows this corresponding event.

4. Due to the ignition of spray, the light is emitted inside the chamber (hot surface) changes, from which the intensity of the light falling on the photo sensor increases; hence the output of Scope Meter also changes to show starting of ignition. As ignition has been stared thus the refractive index of the medium inside the chamber has been also started to change which can be seen at the output of Scope Meter.

5. Thus we read distinct events on the screen of Scope Meter. Start of injection and start of ignition.

6. The time difference of event of injection and event of start of ignition gives the ignition delay of the fuel.

7. The process repeated for a given temperature (350^0C) and injection pressure (100-bar) for different pressures (10-bar, 15-bar, 20- bar and 25-bar) .

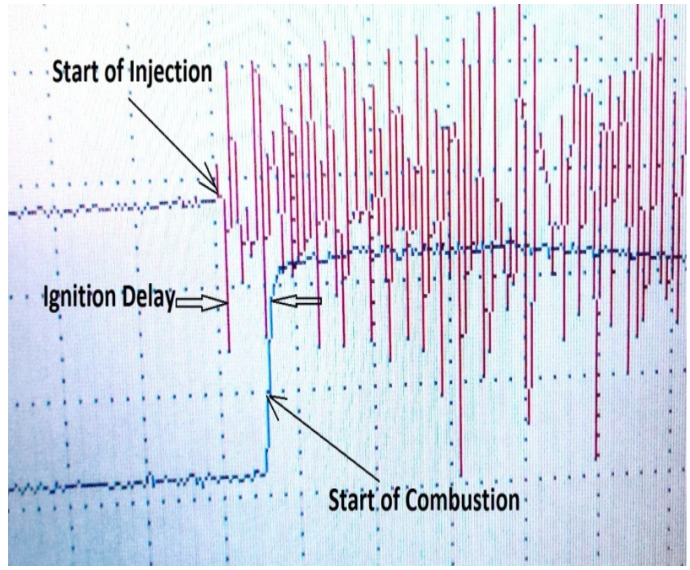

Fig. 3. Different Regions of Combustion

3. RESULTS AND DISCUSSION

For the experimental measurement of ignition delay characteristics, we use single hole nozzle. The fuel used in the study is pure diesel oil and coconut oil-diesel fuel blends (50%:50%) .

All samples were prepared after careful filtration and accurate measurements by using measuring cylinder. Results of Ignition Delay of different types of fuels were obtained. We conducted our study at Air pressures (cylinder pressure) of 10-bar, 15-bar, 20-bar and 25-bar on hot surface temperature (350°C) and injection pressure (100-bar), due to the following reasons:

- At high pressure, ignition delay is short; therefore a detailed feature of process can be only analyzed by using photo sensor methodology which we have adopted here.
- The use of photo-sensor for detecting the start of combustion has also improved accuracy by reducing the installation error of the pressure transducer.
- As operating speed of modern low emission high performance engines is increasing. Therefore the classical concept of ignition delay is required to be seen with a new technique based on optical methods, which was used in our study.

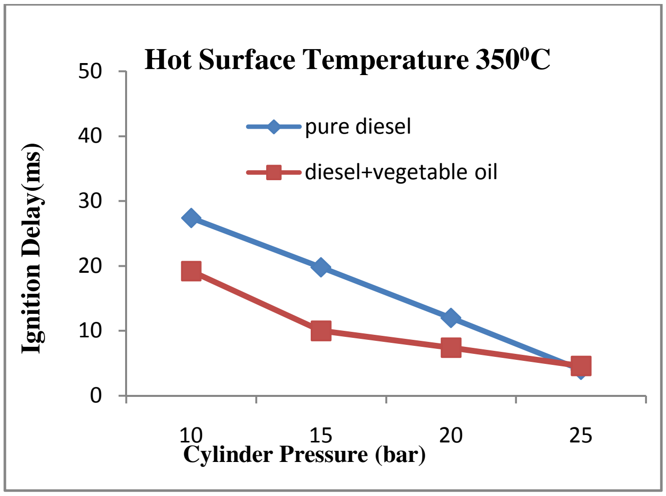

Fig. 4. Comparison of Ignition Delay measured with Pure Diesel and Diesel with Vegetable Oil (50%:50%) at Different Cylinder Pressures and 100 bar Injection Pressure.

Figure 4, shows the comparison of Ignition Delay measured with Pure Diesel and Diesel with Vegetable Oil (50%:50%) for various Cylinder Pressures at 100-bar Injection Pressure.

At 350ºC, the measured Ignition Delay is higher for the Pure Diesel as compared to the Diesel with Vegetable Oil at any Air Pressure (Cylinder Pressures) And as the Air Pressure is increasing, Ignition Delay value is decreasing for both the fuels Pure Diesel and Diesel with Vegetable Oil.

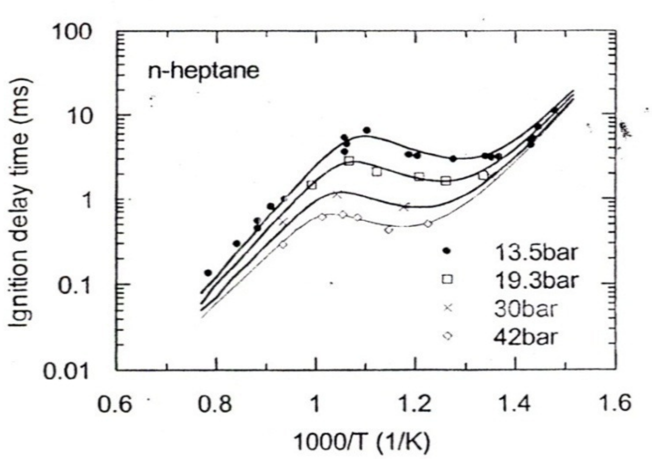

Fig. 5. Effect of Pressure on Ignition Delay. [5]

The ignition delay of n-heptanes under the initial pressure variance is compared with the calculated and measured data as shown in Fig. 5 above. The pressure effect on ignition delay was considered by comparing the ignition delay of n-heptanes for 13.5, 19.3, 30, 42 bar. It was very much clear from the Fig. 5, that with increase in the pressure ignition delay decreases.

4. CONCLUSION

At a given hot surface temperature (350ºC), Ignition Delay is higher for the Pure Diesel as compared to the Diesel with Vegetable Oil (50%:50%) at any Air Pressure (cylinder pressure) And as the Air Pressure is increasing, Ignition Delay value is decreasing for both the fuels Pure Diesel and Diesel with Vegetable Oil.

Ignition delay for Pure Diesel and Vegetable Oil with Diesel fuel are decreasing with increasing Air Pressure (cylinder pressure) at constant hot surface temperature (350) because at a high cylinder pressure more vaporization of fuel as compare to low pressure.

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