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ANALYSIS OF THE IGNITION DELAY OF THE BIODIESEL ON FUEL IGNITION TESTER

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Abstract.

The purpose of this article was analyzed the behavior of the combustion and ignition delay obtained in Fuel Ignition Tester (FIT) to biodiesel and compares it with the n-heptane behavior in the same conditions. Two methods were used to determine the ignition delay (automatically by FIT and the derivative method) and five different temperatures were used. The results showed the two methods present comparable results and the more sensibility of the biodiesel combustion with the temperature increase. In simple words, the ignition delay is more affected by temperature of biodiesel than heptane samples. These preliminary results are important because small temperature changes can generate wrong results of ignition delay and the derivative cetane number (DCN) for biodiesel samples. Observing the behavior of combustion curve shows that final pressure of combustion of both fuel was similar but the combustion velocity is lower for biodiesel than n-heptane. The next steps include the detailed studied of combustion curves for biodiesel in different temperatures.

The purpose of these instructions is to serve as a guide for formatting papers to be published in the Proceedings of the 17th Brazilian Congress of Thermal Sciences and Engineering, ENCIT 2018. The abstract section should describe the objectives, the methodology and the main conclusions of the paper in about 200 words. It should not contain equations or references to bibliography.

Keywords:

Biodiesel, fuel ignition quality, ignition delay, Metrology.

1. INTRODUCTION

Biodiesel is the first option as a partial substitute for petrodiesel because it is renewable, potential carbon neutral and provides secure energy source. The biodiesel is composed of monoalkyl esters of long chain fatty acids from several sources of vegetable oils[1, 2] , animal fats[3, 4], waste cooking oil[5, 6], biodiesel from recovering process[7]and sewage sludge[8]. Nevertheless the similar main components, the combustion behavior of biodiesel could be affected by differ fatty acid compositions even by low concentration components. One of the combustion properties affected by biodiesel components or contaminants is the ignition delay. The ignition delay in a diesel engine is defined as the time interval between the start of injection and the start of combustion [9]. This period is composed of a physical delay, (encompassing atomization, vaporization, and mixing), coupled with a chemical delay (consisting of pre-combustion reactions in the fuel/air mixture). The two time scales are occurring simultaneously [10].

The ignition delay in direct-injection diesel engines have been associated directly with the heat release rate and the timing of the onset of ignition in the thermodynamic cycle and indirectly have influence of the engine performance, effect on engine noise and pollutant formation [11]. Many authors have been reported possible pollutants from biodiesel storage[12] and combustions[13, 14].

Several methods have been applied to determine the ignition delays of differs fuels including shock tube[15], rapid machine compression (RMC)[16, 17], Cooperative Fuel Research (CFR) or the ignition delay can be obtained directly from engines. But these methods requires complex equipment and high-qualified professionals to operate ones. In the last decades the constant-volume spray combustion system designed to measure ignition delay of low-volatility fuels were developed. These systems are simple and cheaper and no requires exhaustive training.

In this work, we use the constant-volume spray combustion system to analyses the ignition delays; as Fuel ignition tester^{tm} is not optimized to works with pure biofuels we use two methodologies to determine the ignition delay; the combustion curves for differ temperatures of soybean biodiesel and n-heptane.

2. METHODOLOGY

2.1 Biodiesel preparation

Biodiesel was prepared from sunflower oil using the transesterification process with a basic catalysis; this process involves the reaction of the oil with methanol while stirring and heating at 45 °C. The dried sunflower oil reacted with the catalyst and potassium hydroxide dissolved in methanol for 45 min at 45 °C. After the reaction had completed, the reaction medium was transferred to a separation funnel and left for 24 h to separate. The biodiesel was separated from the glycerin by decanting. After this step, the organic layer was washed 3 times with a solution of hydrochloric acid, followed by water until the pH was neutral (Aparecida De Almeida et al. 2013; Batista et al. 2013). The obtained biodiesel was dried and characterized according to the Brazilian legislation requirements for biodiesel (ANP, n.d.) (ANP, 2014). The residual product was dried under vacuum to remove residual moisture.

The main properties of soybean biofuel are in table 1.

Properties	
% of esters	99.6%
Chemical Composition	C16:0 11.3% C18:0 3.5% C18:1 22.4% C18:2 54.3% C18:3 8.1%
Oxidative stability	3.83h
Iodine value	126.7 g of I2/100g of sample
Specific Mass	0,885g/mL
Cloud point	-3.2ºC

2.2 The fuel ignition tester (FIT^{tm}) and the determination of Ignition delay (ID)

The ignition and combustion behaviour of the different vegetable oils was determined in a Fuel Ignition Tester (FIT™), a constant volume combustion chamber described by ASTM D 7170. The components of FIT are an insulated and heated high pressure cylinder, an injection system with exchangeable injection nozzles, a heated fuel tank, a piezoelectric pressure transducer for measuring the combustion chamber pressure and a needle lift sensor to detect the

start of injection [18] . The combustion chamber is filled with synthetic air that is exchanged after each injection. A schema of the apparatus can be consulted elsewhere[18, 19]. The main technical settings are in figure 2

Table 2. Technical specifications of start injection of fuel FIT assay[18].

Property	**Initial Conditions (before injection)**
Combustion chamber volume	0.63 L
Combustion chamber pressure	max. 3.5 MPa
Combustion chamber temperature	572ºC – 593ºC
Injection nozzle	Single hole nozzle
Nozzle hole diameter	0.25 mm
Injection nozzle opening pressure	33.0 MPa
Injection pump	Single cylinder injection pump

The determination of ignition delay has been obtained throw Fuel ignition tester (FIT – Waukesha – GE). 100 mL of the sample take a place in the sample vessel, the initial combustion chamber temperature was setting from 573 ° C to 593°C and 15 minutes was allowed to stabilize the temperature. The injection period was adjusted to 2ms, and the ignition delay was set to start (4.75 ± 0.25) ms for the three test injections. The water recirculation system was set to about (30 ± 1) ° C. After the three system check injections, were collected data from 25 injections about pressure and elapse time.

The FIT software calculates the mean and standard deviation of the ignition delay time values of the 25 injections and provides this value in a worksheet. To determine the derived cetane number the FIT uses the following formula where ID is the ignition delay.

Number of cetane derivative = 150.4 1 / ID + 5.3

To guarantee of quality of the data a second method to calculate the ignition delay. We use the de derivative method to calculate considering the first higher value of first derivative as start of combustion (dp/dt).

3. RESULTS

Figure 1 presents the combustion curve obtained by biodiesel at 583°C (856K), can be observed the main properties of combustion on the graph. Injection period is the time of fuel injection injection in the chamber. The ignition delay is the period between start to fuel injection and the start of combustion[20]. The ignition delay determination depends of the method of determination. The FIT determines the ignition delay period when an internal threshold response to the combustion pressure rising a set + 0.2 bar (0.02MPa)[18] above the base pressure 24bar (2.4 MPa). This methodology can caused erroneous determination of the ignition delay periods due low temperature chemistry can result in a small pressure rise prior to primary ignition [21].

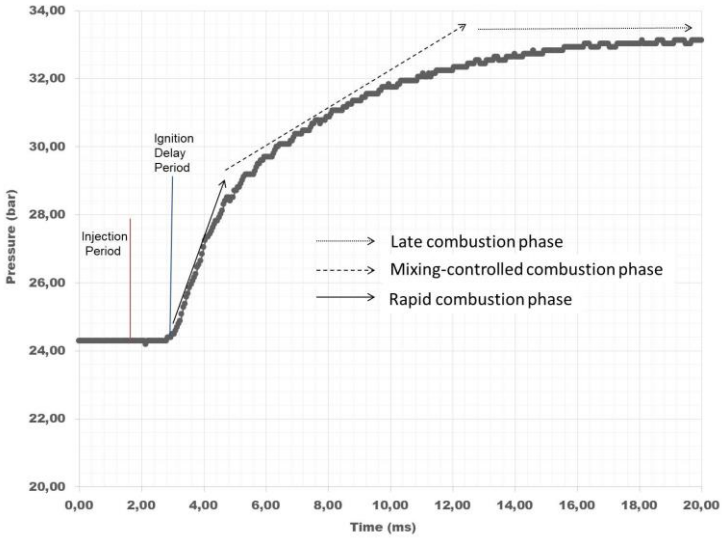

Figure 1: Pressure Curve of biodiesel combustion at 856K

Three distinct regions of figure 1 can be identified in the figure 1 based on speed of pressure increases. The first phase is associated with rapid combustion and presents higher speed increasing. The phase two is the mixing-controlled combustion phase when the burning rate is controlled by the rate of the mixture of air/fuel is disponible to burn. The last phase is the late combustion phase when occur the fuel still not burned start to burn. This curve is not similar of classical curve presented by Heywood[20] because FIT use the constant volume chamber while Heywood curve used variable volume chamber.

The curves for all temperatures and the both fuels present the same three distinct regions. To determine de characteristics of the ignitions delays we apply the methodology of FIT and to avoid the eventual low temperature pressure rise can be misinterpreted as the primary ignition event we use a derivative method to determine the ignition delay (peak pressure rise rate -PPR).

The values of ignition delays of the heptane and biodiesel obtained by both methods were plotted at fig. 2.

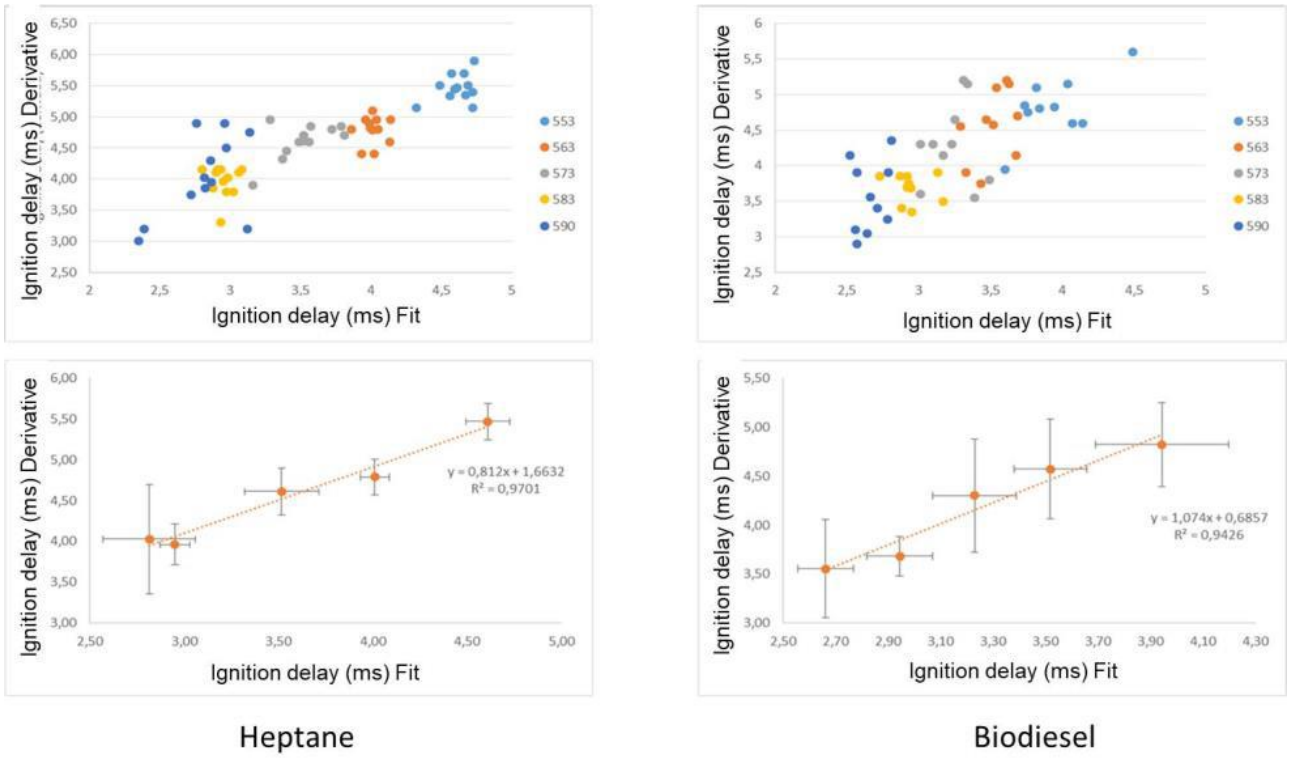

Figure 2 - Ignition delays of heptane and biodiesel obtained automatically by FIT and using derivative method.

The upper pictures in figure 2 present the values of twelve determinations of ignition delays for each temperature to both methods. The lower pictures present the values of ignitions delays by the average and standard deviation. It is clear that ignition delays for biodiesel have the standard error twice higher than heptane when FIT method for ignition delay is used.

The ignition delay obtained by the derivative method present higher values than ignition delay obtained by FIT. However, we should consider that the ID obtained by derivative methods included the value of time of injection. Considering the injection time about 2ms we have that the values obtained by the derivative method would be all smaller than the FIT method.

The correlation between the ID from FIT and the derivative method is very strong having R2> 0.9, indicating that in the initial analysis the methods could be compared. We have obtained an equation allowing the conversion between the values, being possible to compare them together. Although the standard deviation values look be high, the ASTM D7170-16 standard establishes that the reproducibility in the 5ms range is 0.41. That is, except for the values obtained at 590 ° C, the standard deviations of the data obtained by both the FIT and the derivative method are smaller than the reproducibility values.

The distribution of the points is higher homogenous for heptane than for biodiesel, it is not strange once the FIT is adjusted to have better performance with fossil fuels, and the use with biofuels always presents greater variation. Therefore, for the most temperatures tested, the ignition delay determination is adequate for the both fuel and can be determined by the both methodologies applied.

The values of the ignition delay are closer for the both methods indicate that soybean biodiesel and heptane have not phenomena of low temperature rise. Nevertheless, to the higher dispersion of biodiesel measurements indicates the number of replicates for this biofuel into to the FIT should be higher than fossil fuel.

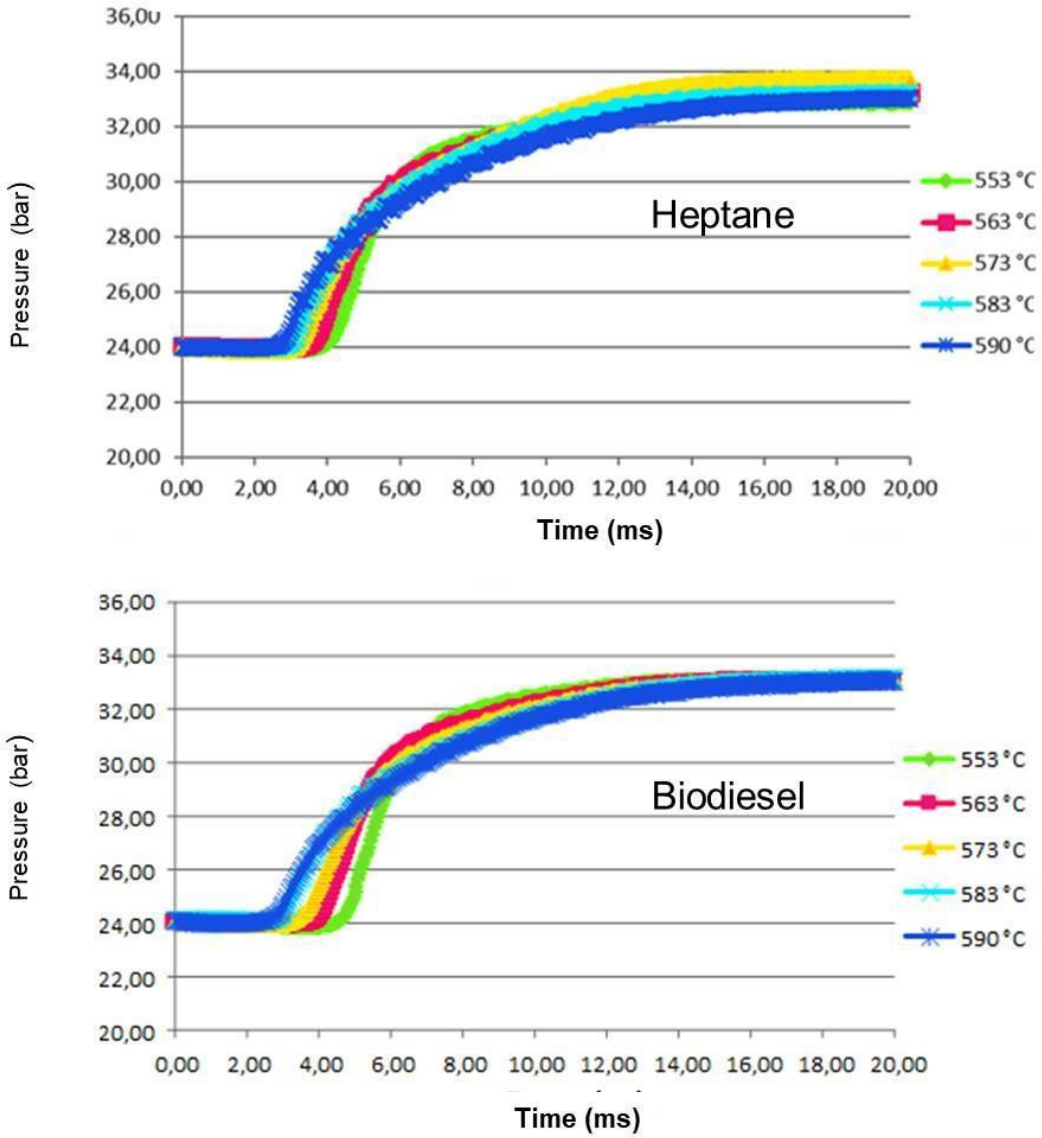

Figure 3 present the combustion curve for heptane and biodiesel.

Although different times of duration of the combustion phases over temperature and samples, in general the premixed combustion phase have, lower duration with the mixing-controlled combustion phase became the main phenomenon. In the future a deep analysis will be done with focus in this behavior.

In general, all samples reach final pressure in 33 bar with initial pressure in 24 bar and the ignition delay decreases with temperature for all of samples. However, there are meaningful differences between the periods of the start of combustion of the heptane and the biodiesel. The ignition delay of heptane is lesser affected by temperature than biodiesel. In numbers, the ignition delay at 590ºC (866K) and 553ºC (826K) for heptane are respectively, 2.66 and 3.94ms while the ignition delays at same temperatures to biodiesel were 2.79 and 5.04ms. This information has been important impact in engines development. The new im

The meaningful difference between results indicates that determination of the ignition delays of biodiesel samples determined by FIT can be increasing the error in the measurements due higher temperature sensibility.

4. CONCLUSIONS

These preliminary results are important because show that the small temperature changes can generate wrong results of the ignition delay and the derivative cetane number (DCN) for biodiesel samples. Observing the behavior of combustion curve shows that final pressure of combustion of both fuel was similar but the combustion velocity is lower for biodiesel than n-heptane. The both method used are able to determine the ignition delays been comparable between them.

To the additions of the final paper the detailed study of combustion curve and the possible identification of Negative Temperature Coefficient phenomenon for n-heptane and biodiesel using the FIT.

5. ACKNOWLEDGEMENTS

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