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Effect of High Ambient Temperature and Biodiesel Derived from Jatropha and Algae on Ignition Delay and Emissions

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ABSTRACT

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Biofuels are one of the largest sources of renewable and sustainable energy, which are made from organic matter or wastes. One of the main biofuels type are the biofuels that is derived from vegetable oils. Nowadays, biofuels are drawing more attention to global scientists because of the scarcity of mineral oil supplies. The primary objective of this analysis is to explore the influence of variability in ambient temperature on the ignition delay period and emission. The type of biodiesel fuel used is the Jatropha Biodiesel with three different blending ratio, which are J40, J30 and J40. The ambient temperature of constant volume chamber (CVC) $T_{i,cvc}$ and combustion chamber (CC), $T_{i,cc}$, was varied from 750 K, 850 K, 950 K and 1100 K. In the form of the hydrocarbon (HC) pollution criterion, nitrogen oxide (NO_x), carbon oxide (CO) and carbon dioxide (CO₂), the emission was studied. While the ignition delay was also studied with biodiesel blending ratio variation. The blending ratio of the biodiesel used were from 20% until 40%. The biodiesel used were algae, Jatropha and waste cooking oil. The finding reveals that the higher value of the ambient temperature mixture induces shorter ignition delay when the CVC and CC are coupled at different ambient temperatures. The emissions data obtained shows that the CO and HC component is lowered while the ambient temperature is higher but the volume of NO_x rises. In the future, biofuels can be inferred as excellent fuel alternatives to replace diesel.

Keywords:

Jatropha Biodiesel; Rapid Compression Machine; Ignition Delay; Emission

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1. Introduction

In the era of modernization, the main problems the automotive industry are up against are the constant increase of standard diesel fuel price, emissions that is polluted and the fuel consumption. As a result of main issue, biodiesel is one of the potential alternative fuel for diesel fuel. Biodiesel has high efficiency of the diesel engine. Biodiesel [1-5] is basically found as alternative fuels to minimize

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hydrocarbon (HC), carbon monoxide (CO) and particulate matter (PM) emissions, however it has led to an escalation in nitrogen (NO_x) oxides emissions. The primary use of biodiesel contributes to a large reduction in emissions of HC, CO and PM without power loss, an increase in fuel consumption and NO_x emissions on diesel engines without alteration or modifications of cars or special fuelling equipment [6-8]. While emissions of NO_x are much higher now, biodiesel can be suitable to satisfy stringent future emissions policies and the depletion of fossil fuels [9-11].

Due to the development of the diesel engine, numerous efforts have been made to follow more strict modern emission regulations, while at the same time increasing the efficiency of diesel engines [12-13]. A constant volume chamber is an excellent tool for testing the impact of temperature on the auto ignition of combustible mixtures as it gives direct measure of ignition delay. The temperature impacts on the ignition cycle are studied up to the initial stages of the increase in pressure resulting from net heat release due to the fuel evaporation and heating. In addition, a connection between the increase in temperature and spray forming could be established on the basis of the data obtained. In diesel engines, ignition is a significant factor in determining the rapid increase in pressure during the initial combustion stage and the corresponding combustion stages. The delay in ignition, are the period or time between the start of the injection and the initiation of the combustion [14,15]. The process in ignition delay divided into two major parts which is the physical and chemical ignition delay. Physical delay processes are associated to the formation of mixture involving atomization, penetration, entrainment and vaporization. Whereas, the chemical ignition to the period required to obtain an exponential increase in the chemical reaction rate comprising of processes such as decomposition and oxidation of fuel [5].

Nonetheless, the utilization of the BDF in diesel engines not only provides appealing and more affordable fuel but also creates issues of higher emission than the petroleum-based diesel [6]. Biodiesel-fuelled diesel engines still have trouble of releasing NO_x and particulate matter (PM) into the atmosphere due to oxidation stability, cetane number, stoichiometric point, and composition of biofuels. Biodiesel has a higher number of cetanes than diesel fuel, nearly no sulphur, no aromatics and contains 10 to 11% oxygen by weight. Such fuel properties lower the emissions of carbon monoxide (CO), hydrocarbon (HC), and particulate matter (PM) in the exhaust gas. For such a reason, multiple emission tests employing biodiesel and its blends indicate that the concentration of pollutants (CO, CO₂, HC, PM, NO_x and deposition) varies depending on the source of biodiesel and the combustion system of engines. Therefore, there is an immediate need to improve emissions from BDF engines to comply with future stringent emission regulations. It has been stated that the application of boost pressure swirl velocity and injection pressure greatly affects the formation of mixtures, ignition delay, turbulence, atmospheric density and ambient pressure, and then affects the propagation of flames combustion characteristics and emission elements [7].

The study is to investigate the impact of the ambient temperature of jatropha-derived biodiesel on both the combustion process and emission using a rapid compression machine (RCM). This study uses three different biodiesel grades which is the J20, J30 and J40 with the aid of rapid compression machine system. The conditions are manipulated by manipulating the ambient temperature of constant volume chamber (CVC) Ti, cvc and combustion chamber (CC), Ti, cc, which was varied from 750K, 850K, 950K and 1100K.

2. Experimental Setup

Biodiesel used was Jatropha biodiesel blended in the automotive lab and the characteristics of the fuel tested are shown in Table 1. The fuel tested were 20 (J20), 30 (J30) and 40 % (J40) Jatropha with the diesel fuel.

Table 1
 Physical properties of Jatropha

Fuel Type	Properties	
	Density (g/m ³)	Kinematic Viscosity (Cp)
A2	0.860	4.4
J5	0.831	3.6
J10	0.878	4.3
J15	0.838	3.6
J20	0.837	3.0
J30	0.838	2.9
J40	0.856	4.7
B15	0.840	3.0

Figure 1 shows the schematic view of blending process. The biodiesel blend was prepared by blending the Jatropha with diesel in different concentrations. The mixture was stirred at 70°C for 2 hours during the blending procedure and the rotating blade speed of 270 RPM was maintained. The experimental apparatus can be separated into distinct systems such as gas analyser for exhaust emission analysis, rapid compression machine and common rail system. Table 2 summarized the experimental condition in this research.

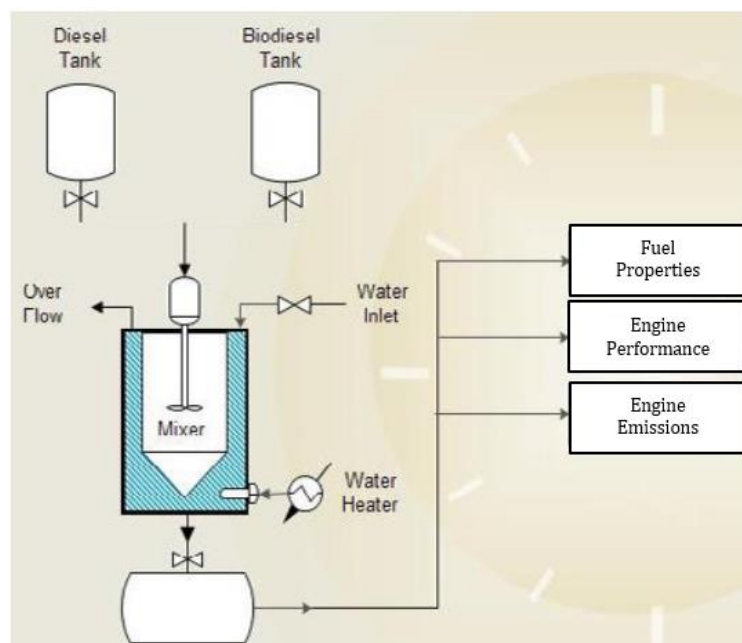


Fig. 1. Blending process of producing biodiesel

Table 2
 Physical properties of Jatropha

Fuel	Injector type	6 holes, $\varnothing = 0.16$ mm
	Fuel type	Jatropha Biodiesel (J20, J30, J40), Algae Biodiesel A2, Palm Oil Biodiesel (B15)
	P_{inj} [MPa]	130
	q_i [ml]	0.04
Ambient gas	$T_{i,cvc}$ [K]	750, 850, 950, 1100
	r_s [m/s]	19
	ρ [kg/m ³]	16.6
	O_2 [vol%]	21

A schematic diagram of a fuel injection system on a rapid compression machine is shown in Figure 2. At the start of the experiment, a free piston is mounted within the cylinders and separated by using a diaphragm. Next, nitrogen gas is loaded into the driver chamber and the pressure reservoir, with the pressure below and above the pressure of the diaphragm respectively. The diaphragm burst when the valve is opened and the piston is forced into a tapered stop ring that is mounted in front of the combustion chamber. After a fixed interval from the time the piston stopped, the fuel will be injected into the combustion chamber. The initial injection temperature and pressure have been used to monitor the combustion behaviour at the end of the injection sequence by the aid of the Pico Scope 3000.

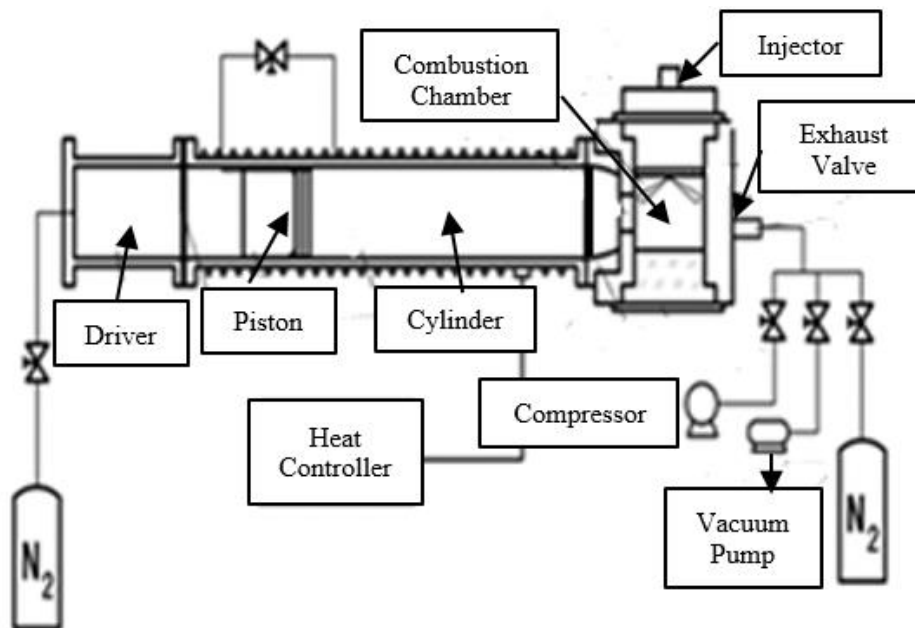


Fig. 2. Schematic diagram of RCM

3. Results and Discussion

The tools that is used to study the ignition delay and emissions regarding the blending ratio of biodiesel is the RCM. The biodiesel that have been testing are Jatropha Biodiesel (J20, J30 and J40). For validation purpose, a comparison between six types of blend biodiesel which are Palm-Oil Biodiesel (B15), Algae Biodiesel (A2) and Jatropha (J2, J5, J10, and J15) was investigated in this experiment.

3.1 Effects of Ambient Temperature on Emissions of Different Type of Biodiesel Blends

The variance of Jatropha biodiesel ignition delay at specific ambient temperature is shown in Figure 3. Based Figure 3, $T_{i,cvc}$ 70°C and $T_{i,cc}$ of 70°C, the ignition delay duration for J20, J30 and J40 are 0.9ms, 1.1ms and 0.6ms. At $T_{i,cvc}$ 70°C and $T_{i,cc}$ of 90°C, 0.8ms, 2.0ms and 0.7ms of ignition delay are recorded for the fuels. As temperature rises until $T_{i,cvc}$ 80°C and $T_{i,cc}$ 80°C, the same trend is found. The ignition delay of 0.6ms, 0.7ms and 0.8ms is lower than the previous data obtained. The temperature for $T_{i,cvc}$ and $T_{i,cc}$ is further increased to 80°C and 90°C respectively. At this particular temperature, the ignition delay period is found to be lowest. The ignition delay occurred at 0.7ms, 0.6ms and 0.4ms for the three Jatropha blends. It is observed from the result that when the ignition delay is shorter as the ambient temperature was increased, it is due to the weaker C-H bond strength

and caused the decrease in bond dissociation energy. Hence, the fuel reactivity was enhanced and ignition delay become shorter.

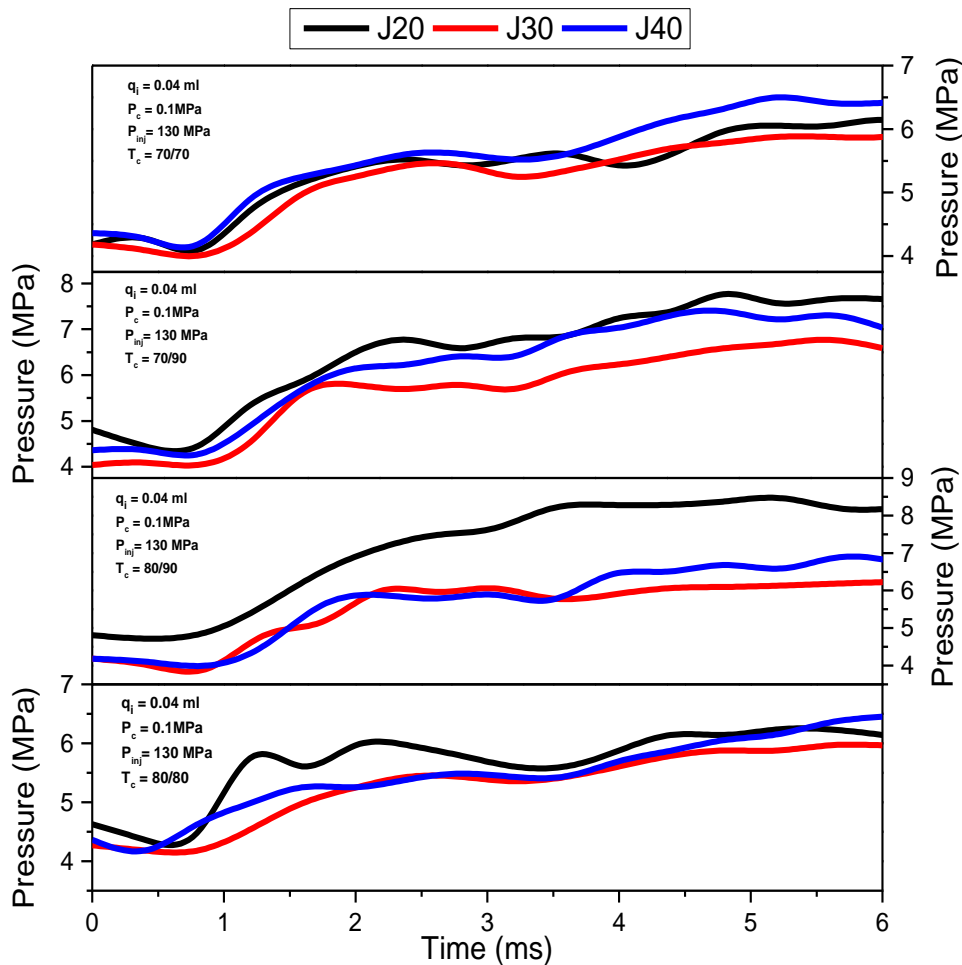


Fig. 3. Variation of ignition delay of Jatropa biodiesel at different ambient temperature

The results obtained is then compared with data from previous study. Figure 4 displays a graph of ignition delay when the ambient temperature was varied for different type of biodiesel and standard diesel. The parameter that were set for the result were $T_{i,cvc}$ at 70°C and 80°C with $T_{i,cc}$ of 90°C respectively and the injection pressure, P_{inj} is 130 MPa. The ignition delay duration for standard diesel (SD) is 2.43 ms. Algae biodiesel A2, jatropa biodiesel J5, J10 and palm oil biodiesel B10, B15 have slightly same figure with standard diesel SD with 2.11 ms, 2.22 ms, 2.15 ms, 2.13 ms and 2.18 ms. The highest ignition delay that is obtained from the graph is the J15 with the duration of 2.75 ms and the shortest ignition delay was B5 with the duration of 1.6 ms.

Figure 4 also it is observed at T_i of 80°C, SD has ignition delay duration of 2.13 ms. Algae biodiesel A2, jatropa biodiesel J5, J10 and palm oil biodiesel B10, B15 have slightly same figure with standard diesel SD with 1.95 ms, 2.08 ms, 2.02 ms, 1.93 ms and 2.05 ms. For T_i of 80°C J15 has the longest duration and B5 has the shortest ignition delay duration with the duration of 2.45 ms and 1.55 ms respectively.

When the temperature is low, the ignition delay period would become longer and the combustion will be incomplete. Meanwhile, when the ambient temperature was higher, the ignition delay became shorter. From these result and observation, it is clear that ambient temperature will affect

the ignition delay in the combustion process. At $T_{i,cvc}$ of 80°C , the ignition delay is shorter than $T_{i,cvc}$ of 70°C . As the ambient temperature of both CVC and CC rises, the ignition delay shortens due to the time. The rise in initial ambient temperature of air has ensured that the ignition delay to be decreased irrespective of percentage of the biodiesel blend and type. This is attributed to the increased fuel atomization and enhanced fuel droplet evaporation due to higher initial ambient temperature. This is because in such a brief ignition period, the spray cannot develop fully

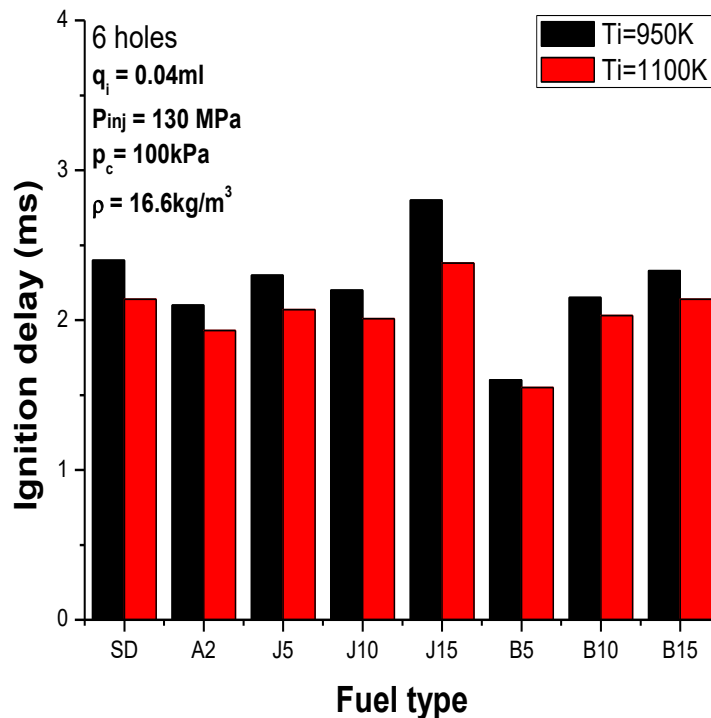


Fig. 4. Effect of variants ambient temperature on ignition delay for variants fuel (SD, A2, B5, B10, B15, J5, J10 and J15)

Figure 5 shows the effect of ambient temperature on exhaust emission for different type of biodiesel. When the temperature increases the value of CO_2 constantly increase except for the J40 which have the decreasing value of CO_2 as the temperature rise. Meanwhile for the NO_x formation, the value decreased for J2, J10 and J20. NO_x is formed by the reaction of nitrogen bound in the fuel with oxygen in the combustion chamber as combustion process takes place. The value of NO_x should be increasing as the temperature of combustion temperature increase as it will provide higher reaction rate for the mixture to react. The high temperature of combustion enhances atomization of fuel and penetration ratios as the charge homogeneity contributes to NO_x production. Whilst, the emission of HC and CO are observed to decrease. An increase in the temperature of combustion will contribute to shorter ignition delay and better fuel mixture. This will lead to the reduction of HC emission. With rising temperatures leading to complete combustion, production of CO_2 is decreased, resulting in low CO emissions at higher combustion temperatures. Due to complete combustion, most of the content of carbon in gasoline is transformed to CO_2 instead of CO.

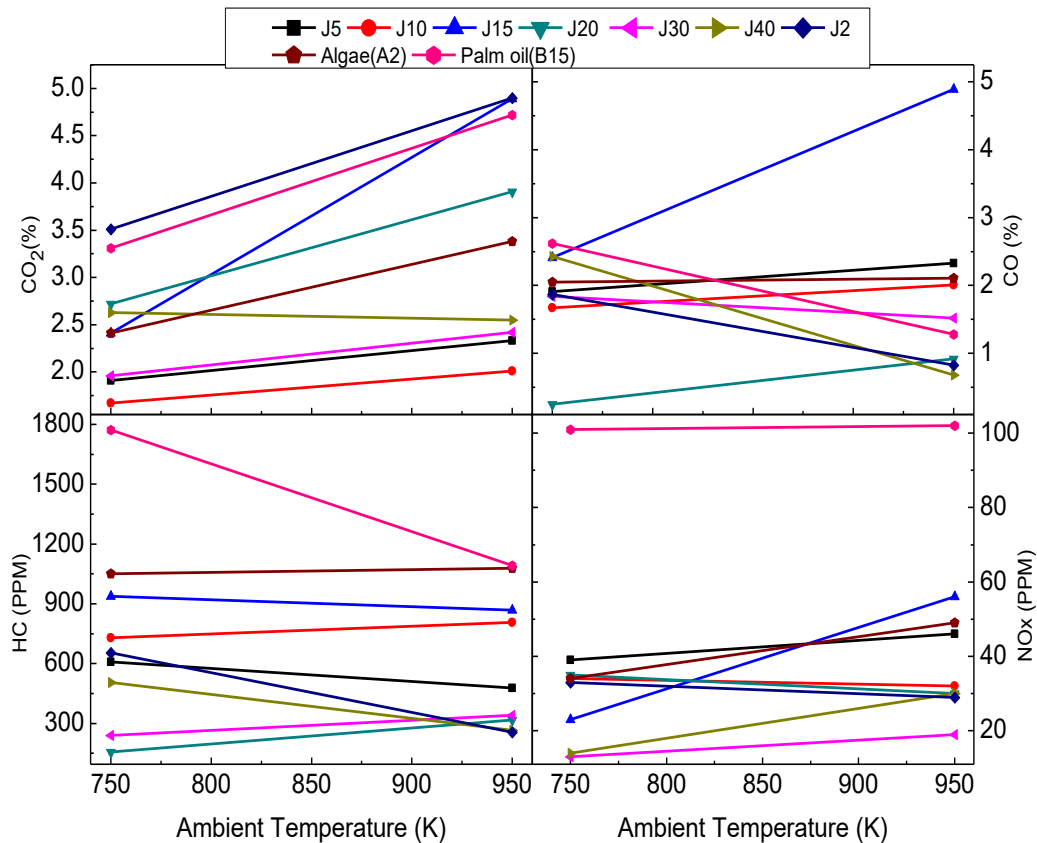


Fig. 5. Effects of ambient temperature on exhaust emission for different type of biodiesel

4. Conclusions

In this paper, the fundamental features of the diesel combustion process have been investigated with a rapid compression machine. Rapid compression machine is a tool that is used for simulating a single compression stroke of an internal combustion engine which features a single free-piston which is pneumatically driven and is stopped by ramming into a tapered ring. The objective of the study has been fulfilled which is to study the effect of ambient temperature on emission and combustion behaviour. The following deduction are obtained through the study

- i. Disregarding the type of biodiesels used, the ignition delay will decrease as the value of ambient temperature increase.
- ii. The fuel atomization will be improved rapidly and fuel mixture formation in the combustion chamber will be enhanced with the aid of high ambient temperature.
- iii. As the ambient temperature rise, the emission value of HC and CO will be lower. Meanwhile, the emission of NOx and CO2 will rise due to the increase in temperature. Improved ignition delay and improved fuel-mixed emissions contribute to reduction of HC and CO, while increased fuel atomization and penetration lead to NOx production. The effect is due to the combustion temperature.

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