Combustion Characteristics of a Diesel Engine Fuelled with B100

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Abstract— In the present study, the combustion characteristics of two different fuel diesel and biodiesel from karanja oil were compared. The experiments were performed at single cylinder direct injection diesel engine at 1500 rpm. The standards of the principal combustion characteristics of the biodiesel were obtained between diesel fuels. The results indicated that biodiesel (B100) may be used without any modification on the engine.
Key words: Diesel Engine, biodiesel (B100)

I. Introduction

Due to the oil crisis of the 1970s, the research interests increased on the alternative fuels used in internal combustion engines have expanded which are renewable, available locally, and cleaner than fossil fuels. Biodiesel derived from the transesterification of animal fats, used cooking oil and vegetable oils, and has similar properties towards diesel. The leading advantages of consuming biodiesel is that it is renewable, biodegradable, oxygenated, non-toxic, free of sulphur and can be used without modifying existing engines and creates less harmful gas emissions. A large number of studies reported in the literature on the effect of diesel and biodiesel combustion characteristics of diesel engines.

The combustion characteristics of fuels are one of the most important parameter to evaluate the performance and emissions characteristics of diesel engines [1]. There are some important parameters that specify the combustion process proficiency are ignition delay, combustion duration, heat release rate, cumulative heat release and in-cylinder pressure [2]. In a diesel engine, the in- cylinder pressure depends on the burned fuel fraction during the premixed burning phase, i.e. early stage of combustion. The cylinder pressure characterizes the ability of the fuel to mix well with air and fuel. In-cylinder peak pressure correspond to large amount of fuel burnt in premixed combustion stage. Shaktivel et al. [3] reported that the peak in-cylinder pressure was noticed as 73.56 bars for diesel and 72.37, 71.69, 71.33, 67.42 and 67.14 bars for B20, B40, B60, B80, and B100 respectively for biodiesel and its blends. This is because of the high viscosity and low volatility of the fuel. Das et al. [4] reported that the peak cylinder pressure for jatropha and karanja biodiesel had a JB100 (7.6%) and KB100 (6.9%) higher peak pressure than that of base diesel. This is attributed to the lower cetane number of the fuel.

Ignition delay is one of the most important parameter in the combustion phenomena. The ignition delay for any fuel can be calculated based on the duration between the start of fuel injection and start of combustion. Das et al. [5] reported that the ignition delay was found lower with the biodiesel as compared to base diesel due to the advancement of start of combustion for biodiesel than diesel. It is mainly due to the advance in injection timing and higher cetane number of biodiesel which improves the ignition quality. Zhang et al. [6] used methyl ester of soybean oil with diesel as fuel and he found that ignition delay for methyl ester was shorter than that of base diesel fuel. The increase in fuel viscosity, particularly for petroleum-derived fuels, results in poor atomization, slower mixing, increased penetration and reduced cone angle. These result in longer ignition delay for diesel fuel [7]. Raheman et al. [8] the authors observed that the increase of RME percentage in the fuel blend appears to reduce the ignition delay, increase the rate of fuel burnt in the premixed phase and shift the start of combustion to an early stage and hence increase the in-cylinder pressure compared to petroleum diesel combustion. The combustion duration was calculated based on the duration between the start of combustion and 90% cumulative heat release. Atul et al. [9] reported that the in-line injection pressure increases with the biodiesel as compared with base diesel because of lesser compressibility of biodiesel and higher fuel density than base diesel. High in-line injection pressure increases the mass flow rate of biodiesel. To maintain the same power output, the fuel flow rate needs to be enhanced more because biodiesel having lesser calorific value (42600 kJ/ kg) than diesel (44050 kJ/kg). The increased injection duration would affect combustion duration. Dattatray et al. [10] reported that that the combustion duration is lower for biodiesel when compared to diesel. The reason for this may be the higher oxygen content in the fuel that improves the combustion process, completing it at a faster rate. S.Bari et al. [11] observed better combustion in premixed phase with biodiesel in comparison of base diesel due to longer diffusive combustion phase of biodiesel than base diesel the total combustion duration of biodiesel was found to be 4.8 ^{0}CA longer than base diesel. Mustafa et al. [12] investigated the combustion characteristics of a rice bran oil methyl ester fueled DI transportation diesel engine for varying load at two speeds, and showed an earlier SOC for biodiesel at all operating points. However they reported a higher combustion duration for biodiesel and its blend. The heat release rate is used to classify the start of combustion, the mass of fuel burned in the premixed mode, and change in combustion rates of fuels [10]. G.Shakti et al. [3] reported the peak heat release rate for diesel and B100 are 62.1 J/^{0}CA and 49.87 J/^{0}CA. Diesel shows higher heat release rate. The main reason for this is increased accumulation of fuel during the relatively longer delay period resulted in higher rate of heat release at the time of the premixed combustion. It is observed that the value of maximum heat release rate decreases with the increase of biodiesel in the fuel. This is due to the lower ignition delay of the biodiesel. Rajshekher et al. [14] calculated the heat release rate for rapeseed methyl-ester (RME) and they observed higher biodiesel combustion rate. They concluded that because of 12 % lower heating value of RME than that of diesel, a higher mass is required to obtain the same energy release. Ayhan et al. [15] Cumulative heat release is also lower for biodiesel blend compared to diesel fuel possibly because of lower calorific value of biodiesel blend. Rajshekher et al. [14]

tested linseed oil methyl ester, jatropha oil methyl ester and coconut oil methyl ester in DI diesel engine and reported that the HRR and CHR for all the biodiesel fuels were almost similar.

II. Experimental Setup

An experimental setup was developed to conduct tests as shown in Figure 1. It consists of a four stroke naturally aspirated diesel engine coupled with alternator, intake air system (air filter, air flow meter, and surge tank) and NDIR principal based AVL Di-gas analyzer for measuring the exhaust gas emissions and an combustion analyzer for computing cylinder pressure-crank angle history for analysis the combustion characteristics of the fuels.

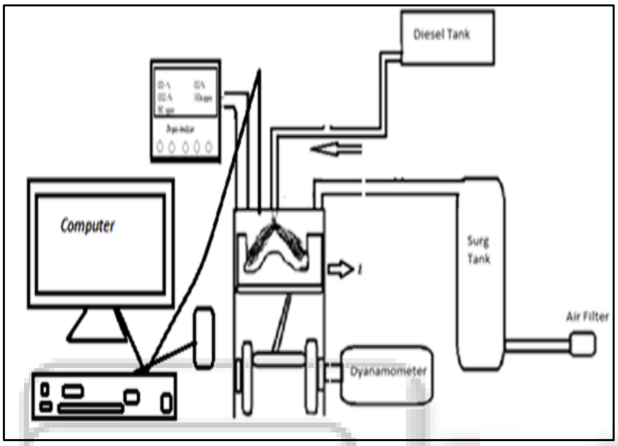

Fig. 1: Experimental Setup

III. Results and Discussion

In-cylinder Pressure- Figure 2. shows the variation of in-cylinder pressure with respect to crank angle for both the fuel diesel and biodiesel. It is observed from figure that in-cylinder peak pressure increased with increase in load percentage at 1500 rpm. If in-cylinder peak pressure compared with base diesel at same power in-cylender peak pressure is shows the high trend for biodiesel.

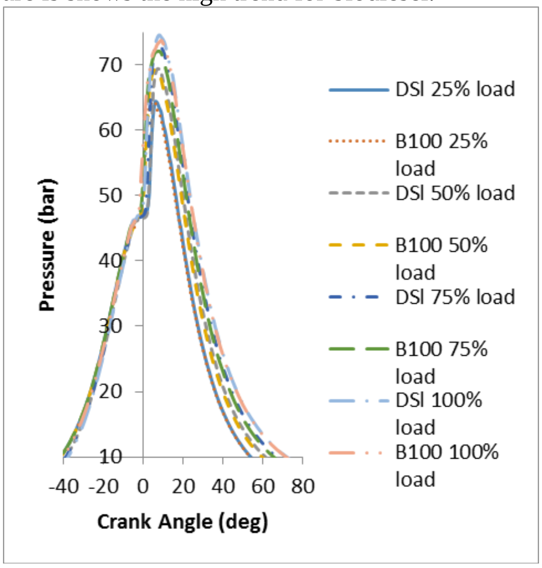

Fig. 2: Variation of in-cylinder peak pressure with CA

In diesel engine, the in-cylinder peak pressure depends on the burnt fuel fraction during the premixed burning phase, i.e. early stage of combustion. The cylinder pressure characterizes the ability of the fuel to mix well with air and fuel. In-cylinder peak pressure correspond to large amount of fuel burnt in premixed combustion stage . Das et al. [4] reported that the in-cylinder peak pressure is high for biodiesel than that of base diesel. It may definitely in-cylinder peak pressure takes place after TDC for safe and efficient operation. Otherwise, a peak pressure occuring very close to TDC.

Ignition Delay- Figure 3. shows the variation of ignition delay with respect to load percentage for both the fuel diesel and biodiesel. It is observed from figure that ignition delay decreased with increase in load percentage at 1500 rpm. If ignition delay compared with base diesel at same load the ignition delay is shows the lower trend for biodiesel. As the engine load increased, more quantity of fuel are injected.

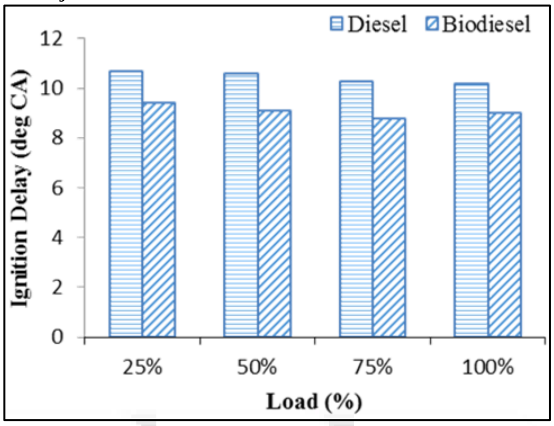

Fig. 3: Variation of ignition delay with load (%)

Therefore, it results in high cylinder air temperature at the time of injection and shorter ignition delay may obtain. Another may be injection timing advanced automatically due to higher bulk modulus and higher cetane number of Karanja biodiesel (CN:58) compared to base diesel (CN

Combustion Duration- Figure 4. shows the variation of duration of combustion with respect to load percentage for both the fuel diesel and biodiesel. It is observed from figure that duration of combustion increased with increase in load percentage at 1500 rpm. If duration of combustion compared with base diesel at same load the duration of combustion is shows the high trend for biodiesel. This is because the mass of fuel has to increased with biodiesel because its having less calorific value than base diesel. For maintaining the same power more fuels is needed to burn.

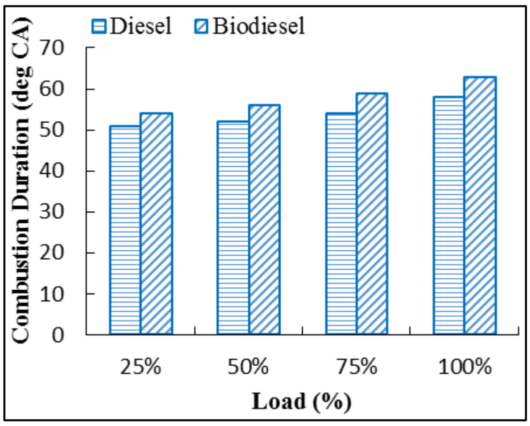

Fig. 4: Variation of combustion duration with load (%)

Heat Release Rate- Figure 5. shows the variation of heat release rate with respect to crank angle for both the fuel diesel and biodiesel. It is observed from figure that heat release rate increased with increase in load percentage at 1500 rpm. If heat release rate compared with base diesel at same load the heat release rate is shows the lower trend for biodiesel.

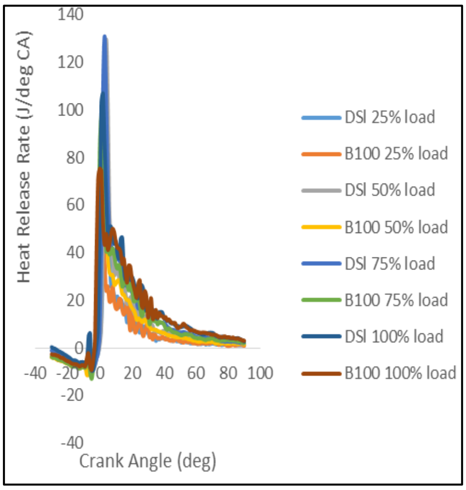

Fig. 5: Variation of heat release rate with CA

This is because, as a significance of the shorter ignition delay, the premix combustion phase for biodiesel is less intense. On the other hand, while running with diesel, increased accumulation of fuel during the relatively longer delay period resulted in higher rate of heat release. Because of the shorter delay, maximum heat release rate occurs earlier for biodiesel in comparison with base diesel. However, the heat release during the late combustion phase for biodiesel is marginally lower than that of base diesel.

Cumulative Heat Release- Figure 6. shows the variation of cumulative heat release with respect to crank angle for both the fuel diesel and biodiesel. It is observed from figure that cumulative heat release increased with increase in load percentage at 1500 rpm. If cumulative heat release compared with base diesel at same load the cumulative heat release is shows the lower trend for biodiesel. The experimental investigation revealed that the overall combustion characteristics were quite similar for biodiesel and base diesel fuel. However, combustion started earlier in the case of biodiesel .Ignition delay was lower and combustion duration was slightly longer for biodiesel compared to base diesel fuel.

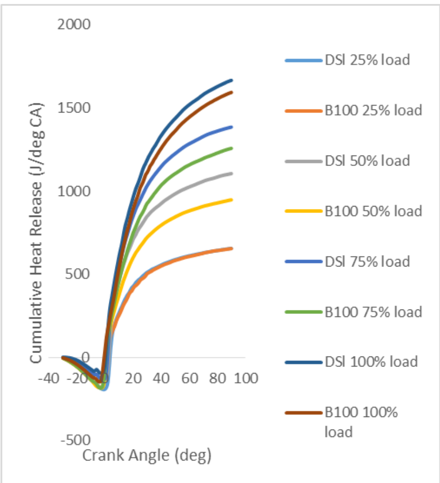

Fig. 6: Variation of cumulative heat release with CA

Lower heat release rate is found for biodiesel compared to diesel during premixed combustion phase. Total heat release was lower in the case of biodiesel in comparison to base diesel fuel.

IV. Conclusions

The present analysis reveals that biodiesel is quite suitable as an alternative to diesel. It is concluded that biodiesel (B100) which results in maximum peak cylinder pressure is the optimum fuel as far as the peak cylinder pressure is concerned. The ignition delays are consistently shorter for B100.

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