VOL. 11, NO. 17, SEPTEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences
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COMBUSTION CHARACTERISTICS OF DI-CI ENGINE WITH BIODIESEL PRODUCED FROM WASTE CHICKEN FAT

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ABSTRACT

Now a days biodiesel fuels are gaining more attraction as promising alternative and substitute fuel resource in place of petroleum diesel because of lower net emissions. The characteristics of biodiesel fueled existing diesel engines are greatly affected by the combustion behavior. The present work is focused on investigation of combustion characteristics of diesel engine fueled with biodiesel derived from waste chicken fat. The experimental investigation was conducted in single cylinder constant speed (1500 rpm) stationary diesel engine at full load condition fueled with neat biodiesel and blends with diesel. Preheated biodiesel was also used to study the combustion behavior of the fuel. The experimental results revealed that as compared to diesel, biodiesel has early start of combustion and shorter delay period. More oxygen content, higher cetane number and lower compressibility of biodiesel have been identified as main reasons for this advancement of combustion and reduced delay period. It is also observed that the heat release rate of biodiesel in both premixed and diffused combustion is different that of diesel. Lower volatility, higher density, higher viscosity, lower calorific value and shorter delay period of the biodiesel are the main reasons for its changes in combustion behavior.

Keywords: combustion, biodiesel, cylinder pressure, heat release.

1. INTRODUCTION

The combustion process in diesel engine is a complex phenomenon. The effective combustion is affected by various process such as self ignition, atomization and evaporation of fuel, mixing of fuel with air, delay period, heat release rate and heat transfer between combustion gases and cylinder walls etc. [1]. The homogenous air fuel mixture formation is mainly influenced by the fuel injection characteristics. Higher the injection pressure the faster the combustion rates resulting improved performance. But at very higher injection pressure, the fuel droplet size decreases and increases the momentum of fuel droplets rapidly. These higher momentum fuel droplets strikes and stick on the cylinder walls resulting increasing the heat transfer to the cylinder walls during combustion [2]. The properties of biodiesel and its blends have great influence on the engine characteristics, because its physical and chemical properties are different from those of diesel. Viscosity of biodiesel is higher than diesel fuel. Investigations revealed that use of higher viscosity biodiesel leads to reduced atomization quality of fuel, consequently increase average droplet size and break up time [3]. Heat release rate and combustion characteristics are to be known in order to obtain reduced fuel consumption. Many investigations were carried out on combustion behavior and ignition delay of diesel engine with various biodiesels. The parameters varied for these studies were fuel injection timing, fuel injection pressure, compression ratio, engine loads and fuel blend ratio etc. These studies results revealed that the early start of combustion, reduced ignition delay, increased premixed combustion and decreased diffused combustion with biodiesel. Biodiesel has calorific values less than diesel fuel there by causes specific power loss [4]. The BSFC of the engine with biodiesel is higher than diesel, because the biodiesel contains about 12% less heating value than diesel [5]. Several techniques such as viscosity reduction additives, preheating [6, 7], exhaust gas recirculation [8], blending [9] and doping etc. have been employed in the large scale application of biodiesel. Many studies reported that the combustion behavior of biodiesel and diesel are not identical. Even though biodiesel possesses many advantages over diesel however some properties affects the delay period, peak pressures, and heat release rate etc.

2. MATERIALS AND METHODS

2.1 Fuel

This work describes the combustion behavior of diesel engine with biodiesel produced from waste chicken fat. The method adopted for preparation of biodiesel from chicken fat oil for this work is Transesterification which is a process of using methanol (CH_3OH) in the presence of potassium hydroxide (KOH) as catalyst to chemically break the molecules of chicken fat oil in to an ester and glycerol. 1000 ml of chicken fat oil after filtration is taken in a volumetric flask is stirred manually and simultaneously heated with the water bath heating. When the temperature of raw oil reaches 60°C the methanol (200 ml) and KOH (7.5 g) solution, which is prepared separately, is poured into the oil volumetric flask and the volumetric flask is closed with an air tight lid. Now the solution is stirred at high speeds. Care should be taken that the temperature does not exceed 60°C as methanol evaporates at temperature higher than 60°C. After continuous stirring of this solution for an hour, the solution is transferred to a separating glass conical flask. Now separation takes place and biodiesel gets collected in the upper portion whereas glycerin gets collected in the bottom portion. The glycerin is removed from conical flask by opening cock. Then the biodiesel is washed with distilled water repeatedly to remove the soap oil completely. Now this biodiesel is heated to temperature

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above 100°C to vaporize the water content in it. The resulting product is chicken fat biodiesel (CFBD/B100) which is ready for use. 880 ml chicken fat biodiesel is yielded from 1000 ml of raw chicken fat oil. The conversion efficiency or yielding efficiency of chicken fat biodiesel production by transesterification process is 88%. The various properties of chicken fat biodiesel (CFBD) produced from transesterification process; petroleum diesel (PD) and ASTM standard specification for biodiesel (B100) fuel are given in the Table-1. The blends B10, B20, B30 and B40 were consider for the study of combustion characteristics and compared with diesel fuel behaviour. Preheated biodiesel was also used for the study to investigate the characteristics.

Table-1. Properties of Chicken Fat Biodiesel (CFBD) and Petroleum Diesel (PD).

Property	**Unit**	**PD**	**CFBD**	**ASTM Standards** [10]
Density	g/cc	0.831	0.862	0.87-0.89
Kinematic Viscosity at 40°C	cSt	2.58	4.93	1.9-6.0
Flash Point	°C	50	160	130 minimum
Lower Calorific value	kJ/kg	42500	40170	37500
Cetane number[11]	-	48	57	48-70
C	%	87	77.83	-
H	%	13	11.97	-
O	%	0	10.10	-

2.2 Engine

The setup consists of single cylinder, four strokes, water cooled, naturally aspirated, stationary, direct injection compression ignition engine coupled to eddy current dynamometer. It is also provided with necessary sensors with transmitters for combustion pressure and crank angle measurements. All these signals are interfaced to computer through signal conditioner and signal converter for computerization. The engine analysis software "Lab View" based software developed by TECH-ED is used for testing combustion analysis of given engine test setup. This software can serve most of the Engine testing application needs including monitoring, reporting, data logging. The experimental setup used for the study is shown in Figure-1.

Figure-1. Experimental setup.

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3. RESULTS AND DISCUSSIONS

3.1 Combustion characteristics with fuel blending

This section highlights the effect of chicken fat biodiesel (CFBD/B100) and its blend in petroleum diesel on combustion characteristics like cylinder pressure variation, heat release rate and cumulative heat release rate with crank angle and compared with PD. This section also includes the variation of cylinder peak pressure of various fuels with engine load. The blends B10, B20, B30 and B40 were consider for the study of combustion characteristics and compared with diesel fuel behaviour.

3.1.1 Cylinder pressure

Figure-2 shows variation of cylinder pressure with crank angle for complete cycle at 3.72 kW load. It is observed that the curves are overlapped for all fuel blends during cycle except the crank angle range between 350^o to 450^o (i.e. during the combustion near to TDC). For the crank angle range between 350^o to 450^o, the cylinder pressure variation is shown in Figure-3 to know the attainment of peak pressure for all fuels. From this, it is observed that the attainment of peak pressure is slightly advanced with increase in percentage of biodiesel in diesel.

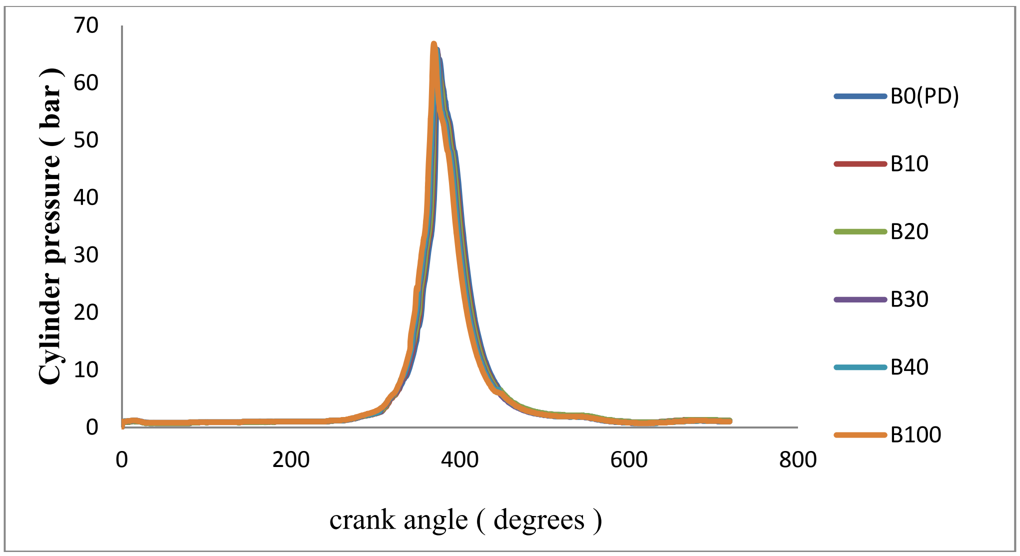

Figure-2. Variation of cylinder pressure with crank angle at 3.72 kW load.

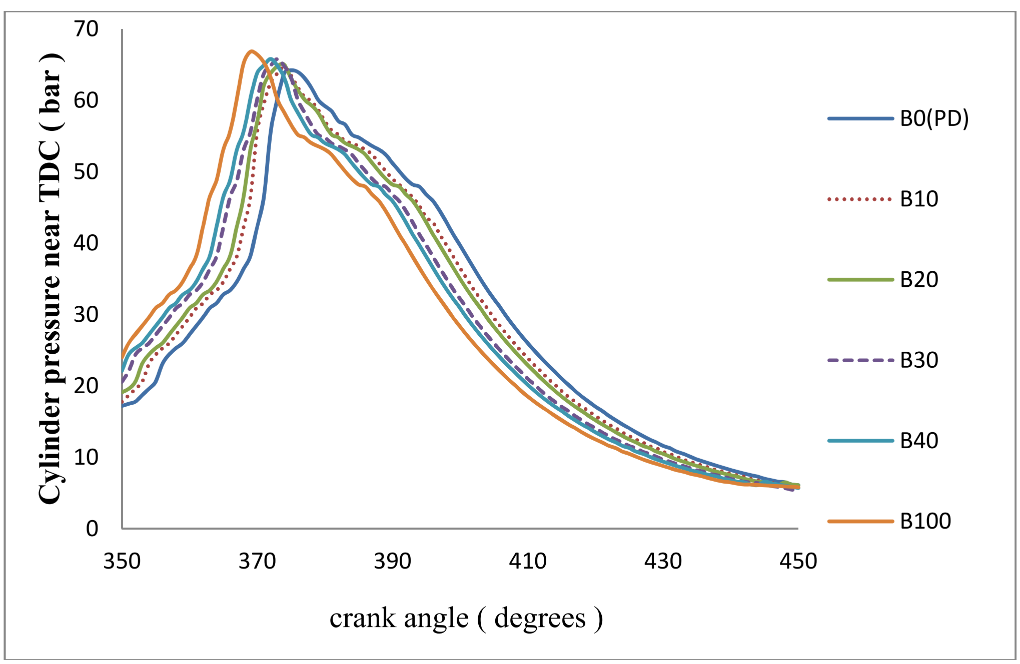

Figure-3. Variation of cylinder pressure with crank angle during combustion process at 3.72 kW load.

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3.1.2 Peak pressure

Figure-4 shows the variation of cylinder peak pressure of B0, B10, B20, B30, B40 and B100 fuels with engine load. Peak pressure increases with increase in engine load for all fuels. Peak pressure of B100 is higher than PD at all loads. Peak pressure also increased with percentage of biodiesel in the blend. This is mainly due to more oxygen content in biodiesel leads to complete combustion results higher pressure. Figure-5 shows the occurrence of cylinder peak pressure in terms of crank angle for all fuels at 3.72 kW engine load. Compared to PD, biodiesel and its blends peak pressure occurrence are observed early because of more oxygen presence and early start of combustion process.

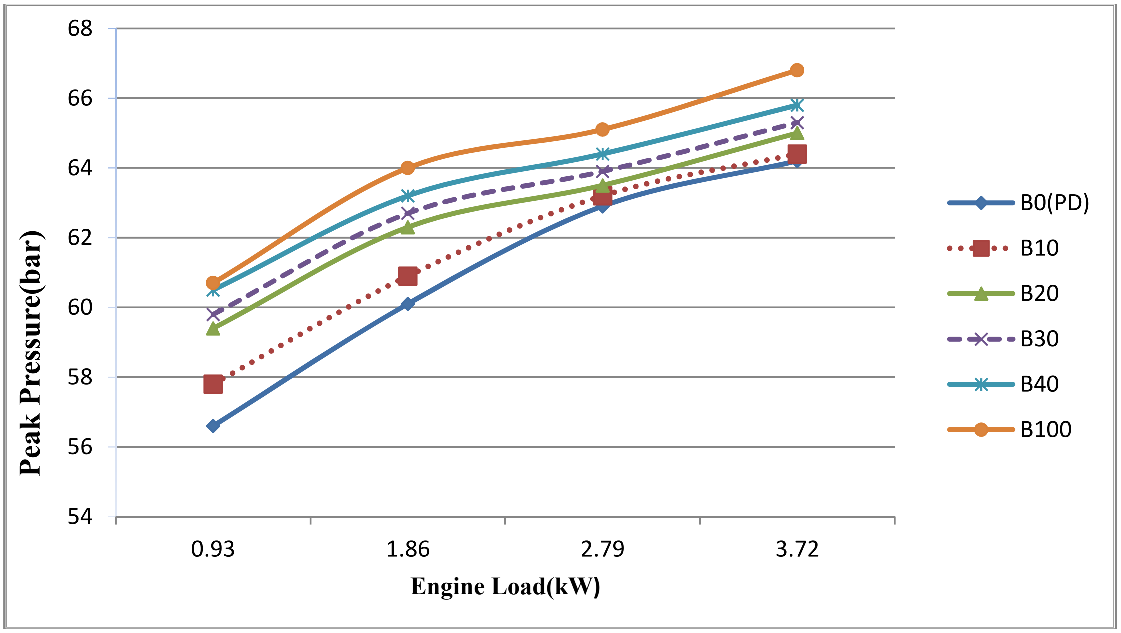

Figure-4. Variation of cylinder peak pressure with engine load (BP).

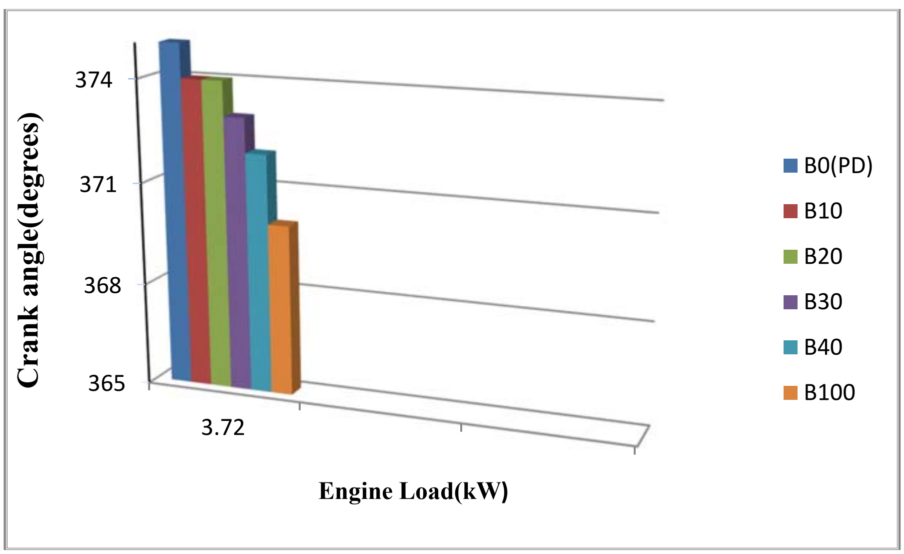

Figure-5. Attainment of peak pressure in terms of crank angle at 3.72kW load.

3.1.3 Heat release rate

Knowledge of heat release rate of fuel is very essential for cooling system design. The comparison of heat release rate of various fuel combinations at 3.72 kW load is shown in Figure-6. The maximum heat release rate (51.26 J/^{o}CA) is observed for biodiesel fuel at 360^o crank angle. Cumulative heat release rate for crank angle ranges between 340^o to 415^o is shown in Figure-7. The area under cumulative heat release rate curve indicates the net heat released during the given period of cycle. During premixed combustion period biodiesel fuel liberates more heat due to early start of combustion and higher cetane

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number. However the area under B0 (PD) in diffused combustion period is higher than all other fuel blends. This is due to liberation of more heat of PD than biodiesel during diffused combustion.

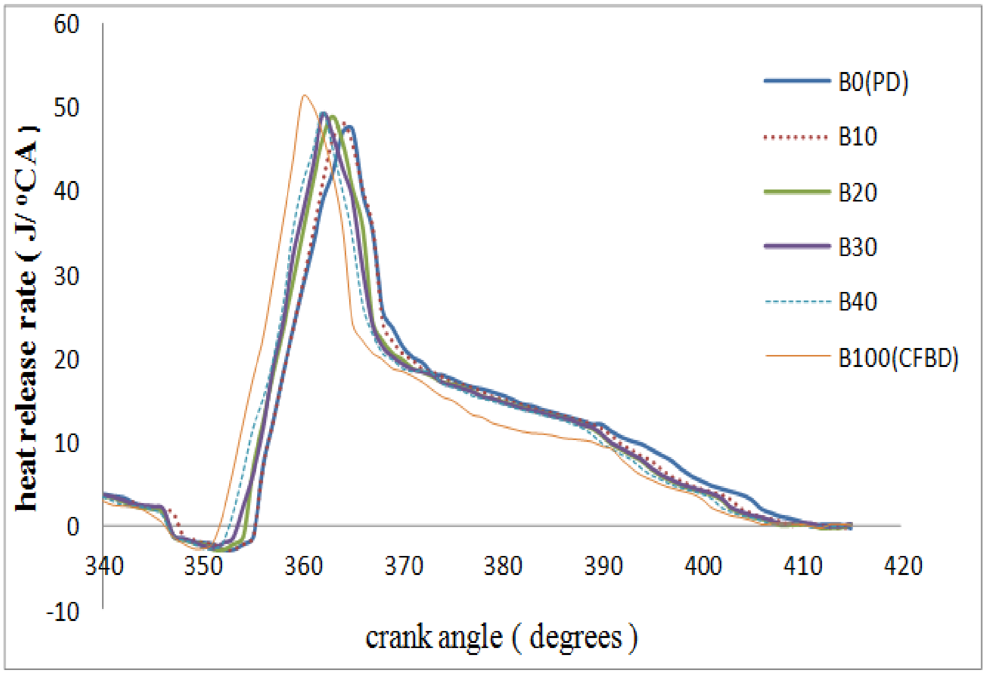

Figure-6. Variation of Heat release rate with crank angle at 3.72 kW load.

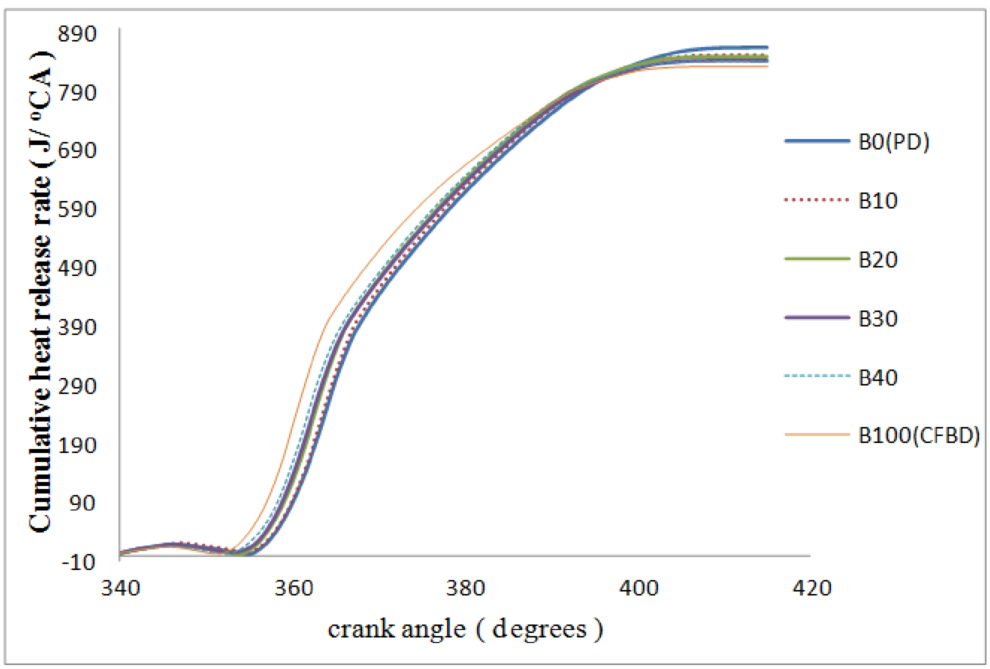

Figure-7. Variation of cumulative Heat release rate with crank angle at 3.72 kW load.

3.2 Engine characteristics with fuel preheating

From Table-1 the properties of chicken fat biodiesel (B100) are similar to petroleum diesel (PD/B0). The higher viscosity value of biodiesel is one of the limitations to use in CI engine. Blending and heating of these oils greatly reduces the viscosity and hence to overcome the high viscosity problem, the preheating of fuel is done [12, 13]. The high viscosity of biodiesel may be due to its high molecular weight compared to diesel. The viscosity is determined at different temperature to

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences
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know the effect of temperature on viscosity. The variation of viscosity of B0 (PD) and B100 (biodiesel) with temperature is shown in Figure-8

The viscosity of B100 (biodiesel) at 50°C is almost equal to viscosity of B0 (PD) at 30°C (room temperature at work place). Hence B100/ biodiesel preheated to 50°C (B100PH) are also used for the test.

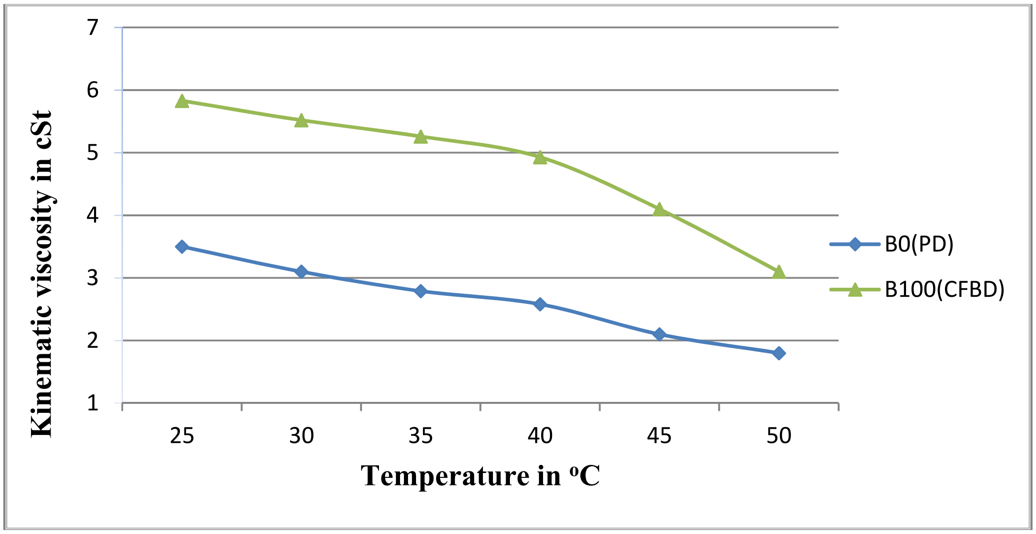

Figure-8. Variation of viscosity of fuel with temperature.

3.2.1 Cylinder pressure

The variation of cylinder pressure with crank angle for complete cycle at 3.72 kW power output for B0 (PD), B100 and B100PH fuels is shown in Figure-9. It is observed from the Figure that considerable difference in pressure variation is observed during combustion process only. Figure-10 shows rise of pressure during combustion process near to TDC i.e. 350°-450° crank angle at 3.72 kW power output. The peak pressures of B100 and B100PH fuels are slightly greater than B0 (PD). Peak pressure of fuels is decreased with preheating. The preheated fuels pressure variation curves observed very close to B0 (PD). This may be due to reduction of viscosity of preheated fuels behaving almost similar to B0 (PD). B100PH records slightly advanced pressure rise curves compared to B0 (PD).

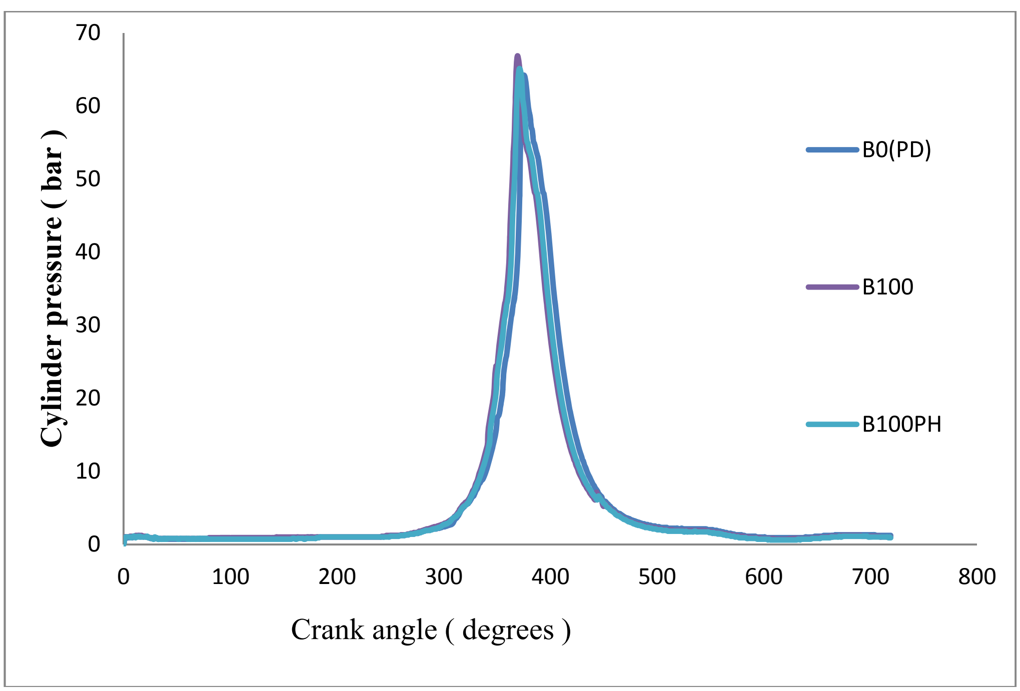

Figure-9. Variation of cylinder pressure with crank angle at 3.72 kW load.

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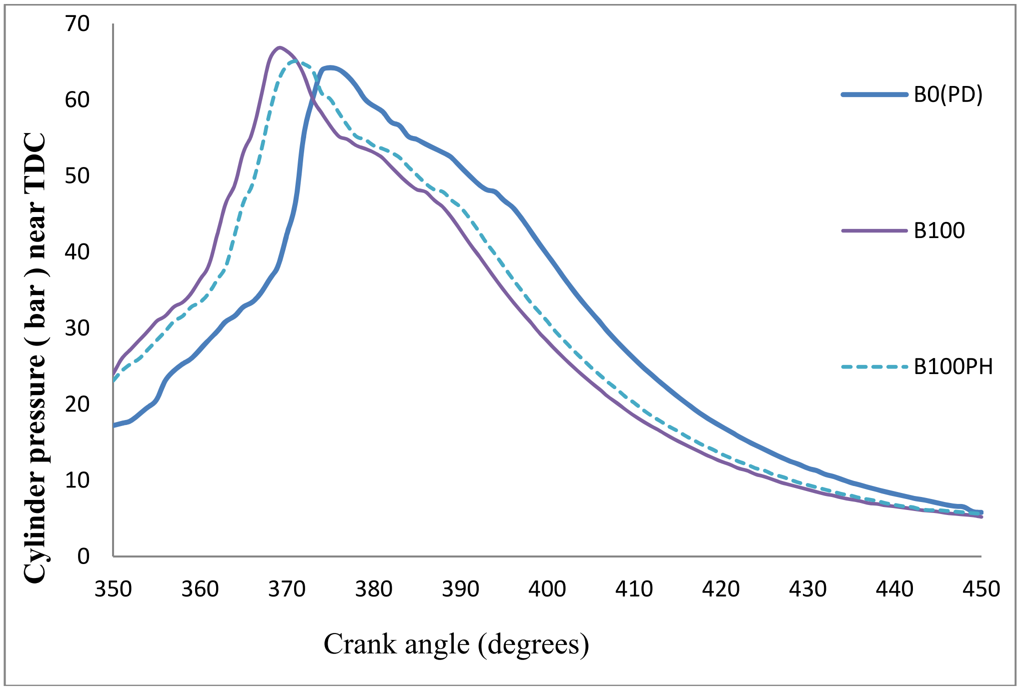

Figure-10. Variation of cylinder pressure near TDC with crank angle at 3.72 kW load.

Figure-11 shows the variation of cylinder peak pressure with engine load for all fuels. Cylinder peak pressure increases with engine load. Highest peak pressures are observed at full engine load for all fuels. Peak pressures are decreased with preheating for all loads. The peak pressures of B0 (PD), B100 and B100PH fuels at 3.72 kW engine load are measured as 64.7, 67.2 and 65.5 bar respectively. Attainment of peak pressure in terms of crank angle at 3.72 kW load for all fuels are shown in Figure-12. B0 (PD), B100 and B100PH fuels observe peak pressures at 375^o, 369^o and 371^o of crank angle at 3.72 kW engine load.

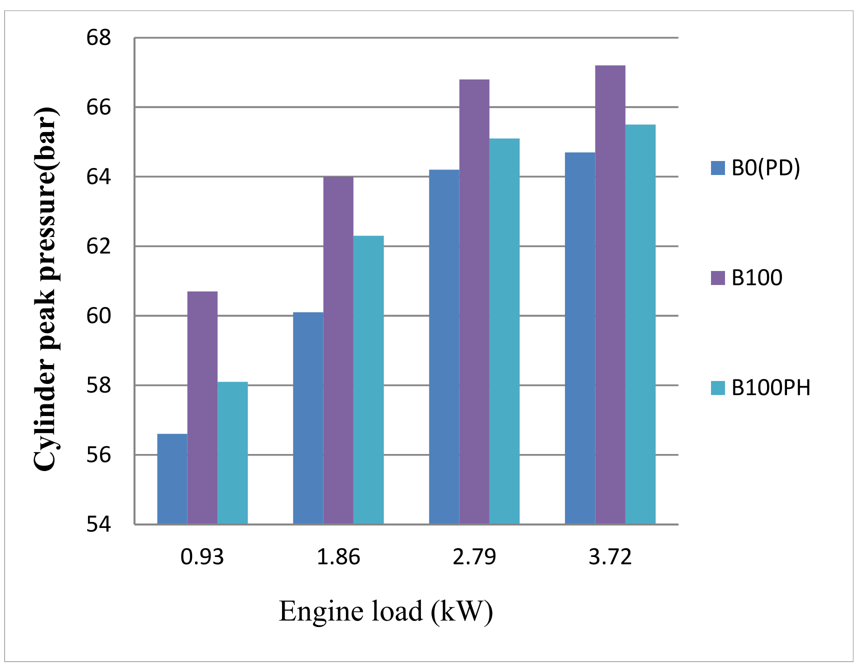

Figure-11. Variation of cylinder peak pressure with engine load (BP).

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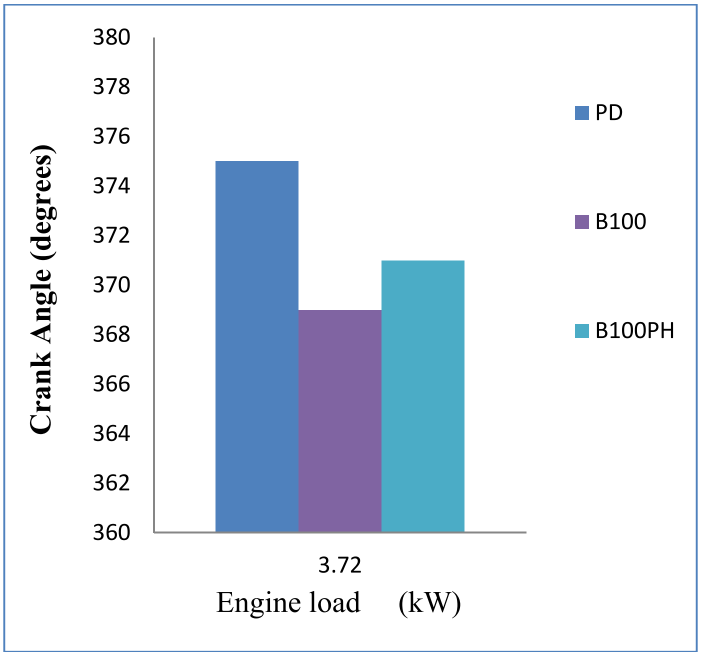

Figure-12. Attainment of peak pressure in terms of crank angle at 3.72 kW load.

3.2.2 Heat release rate

The rate of cooling water to be circulated for engine cooling depends on the rate of heat release during combustion. The variation of heat release rate with respect to crank angle at 3.72 kW engine power output for B0 (PD), B100 and B100PH fuels is shown in Figure-13. The cumulative heat release rate at 3.72 kW power output is shown in Figure-14. The area under this curve indicates the total net heat released during the combustion process. It is observed that heat release rate curves of preheated fuel B100PH is close to B0 (PD) fuel. This may be due to reduced viscosities of preheated fuels behaving similar to B0 (PD). Decreased premixed combustion and increased diffused combustion is observed with preheated fuel.

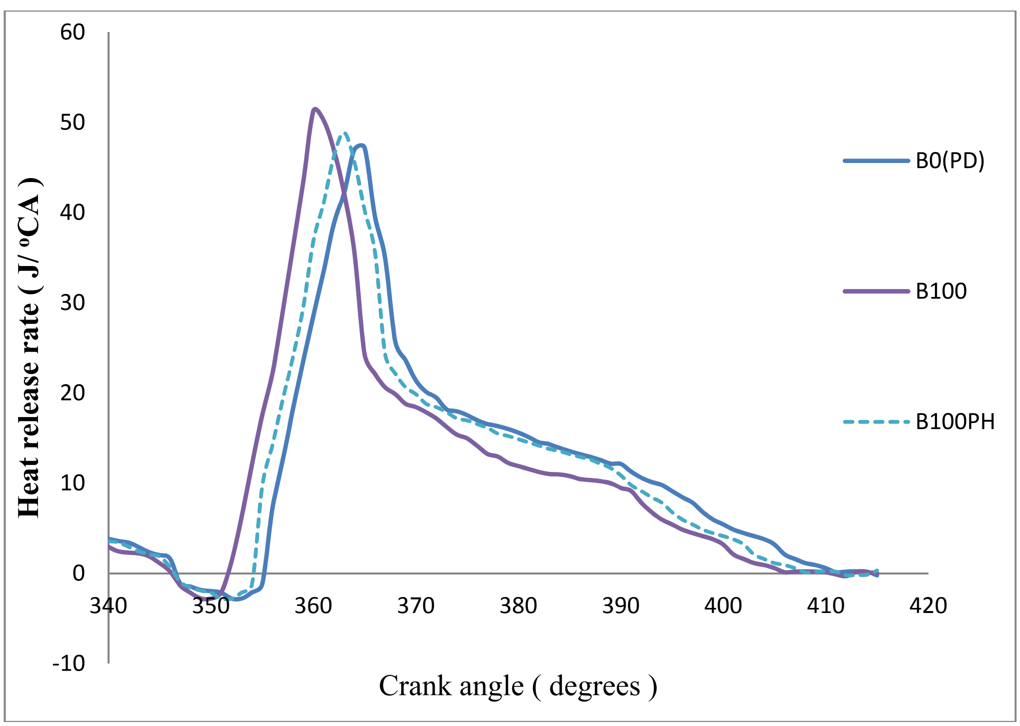

Figure-13. Variation of heat release rate with crank angle at 3.72 kW load.

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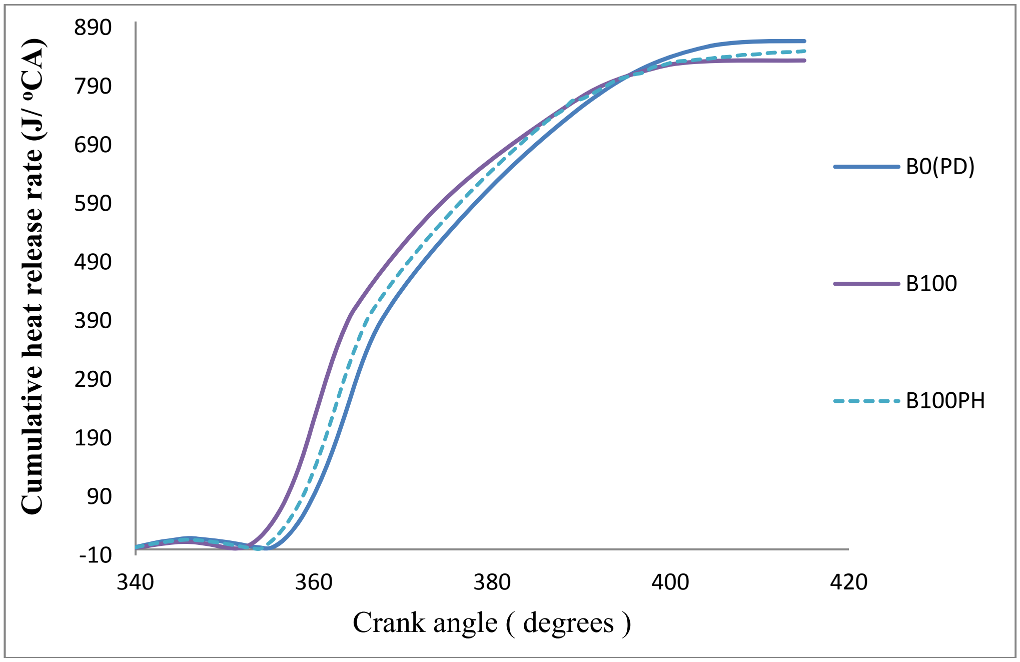

Figure-14. Variation of cumulative heat release rate with crank angle during combustion at 3.72 kW.

4. CONCLUSIONS

Biodiesel has higher viscosity, higher cetane number and lower compressibility as compared to the diesel fuel. These fuel properties have an impact on engine characteristics. The key findings of this article are as follows:

- Biodiesel and its blends have the shorter ignition delay compared to diesel fuel. The primary reason of shorter ignition delay of biodiesel is its lower compressibility, higher viscosity and cetane number.
- The HRR is more for biodiesel and its blends in premixed combustion and less in diffused combustion compared to diesel fuel. The cumulative heat released by biodiesel and its blends is lower compared to diesel because of lower calorific value of biodiesel
- The peak cylinder pressure of biodiesel fuel is higher than petroleum diesel due to early start of combustion, shorter delay period and more oxygen content of the biodiesel.
- Attainment of peak pressure was observed close to TDC for biodiesel and its blends compared to diesel fuel.
- All combustion characteristics of biodiesel with preheating are close to diesel. This is mainly due reduction of viscosity of these fuels leading similar behavior as diesel fuel.

ACKNOWLEDGEMENTS

The Authors thank the management of Sai Spurthi Institute of Technology, Sathupally, India, 507303, for providing necessary experimental facilities and support.

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