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Research Article

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Combustion characteristics of CI engine fuelled with Mahua oil methyl ester blends operating in part load condition at advanced injection timing

Vagesh Shangar R.* and Hariram V.

Department of Automobile Engineering, Hindustan Institute of Technology & Science, Hindustan University, Padur, Chennai, Tamil Nadu, India

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ABSTRACT

The usage of transesterified oil blends on various CI engine applications have proved successful where reduced emissions and better performance characteristics are noticed. The usage of edible oils for biodiesel production is a major disadvantage rising to food scarcity and hence the application of non edible oils has become the need of the hour. The monitoring of engine combustion characteristics is highly essential in order to understand the engine behaviour and effectiveness of the fuel powered. Adjustments of injection timing enable the improvement of performance and engine emissions. The current study evaluated the various combustion characteristics of CI engine fuelled with B10 and B20 blends of Mahua biodiesel blends which was processed from non edible Mahua oil by acid esterification followed by alkaline esterification. The experiments were carried on a single cylinder, direct injection 3.5kW CI engine running at constant speed of 1500 rpm. The combustion parameters like In cylinder pressure and heat release were evaluated at 50% engine loading because the diesel genset engines also run on part load conditions. The blends exhibited slightly increased delay period and reduced peak cylinder pressure compared to diesel. The peak heat release was also slightly less compared to diesel.

Keywords: Combustion, Injection timings, Mahua biodiesel blends, Part load operation

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INTRODUCTION

Compression ignition engines play a major role in the automotive and industrial economy where they find variety of applications in all kinds of automotives and gensets. Combustion studies of engine have gained prominence in the recent years it is an important factor in determining the development of the engine. The study of combustion characteristics involving the alternate fuels is essential in order to examine the fitness of the fuels in the engine [4,5,10].The combustion and performance characteristics were evaluated with varying injection timing on single cylinder diesel engine where on advancing the IT resulted in higher heat release rate in premixed combustion phase and the delay period was observed to be longer and this also promoted the phenomenon of knocking combustion where the rate of heat released was extremely higher.. The peak pressure was towards TDC when injection timing was retarded. Improvement on thermal efficiency and emission characteristics were observed when the start of injection was advanced [1].Camphor oil blends was fuelled in direct injection CI engine and the experimental investigations were evaluated where the 30% blend exhibited good performance compared to other fuel blends. The ignition delay of the camphor oil blends was found higher than diesel and the peak pressure of the blends were slightly less than that of diesel and also the peak pressure increased with increasing percentage of blends. The heat releases of camphor blend and diesel fuel were found quite similar and the increasing blend proved the advancement of the crank angle for the peak heat release [8].The combustion characteristics were evaluated using hazelnut kernel biodiesel on a direct injection CI engine at varying loading and varying injection pressures. The peak cylinder pressure was generally found higher for diesel fuel than the blends at all settings. The peak pressure was also found to be away from TDC on addition of blends which could have been due to the poor combustion and atomization. The peak pressure also increased with increasing engine loading and increasing compression ratio. The rate of pressure rise was found to be low for the biodiesel blends compared to diesel. The ignition delay reduced with increasing percentage of blends. Ignition delay increased with advanced injection timing due to higher heat release in the premixed phase and vice versa was observed on retarding IT[3].

Combustion of biofuels was observed on varying the injection timing at part load condition where the injection timing was adjusted by varying the shim thickness. The peak pressure reduced and moved away from TDC when the injection timing was retarded. High peak pressure was observed for advanced injection timings and was closer to TDC. Retarded injection timings considerably increased the exhaust gas temperatures [14, 15].Combustion characteristics were evaluated on a common rail diesel engine at part load conditions where the biodiesel blends shown good changes in BSFC at part loads than diesel. The brake thermal efficiency reduced for the blends at lower loads and it improved at higher loads. The peak cylinder pressure of the biodiesel blends was found to be lower compared to diesel which could be due to the lower calorific value of the blends [2]. Jatropha methyl ester was fuelled in CI engine and the combustion parameters were evaluated on varying the injection timing where the retarding of injection timing by 3° resulted in fruitful result of increase in brake thermal efficiency and the advancement of injection timing resulted in drop of BTE. The peak pressure increased with the advancement of injection timing and also it moved towards TDC [6].Mahua biodiesel blends was fuelled in CI engine and tested at all BMEP where it was observed that at part load conditions, the BTE was lower for the blends compared to diesel and at full load conditions, the BTE was higher for B20 blend compared to diesel. Similarly the BSEC of B20 was almost similar to diesel at full load conditions [11].In this study, the combustion parameters were evaluated for mahua biodiesel blends at 50% engine load. Piezo electric transducer was used for the combustion study and the In cylinder pressure was recorded and from the data other parameters like heat release were found out.

Nomenclature and Abbreviations	
ASTM	American Society of Testing materials
CI	Compression Ignition
CR	Compression ratio
IT	Injection Timing
B10	10% biodiesel and 90% diesel
B20	20% biodiesel and 80% diesel
ROPR	Rate of pressure rise
NHR	Net heat release
HRR	Heat release rate
CHR	Cumulative heat release
BTE	Brake Thermal efficiency
BMEP	Brake mean effective pressure
BSEC	Brake specific energy consumption
bTDC	Before Top dead center

2. Experiments and Procedure

The Mahua oil methyl ester processed by two step esterification process was blended with diesel on volume basis where B10 and B20 blends were prepared. The properties of the fuel blends can be referred from Table 1 where the density and viscosity increased with increasing biodiesel content in the diesel fuel. The calorific value of the blends was found to be slightly lower than diesel. The flash point was found to be higher than diesel. The FFA reduced drastically after the esterification process and was found similar to that of diesel. The cetane number of the blends shown a slight reduction compared to diesel. The engine experimentation was done on Kirloskar make TV1 model which rates 3.5kW @ 1500 rpm with the displacement of 661 cc. The CR is 17.5 and the injection timing can be varied from 0° to 25° bTDC. Load can be applied with the help of eddy current dynamometer and load range of 0 to 12 kg can be applied. Combustion characteristics can be studied by piezoelectric sensor and the data acquisition system with CPU interfacing enables to read and process the data. The detailed specification of the engine set up can be viewed from the Table 2.

Table 1.Properties of fuel blends

Fuel Properties	ASTM Standard	Straight Diesel	B10	B20
Density at 15°C (Kg/m³)	860-900	836	843	847
Kinematic viscosity at 40°c(mm^2/s)	860-900	3.0	3.12	3.16
Calorific value (MJ/Kg)	1.9-6.0	44.8	43.3	42.3
Flash point (°c)	min 130	69	77	90
Acid value, mg KOH	<0.8	0.33	0.38	0.41
Cetane index	-	52	50	50

Table 2. Engine Specifications

Engine Parameters	Specifications
Make and Model	Kirloskar TV1 oil engines
Type	Single cylinder /4 stroke
Bore/Stroke	87.5mm/110mm
Rated Power	3.5kW @1500 rpm
Compression ratio	17.5:1
Injection Timing	23° bTDC
Loading type	SAJ Eddy current dynamometer
Piezo electric sensor	PCB Piezotronics make SM111A22
Piezo sensor range	5000 psi
Crank angle sensor	Kubler make model 8.3700
Data Acquisition device	NI USB 6210 M series
Engine control unit	PE 3 series ECU

RESULTS AND DISCUSSION

3.1 Brake Thermal Efficiency

The influence of injection timing on the brake thermal efficiency can be viewed from Figure 1 for diesel and mahua methyl ester blends where the advancement of injection timing showed slight increase in brake thermal efficiency which may be due to the fact that advanced injection timing provided better combustion giving sufficient time for the mixture formation. It could also be referred that the BTE reduced with increasing amount of biodiesel. The BTE increased by around 2.5% when the spill timing was advanced. At standard setting, the BTE of blend reduced by around 2% compared to diesel and at advanced setting, this reduction was around 3%.The reduced BTE of the blends in comparison to diesel over the varying settings couldbe due to the lower heating value of the blends and poor mixture formation at part load conditions [12].

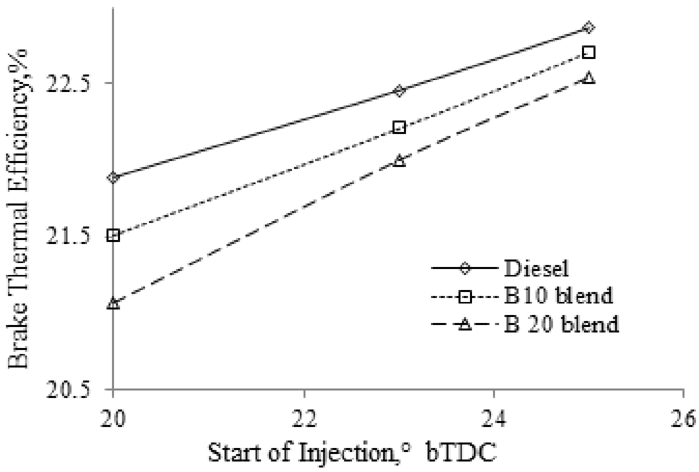

Figure 1. Brake thermal efficiency of biodiesel blends at varying IT

3.2 Cylinder Pressure and Rate of pressure rise

The variation of In-cylinder pressure at standard setting of 23° bTDC and advanced injection timing of 25° bTDC can be referred from Figure 2 and4. At injection timing of 23° bTDC, the ignition delay was found to be about 17°

for diesel and it increased with the increasing content of biodiesel where the delay period was observed to be 17.5° and 18° for B10 and B20 blends. The slight reduction of cetane number of the blends could be the reason for the increased delay period of the blends. Effective combustion took place during the premixed phase of combustion than the diffusion phase [7].During the advanced injection timing of 25° bTDC, the delay period was found to be further higher for all the fuels tested compared to the standard timing. The peak pressure of diesel at standard timing was about 66.3 bar where as it reduced slightly for the blends and it was 65.4 bar and 64.3 bar respectively for B10 and B20 blends. At advanced injection timing, the peak pressure increased due to the better mixture formation [9,13] and it was found to be 67.1 bar for diesel and 65.9 bar and 65.3 bar for B10 and B20 blends respectively.

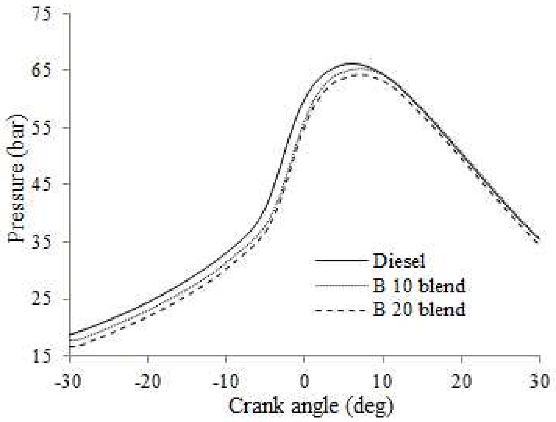

Figure 2. Pressure crank angle at 23°C bTDC

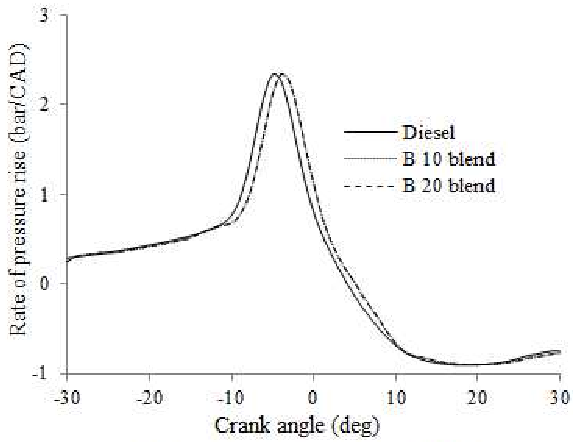

Figure 3. Rate of Pressure rise at 23°C bTDC

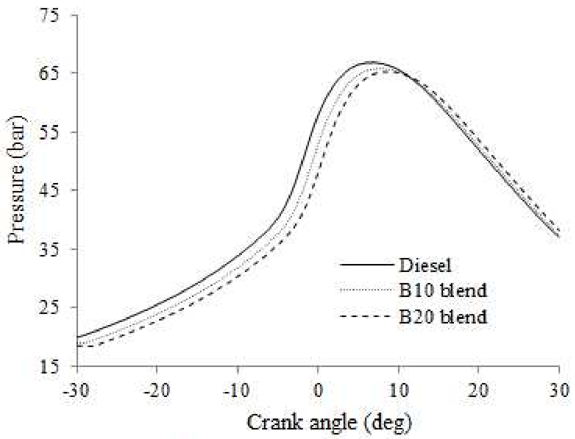

Figure 4. Pressure crank angle at 25°C bTDC

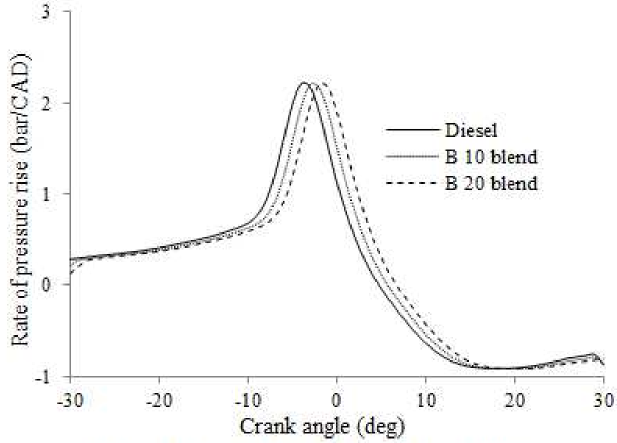

Figure 5. Rate of Pressure rise at 25°C bTDC

The peak pressure slightly moved away from Top dead centre with the addition of blends. The variation in delay period and maximum pressure can be seen from Figure 6 and 7 where during the retarded timing, the peak pressure was low compared to straight diesel and the delay period was also less. The ROPR variation is shown in Figure 3 and 5 where the maximum ROPR shifted away from TDC on advancement of Injection timing. Also it is to be noted that the maximum ROPR moved away from TDC with increasing blend percentage.

3.3 Variation in Heat release

The Net heat release variation for diesel and methyl ester blends are shown in Figure 8 and 9 where at standard timing, the maximum heat release rate was 41.3J/CA for diesel. The Net heat release decreased with increasing biodiesel concentration which could be due to the slightly lower calorific value of the blends, where it reduced slightly to 40.4J/CA and 39.3J/CA for B10 and B20 blends. The peak HRR also moved away from TDC with increasing blend proportions. At advanced injection timing, the magnitude of heat release was slightly high compared to the normal injection timing. About 42.2J/CA was observed for diesel at advanced setting and for the

B10 and B20 blends, it was 41J/CA and 39.5J/CA.The occurrence of peak heat release was observed to be more away from TDC compared to normal injection timing.

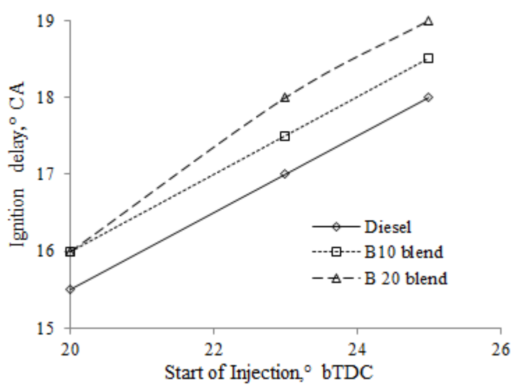

Figure 6. Ignition delay for blends at various IT

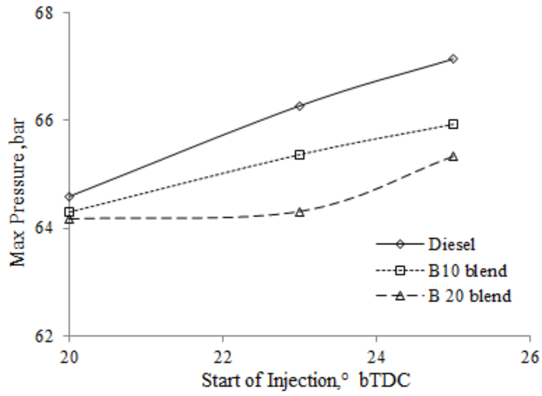

Figure 7. Peak Pressure for blends at various IT

The cumulative heat release rate was found to be slightly higher at advanced injection timing for all the fuels and on comparing diesel with the blends, the CHR of the blends was found to be slightly lower than the diesel at both the injection settings.

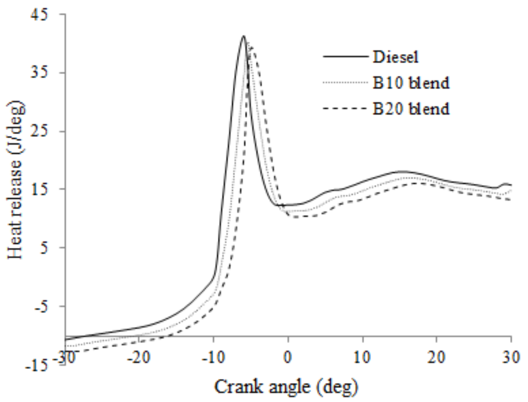

Figure 8. Net heat release at 23°bTDC

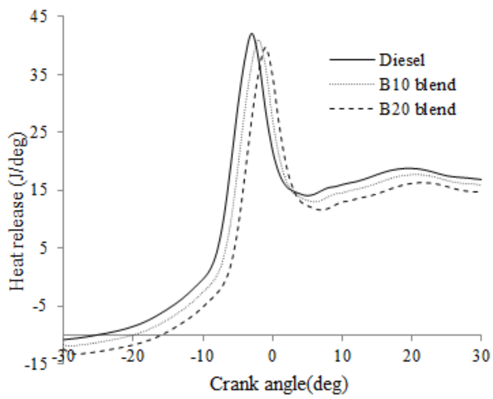

Figure 9. Net heat release at 25°bTDC

CONCLUSION

The combustion parameters were studied using mahua biodiesel blends at 50% engine loading at the standard setting and advanced injection timing where the advanced IT setting in general exhibited better performance characteristics. The BTE increased by 2.5% when the injection timing was advanced and it reduced to around 3% with the application of blend. The ignition delay was found high for B20 blend at advanced injection timing which was around 19° and the peak pressure was high at advanced IT for diesel which was about 67.2 bar and reduced slightly with the addition of blends and moved away from TDC. Low peak pressure of 64.3 bar was observed for B20 blend at standard timing. High NHR was observed for diesel at 25° bTDC timing of 42.2 J/CA and it reduced with the blends. Low heat release was observed for B20 blend of about 39.3 J/CA. The cumulative heat release was slightly low for biodiesel blends compared to diesel.

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