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Effect of Injection Timing on Characteristics of Polanga Oil Methyl Ester Fuelled Direct Injection CI Engine

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Abstract:-Fuel injection timing is one of the most important parameters which affect the engine performance and emission characteristics for a conventional diesel engine (CDE). The present study objective is to investigate the effect of fuel injection timing(FIT) on the performance, emission and combustion characteristics of neat Polanga biodiesel i.e. Polanga oil methyl ester (PME) fuelled direct injection (DI) compression ignition(CI) engine and compared the results with base line data of diesel engine. This study evaluated that PME fuel showed better performance and emission characteristics at advanced injection timing among the selected fuel injection timings and the most better values obtained at 80% of full load.

***Key-Words:* -CDE, CI,** DI, FIT, PME

1 Introduction

Energy is an essential input for human being to develop in economical, social, and improving the quality of life. Energy demand is also growing at a faster rate with increasing trends of modernization and industrialization, and turned to focus on alternative fuels. Moreover, the availability of fossil resources diminished by day to day which drives to study on conventional diesel engine with the use of alternative fuels. For the past few decades, efforts have been made to commercialize various alternative fuels such as vegetable oil(soya bean oil , rapeseed oil, palm oil, sunflower oil, karanja, jatropha, polanga, rice bran, Moringa oleifera ,Uppage etc.), animal fat(beef tallow etc.),alcohol(Methanol, Ethanol), compressed natural gas, biogas, liquid petroleum gas, hydrogen.

Using of Vegetable oils in diesel engines is not a new concept. In 1900, 'Rudolf Diesel' demonstrated his first diesel engine run with peanut oil as fuel at the World Exhibition at Paris. However, due to enormous availability of petro-diesel, research activities on vegetable oil were not seriously pursued. Directly using of vegetable oils as fuel to run diesel engine is made a serious problems such as choking of injector, carbon deposits inside the cylinder more unburnt HC emissions due to its high viscosity. Hence it becomes necessary to convert the vegetable oils as methyl esters or ethyl esters to ensure the standards of ASTM protocol as fuel in diesel engine. Biodiesel fuel is an alternative, renewable, biodegradable, nonflammable, non toxic green fuel. The common edible oils of biodiesel are palm oil, coconut oil, sunflower oil, and peanut oil etc., where as Jatropha, Neem, Karanja, Rubber, Rice bran, Mahua, Moringa oleifera Polanga, Uppage etc. are the non-edible oil sources of biodiesel. Biodiesel is a renewable feed stock and as for as environmental concern it is clean burning free sulfur fuel.

2 Literature Review

Most of the researchers have reported that the performance of biodiesel fuelled diesel engine is poor than petro-diesel operated engine. Interestingly, some of the researchers have reported that thermal efficiency is higher with biodiesel than diesel fuel [1]. Some of the investigations showed that lower HC, CO and particulate matter emissions, but higher NOx emission for biodiesel [16, 17]. The biodiesel operation reduces the harmful emissions viz., CO, HC and smoke but with little increment of NOx emissions relative to diesel fuel [2]. The biodiesel blends and neat biodiesel in diesel engine reduces carbon monoxides about 3-15% [3] unburnt hydrocarbons about 6-40% [4] and smoke density to 45% [5] compared to ULSD (ultra low sulfur diesel). However, NOx increased up to 26% [6], BSFC increased by 6-15% [7] decreases in brake thermal efficiency up to 9% [8]. Fujia Wu et al. [9] reported that the NOx reduced in descending order are: CME, PME, SME, WME, and RME; PM emissions reduction varies from 53%-69%. Sahoo et al. [10] concluded that 50% jatropha biodiesel blend showed maximum power with less smoke amongst all the biodiesels and their blends than diesel. Agarwal et al.[11] reported that the rice bran biodiesel fuelled engines produce less CO, unburned HC, and PM emissions compared to diesel fuel but higher NOx emissions. Palash et al. [12] observed that biodiesel blends have strong beneficial impacts on HC, CO and PM emissions but adverse effects on NOx emissions. Similar trends have also been reported by other researchers [13, 14]. Avinash et al. [15] observed that Calophyllum Inophyllum (polanga) biodiesel and additives showed BTE increased and lower in BSFC than diesel. As retardation of injection timing reduces the peak cylinder pressure which results in lower peak cylinder temperatures, consequently NOX emissions lessen [18]. In contrast, advanced injection timing decreases CO and HC emissions. Zeng et al. [19] observed that the volumetric efficiency decreases with advanced injection timing.

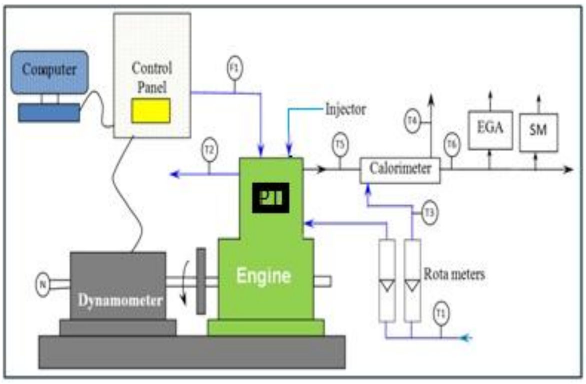
Table 1. Important Properties of Fuels

Property	HD	PME
Density@15^{o}C-kg/m3	840	870
LHV - MJ/kg	43.0	39.994
Kinematic Viscosity@40^{o}C– cSt	2.5	4.35
Cetane Number	48	55

3 Materials and Methods

Test Fuels

The test fuel sample in the present study has chosen as neat PME and compared the results with HD fuel normal engine operation. The polanga seed oil is one of the most suitable feedstock among the non edible feed stocks in India. Some of the important properties of neat PME and high speed diesel (HD) fuel are given in Table 1.



T1, T3-Water inlet Temperature
T4-Calorimeter exit temp.
T2-Engine water jacket outlet
T6- EGT after Calorimeter
PT- Pressure transducer
EGA-Exhaust gas analyzer
N-RPM encoder

Fig. 1 Schematic view of Engine Test Setup

4 Test Setup and Method

Experimental set up is shown in Fig.1. The Test setup engine equipped with eddy current type dynamometer for loading and specifications of test engine is shown in table 2. The setup equipped with the necessary arrangements to measure in cylinder pressure and crank-angle etc. The performance parameters like BP, BTE and BSEC can be evaluated by measuring the observations viz., speed and load on the engine, rate of fuel consumption, and airflow rate, with suitable instruments provided on the engine setup. The emissions directly measured with exhaust gas analyzer and Hartridge Smoke Meter. Each test conducted on engine after attaining steady condition only.

Table 2

Specifications of Test Engine

Type	Kirloskar, TV1,1 cylinder, 4-s, DI diesel engine
Injection pressure	200 bar
Rated power	5.2 KW (7 HP) @1500 RPM
Cylinder Bore	87.5 mm
Stroke length	110 mm
Compression ratio	17.5 : 1
Standard Injection Timing	23° bTDC

4 Results & Discussion

4.1 BTE

The Fig.2 shows the variation of BTE with FIT (fuel injection timing) for PME. At 80% load the BTE of PME is observed to be 24.4%, 25.4%, 25.85% and 25.2% at FITs 20° bTDC, 23° bTDC, 26° bTDC and 29° bTDC respectively where as it is 30.25% for HD fuel at normal operation. With advancing in the injection timing by 3°CA lead to better improvement in BTE when compared to other FITs for PME. The highest BTE for PME is found to be 25.85% at an injection timing of 26°bTDC, at 80% load.

4.2 BSEC

The Fig.3 shows the BSEC versus FIT (fuel injection timing) for PME. At 80% load, the BSEC of PME is noted as 14.75, 14.75, 13.93 and 14.29 MJ/kg-h at 20, 23, 26 and 29°bTDC respectively where as it is 11.9 MJ/kg-h for HD fuel normal engine operation. With advancing in the injection timing by 3°CA showed better improvement in BSEC due to it had sufficient time for better mixture formation thereby the required fuel amount reduced for the same power developed for PME operation but higher than HD fuel. The lowest BTE is observed for PME at an injection timing of 26°bTDC, and it is found to be 13.93 MJ/kg-h which is best value among all injection timing BTE values.

4.3 Carbon Monoxide (CO)

From the Fig. 4,the CO emission is decreased by 14.16%, 34%, 44% and 39% for PME at injection timings 20° bTDC, 23° bTDC, 26° bTDC and 29° bTDC respectively, when compared to HD fuel operation. It is noted that CO emission increased by retarded injection timing while decreased by advanced injection timing when compared to standard injection timing operation. At 80% load the lowest CO emission is observed at 26°bTDC for PME fuel operation as 0.06%v where as it is 0.1% v for diesel. The CO emission values obtained for PME fuel as 0.09%v, 0.06%v and 0.07%v, at 20°bTDC, 23°bTDC, and 29°bTDC respectively, at 80% load.

4.4 Hydro Carbon (HC)

From the Fig.5, it is noted that HC emission increased with retarding injection timing while decreased with advanced injection timing when compared to standard injection timing operation. It is seen that the lowest HC emission for PME fuel with the best injection timing as 26°bTDC amongst all injection timings. The lowest HC emission value is noticed as 23ppm at 26°bTDC for PME fuel operation, at 80% of full load. The HC values at 20°bTDC, 23°bTDC, and 29°bTDC as 30ppm, 28ppm and 26ppm respectively, for PME fuel, where as it is 40ppm for HD fuel at 80% of full load.

4.5 NOx Emission

From the Fig.6 the NOx emission level increased with advanced injection timing as it is expected due to more fuel burned during premixed combustion while NOx decreased with retarded injection timing most of the fuel burning during expansion stroke resulting in low cylinder temperature when compared to standard injection timing. At 80% of full load the NOx emission levels for PME are found to be 1037ppm, 1121ppm, 1130ppm and 1104ppm at 20° bTDC, 23° bTDC, 26° bTDC and 29° bTDC respectively, where as it is 1080ppm for diesel normal operation. The similar trend of results reported for advanced and retarded injection timing in the literature published [224].

4.6 Smoke Emission

The Fig.8 shows smoke opacity variation for different injection timings. The smoke density increases as the load increases due to lower excess air ratio (rich mixture) at higher load operating condition. The lowest smoke opacity is observed for PME operation at 26°bTDC when compared to amongst fuel injection timings selected. Smoke levels of PME fuel operation (at 80% of full load) for 20°bTDC , 23°bTDC , 26°bTDC and 29°bTDC are found to be 41HSU,34HSU, 30HSU, and

37HSU,respectively,whereas smoke opacity is 46HSU for diesel fuel(HD) normal operation.

4.7 Combustion Analysis

The peak HRR variation with load for PME fuel at different injection timing and the heat release rate variation with respect to crank angle degree (340-380^{o}) at 80% of full load are depicted in Fig.9 and Fig.10 respectively. It is observed from the Fig.9 that peak HRR values linearly increased with load for PME as well as HD fuel. The Fig10 shows the maximum HRR value increased with advanced injection timing due to increased ignition delay while it is decreased with retarded injection timing due to reduced ignition delay. And also it is observed that the lowest peak HRR values at 20^{o} bTDC and the highest values at 26^{o} bTDC which is best injection timing for PME. At 80% load the peak HRR values are observed to be 58 J/^{o}CA, 65 J/^{o}CA, 68.03 J/^{o}CA, and 65.87 J/^{o}CA, for injection timings 20°bTDC, 23°bTDC, 26°bTDC and 29°bTDC respectively, for PME fuel operation where as it is 79.09 J/^{o}CA for HD fuel normal operation.

Fig.11 shows the PCP is lowest at 20^{o} bTDC and the maximum values obtained at 26^{o} bTDC which is considered as best injection timing. At 80% of full load the peak cylinder pressure values for PME fuel operation are observed to be 55bar, 56.6bar, 57.84 bar, and 56 bar for injection timings of 20°bTDC , 23°bTDC , 26°bTDC and 29°bTDC respectively, where as it is 65 bar for HD fuel normal engine operation. The Fig.12 shows Cylinder Pressure versus CA for different injection timings for PME fuel and diesel fuel at standard injection timing, at 80% load operation.

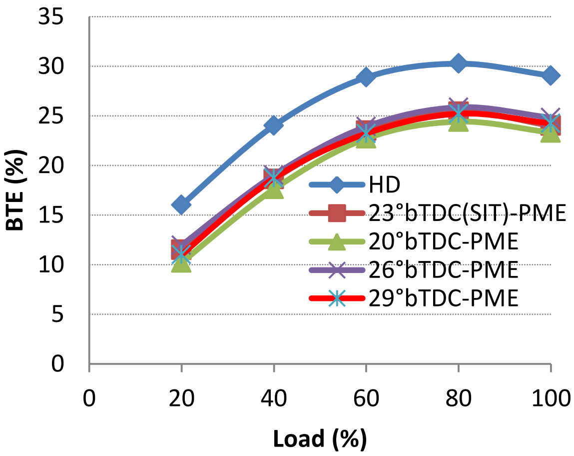


Fig.2 BTE vs. load for different FITs for PME fuel

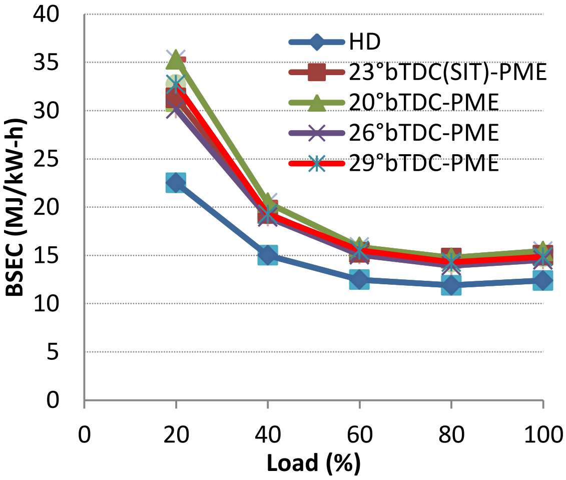


Fig.3 BSEC variation for different FITs for PME

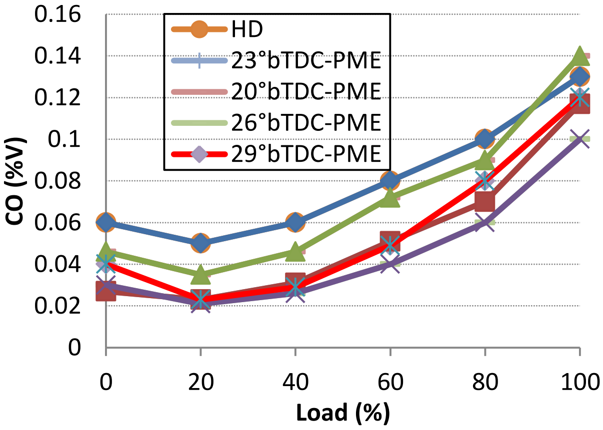


Fig.4 Variation of CO for different FITs for PME fuel

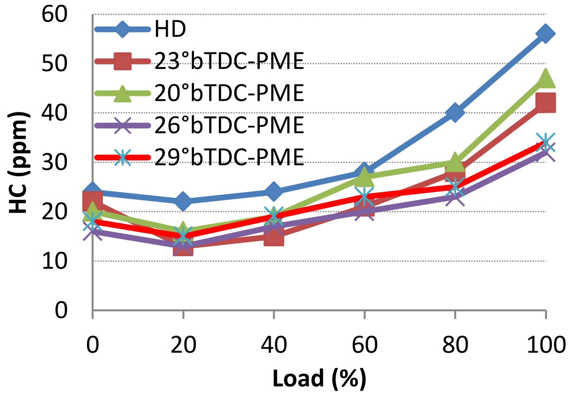


Fig.5 Variation of HC for different FITs for PME fuel

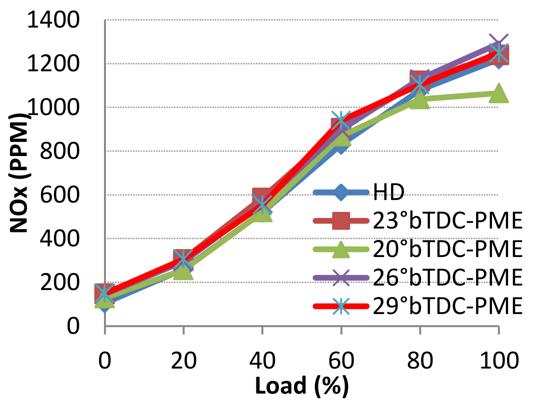


Fig.6. Variation of NOx for different FITs for PME

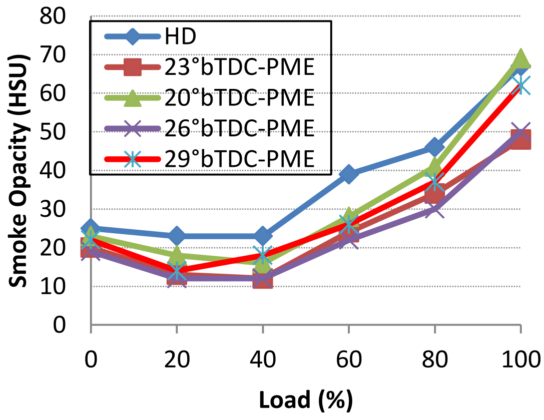


Fig.7 Variation of smoke for different FITs for PME

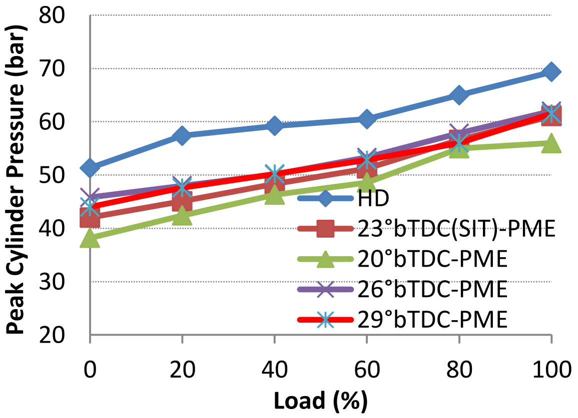


Fig.8 Peak HRR for different FITs for PME

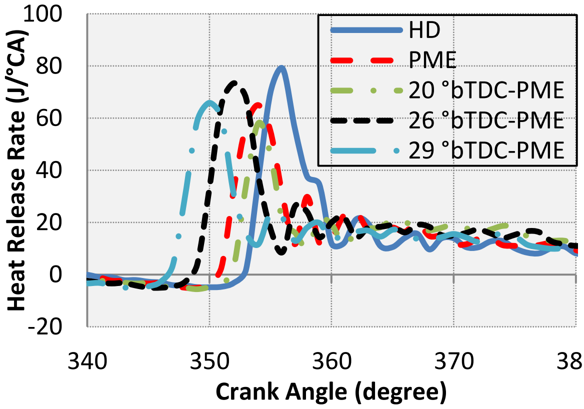


Fig.9 HRR vs. CA for different FIPs for PME at 80% load

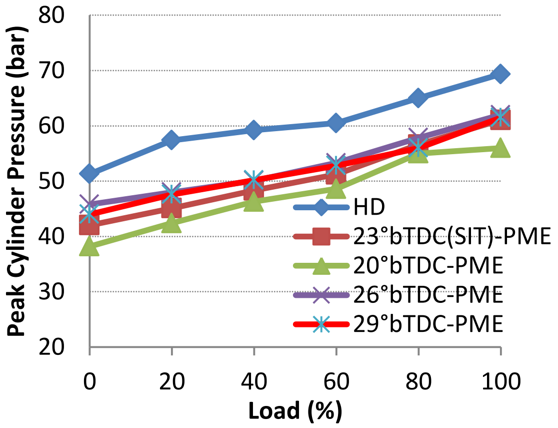


Fig.10 Variation of Peak CP for different FITs for PME

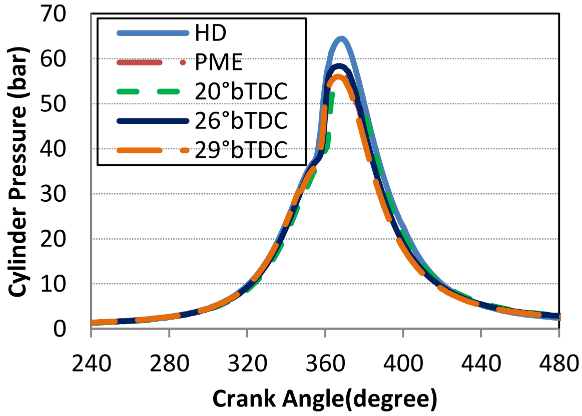


Fig.11 CP vs.CA for various FITs for PME at 80% load

5 Conclusions

At the injection timing of 26^{o} CA bTDC the test engine has showed overall best results, amongst the selected FIPs for PME when compared to HD fuel at 80% of full load and the results shown below.

- The BTE is about 25.85% and it is lowered about 4.41%than HD fuel.
- The BSEC is 13.93MJ/kW-h and it is higher 2.02 MJ/kW-h than HD fuel.
- The HC emission is noted as 23 ppm and reduction is about 40%.
- The CO emission is found to be 0.06%vol. and it is lowered by about 48%.
- The NOx emission is identified as1130ppm and increased by about 2.2%.
- The smoke emission is about 30 HSU and it is lowered by about 34.78%.
- The peak cylinder pressure (PCP) is 57.84bar and decreased by about 11.4%.
- The peak HRR is found to be about 68.03J/^{o}CA and decreased by about 13.98%.

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