ISSN: XXXX-XXXX
Volume (01) _Issue (02)

International Journal of Engineering Technology Research & Management

EFFECT OF FUEL INJECTION PRESSURE ON CHARACTERISTICS OF POLANGA OIL METHYL ESTER FUELLED DIRECT INJECTION CI ENGINE

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ABSTRACT

Fuel injection pressure is one of the most important parameters which affect the engine performance and emission characteristics for a conventional fuel mode (CFM) diesel engine. The present study objective is to investigate the effect of fuel injection pressure (FIP) at the range of 200-240bar on the performance, emission and combustion characteristics of neat Polanga biodiesel i.e. Polanga oil methyl ester (PME) fuelled direct injection compression ignition (DICI) engine and compared the results with base line data of CI diesel engine. This study evaluated that PME fuel showed better performance and emission characteristics at 230bar injection pressure among the selected fuel injection pressures and the most better values obtained at 80% of full load.

Keywords:
CFM, DICI, FIP, PME

INTRODUCTION

Energy is need for improving the quality of life of human being. The trend of Energy demand is also growing speedily with of modernization and industrialization which 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.

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. Jaichandar et.al [18]showed that improvement in BTE, BSFC and

substantial improvements in reduction of emissions for TRCC operated at higher injection pressure by improved combustion, due to better air motion inside the cylinder and high pressure injection, increased the oxides of nitrogen (NOx).Increasing injection pressure decreased ignition delay, and increased peak in-cylinder pressure and maximum HRR. Metin Gumuset.al[19] observed in his study at four different fuel injection pressures (18, 20, 22, and 24 MPa) BSFC, CO_2, NOx and O_2 emission increased, smoke ,HC and CO emissions decreased with low injection pressures where as these values decreased with increased injection.

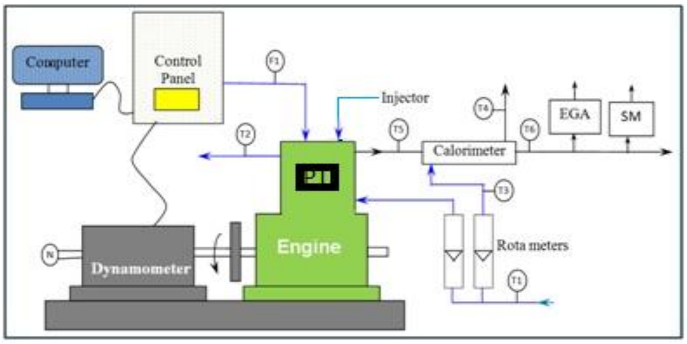
MATERIAL & METHODS

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.

Table 1. Important Properties of Fuels

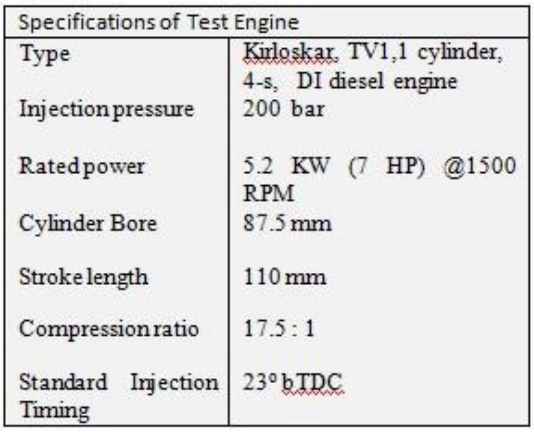
Property	HD	PME
Density@15°C-kg/m3	840	870
LHV - MJ/kg	43.0	39.994
Kinematic Viscosity@40°C– cSt	2.5	4.35
Cetane Number	48	55



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

Fig. 1 Schematic view of Engine Test Setup

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

TEST SETUP & METHOD

The Test setup engine equipped with eddy current type dynamometer for loading and specifications of test engine is shown in table 2. Experimental set up is shown in Fig.1. 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.

RESULTS & DISCUSSION

Brake thermal efficiency

Normally, the higher viscosity of biodiesel prompts them to be injected at higher injector opening pressure as compared to diesel [23]. The effects of FIP on brake thermal efficiency for PME at different loads are shown in Fig. 4.2. The highest BTE is observed at 230bar for PME amongst all FIPs tested due to improved atomization of fuel, better spray characteristics and good mixture formation with air at higher injection pressure that leads to improve the combustion. It is also observed that, too high FIP (260 bar) leads to delayed injection negating the gain due to higher fuel injection pressures [24]. At 230bar FIP the BTE is observed to be higher value amongst all the FIPs tested. The BTE values for PME are obtained as 25.85%, 26.06%, 26.4%, 26.9% and 26% at 200bar, 210bar, 220bar, 230bar and 240bar respectively where as it is 30.25% for HD fuel at manufacturer set standard injection pressure and standard injection time (SIP, SIT) at 80% of full load. From this investigation it can be found that the brake thermal efficiency increases from 25.85% to 26.9% when the FIP is increased from 200bar to 240bar at 80% of full load.

Brake specific energy consumption (BSEC)

The effects of FIP on brake specific energy consumption for PME at different loads are shown in Fig.4.3. The lowest BSEC is observed at 230bar for PME amongst all FIPs tested due to improved atomization of fuel, better spray characteristics and mixture formation with air at higher injection pressure that resulted in improved combustion. It is also observed that, too high FIP (above 240 bar) lead to delayed injection negating the gain due to higher fuel injection pressures [24]. The BSEC observed to be the lowest at FIP of 230bar as optimum injection pressure correspondingly with higher BTE obtained. The BSEC values for PME are obtained as 13.93 MJ/kW-h, 13.814 MJ/kW-h, 13.64 MJ/kW-h, 13.38 MJ/kW-h and 13.85 MJ/kW-h at 200bar, 210bar, 220bar, 230bar and 240bar respectively where as it is 11.9MJ/kW-h for HD fuel at manufacturer set injection pressure and time, at 80% of full load.

HC emission

Fig. 4.4 shows the effect of FIP on HC emissions. Normally, the HC emissions are reduced upto medium loads and then increased upto high loads because of low gas temperature and slower chemical reaction rate leads to higher HC emissions in the exhaust at low loads and low volumetric efficiency leads to high emissions at higher loads. Because of better combustion for PME fuel a significant drop in HC emission is observed at 230bar FIP. The improved atomization leads to a reduced ignition delay thereby better premixed combustion that has enhanced engine performance with PME. Increased FIP well atomizes the viscous biodiesel that enables it to mix appropriately with air and this could be cause for the reduced HC emission level. This is facilitated by the increased thermal efficiency and wall wetting phenomenon [22]. From the figure the HC values for PME are obtained as 23ppm, 24ppm, 22ppm, 21ppm and 25ppm at 200bar, 210bar, 220bar, 230bar and 240bar respectively where as it is 40 ppm for HD fuel at manufacturer set injection pressure and injection time, at 80% of full load. HC reduced from 28ppm to 21ppm for PME with the increased FIP from 200bar to 240bar at 80% of full load. Many researchers have found in their investigation that very high FIP leads to a considerable amount of portion of combustion occurring in diffusion phase on account of shorter ignition delay [24] while too high FIP lead to delay in injection negating gain due to higher FIP. Due to sluggish combustion of PME fuel at lower FIPs will lead to increased exhaust gas temperature. With Sluggish combustion of biodiesel, i.e. low heat release rates are observed in the case of the FIP of 200bar.

CO emission

Fig.4.5 shows the effect of IOP on CO emission for PME fuel. The trend of CO emission variations is observed to be similar to that of HC emissions, with the lowest CO emission noted at 230bar fuel injection opening pressure. CO emission at 230bar FIP is found to be 0.07%volume for PME fuel operation. The CO emission is mainly dependent upon cylinder temperature, oxygen availability and resident time for reaction. CO emission is reduced with the increasing of fuel opening injection pressure but for too FIP (240bar) may be negated the gain of reduction due to poor combustion of fuel. From Fig.5.24 the CO values for PME are found to be 0.07 vol., 0.06 vol., 0.06 vol., 0.05 vol. and 0.08%vol. at 200bar, 210bar, 220bar, 230bar and 240bar respectively where as it is 0.1%vol. for HD fuel at manufacturer set injection pressure and injection time, at 80% of full load. CO is reduced from 0.07%vol. to 0.05%vol. for PME with the increased FIP from 200bar to 230bar at 80% of full load.

NOx emission

Nitric oxide emission is formed at higher engine cylinder temperature during combustion. NOx emission increased with the increase in FIP due to faster combustion and higher temperatures reached in the cycle as shown in Fig. 4.6. As FIP increases the NOx emission increased considerably. The reason for higher NOx emissions with higher FIP due to better combustion prevailing in the combustion chamber of engine cylinder and more heat released during premixed combustion [24]. NOx emissions at 230bar are found to be higher for PME operations amongst all the FIPs. From this figure the NOx emission levels for PME are obtained as 130ppm,1140ppm,1159ppm,1164ppm and 1136 at 200bar, 210bar, 220bar, 230bar and 240bar respectively where as it is 1080ppm for HD fuel at manufacturer set injection pressure and injection time, at 80% of full load.

Smoke emission

Fig. 4.7 shows the effect of FIP on smoke opacity. It is observed that the Smoke levels decreases with increase in the FIP due to improved mixture formation that resulted from a well-atomized spray. The smoke emission decreases with increasing FIP upto 230bar and then increases at 240bar FIP. The lowest smoke opacity is observed at 230bar. From the Figure the Smoke Opacity values for PME at 26^{o}bTDC are obtained as 30HSU, 27HSU, 26HSU, 24HSU and 31HSU at 200bar, 210bar, 220bar, 230bar and 240bar respectively where as it is 46HSU for HD fuel at manufacturer set injection pressure, injection time, at 80% of full load. Smoke is reduced in the range of 30HSU to 24HSU for PME fuel with the increased FIP from 200bar to 240bar at 80% of full load. As the injection pressure rises, the fuel particle diameters will be reduced to smaller. As a result, fuel–air mixture will become better during the ignition period, and so smoke opacity will be less [21].

Combustion analysis

Fig.4.8 reveals that the HRR variations are linearly with static fuel injection pressure (FIP) as well as with load. It can be found that the peak heat release rate of PME fuel is always lower than high speed diesel fuel operation. It is evident from the Fig.4.9 that higher premixed heat release with the enhanced FIP due to better fuel atomization of biodiesel. 230bar FIP showed a significant improvement in combustion. From the Fig.4.9 the peak HRR values for PME at 26^{o}bTDC are obtained as 68.03J/^{o}CA, 70 J/^{o}CA, 71.01 J/^{o}CA, 73.4 J/^{o}CA and 70.08 J/^{o}CA at 200bar, 210bar, 220bar, 230bar and 240bar respectively where as it is 79.09 J/^{o}CA for HD fuel at 80% of full load. The similar results are reported in the literature [20].

Fig.4.10 the maximum PCP is identified at 230bar FIP for PME. It can be noted that at 230bar FIP the peak cylinder pressure is higher than that of other FIPs tested at 80% of load. From the Fig.4.11 the maximum HRR values for PME at 26^{o}bTDC are obtained as 58.44bar, 55.3bar, 58.96bar, 59.7bar and 57.6bar at 200bar, 210bar, 220bar, 230bar and 240bar respectively where as it is 65bar for HD fuel (standard operating conditions) at 80% of full load.

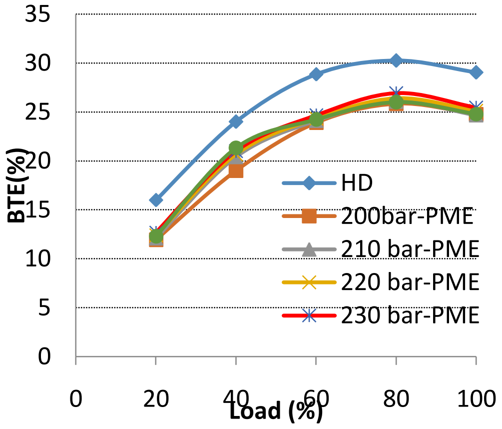


Fig.4.2 Variation of BTE at different FIPs ,26^{o}bTDC

ISSN: XXXX-XXXX
Volume (01) _Issue (02)

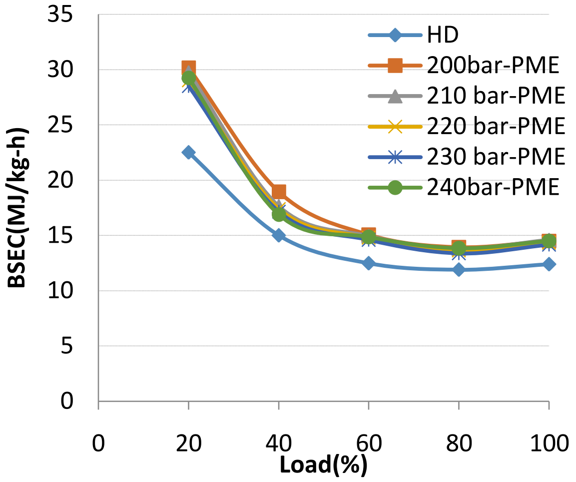


Fig.4.3 Variation of BSEC with FIPs at 26°bTDC

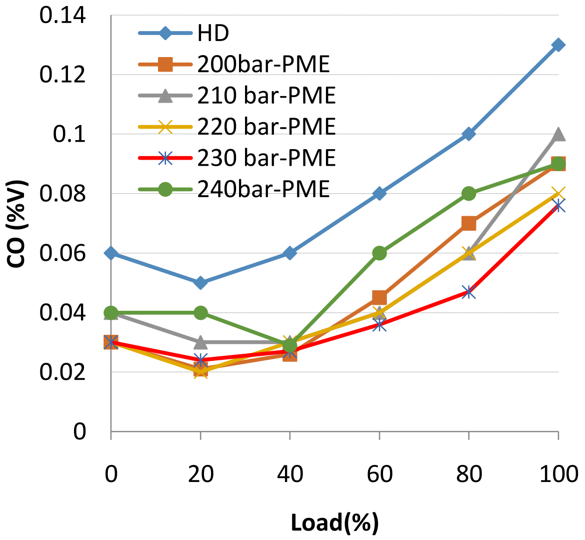


Fig.4.5 Variation of CO for different FIPs, at 26°bTDC

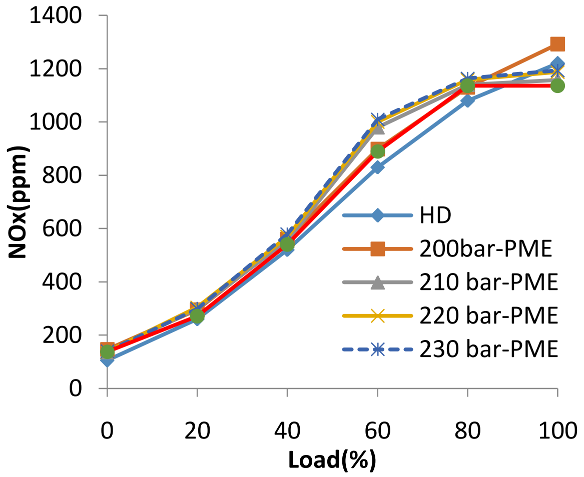


Fig.4.6 Variation of NOx emission with FIPs, at 26°bTDC

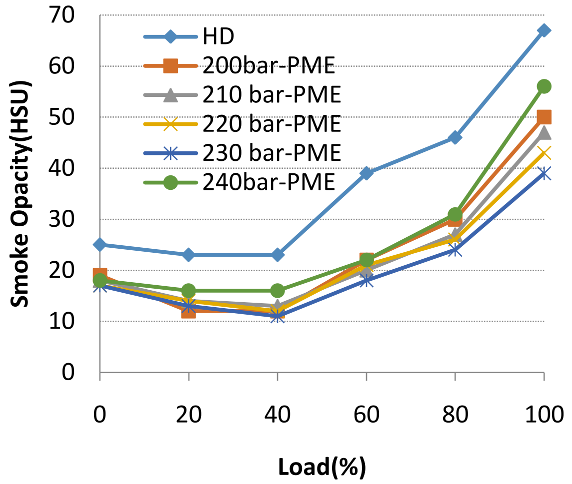


Fig. 4.7 Smoke Variation for different FIPs,26°bTDC

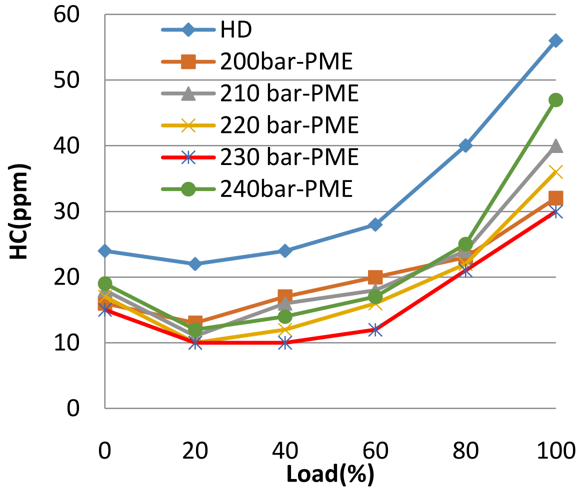


Fig.4.4 HC Variations for different FIPs 26°bTDC

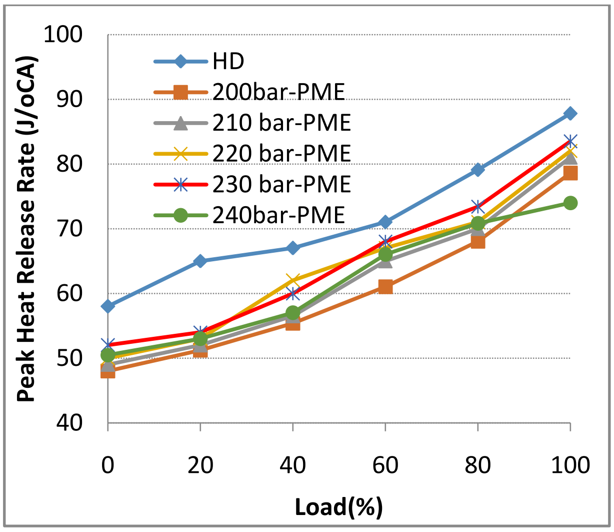


Fig.4.8 Peak HRR Variation for various FIPs, at 26°bTDC

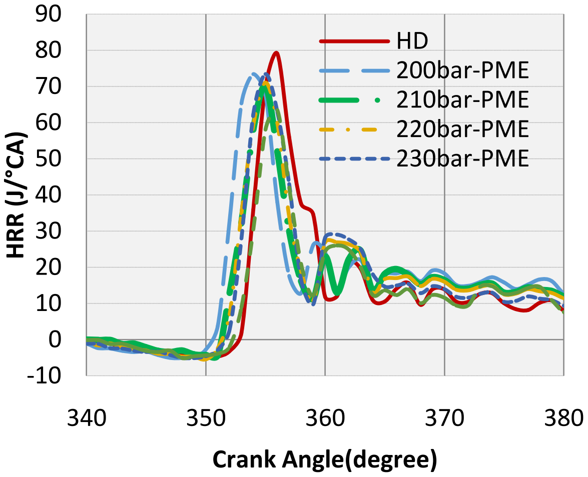


Fig.4.9 HRR vs.CA at 26°bTDC for PME, 80% load

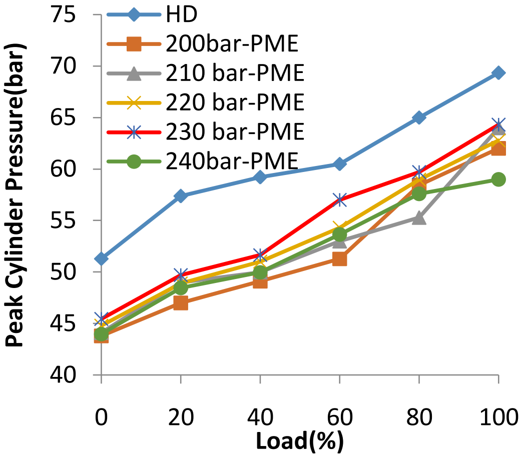


Fig.4.10 PCP Variation with different FIPs, 26°bTDC

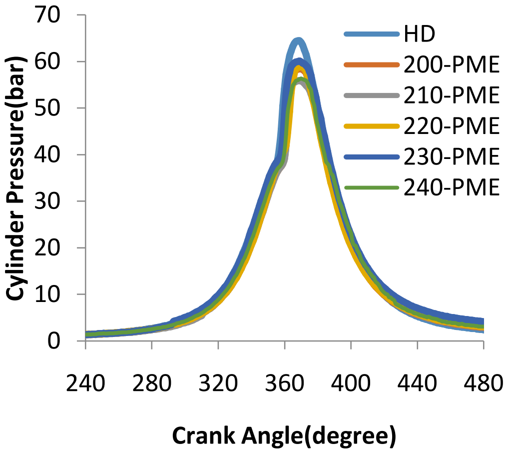


Fig.4.11 CP variation for different FIPs at 80% load

CONCLUSIONS

[1] The BTE is 25.92% and 3.3% less than HD fuel normal engine operation.
[2] The BSEC is about 13.93MJ/kW-h and 1.479 MJ/kW-h it is higher than HD fuel normal engine operation.
[3] The HC emission is noted as 21 ppm and 47.5% reduction in comparison to HD fuel normal engine operation.
[4] The CO emission is found to be 0.05%vol. and it is 53.46% less in comparison to HD fuel normal engine operation.
[5] The NOx emission is identified as1130ppm and 4.63% less in comparison to HD fuel normal engine operation.
[6] The smoke emission is 24 HSU and 47.82% less in comparison to HD fuel normal engine operation.
[7] The peak cylinder pressure (PCP) is 59.7bar and 8.15% lower in comparison to HD fuel normal engine operation.
[8] The peak heat release rate (HRR) is found to be 73.4J/^{o}CA and 7.19% lower than HD fuel normal engine operation.

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