An Experimental Investigation of Unattended Methyl Ester of Paradise Oil as Fuel in Diesel Engine

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Abstract: ***Engine tests have been executed with the intention of obtaining the performance, emission and combustion characteristics of a diesel engine running on methyl ester of paradise oil (MEPS) and its diesel blends. From the emission analysis it was observed that there has been a significant reduction in smoke and hydrocarbon emissions by way of 35% and 25% respectively for MEPS 55% blend and 45% and 30% reduction for MEPS 100. But, there has been an increase of 6% and 9% NOx emission for MEPS 55 and MEPS 100 respectively. Brake thermal efficiencies of MEPS and its diesel blends are slightly decrease than that of std. diesel. From the engine analysis, it was found that the overall performance of MEPS and its diesel blends had been just like that of std. diesel.***

1. Introduction

Compression ignition engines play a extra function than spark ignition engines specially in the subject of heavy transportation and agriculture sectors on account of their better thermal efficiency and durability. In the light of diminishing fossil fuel reserves, and increasing consumption of energy for maintaining development, there is a want to search for alternative sources of electricity based on renewable fuels consisting of vegetable oil and its derivatives. Fuels of bio-starting place can provide a feasible way to this world wide petroleum crisis. Similarly, bio-fuels offer many benefits, including sustainability, reduction of greenhouse gas emissions, nearby improvement and improvement in agriculture [1–4]. The chemical composition of bio-fuels helps in decreasing the emission of unwanted components when they are burned [5–7].

Considerable efforts had been made to increase vegetable oil derivatives that approximate the residences and overall performance of hydrocarbon – primarily based diesel fuels. The problem of substituting triglycerides for diesel fuels are their high viscosities and poor volatilities.

Those problem may be overcome via producing bio-diesel by means of a procedure known as transesterification [8–12]. Biodiesel has a higher cetane number as compared to neat vegetable, which results in shorter ignition delay and combustion duration and subsequently low particulate emissions [13–19].

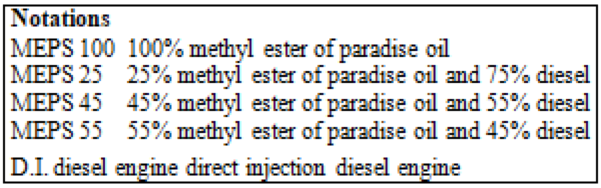
Within the present investigation the transesterification process changed into completed to convert paradise oil into methyl ester. This system entails making the triglycerides of paradise oil react with methanol inside the presence of a potassium hydroxide (KOH) catalyst to supply methyl ester (bio-diesel). This methyl ester and its diesel blends had been successfully tried in a D.I. diesel engine as its fuel. The performance, emission and combustion charactristics were studied and as compared with those of diesel.

2. Potential and Characterization of Paradise Seed Oil

The botanical name for paradise tree is Simarouba Glauca. Paradise tree is a multipurpose tree capable of growing at the degraded soils. it may adapt to a huge variety of temperatures (10–45°C) and altitudes as much as one 1000 meter above sea level. Seeds contain 50–65% oil that can be extracted through conventional method. Each properly-grown tree yields 15–30 kg nutlets equal to 2.5– 5 kg oil and approximately the same quantity of oilcake. This quantities to a 1000–2000 kg oil/ha/yr (400–800 kg/acre/12 months) and about the same amount of oilcake. For a long-term strategy, cultivation of simarouba is endorsed inside the abundantly available marginal/ wastelands to attain self-sufficiency in oils and its implementation will be economically possible and ecologically sustainable. This oil is well suited for the manufacture of pleasant soaps, lubricants, paints, polishes, prescription drugs, and so on. [20].

2.1 Test fuel

The methyl ester of paradise oil used in the present investigation contains nearly 65% methyl oleate. Literatures indicate that the presence of methyl oleate in methyl ester will reduce the carbon deposits, injector coking and enhance smooth engine performance [7].



Notations	
MEPS 100	100% methyl ester of paradise oil
MEPS 25	25% methyl ester of paradise oil and 75% diesel
MEPS 45	45% methyl ester of paradise oil and 55% diesel
MEPS 55	55% methyl ester of paradise oil and 45% diesel
D.I. diesel engine	direct injection diesel engine

Table 1: Physical-chemical properties of methyl ester of paradise oil and diesel

Properties	Diesel	Methyl ester of paradise oil
Moisture by D&S method	Nill	Nill
Density @ 40 ºC in gm/cc	0.84	0.8752
Kinematic viscosity @40ºCin CST	3-4	5.4
Conradson carbon residue (%w/w)	0.1	0.18
Copper strip corrosion @ 100 ºC for 3 h	Not worse than No.1	Not worse than No.1
Flash point	74ºC	141.2ºC
Sediments in hexane, %	-	0.05
Pour point	-23ºC	2ºC
Acid number as mg KOH/gm	-	0.1
Lower heating value kj/kg	42,700	38,485
Sulphur mass %	0.8	0.13
Saponification value	-	191.5
Iodine value	-	46.0
Cetane number	47	64

The important properties of methyl ester of paradise oil are comparable with the those of diesel as shown in table 1. The saponification quantity (SN), iodine value (IV) and cetane number (CN) of methyl ester of paradise oil (MEPS) have been calculated empirically and used to establish its suitability for use as bio-diesel which can meet the specification of US bio-diesel standard (ASTM D 6751).

SN and IV of paradise oil methyl ester were calculated from fatty acid methyl ester compositions with the help of Eqs. (1) and (2), respectively [21]:

$$SN= SUM\ (560*Aj)/MWi \quad (1)$$

$$IV= SUM\ (254*D*A)/MWi \quad (2)$$

Where A_i is the percentage of each component, D is the number of double bonds and MW_i molecular mass of each component. Cetane number of MEPS was calculated from Eqn. (3) [21]

$$CN = 46.3+5458/SN-0.225*IV \quad (3)$$

3. Experimental set-up

The schematic diagram of the experimental set-up used to carry out the present investigation is shown in Fig. 1. The specification of the engine used for the take a look at is given in table 2. A single cylinder four-stroke air-cooled diesel engine developing 4.4 kW at 1500 rpm was used for the research work. This engine was coupled to a BENZ eddy-modern-day dynamometer with a control system. The engine used within the observe is Direct Injection (DI) type. The fuel injection system and nozzle information are given underneath:

Nozzle configuration

Type of fuel injection	Pump-line–nozzle injection system
No. of holes	3
Nozzle opening pressure	207-215 bar
Needle lift (mm)	0.25
Spray-hole diameter (mm)	0.25
Cone angle	110º

Exhaust emission from the engine was measured with the help of QRO TECH, QEO-402 fuel analyzer and smoke emission changed into mea- sured with the help of the Bosch Smoke meter. The list of instruments used for measuring various parameters and measurement strategies are present in table 3. The list of instruments and the range, accuracy and uncertainties are given in table 4

3.1 Error analysis

Errors and uncertainties in the experiments can get up from instrument selection, condition, calibration, environment, observation, reading and test planning. Uncertainties evaluation is wanted to prove the accuracy of the experiments. An uncertainty evaluation turned into accomplished the use of the method described by using Holman [22].

The entire percent of uncertainty of this test is calculated as given below.

Overall percent uncertainty of this test is

= Square root of {(uncertainty of TFC)^2 + (uncertainty of BP)^2 + (uncertainty of BSFC)^2 + (uncertainty of brake thermal efficiency)^2 + (uncertainty of CO)^2 + (uncertainty of CO2)^2 + (uncertainty of UBHC)^2 + (uncertainty of NO_x)^2 + (uncertainty of Bosch smoke number)^2 + (uncertainty of EGT)^2 + (uncertainty of pressure pick up)^2}

= Square root of {$(1.5)^2 + (0.2)^2 + (1.5)^2 + (1)^2 + (0.2)^2 + (0.15)^2 + (0.2)^2$
$+ (0.2)^2 + (1.0)^2 + (0.15)^2 + (1.0)^2$}

= ±2.8%

4. Performance Analysis

4.1. Brake Thermal Efficiency

The developments of the brake thermal efficiency of methyl ester of paradise oil and its diesel blends are present in Fig. 2. It's far observed from that the brake thermal efficiency for diesel is higher the ones of methyl ester and its diesel blends. MEPS 25 blend intently accompanied the trend of diesel in the case of brake thermal performance. The decrease in brake thermal efficiency for better blends can be because of the lower heating value and higher viscosity of blends with a higher proportion of methyl ester.

4.2. Exhaust Gas Temperature

Fig. 3 suggests the variation of exhaust gas temperature with load for methyl ester and its diesel blends and diesel. It is observed that as the proportion of methyl ester will increase in the blend, exhaust gas temperature also increases at full load. This will be because of the oxygen content material of MEPS, which improves combustion, and for this reason will increase the exhaust gas temperature.

4.3. Emission Analysis

4.3.1. Oxides of nitrogen (NOx)

Fig. 4 indicates the variation of NOx emission with load for methyl ester of paradise oil and its diesel blends. It was observe that NOx emission will increase by way of 6% for MEPS 55 and 9% for MEPS100 at full load.

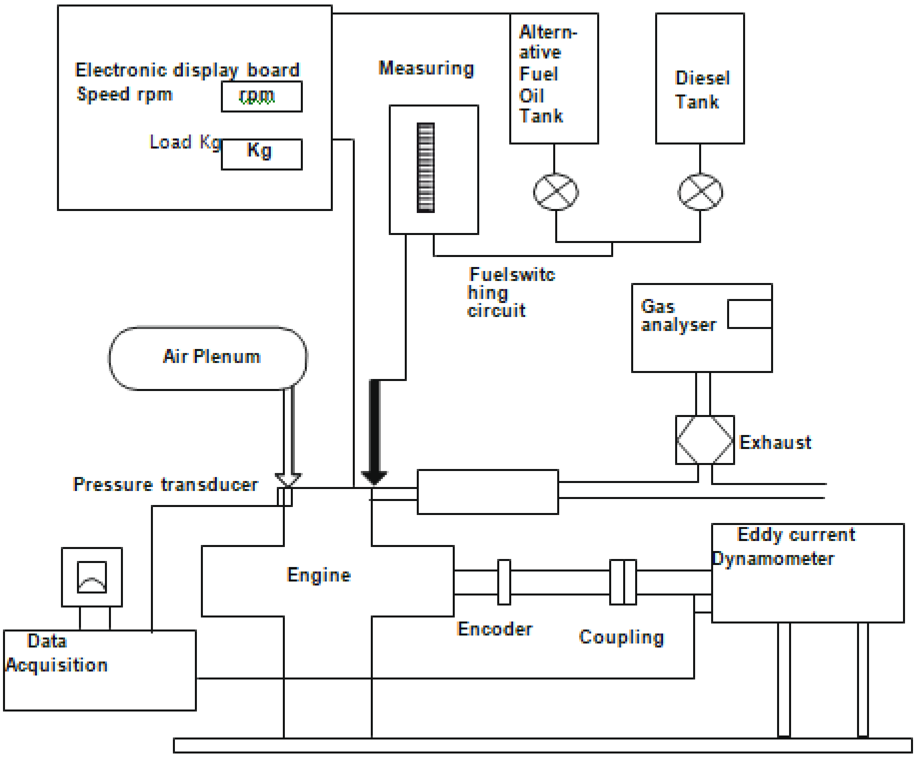


Figure 1: Schematic diagram of the experimental set-up

Advanced injection timing is widely known to yield accelerated NOx by shifting the start of combustion in earlier and raising peak in-cylinder temperatures [23–25]. No matter the marginally higher viscosity and lower volatility of the methyl ester, the ignition delay seems to be lower than that of diesel.

Accordingly, a shorter ignition delay for biodiesel also might also advance the start of combustion and make a contribution to higher NOx emissions. Further, the oxygen present within the fuel might also provide additional oxygen for NOx formation, thereby increasing its level of emission.

Table 2: Engine specifications

Model	Kirloskar TAF1
Type	Single cylinder, four stroke, direct injection
Piston type	Bowl-in-piston combustion chamber
Capacity	661cm³
Bore & sroke	87.5mm x 110mm
Compression ratio	17.5:1
Speed (constant)	1500rpm
Rated power	4.4kw
Dynamometer	Eddy current
Cooling system	Air cooling
Injection timing	23ºBtdc
Injection pressure	200bar

Table 3: List of Instruments used for measuring various parameters and measurement techniques

Instrument	Purpose	Make and model	Measurement techniques
Exhaust meter	Measurement of HC, CO, CO2 and NOx emissions	QRO 401, QROTECH Co. Ltd., Republic of Korea	Electro chemical sensor
Smoke meter	Measurement of smoke emission	TI diesel tune, 114 smoke density meter, TI tran Service	-
EGT indicator	Measurement of exhaust gas temperature	-	K –type (Cr Al) thermocouple
Speed measuring unit	Measurement of engine speed	-	Magnetic pick up type
Pressure transducer and charge amplifier	Measurement of cylinder pressure	Type 5015A, Kistler Instruments, Winterthur, Switzerland	-
Crank angle encoder	-	-	Magnetic pick up type
Load indicator	Loading device	BENZ	Strain gauge type load cell

Table 4: List of instruments and the range, accuracy and percentage uncertainties

S.NO	Instrument	Range	Accuracy	% uncertainties
1	Gas analyzer	NOx 0-5000ppm HC CO CO2	±20ppm ±15ppm ±0.02% ±0.2	±0.2 ±0.2 ±0.2 ±0.15

2	Smoke level measuring instrument	BSN 0-10	±0.2	±1.0
3	EGT indicator	0-900ºC	±1ºC	±0.15
4	Speed measuring unit	0-10000ppm	±10rpm	±1.0
5	Load indictor	0-100kg	±0.1kg	±0.2
6	Burette for fuel measurement	-	±0.2cc	±1.5
7	Digital stop watch	-	±0.2s	±0.2
8	Manometer	-	±1mm	±1.0
9	Pressure pick up	0-110bar	±1bar	±0.1
10	Crank angle encoder	-	±1º	±0.2

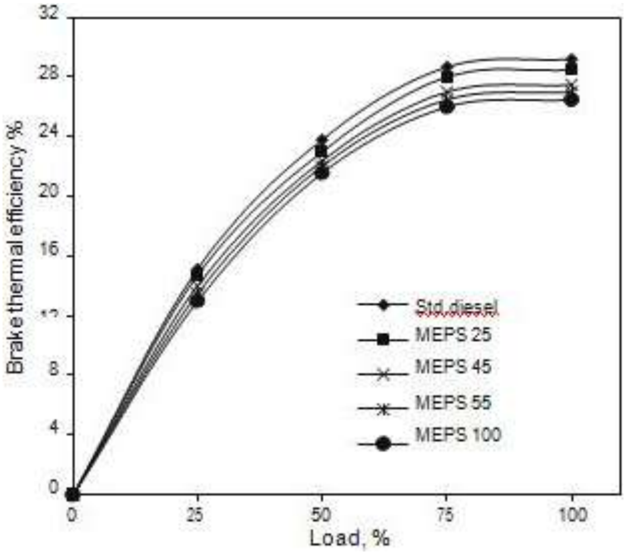


Figure 2: Variation of brake thermal efficiency with load for MEPS and its diesel blends

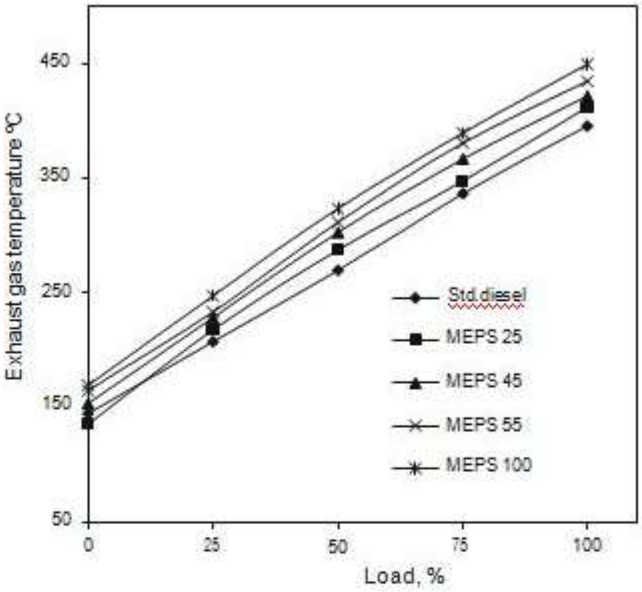


Figure 3: Variation of exhaust gas temperature with load for MEPS and its diesel blends

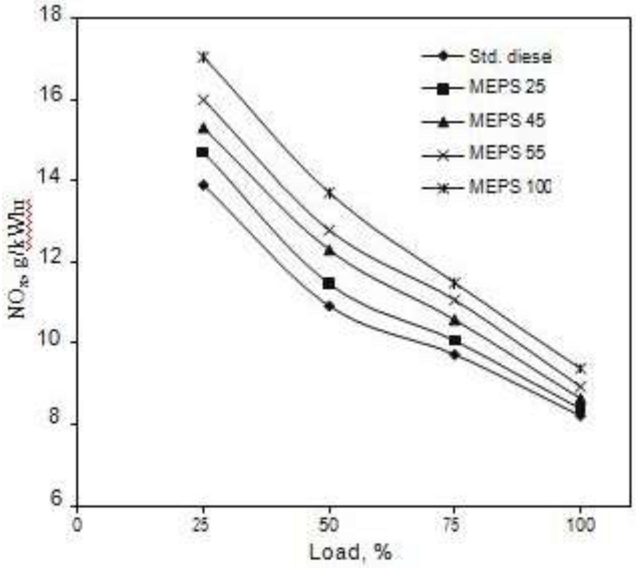


Figure 4: Variation of NOx with load for MEPS and its diesel blends

4.3.2 Smoke

Fig. 5 suggests the variation of the Bosch smoke quantity with load for various methyl ester blends and diesel. 40% reduction in smoke emission for MEPS 100 and 35% reduction for MEPS 55% blend were recorded. it is also exciting to note that a high reduction in smoke emission is located with an increase within the percentage of MEPS in the blend, specially at higher load. Better combustion temperature, longer combustion duration at the side of greater diffusive combustion can be the reasons for this significant reduction in smoke emission.

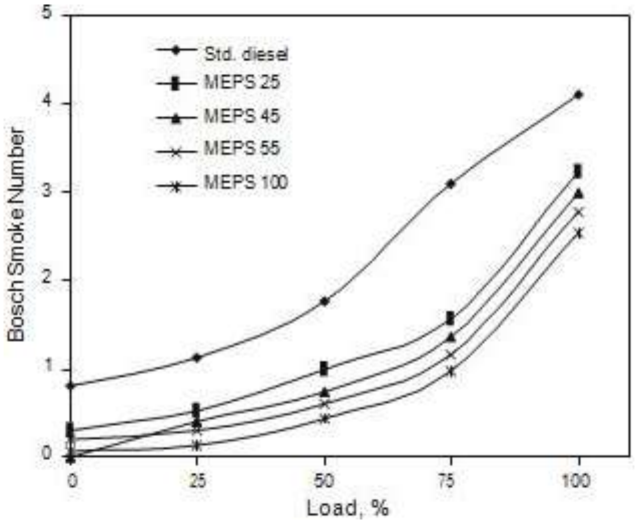


Figure 5: Variation of Bosch Smoke Number with load for MEPS and its diesel blends

4.3.3. Hydrocarbon emission

It is known that unburned hydrocarbon is also an vital parameter for determining the emission behavior of the engines. Fig. 6 shows the variation of HC emission with load for methyl ester of paradise oil and its diesel blends. It is observed from the figure that neat methyl ester produces incredibly lower HC, as compared to that of diesel. This may be attributed to the provision of oxy- gen in methyl ester, which helps better combustion. Also, it is interesting to note that the hydrocarbon emission decreases with an increase in the percentage of methyl ester within the blend. For example, there has been a discount of 25% in hydrocarbon emission for MEPS 55, whereas it is 30% for MEPS 100.

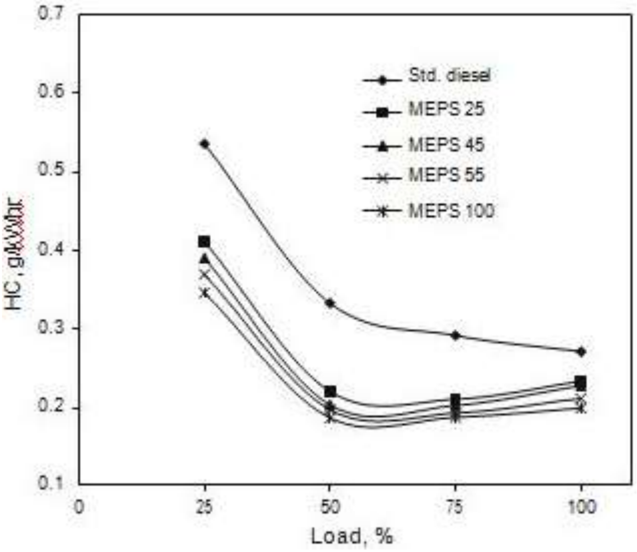


Figure 6: Variation of hydrocarbon emission with load for MEPS and its diesel blends

5. Combustion Analysis

Fig. 7 shows the variation of cylinder pressure with crank angle for methyl ester of paradise oil and its diesel blends. The cylinder peak pressure decreases as the percentage of methyl ester within the blends increases but, for all methyl ester blends peak cylinder pres- sure is decrease than for diesel. In all respect engine load combustion starts offevolved in advance for methyl ester blends than for diesel. This can be in part owing to advanced injection timing (because of a better bulk modulus and higher density of bio-diesel) [23–25].

Fig. 8 present the assessment of the heat release rate of methyl ester of paradise oil and its diesel blends. The premixed heat release is lower for the MEPS blends in comparison to that of diesel, possibly because of the decrease heating value of the methyl ester blend. As the percentage of MEPS inside the blend will increase, the maximum heat release rate decreases and the crank angle at which it takes place advances. it's far determined that the ignition delays of MEPS and its diesel blends are lower than that of diesel and are decreasing with an increase in the percentage of MEPS within the blend. As result of the high in-cylinder temperature existing during in fuel injection, biodiesel might also go through thermal cracking; as a result of this, lighter compounds are produced, which might have ignited earlier, ensuing in a shorter ignition delay [25,26].

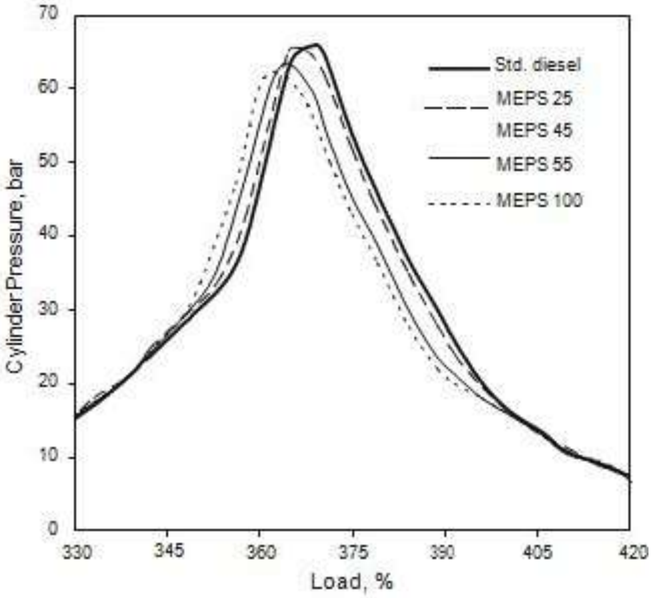


Figure 7: Comparison of cylinder pressure with Crank angle for methyl ester blends and diesel at full load

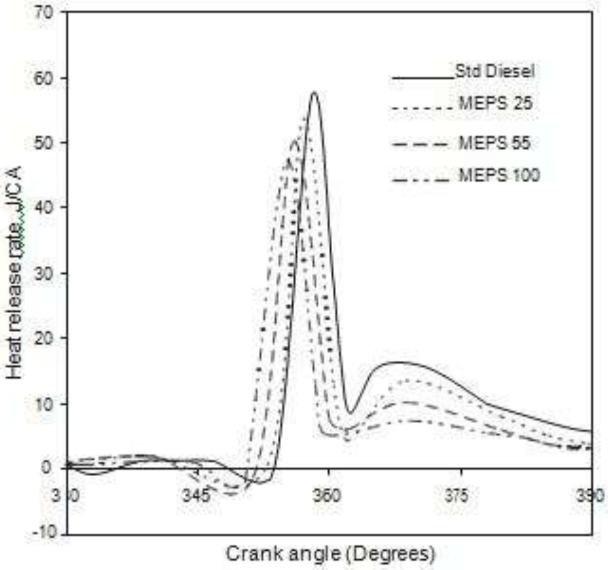


Figure 8: Comparison of heat release rate with Crank angle for methyl ester blends and diesel at full load

6. Conclusion

The overall performance, emission and combustion characteristics of a 4.4 kw DI compression ignition engine fuelled with MEPS and its the realization of the present investigation is summarized as follows:

- Brake thermal efficiencies of MEPS and its diesel blends had been slightly lower than that of std. diesel.
- A substantial reduction in HC and Smoke emissions by means of 25% and 35% respectively were recorded for MEPS 55% blend whereas, 30% and 45% reduction have been recorded for MEPS 100%.
- A slight increase of 6% and 9% NOx emissions have been recorded for MEPS 55% and MEPS 100% respectively.
- Combustion characteristics of MEPS and its diesel blends are comparable with those of std. diesel.

Based on the analysis, it changed into concluded that methyl ester of paradise oil and its diesel blends can be substituted as fuels for diesel engines.

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