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ORIGINAL ARTICLE

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PERFORMANCE, COMBUSTION AND EMISSION ANALYSIS OF DIESEL ENGINE FUELLED WITH BLENDS OF DIESEL AND MAHUA OIL METHYLE ESTERS WITH RETARDATION OF INJECTION TIMING

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Abstract:

Mahua oil, is considered as potential alternative fuels for diesel engines. In order to reduce the problems posed by straight vegetable oils in operation transesterification of vegetable oils is found to be more suitable fuel processing technique...A single cylinder constant speed air-cooled four-stroke direct injection diesel engine of 4.4 KW which is commonly used in the agriculture sector for driving pumps and in small electrical generators is selected for the experimental investigations. The performance, emission and combustion characteristics are analyzed. The combustion parameters considered for this analysis are ignition delay, cylinder pressure and rate of heat release. The brake thermal efficiency is slightly reduced and the Hydrocarbon (UBHC), carbon monoxide (CO) and particulate emissions in the exhaust are reduced when fuelled with methyl ester compared to diesel. The results show that methyl esters of vegetable oils can be successfully used in existing diesel engines without any modifications.

KEY-WORDS:

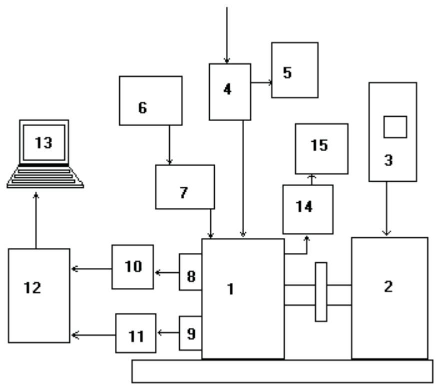
transesterification, performance, emission, combustion.

1.0 INTRODUCTION

It is a large deciduous tree and grows in semi arid, tropical and sub-tropical areas, in altitude up to 1200m. It grows even on rocky, sandy, dry shallow soils and tolerates waterlogging conditions. Madhuca Indica longifolia grows only in South India. Fruits mature and fall in April to July in North, August to September in South. They are fleshy, green berry, yellowish or orange brown when ripe.2.5 to 5 cm long; latifolia oblong and longifolia ovoid, contain 1 to 4 tiny seeds, the yield pr tree is 20 to 40 kg kernels. The fallen are picked or felled by shaking of branches. The rind has to be removed by hand and beating with stones decorticates seed. The drying and desertification yield 70% kerned on the weight of seed. The oil content of kernel is about 46% in Latifolia and 52% in longleaf. The oil yields in an expeller are nearly 35%, 37%.

EXPERIMENTAL SETUP

Title : PERFORMANCE, COMBUSTION AND EMISSION ANALYSIS OF DIESEL ENGINE FUELLED WITH BLENDS OF DIESEL AND MAHUA OIL METHYLE ESTERS WITH RETARDATION OF INJECTION TIMING Source:Golden Research Thoughts [2231-5063]M.V.MALLIKARJUN[1],VENKATA RAMESH MAMILLA[2], G.LAKSHMI NARAYANA RAO[3] yr:2013 vol:2 iss:8



1. Diesel engine
2. Swinging field electrical dynamometer
3. Dynamometer controls
4. Air box
5. U-tube manometer
6. Fuel tank
7. Fuel measurement flask
8. Pressure pick up
9. TDC position sensor
10. Charge amplifier
11. TDC amplifier circuit
12. A/D card
13. Personal computer
14. Exhaust gas analyzer
15. AVL smoke meter

Figure.1: Layout of engine test rig

Table.1 Engine specifications

Engine Type	Four stroke, stationary, constant speed, direct injection, diesel engine
Make	Kirloskar
Model	TAF1
Maximum Power	4.4 kW @ 1500 RPM
Maximum Torque	28 N-m @ 1500 RPM
Bore	87.5 mm
Stroke	110 mm
Compression Ratio	17.5:1
Injection Timing	23.4^0 bTDC
Loading Type	Electrical Dynamometer

Table.2 Comparison of performance and emissions of methyl esters and their blends

FUEL		BTE (%)	CO (%)	UBHC (ppm)	NOx (ppm)	PM (mg/m^3)
Diesel		33.36	0.25	48	510	140
MIME	20%MIME	31.52	0.24	38	552	132
	40% MIME	30..56	0.22	34	602	126
	60% MIME	29.55	0.2	30	680	114
	80% MIME	28.66	0.18	26	736	92
	MIME	27.6	0.16	21	821	86

3.0 RESULTS AND DISCUSSIONS

3.1 Combustion Characteristics with Retardation of Injection Timing

This work focuses on the implementation of retardation of injection timing technique for reducing NOx emissions of 20% blends of methyl ester. Tests are conducted at three different injection timings i e at standard injection timing of 23.40 bTDC and retarded injection timings of 20.90 bTDC and 18.40 bTDC. The variations of combustion, performance and emission characteristics with these injection timings are studied. The effect of retarding the injection timing on combustion parameters viz. start of combustion, peak pressure and rate of heat release are discussed in this section.

3.2 Start of Combustion (SOC)

The variation in start of combustion (SOC) for 20% methyl ester blend with brake power at various injection timings is shown in Figure.2. It is observed that the SOC occurs closer to TDC when the load is increased, as the cylinder temperature is higher at the time of injection. It is also observed that the SOC is retarded with retardation in injection timing due to late admission of fuel in to the combustion chamber. This results in combustion continuing in the expansion stroke of piston after TDC and this will decrease the power output of the engine.

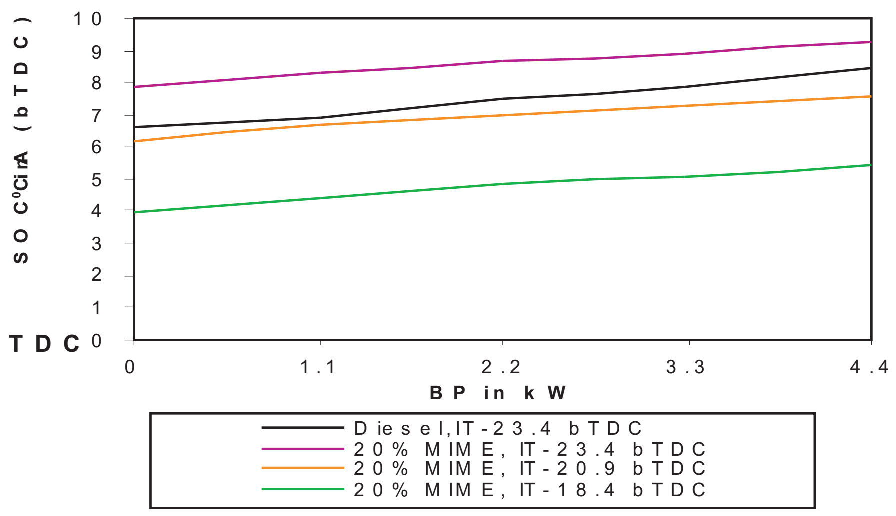


Figure.2: Variation of start of combustion with injection timing for 20%MIME

3.3 Ignition Delay (ID)

As the beginning of fuel injection and start of combustion are known, ignition delay is calculated from
ID = SOI – SOC

Where SOI – Start of injection in 0CA
SOC – Start of combustion in 0CA

Figure.3 show the variation of ignition delay with brake power for diesel and 20% blends of methyl ester at various injection timings. It is observed that for 20% blend the ignition delay decreases with increase in brake power at all injection timings. This is due to higher combustion chamber wall temperature and reduced exhaust gas dilution at higher brake powers. The ignition delay is shorter for 20% blend at all injection timings compared to diesel at all loads. As the injection timing is retarded, the temperature and pressure of air at the time of injection are high and this helps fuel vaporization and reduces the ignition delay.

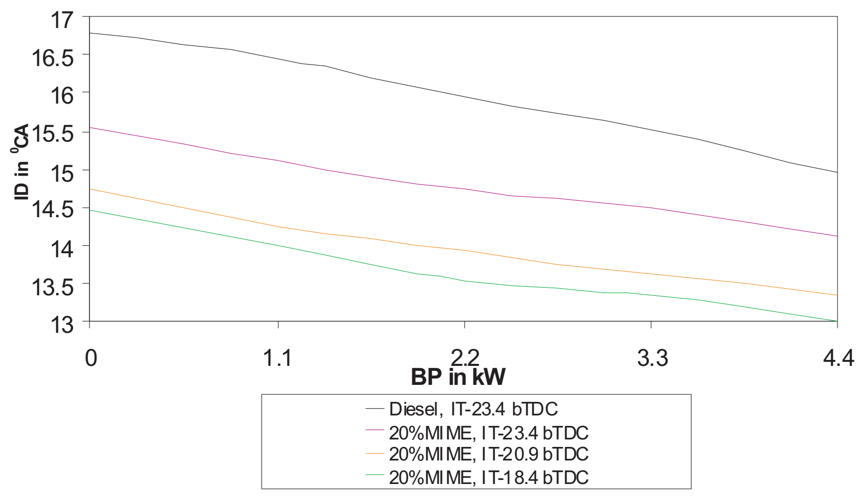


Figure.3: Variation of ignition delay with injection timing 20%MIME

3.4 Variation of cylinder pressure

The variations of cylinder pressure with crank angle at rated power for 20% blend methyl ester at the injection timings of 23.40 bTDC, 20.90 bTDC and 18.40 bTDC are shown in Figure.4. At the normal injection timing of 23.40 bTDC, cylinder pressures for 20% methyl ester is almost equal to that of diesel. As the injection timing is retarded there are two distinct regions in the variation of cylinder pressure with crank angle. In the region from 70 bTDC to 170 aTDC cylinder pressures for the retarded injection timings are below the cylinder pressures for the normal injection timing. This is due to fact that the start of combustion is delayed as the injection timing is retarded. The expansion of gases results in a decrease in cylinder pressure below that for the normal injection timing. In the region after 170 aTDC the delayed combustion of gases results in higher cylinder pressures compared to the cylinder pressures for normal injection timing.

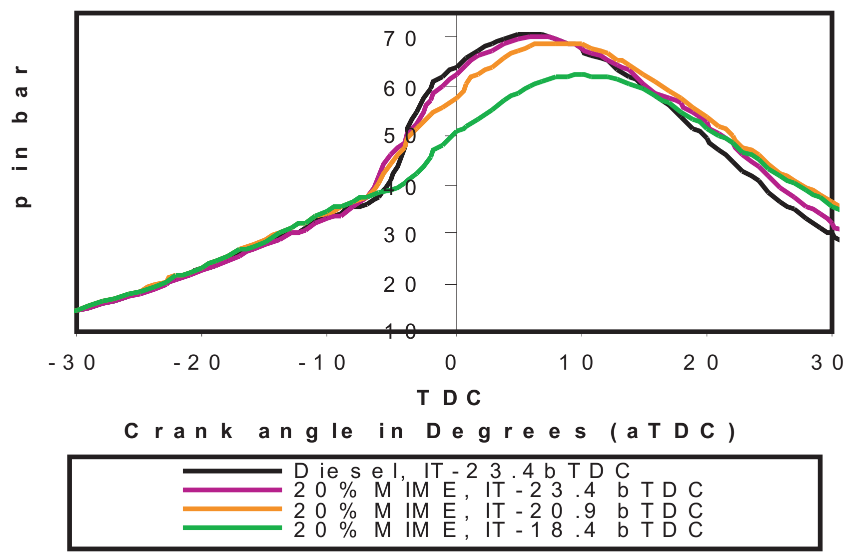


Figure.4: Variation of cylinder pressure with injection timing for 20%MIME at rated load (4.4kW)

3.5 Peak Pressure (pmax)

Figure.5 show the variation of peak pressure with brake power for 20% blend methyl ester at the injection timings of 23.40 bTDC, 20.90 bTDC and 18.40 bTDC. It is observed that the peak pressure increases with brake power at all the injection timings due to increased amount of fuel burnt at higher brake powers. At any given brake power, the peak pressure decreases as the injection timing is retarded due to late combustion. For instance, it is seen from Figure 5.14 at rated power (4.4kW) the cylinder peak pressures for 20% MIME are 70.18 bar, 69.07 bar and 62.44 bar respectively at the injection timings of 23.40 bTDC, 20.90 bTDC and 18.40 bTDC. It is also observed that when the injection timing is retarded the crank angle at which the cylinder peak pressure occurs is delayed due to the late combustion of fuel.

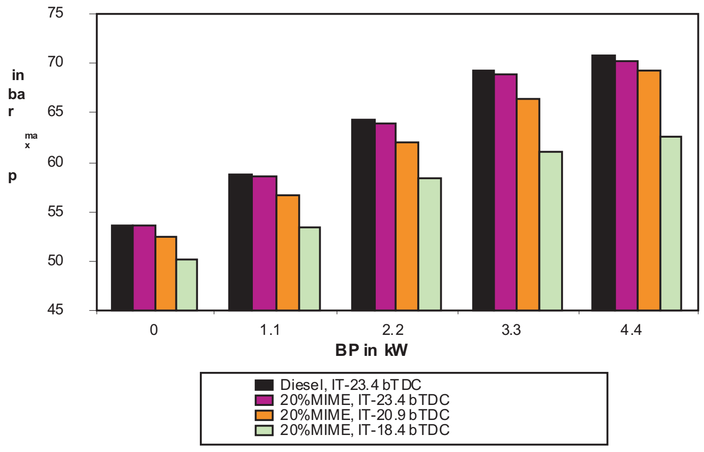


Figure.5: Variation of peak pressure with injection timing for 20%MIME

3.6 Rate of Heat Release (Q)

The variation in rate of heat release with injection timing for 20% blended fuel at rated brake power (4.4kW) is shown in Figure.6. It can be seen that the heat release rate curves of 20% blend show similar patterns, which can be summarized as follows:

i.Delayed start of heat release with retardation of injection timing. For instance, from the figure.6 for 20% MIME, for the three injection timings of 23.40 bTDC, 20.90 bTDC and 18.40 bTDC the heat release rates start at 8.70, 6.80 and 4.60 CA before TDC respectively.
ii.The peak heat release rates decrease as injection timing is retarded. For 20% MIME, from the figure.6 the peak heat release rates are 68.2, 56.7 and 52.6 J/0CA respectively for the injection timings of 23.40 bTDC, 20.90 bTDC and 18.40 bTDC.
iii.The angle at which peak heat release rate occurs is delayed as start of combustion is delayed. For 20% MME, for the injection timings of 23.40 bTDC, 20.90 bTDC and 18.40 bTDC, the occurrences of peak heat release rate are at 60, 50 and 10 CA before TDC respectively.
iv.The retarded injection timings results in higher heat release rates after TDC (in the expansion stroke) due to delayed start of combustion.

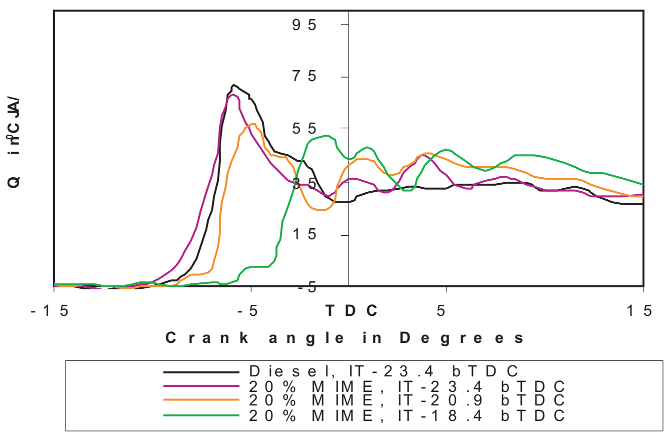


Figure.6: Variation of heat release rate with injection timing for 20%MIME at rated load (4.4kW)

4.0 Performance and emission characteristics with retardation of injection timing

This section describes the effect of injection timing on performance and emissions of an engine fuelled with 20% blend of methyl ester.

4.1 Brake Thermal Efficiency (BTE)

Figure.7 compare the brake thermal efficiency for 20% blend of methyl ester at various brake powers for three injection timings. It is observed that at any brake power the brake thermal efficiency is maximum for diesel at standard injection timing. Retardation of injection timing leads to late start of combustion and combustion continues in the expansion stroke of the piston. This result in smaller peak heat release rate and reduces the effective pressure to do work. Consequently, the work output is less for retarded injection timings and therefore the brake thermal efficiency decreases as the injection timing is retarded. At any brake output, the decrease in brake thermal efficiency is highest for 18.4 bTDC compared to standard injection timing. At rated power, the brake thermal efficiencies for 20% MIME are 31.52%, 30.89% and 29.96% respectively for the injection timings of 23.40 bTDC, 20.90 bTDC and 18.40 bTDC.

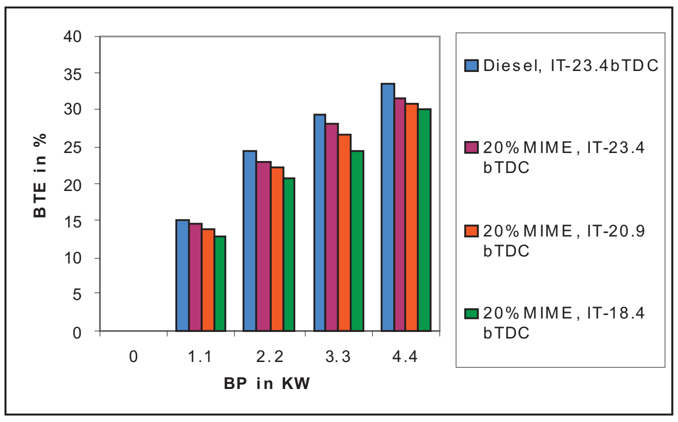


Figure.7: Variation of brake thermal efficiency with injection timing for 20%MIME

4.2 Exhaust Gas Temperature (Teg)

The variation in exhaust gas temperature with load for different injection timings is shown in Figure.8. It is observed that for 20% blend the exhaust gas temperature increases with increase in power output as more fuel is burnt at higher loads to meet the power requirement. With retardation of injection timing, the start of heat release and also the angle at which peak heat release rate occurs are delayed. This indicates late burning of fuel and results in the increase of exhaust gas temperature as the injection timing is retarded.

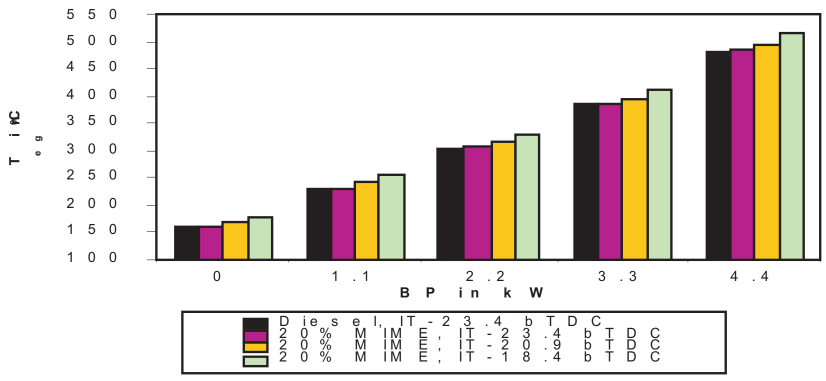


Figure.8: Variation of exhaust gas temperature with injection timing for 20%MIME

4.3 Unburned hydrocarbon (UBHC) Emissions

The unburned hydrocarbon (UBHC) emissions for the various 20% blends for the three injection timings are shown in Figure.9. It is observed that at any power output the unburned hydrocarbon emissions slightly increase as the injection timing is retarded but it is less than that of diesel at standard injection timing. Retardation of injection timing results in delayed combustion and combustion continues in the expansion stroke of piston and increases UBHC emissions.

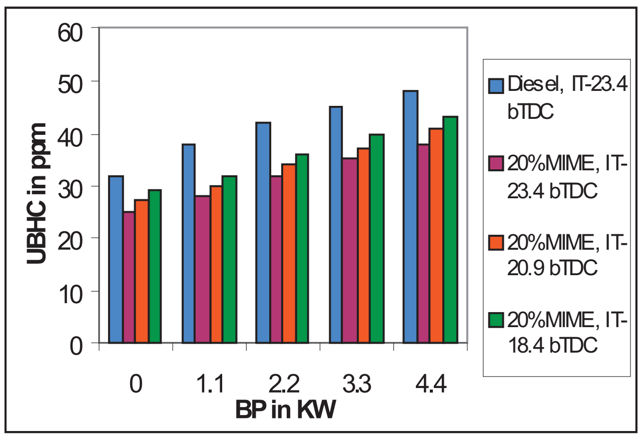


Figure.9: Variation of UBHC with injection timing for 20%MIME

4.4 Carbon Monoxide (CO) Emissions

The CO emissions for the 20% blend for the three injection timings are shown in Figure.10. It is observed that the CO emission is maximum at full load and it is found to be less than 0.27%. It is also seen that at any power output the CO emissions increase with retardation of injection timing. The theory of CO formation holds that, in the premixed combustion phase, the CO concentration increases rapidly to the maximum value in the flame zone. The CO formed by this path is then oxidized to CO2 but at a slower rate. Therefore, one possible explanation for the increase in CO with retardation in injection timing is that lesser time is available for the oxidation process to occur, leaving more CO in exhaust.

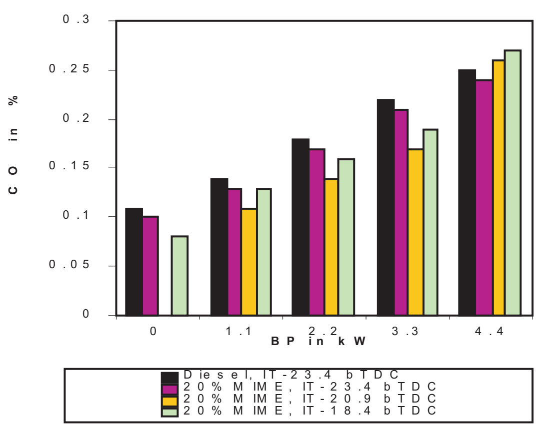


Figure.10: Variation of carbon monoxide with injection timing for 20%MIME

4.5 Nitrogen Oxide (NOx) Emissions

The variation of NOx for diesel and 20% blends with brake output at various injection timings is shown in Figure.11. It is observed that the NOx emission of 20 % methyl ester is higher than that of diesel at standard injection timing. The NOx emissions decrease as the injection timing is retarded. At the time of

SOC, the accumulated fuel is less when injection is retarded and therefore premixed combustion stage is less intense leading to lower rate of heat release. This results in lower combustion pressure and temperature. As NOx emissions predominantly depend on temperature, the NOx emissions decrease as desired.

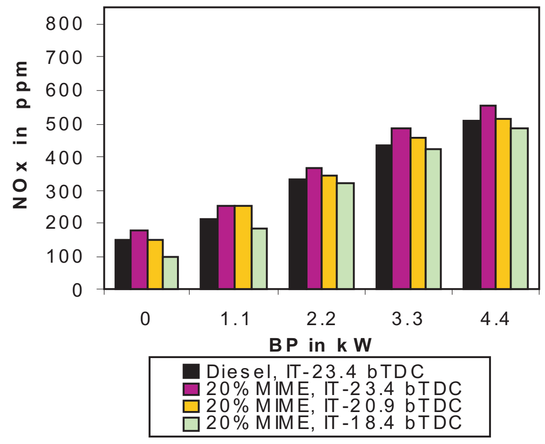


Figure.11: Variation of nitrogen oxide with injection timing for 20%MIME

5.0 Summary of Tests With Retardation Of Injection Timing:

The effects of injection timing retardation on combustion, performance and emission parameters are shown in Table .

Table.3 Comparison of performance and emissions of methyl ester and its blends

Parameter	Injection Timing (bTDC)	Diesel	20% MIME
BTE	23.4° CA	33.36	31.52
	20.9° CA		30.89
	18.4° CA		29.96
UBHC	23.4° CA	48	38
	20.9° CA		41
	18.4° CA		43
CO	23.4° CA	0.25	0.24
	20.9° CA		0.23
	18.4° CA		0.27
PM	23.4° CA	140	132
	20.9° CA		144
	18.4° CA		150
NOx	23.4° CA	510	552
	20.9° CA		505
	18.4° CA		482

The effect of retardation of injection timing on the performance, emission characteristics and cost per hour of operation for 20% blend of methyl ester can be summarized as follows:

Retarding injection timing reduces the brake thermal efficiency for all the blends.
The brake thermal efficiency is lowest at 18.40 bTDC injection timing for 20% blend.
UBHC, CO and Particulate matter increase for 20% blend when injection timing is retarded compared to diesel at standard timing. At 20.9 bTDC, the above emissions are less compared to those of diesel at

standard injection timing.
For 20% blend, NOx emissions are reduced when injection timing is retarded. At injection timing of 20.90 bTDC, 20% MIME gives lowest NOx when compared to diesel.
The cost per hour of operation is lowest for 20% MIME. Use of 20% MIME is recommended for use in metropolitan cities as well as for rural areas where it is easily available. It will help to improve rural economy.

6.0 CONCLUSIONS

The effects of retardation of injection timing on combustion, performance and emission parameters of 20% blend of methyl ester and diesel fuel can be summarized as follows:

- Start of combustion and occurrence of maximum rate of heat release retard with retardation of injection timing. The magnitude of peak pressure and maximum rate of heat release decrease with increase in retardation of injection timing.
- The brake thermal efficiency is found to decrease when the injection timing is retarded and reduces with increase in retardation of injection timing.
- The nitrogen oxide emissions reduce with increase in retardation of injection timing but other components of emissions like unburned hydrocarbon, carbon monoxide and soot concentration increase.

Hence it is recommended to use injection timing of 20.9oCA bTDC for 20%blend of MIME from the emissions and economy point of view.

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