Performance evaluation of a diesel engine fueled with methyl ester of castor seed oil

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Abstract:

Diesel engines are widely used as power sources in medium and heavy-duty applications because of their lower fuel consumption and lower emissions of carbon monoxide (CO) and unburned hydrocarbons (HC) compared with gasoline engines. Rudolf Diesel, the inventor of the diesel engine, ran an engine on groundnut oil at the Paris Exposition of 1900. Since then, vegetable oils have been used as fuels when petroleum supplies were expensive or difficult to obtain. With the increased availability of petroleum in the 1940s, research into vegetable oils decreased. Since the oil crisis of the 1970s research interest has expanded in the area of alternative fuels. The difficulties associated with using raw vegetable oils in diesel engines identified in the literature are injector coking, severe engine deposits, filter gumming problems, piston ring sticking, and injector coking and thickening of the lubricating oil. The high viscosity and low volatility of raw vegetable oils are generally considered to be the major drawbacks for their utilization as fuels in diesel engines. Castor methyl ester (CME) blends showed performance characteristics close to diesel. Therefore castor methyl ester blends can be used in CI engines in rural area for meeting energy requirement in various agricultural operations such as irrigation, threshing, indistries etc.

Keywords: diesel engines, filter gumming, Castor methyl ester

1. INTRODUCTION

Energy conservation and emissions have become of increasing concern over the past few decades. As automobiles are one of the major sources of energy consumption and urban emissions, engineers concerned are under significant pressure to improve their energy efficiency and reduce exhaust emission levels. While tremendous effort has been devoted in improving performance and reducing emissions of current engines, new technologies are also getting attention. A technological thrust is currently in progress to develop CASTOR OIL which exhibit higher thermal efficiency and improved exhaust emissions. The castor oil concept is not new. For the past two decades many have conducted experiments on low heat rejection engines. Although promising, the results of the experimental investigations have been somewhat mixed. The concept castor oil Better fuel economy, increased engine life, reduction in HC, CO and PM emissions, and lower combustion noise due to reduced pressure increasing rate, increased exhaust gases energy and ability of operating low Cetane fuels.

2. PROPERTIES

Castor oil properties indicate a very low pour and cloud points which make this biofuel a good alternative in winter conditions. Also, mixtures of 20 (B20) and 10 (B10) percent biodiesel-petroleum diesel showed good flow properties. It indicates that castor oil biodiesel also could be used as petroleum diesel additive improving both environmental and flow behavior of the mineral fuel. The properties of the B100 combustible and its B10 and B20 mixtures are comparable to those of petroleum diesel and acceptable within what is specified for biodiesel in the ASTM D 6751 standard (with the exception of viscosity and humidity in B100). It was found that viscosity was higher as the proportion of biodiesel in the mixtures increased. However, this event does not affect the atomization characteristics. B100 has the highest flash and ignition points. Increasing the proportion of biodiesel in the mixture elevates its flash and ignition temperatures. A higher flash point translates into a higher level of safety in combustible transport and storage. It is important to highlight that both cloud and pour points decline as more biodiesel is added to petroleum diesel. This implies a higher level of stability at lows temperatures, making B100 an ideal combustible for those regions with extreme seasonal weather as it doesn't require any kind of additives to conserve its fluidity. Additionally to the combusting properties that were analyzed, biodiesel displays ability as a solvent, which allows it to remove any impurities, thus preventing the formation of sediments that could potentially obstruct pipes and filters. In a similar fashion, biodiesel has a higher cooling capacity, as it presented an increase of 18.2% in return temperature when compared to petroleum diesel. This aspect is key in the conservation of the engine components.

3. EFFECT OF VARIOUS PARAMETERS ON THE YEILD OF BIODIESEL

3.1 Molar ratio:

The stoichiometric transesterification requires 3 mol of the alcohol per mole of the triglyceride to yield 3 moles of the fatty esters and 1 mol of the glycerol. However, the transesterification reaction is an equilibrium reaction in which a large excess of alcohol is required to drive the reaction close to completion in a forward direction. The molar ratio of 6:1 or higher generally gives the maximum yield (higher than 98% by weight). Lower molar ratios require a longer time to complete the reaction. Excess molar ratios increase the conversion rate but leads to difficulties in the separation of the glycerol. At optimum molar ratio only the process gives higher yield and easier separation of the glycerol. The optimum molar ratios depend on the type and quality of the vegetable oil used. Different molar ratios from 1:3 to 1:10 (oil to methanol) were used to determine the optimum value of molar ratio for the production of biodiesel from castor oil. Optimum molar ratio was found to be 1:7 and the yield of methyl ester was 94-97% at 65^0 C and 1%w/v of catalyst for a period of 2 hours.

3.2. Amount of catalyst:

The alkaline catalysts such as sodium hydroxide and potassium hydroxide are most widely used. These catalysts increase the reaction rate several times faster than acid catalysts. Alkaline catalyst concentration in the range of 0.5 to 1% by weight yields 94 to 99% conversion efficiency. Further increase in catalyst concentration does not increase the yield, but it adds to the cost and makes the separation process more complicated.

3.3. Reaction temperature:

The rate of the transesterification reaction is strongly influenced by the reaction temperature. Generally, the reaction is carried out close to the boiling point of methanol (60 to 70°C) at atmospheric pressure. With further increase in temperature there is more chance of loss of methanol.

3. 4. Rate of stirring:

The mixing effect is more significant during the slow rate region of the transesterification reaction and when the single phase is established, mixing becomes insignificant. Understanding the mixing effects on the kinetics of the transesterification process is a valuable tool in the process scale-up and design. Generally, after adding the methanol and catalyst to the oil, stirring for 5 to 10 minutes promotes a higher rate of conversion and recovery.

4. EXPERIMENTAL PROGRAMME

4.1. The Experimental Setup:

A twin cylinder, four stroke, constant speed, water cooled, direct injection diesel engine is used for the experiments conducted. The technical specifications of the engine are as below.

Specification of the engine used.

Make and model	Kirloskar diesel engine
General details	4-Stroke, water cooled, variable compression ratio engine, compression ignition
Number of cylinder	Single cylinder
Bore	87.5 mm
Stroke	110 mm
Swept volume	661 cc
Rated output	3.5 kW at 1500 rpm
Compression ration	17.5
Rated speed	1500 rpm
Temperature sensor	RTD PT 100 and K-type thermocouple
Load indicator	Digital, range 0–490.5 kN
Dynamometer	Type – eddy current, water cooled
Load sensor	Strain gauge load cell
Fuel flow transmitter	DP transmitter
Air flow transmitter	Pressure transmitter
Rotameter	Pressure transmitter

4.2 INSTRUMENTATION:

4.2.1. Load measurement:

Hydraulically loaded dynamometer was used to load the engine. In this work, for the given engine specifications, the maximum load that can be applied on the engine is calculated as 7.46 Kg.

4.2.2. Engine speed measurement:

Engine speed was measured with the help of a tachometer. Here, the engine was run at rated speed i.e., at 1500 rpm throughout the experiment.

4.2.3. Fuel measurements:

The fuel flow i.e. diesel and biodiesel, was measured using a calibrated burette (of capacity 50c.c) and a stopwatch.

4.2.4. Temperature measurements:

For calculating the heat transfer through the liner, four holes of 2 mm diameter, two at each axial position is drilled to depth of 3mm and the other to a depth of 6 mm from the periphery of the liner. This arrangement of thermocouples is shown in the fig. In order to sense the temperature in the liner, chromel-alumel type thermocouples are used and these are fixed in the drilled holes of liner. Finally these thermocouples are connected to the data acquisition system for obtaining the corresponding temperature readings. By knowing the temperature, material properties rate of heat transfer through liner can be calculated.

4.2.5. Measurement of exhaust gas temperature:

Thermocouples are arranged at the outlet of the exhaust port for sensing the corresponding temperature.

4.2.6. Measurement of exhaust gas smoke density:

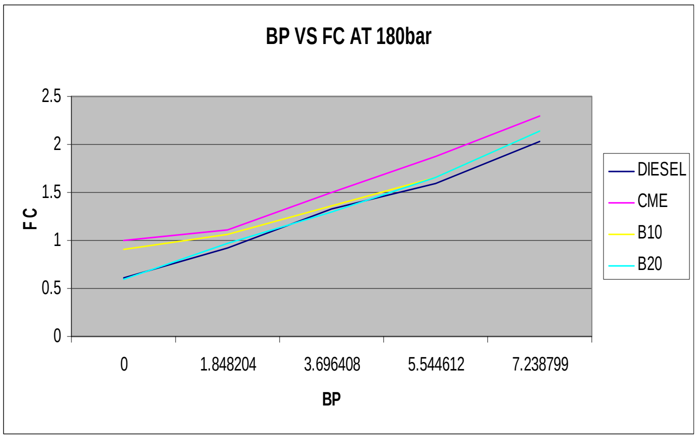
Smoke density of the exhaust gas of the engine was measured when the engine was run at different injection pressures, with different fuels (diesel and biodiesel) and with TBC and without TBC using KOMYO smoke meter.

5. Experimental Results:

Eight sets of experiments were conducted on twin cylinder direct injection diesel engine diesel and biodiesel and it's two blends (B 25,B 50) as fuels at two pressures (at 180 bar and 240 bar). In each set of tests readings of engine power, fuel consumption, exhaust gas temperature, and so on, were taken for zero to full load at constant speed.

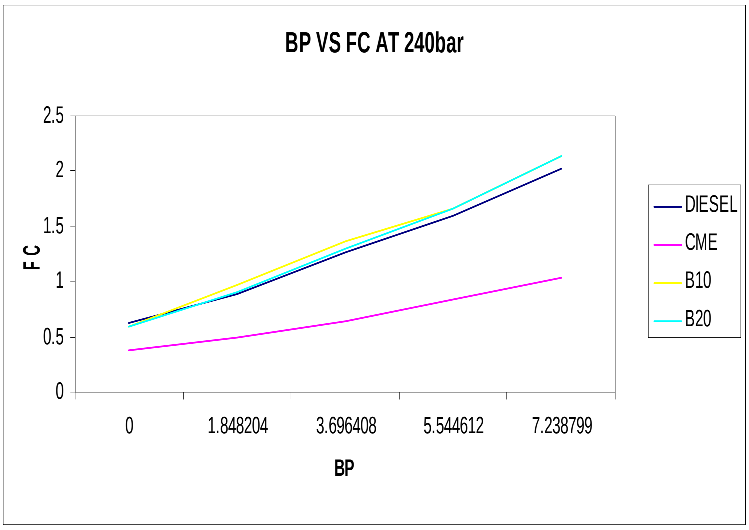
5.1. Fuel consumption:

DIESEL	CME	B10	B20
Mf(FC)	Mf(FC)	Mf(FC)	Mf(FC)
0.633	0.374	0.587	0.599
0.893647	0.499	0.966	0.907
1.266	0.637	1.361	1.302
1.599158	0.832	1.664	1.664
2.0256	1.032	2.139	2.139



FC of diesel, biodiesel and its blends at 180 bar injection pressure

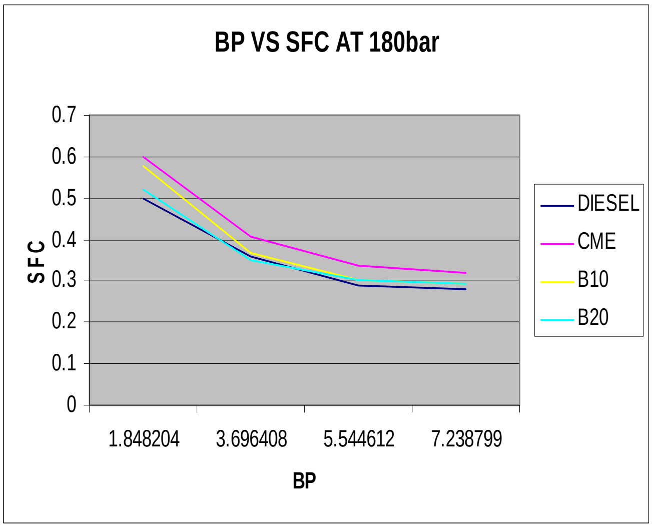
DIESEL	CME	B10	B20
Mf(FC)	Mf(FC)	Mf(FC)	Mf(FC)
0.60768	0.998	0.907	0.587
0.920727	1.109	1.069	0.966
1.321043	1.497	1.361	1.30
1.599158	1.872	1.664	1.664
2.0256	2.304	2.1394	2.139



FC of diesel, biodiesel and its blends at 240 bar injection pressure

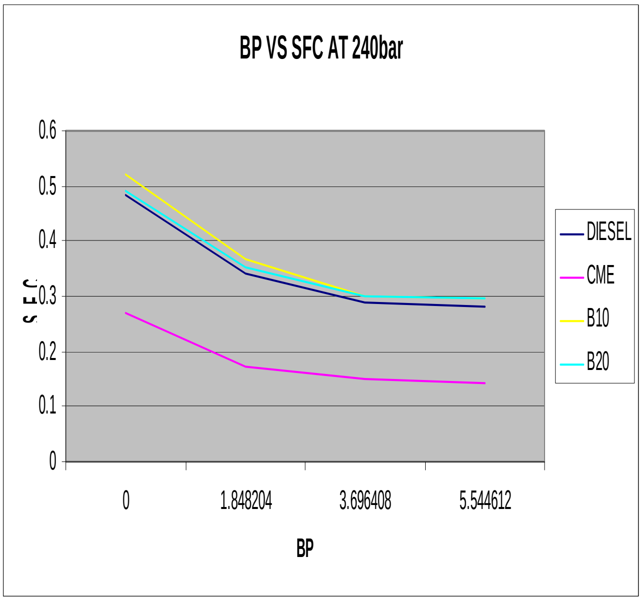
5.2 Specific fuel consumption:

DIESEL	CME	B10	B20
sfc(mf/bp)	sfc(mf/bp)	sfc(mf/bp)	sfc(mf/bp)
0.483522	0.2701	0.522	0.491
0.342495	0.1724	0.3683	0.352
0.288417	0.1500	0.300	0.300
0.279825	0.1426	0.295	0.295



SFC of diesel, biodiesel and its blends at 180 bar injection pressure

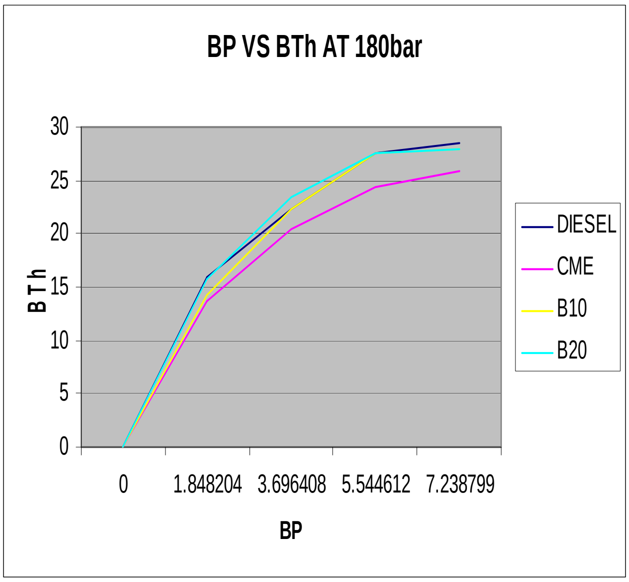
DIESEL	CME	B10	B20
sfc(mf/bp)	**sfc(mf/bp)**	**sfc(mf/bp)**	**sfc(mf/bp)**
0.483522	**0.2701**	**0.522**	**0.491**
0.342495	**0.1724**	**0.3683**	**0.352**
0.288417	**0.15**	**0.3**	**0.3**
0.279825	**0.1426**	**0.295**	**0.295**



SFC of diesel, biodiesel and its blends at 240 bar injection pressure

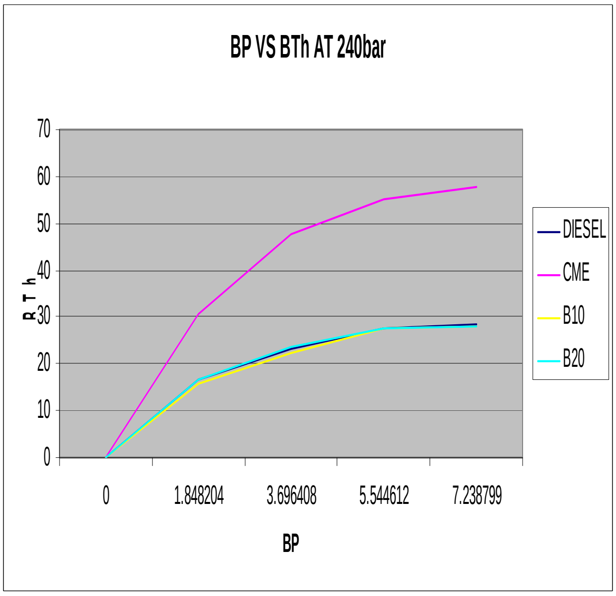
5.3 Brake thermal efficiency

DIESEL	CME	B10	B20
Bth efficiency	Bth efficiency	Bth efficiency	Bth efficiency
0	0	0	0
15.97698	13.748	14.257	15.784
22.27095	20.367	22.404	23.422
27.59661	24.441	27.49	27.496
28.44387	25.926	27.920	27.920



Brake thermal efficiency of diesel, biodiesel and its blends at 180 bar injection pressure

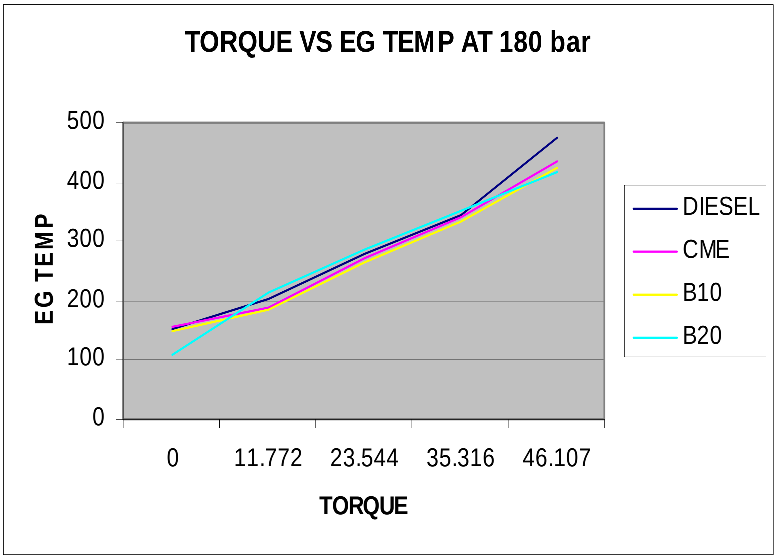
DIESEL	CME	B10	B20
Bth efficiency	Bth efficiency	Bth efficiency	Bth efficiency
0	0	0	0
16.46114	30.551	15.784	16.803
23.23925	47.864	22.404	23.42
27.59661	54.99	27.496	27.496
28.44387	57.335	27.920	27.920



Brake thermal efficiency of diesel, biodiesel and its blends at 240 bar injection pressure

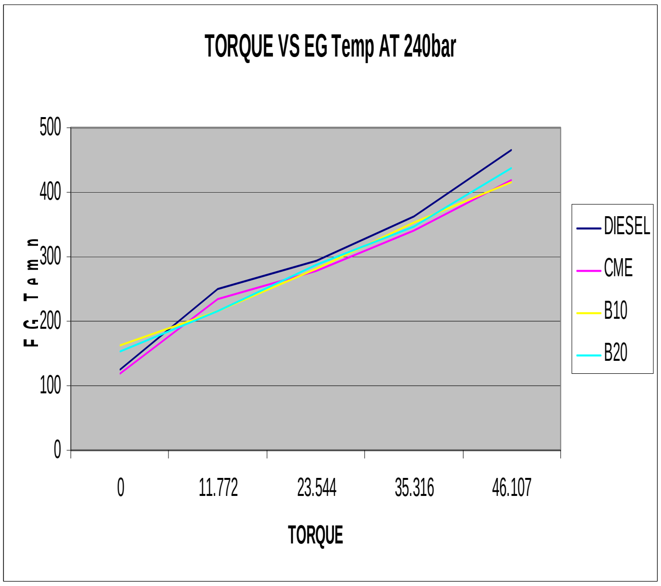
5.4 Exhaust gas temperatures

DIESEL EG TEMP °c	CME EG TEMP °c	B10 EG TEMP °c	B20 EG TEMP °c
125	120	161	154
250	235	215	215
295	279	280	287
362	340	354	348
465	420	416	438



Exhaust temperatures of diesel biodiesel and its blends at 180 bar injection pressure

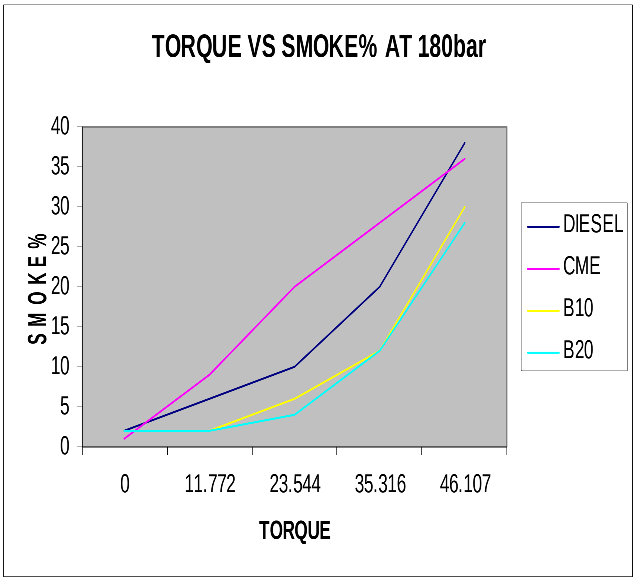
DIESEL EG TEMP °c	CME EG TEMP °c	B10 EG TEMP °c	B20 EG TEMP °c
152	155	148	110
202	190	183	212
280	272	263	285
343	340	335	350
476	436	423	417



Exhaust temperatures of diesel biodiesel and its blends at 240 bar injection pressure

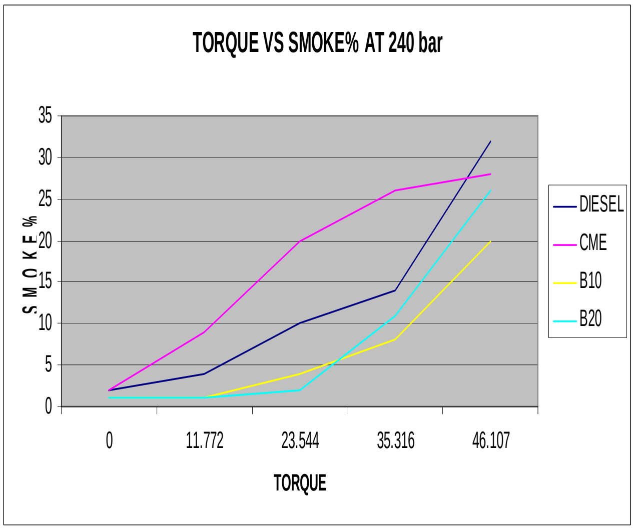
5.5 Smoke density

DIESEL	CME	B10	B20
SMOKE %	SMOKE %	SMOKE %	SMOKE %
2	2	1	1
4	9	1	1
10	20	4	2
14	26	8	11
32	28	20	26



Smoke density of diesel and biodiesel and its blends at 180 bar injection

DIESEL	CME	B10	B20
SMOKE %	SMOKE %	SMOKE %	SMOKE %
2	4	2	2
6	9	2	2
10	20	6	4
20	28	12	12
38	36	30	28



Smoke density of diesel and biodiesel and its blends at 240 bar injection

6. RESULT DISCUSSION

6.1 BRAKE POWER

The brake power developed by the engine on different load conditions starting from no load to7.23 kN. As the load increases the BP developed by engine increases for all blends of biodiesel. At maximum load i.e. 7.23 kN, the B10 blend developed 1.5%, 1.76% and 0.75% more BP when petroleum diesel ,B0, and B20 blends were used, respectively. From the results it is concluded that the biodiesel blend B10 developed more BP at higher loads.

6.2 Total fuel consumption (TFC)

As the load increases no doubt the fuel consumption also increases, but during the study, fuel consumption on various loads was found lesser with B0 compared to blended fuel. It may be due to the decrease in overall calorific value of fuel by increasing percentage of blend. At the maximum load i.e. 7.23 kN, B10 shows 8.14%, 5.34% and 7.46% less fuel consumption as compared to B0, and B20, respectively. In overall prospect, fuel consumption is improved at maximum load in blend B10.

6.3. Brake specific fuel consumption (BSFC)

The variation of brake specific fuel consumption with respect to load is presented in Fig. 3. For all blends tested, brake specific fuel consumption is found to decrease with increase in load. This is due to the higher percentage increase in brake power with load as compared to the increase in fuel consumption. But at no load conditions the developed brake power is less and hence the BSFC is more on that load for all blends. Using lower percentage of biodiesel in biodiesel-diesel blends i.e. B10, the brake specific fuel consumption of the engine is lower than that of diesel (B0) for all loads. In case of B20, the brake specific fuel consumption is found to be higher than that of diesel (B0). With increase in biodiesel percentage in the blends, the calorific value of fuel decreases. Hence, the specific fuel consumption of the higher percentage of biodiesel in blends increases as compared to that of diesel (B0)

6.4 Brake thermal efficiency

In all cases, brake thermal efficiency was having tendency to increase with increase in applied load. This was due to the reduction in heat loss and increase in power developed with increase in load. The maximum brake thermal efficiency at 7.23 kN load is about 28.89% for B10, which is 14.14% higher than that of B0. The maximum brake thermal efficiency was obtained as 26.14% and 26.66 while using B0 and B20, respectively, which was lower by 9.51% and 7.71%, respectively to B10. Hence B10 yields good thermal efficiency compared to B0, B10 and B20. Initially the thermal efficiency of the engine was improved with increasing concentration of the biodiesel in the blend. The possible reason for this is the additional lubricity provided by the biodiesel. The molecules of biodiesel contain some amount of oxygen, which takes active part in the combustion process. It is noticed that after a certain limit with respect to diesel ester blend, the thermal efficiency trend was reverted and it started decreasing as a function of the concentration of blend. This lower brake thermal efficiency was obtained for B20 which could be due to the reduction in calorific value and increase in fuel consumption as compared to B10.

6.5 Exhaust gas temperature

Up to B05 the exhaust gas temperature was lower; thereafter it increased with increasing blends. This reveals that the effective combustion is taking place in the early stage of strokes and there is reduction in the loss of exhaust gas energy. This fact is reflected in brake thermal efficiency and brake specific fuel consumption results as well. When biodiesel concentration is increased, the exhaust gas temperature increases by same value. The highest exhaust gas temperature is observed as 265 _C in B20 blend at 145.29 kN load. The diesel mode exhaust gas temperature is observed as 187.7 _C at 145.29 kN load. The higher exhaust gas temperature may be because of better combustion of the castor ethyl ester as it contents oxygen molecule which helps in proper combustion.

7. CONCLUSION

Biodiesel is a clean burning fuel that is renewable and biodegradable. Castor methyl ester (CME) blends showed performance characteristics close to diesel. Therefore castor methyl ester blends can be used in CI engines in rural area for meeting energy requirement in various agricultural operations such as irrigation, threshing, indistries etc. Although the calorific value of pure CME is lower than that of diesel by about 15%. The blend B10 exhibits a calorific value about 45.50 MJ /kg that is only 2% lower than that of diesel. With this blend engine develops better power when compared with power output with diesel. diesel engine.in view of cost also

0.9 lit of diesel	=Rs 36	(diesel liter Rs 40)
0.1 lit of CME	=RS08	(cme liter Rs 80)
Total lit of 10% CME	=Rs44	

It costs just by Rs 4 than petroleum diesel High power output is reported in many other studies it may be due to better lubricity which reduces friction loss and better combustion of blends. The trends of smoke for CME are same as that of diesel at lower loads and slightly higher at full loads. Hence CME can be alternately used as fuel for diesel engines

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