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Performance, emission and combustion analysis on bio diesel mixture with diesel as an alternative fuel for ci engine

Mr.Sundaraeswaran.S.P, Karthik Sankar.D, Jeevanandham.K, Inbarasu.S, Kavin.B

#Assistant Professor, UG Scholars,

Department of Mechanical Engineering, EBET Group of Institutions, Mullipuram Post, Nathakadaiyur, Tirupur, India.

spsundaresan@gmail.com

***Abstract*— This paper presents the performance and emission contours of a Bio diesel mixture with diesel fuelled compression ignition (CI) engine. The Researches regarding blend of diesel and many bio diesel has been done already with dual mixture, very few works have been done with the combination of five different bio diesel blends with diesel and left lot scope in this area. The present study bring out an experimental of five bio diesel from sesame oil, Neem oil, Groundnut oil, coconut oil and sunflower oil and they are blended with diesel at various mixing ratio. The effect of five bio diesel works in engine and exhaust emission were examined in a single cylinder, direct injection, air cooled and high speed diesel engine at various engine loads with constant engine speed of 1500 rpm. Among the blend 30% of bio diesel mixture shows good performance on par with diesel fuel operation with respect to brake thermal efficiency and heat releases rate at full load. The brake thermal efficiency of blend A was found higher than diesel. The emission of smoke, Hydrocarbon and nitrogen oxide of five bio diesel blend were lower than that of diesel and the exhaust gas temperature for five bio diesel blend was lower than diesel**

***Keywords*— Emission analysis, Bio diesel, Alternate fuel, five bio diesel mixture**

I. INTRODUCTION

The preservation of energy is decreasing now a days and it
alleged that it leads to energy demand. In the last two decades, alternative fuels have obtained and identified as essential. A potential bio diesel substitutes diesel oil, consisting of ethyl ester of fatty acids produced by the transesterification reaction of triglycerides of vegetable oils and ethanol with the help of a catalyst. In addition, bio diesel is better than low diesel fuel in terms of very sulphur content and it is also having higher flash and fire point temperatures than in diesel fuel. A lot of research work pointed out that bio diesel has received a significant attention and it is a possible alternative fuel. Bio diesel and its blends with diesel were employed as a fuel for diesel engine without any modifications in the existing engine.

L. Ranganathan, et al., (2011) in his research work, different parameters for the optimisation of bio diesel production were investigated and then experiments were conducted to study the performance and emission characteristics of a four-stroke, single cylinder, direct-injection, naturally aspirated diesel engine using cotton seed oil (CSO)-based fuels. The blends were prepared with 20% CSO and 40% cotton seed oil methyl esters (CSOME) separately with neat diesel on volume basis as diesel fuels. A maximum of 77.5% bio diesel were achieved with 20% methanol in the presence of 0.5% sodium hydroxide. The experimental results showed that the reduction in smoke, hydrocarbon (HC) and carbon monoxide (CO) emissions were observed for CSOME and its diesel blends along with increased NOx. However, a reduction in NOx, increase in smoke, HC and CO emissions were observed for CSO 100 and its diesel blends compared to those of neat diesel.

On the other hand specific energy consumption and oxides of nitrogen of WCO bio diesel blends are found to be higher than diesel. In addition combustion characteristics of all bio diesel blends showed similar trends when compared to that of conventional diesel. The quality of bio diesel is most important for engine parts and various standards have been specified to check the quality. The important properties of safflower oil and its methyl ester (bio diesel), such as density, kinematics viscosity, flash point, iodine number, neutralization number, pour point, cloud point, and cetane number, are found out and compared to those of No. 2 petroleum diesel. Fuel properties of methyl esters of Carthamus tinctorius L. oil compare well with ASTM and EN bio diesel standards.

G. Venkata Subbaiah, et al., (2011) investigates experimentally the performance, and exhaust emission characteristics of a direct injection (DI) diesel engine when fuelled with rice bran oil bio diesel (RBD) and its 2.5%, 5%, and 7.5% ethanol blends over the entire load range. The experimental test results showed that the maximum brake thermal efficiency was obtained with 2.5% ethanol blended with RBD and are 6.98%

and 3.93% higher than that of diesel fuel (DF) and bio diesel, respectively, at full load of the engine. Among the ethanol blends the minimum brake specific fuel consumption of 0.339 was observed with 2.5% ethanol. The exhaust gas temperature of the bio diesel was reduced by the ethanol blending. The lowest carbon monoxide, hydrocarbons and unused oxygen emissions were recorded with 2.5% ethanol blend. The smoke of the bio diesel was reduced by 20% when blended with 7.5% of 9 ethanol. The intensity of sound with bio diesel and its ethanol blends was lower than that of DF at full load of the engine. The maximum reduction of smoke was 27.47% with 2.5% ethanol blending. Hence the 2.5% ethanol blended with bio diesel could improve the performance and reduce the emissions of the diesel engine.[2]

M. S yanarayana, et al., (2011at) investigates the neat vegetable oils having high viscosity and low volatility could result in incomplete combustion in engine operation. The remedy for this is conversion of vegetable oils into bio diesels in order to reduce viscosity and increase volatility, thereby improving the performance in a CI engine. Bio diesel is methyl ester derived from vegetable oils (edible and non edible oils) or animal fats. Bio diesel can be used in pure form or as a blended form with diesel fuel and tested in CI engines with little or no modifications. This article presents the results of investigations carried out on a single cylinder, four stroke, and direct injection diesel engine operated with bio diesels of coconut oil, palm oil, and rubber seed oil. Comparative analysis in terms of brake power, brake thermal efficiency, brake specific fuel consumption, CO, HC, and NOx are discussed. The brake thermal efficiency of palm oil bio diesel is found higher and lower brake specific fuel consumption compared to bio diesels of coconut oil and rubber seed oil. Rubber seed oil bio diesel shows less emission (CO and NOx) compared to coconut oil bio diesel and palm oil bio diesel. The economic analysis indicates that rubber seed oil bio diesel is less costly compared to bio diesel of coconut and palm oils, and to diesel fuel.[3]

M. Satyanarayana, et al., (2012) studied experimentally the locally available bio fuels, such as rubber seed oil (non edible oil), coconut oil, and palm oil (edible oils), were used as alternative fuels to diesel in a compression ignition engine. The properties of these oils, such as viscosity, specific gravity, 10 calorific value, flash point, and fire point, were determined. The effect of temperature on viscosity of vegetable oils (rubber seed oil, coconut oil, and palm oil) was examined. It was found that the viscosity of coconut oil reduces drastically compared to rubber seed oil and palm oil at all temperatures (40–80 o C). High viscosity of vegetable oils was reduced by preheating to use directly in engines. The performance and emission characteristics of a single cylinder, direct injection diesel engine were determined using diesel and vegetable oils (unheated and preheated conditions). The CO emission was reduced and performance improved for preheated vegetable oils. It is concluded that from the findings of experimentation, the preheated vegetable oils could be used as substitutes to diesel fuel for short-term engine operation.[4]

N. Balakrishnan, et al., (2015) studied about the biomass-derived bio diesel and producer gas are the renovated sources of renewable fuel. In the present study, experiments have been conducted with mixed fuel mode using producer gas as an inducted fuel and near to waste–used vegetable oil bio diesel as an injected fuel in a four-stroke, naturally aspirated, variable compression ratio engine. The results have been compared with single fuel and dual fuel modes of operation with an optimized compression ratio of 18 and fuel injection pressure of 200 bars. Producer gas is collected from the gasifier and stored in gas bags and then supplied to the engine through air surge tank to maintain uniform gas quality, whereas bio diesel is used in the form of B23. The result shows that the maximum brake thermal efficiency of 26.77% is comparable with the dual fuel mode of operation, ignition delay of 13.64◦ is less than the dual fuel mode, and smoke opacity has been reduced up to 16% compared with the conventional fossil fuel. It has been concluded that the internal combustion engine could run with all fuel modes without any modifications and the performance is found to be comparable with that of fossil diesel.[5]

C. Hamamci, et al., (2011) experimented the safflower (Carthamus tinctorius L.) oil was extracted from the seeds of the safflower that grows in Diyarbakir, SE Anatolia of Turkey. Carthamus tinctorius L. seed oil was investigated as an alternative feedstock for the production of a bio diesel fuel. By traditional solvent extraction, oil was obtained and bio diesel was prepared from safflower by transesterification of the crude oil. A maximum conversion of 93% (oil to ester) was achieved using 100% excess methanol, i.e., molar ratio of methanol to oil is 6:1 and catalyst (Noah) concentration of 0.5% at 65oC. The viscosity of bio diesel oil is nearer to that of petroleum diesel and the calorific value is about 5.5% less than that of diesel. The quality of bio diesel is most important for engine parts and various standards have been specified to check the quality. The important properties of safflower oil and its methyl ester (bio diesel), such as density, kinematics viscosity, flash point, iodine number, neutralization number, pour point, cloud point, and cetane number, are found out and compared to those of No. 2 petroleum diesel. Fuel properties of methyl esters of Carthamus tinctorius L. oil compare well with ASTM and EN bio diesel standards. The present experimental results support that methyl ester of safflower seed oil can be successfully used as diesel.[6]

Hifjur Raheman, et al., (2013) investigated a 10.3-kW single-cylinder water-cooled direct-injection diesel engine was evaluated using blends of bio diesel (B10 and B20) obtained from a mixture of mahua and simarouba oils (50:50) with high-speed diesel (HSD) in terms of brake specific fuel consumption, brake thermal efficiency, and exhaust gas temperature and emissions such as CO, HC, and NOx. Based on performance and emissions, blend B10 was selected for long-term use. Experiments were also conducted to assess soot deposits on engine components, such as cylinder head, piston crown, and fuel injector tip, and addition of wear metal in the lubricating oil of diesel engine when operated with the bio diesel blend (B10) for 100 h. The amount of 12
soot deposits on the engine components was found to be, on average, 21% lesser for B10-fueled engine as compared with HSD-fuelled engine due to better combustion. The addition of wear metals such as copper, zinc, iron, nickel, lead, magnesium, and aluminium, except for manganese, in the lubricating oil of B10-fueled engine after 100 h of engine operation was found to be 11% to 50% lesser than those of the HSD-fuelled engine due to additional lubricity.[7]

Harveer S. Pali, et al., (2014) deals with an underutilized vegetable oil; Sal seed oil (Shorea Robusta) as a feedstock for bio diesel production. The production potential of Sal seed oil is very promising (1.5 million tons in a year) in India. The pressure filtered Sal seed oil was transesterified into Sal Methyl Ester (SME). The kinematic viscosity (5.89 cSt), density (0.8764 g/cc) and calorific value (39.65 MJ/kg) of the SME were well within the ASTM/EN 13 standard limits. Various test fuels were prepared for the engine trials by blending 10%, 20%, 30% and 40% of SME in diesel on volumetric basis and designated as SME10, SME20, SME30 and SME40 respectively. The BTE, in general, was found to be decreased with increased volume fraction of SME in the blends. At full load, BSEC for SME10, SME20, SME30 and SME40 were 13.6 MJ/kW h, 14.3 MJ/kW h, 14.7 MJ/kW h and 14.8 MJ/kW h respectively as compared to 13.9 MJ/kW h in case of diesel. At higher load conditions, CO, UHC and smoke emissions were found lower for all SME blends in comparison to neat diesel due to oxygenated nature of fuel. SME10, SME20, SME30 and SME40 showed 51 ppm, 44 ppm, 46 ppm and 48 ppm of UHC emissions respectively as compared to 60 ppm of diesel. The NOx emissions were found to be increased for SME based fuel in comparison to neat diesel operation. At peak load condition, SME10, SME20, SME30 and SME40 had NOx emissions of 612 ppm, 644 ppm, 689 ppm and 816 ppm as compared to 499 ppm for diesel. It may be concluded from the experimental investigations that Sal seed bio diesel is a potential alternative to diesel fuel for reducing dependence on crude petroleum derived fuels and also to reduce pollution significantly.[9]

Nomenclature

BSU	Bosh smoke meter
BTDC	before top dead centre
CA	crank angle
SSO	sesame oil blend
NMO	neem oil blend
CCNO	coconut oil blend
GNO	groundnut oil blend
SFO	sunflower oil blend
CO	carbon monoxide
CO2	carbon dioxide
EGT	exhaust gas temperature
NO	nitric oxide
Ppm	part per million
CCI	calculated cetane index
BDM	Bio diesel mixture
Y	total percentage uncertainty
↑	increase in values
X_1	uncertainty of fuel consumption
X_2	uncertainty of brake power
X_3	uncertainty of air consumption
X_4	uncertainty of NO emission
X_5	uncertainty of HC emission
X_6	uncertainty of CO emission
X_7	uncertainty of smoke emission
X_8	uncertainty of pressure measurement
X_9	uncertainty of speed measurement
X_{10}	uncertainty of CO2 measurement
X_{11}	uncertainty of temperature measurement
↓	decrease in value

Table 1

Property	DL	SSO	NMO	CCNO	GNO	SFO	BDM
Density @ 15 ˚C (g cm3)	0.85	0.8672	0.900	0.8733	0.89	0.884	0.855
Kinematic viscosity @ 40 ˚C in cST	2.049	4.2	5.5	2.83	4.6	3.6	4.8
Flash point ˚C	78	170	110	110	130	170	125
Higher calorific value in MJ/kg	42.57	40.5	39.89	39.58	40	41.69	42
Cetane number/CCI	47.73	50.48	55.31	70	50.48	49.2	59.2
Pour point ˚ C	-6	-14	4	-12	-14	-7	-6
Cloud point ˚ C	<10	-6	8	-3	10.7	-5	-8

Table 1

2. TEST FUEL

The blends of SSO,NMO,GNO,CCNO,and SFO were prepared in following proportions on volume basis.90% of diesel and 10% of BDM (SSO10,NMO10,GNO10,CCNO10 and SFO10). 70% of diesel and 30% of BDM (SSO30,NMO30,GNO30,CCNO30 and SFO30) were prepared. Before and After each blending, examined in accordance with the standards of Bureau of Indian standards (BIS)15607(2005),Table 1 present the fuel properties of all the fuel tested. CCI is the calculated cetane index. The cetane index is an approximation to cetane number computed from the empirical correlation given in Colin R. Ferguson. The index is useful because it is cheaper to obtain than to measure experimentally actual cetane number.

3. EXPERIMENTAL SET UP

The experimental set up was shown in Fig 1.A single cylinder four stroke water cooled direct injection diesel engine (the fuel is injector directly into the cylinder in which the bowl in the piston crown serve as the combustion chamber) was used for this experimental study (refer Table 2) for engine details.The engine cylinder was fitted with a piezo electric transducer for sensing in cylinder pressure. A top dead centre (the crank position at which the piston comes to rest when the cylinder volume is minimum) pulse pick up was fitted to sense

the crank angle and an eddy current dynamo meter was fitted to the engine to apply load and measure the power output of the engine at various loads. The high speed data acquisition system was used to record the pressure crank angle data. The air, diesel consumption measurements were obtained from pressure transmitter interfaced instruments. A specialized software was interfaced with the engine with the help of suitable hardware so that the sensors and transducers provided the required input to the software for calculation of performance parameters. The CO, NO, and HC emissions were measured by AVL five gas analyser at various loads on the engine. The smoke emission was measured by Bosch smoke meter.

4.TEST PROCEDURE

The engine was warmed up before starting the experiment and then the engine outlet water temperature was maintained constant by controlling the cooling water flow rate. Diesel, neat BDM and SIX blends of BDM(BDM 25, 30, 60,70,80,90) were used as test fuels in a DI diesel engine with variable load conditions at a constant engine speed of 1500 rpm. For each operating condition of engine load, the specific fuel consumption, engine power output, exhaust emissions, and crank angle cylinder pressure were obtained. The cylinder pressure e crank angle data were averaged out for 100 combustion cycles. All experimental measurements were repeated many times and averaged for improved test result accuracy and dependability. The brake thermal efficiency, brake specific energy consumption, and volumetric efficiency were calculated for each load by the software installed in the set up. The heat release rate, ignition delay, maximum rate of pressure rise and combustion duration were calculated from pressure crank angle data. All the emission parameters were measured using exhaust gas analyser and smoke meter.

General details	Single cylinder,water cooled
Make	Kirloskar TAF 1
Cubic capacity	661 cc
Bore	87.5mm
Stroke	110mm
Compression ratio	17.5:1
Speed (constant speed)	1500 rpm
Rated power	4.4KW
Dynamometer	Eddy current
Pressure pick up	Piezotronics HSM111A22

Table 2
Engine details

5. ERROR ANALYSIS

The experimental uncertainty may be taken as the possible value the error may have. Error and uncertainties in the experiments can arise from instrument selection, calibration, condition, environment, observation, reading and test planning. Uncertainty analys is is needed to prove the accuracy of the experiments.

Percentage uncertainties of various parameters like total fuel consumption, specific fuel consumption, brake power and brake thermal efficiency were calculated using the percentage uncertainties of various instrument given in the Table 3.

Total percentage uncertainty of this experiment is

=Square root of {(uncertainty of TFC)^2
+(uncertainty of brake power)^2
+(uncertainty of specific fuel consumption)^2
+(uncertainty of brake thermal thermal efficiency)^2
+(uncertainty of CO)^2 + (uncertainty of $C0_2$)^2
+(uncertainty of UBHC)^2 + (uncertainty of NO_x)^2
+(uncertainty of Bosch smoke number)^2
+(uncertainty of EGT indicator)^2
+(uncertainty of pressure pick up)^2}

= square root of $\{(1)^2 + (0.2)^2 + (1)^2 + (0.2)^2 + (0.15)^2 + (0.2)^2 + (0.2)^2 + (0.15)^2 + (1)^2\}$
$= \pm 3\%$

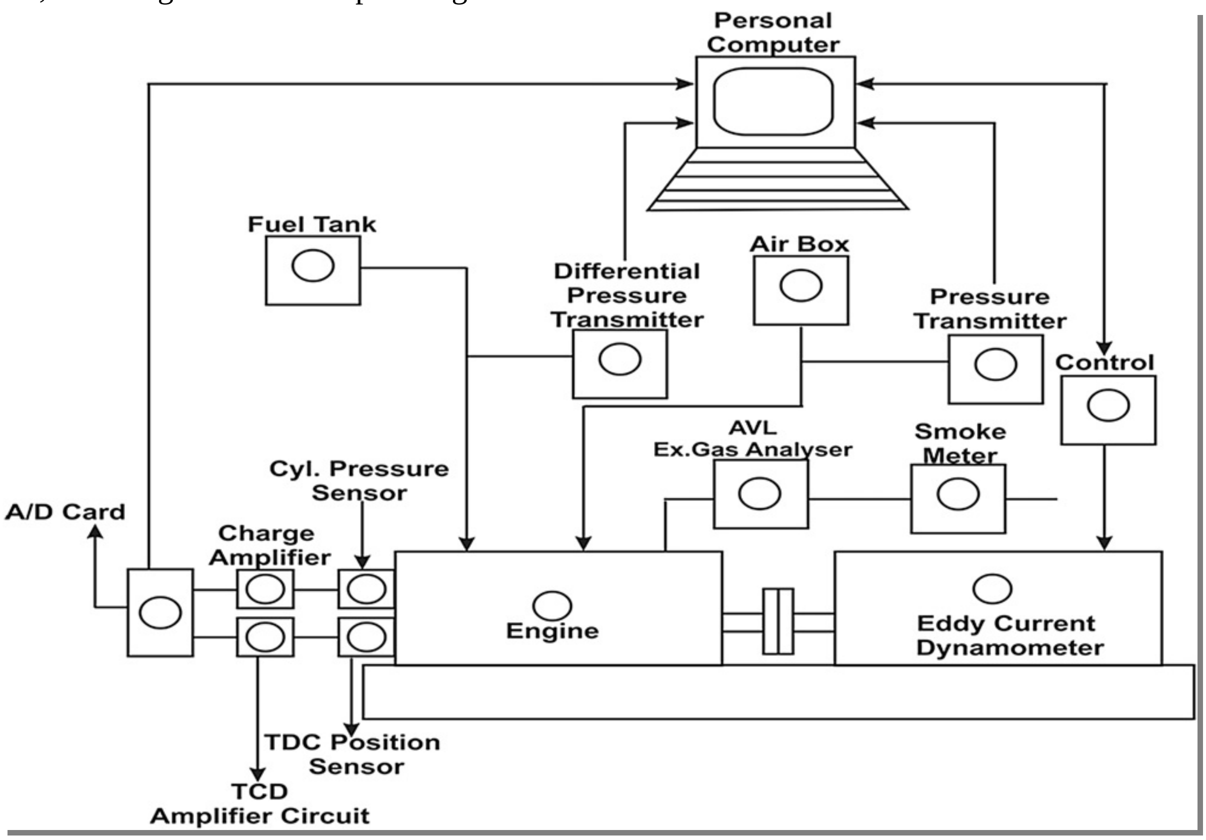

Fig.1 Experimental Setup

TABLE 3

List of instrument and its range, accuracy, measurement technique and uncertainties

Instruments	**Range**	**Accuracy**	**Measurement techniques**	**percentage uncertainty**
1. Gas Analyser	CO 0-10%	± 0.02%	NDIR principle(Non-	± 0.2
		± 0.03%	depressive infra red sensor)	± 0.15
	CO2 0–20%	± 20ppm		± 0.2
UBHC 0–10,000ppm	± 10ppm			± 1
	Nox 0–5000ppm	± 0.1	Electro chemical sensor.	± 0.15
2. Smoke level measuring instrument	SN 0–10	± 1° C		± 0.1
3. EGT indicator	0–900 1C 71 1C	± 10rpm	k-type (Cr Al) thermocouple	± 0.2
4. Speed measuring unit	0–10,000 rpm	± 0.1kg	Magnetic pick up	± 1
5. Load indicator	0–100 kg 70.1 kg	± 0.1cc	Strain gauge type load cell	± 0.2
6. Burette for fuel measurement		± 0.6s		± 1
7. Digital stop watch		± 1mm		± 0.2
8. Manometer 71mm		± 0.1kg		± 1
9. Pressure pick up	0–110 bar	± 1°		± 0.1
10. Crank angle encoder			Magnetic pick up type	± 0.2

6. RESULT AND DISCUSSION

6.1. *Performance characteristics*

The variation of SFC with brake power output is shown in Fig. 2. Since the heat content of the BDM is higher than that of diesel fuel, a very minimum hike in fuel consumption is obtained with BDM mode. In Five different mode of bio diesel is notable increase in fuel consumption is obtained between 75% load and full load. The main reason for the increased fuel consumption is due to the beginning of knock at 75% load. This is clearly seen in P–y diagram (Fig. 6). Unusual hike of peak pressure, more fluctuation in cylinder pressure

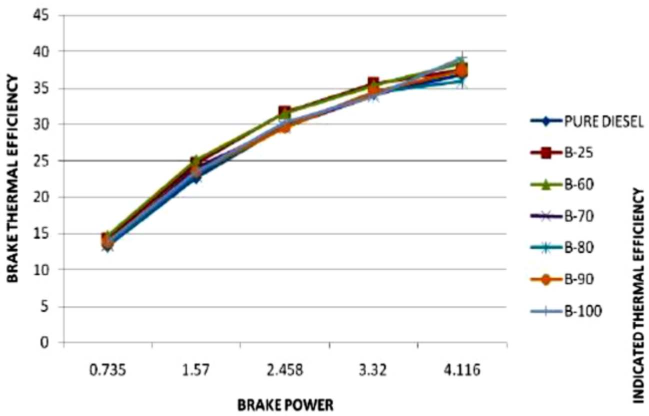

Fig.3. Brake power Vs Brake Thermal Efficiency

Fig. 3 – Fig.10 indicate the variation of various performance and emission parameters with respect to load or brake power. It is observed from the figures that brake thermal efficiency and mechanical efficiency increase with increase in load, B25 and B60 give maximum brake thermal efficiency and mechanical efficiency respectively. Highest indicated thermal efficiency is obtained for B100

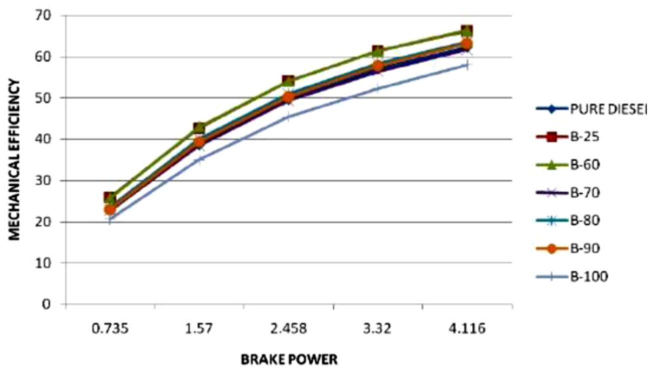

Fig.4. Brake power Vs Mechanical Efficiency

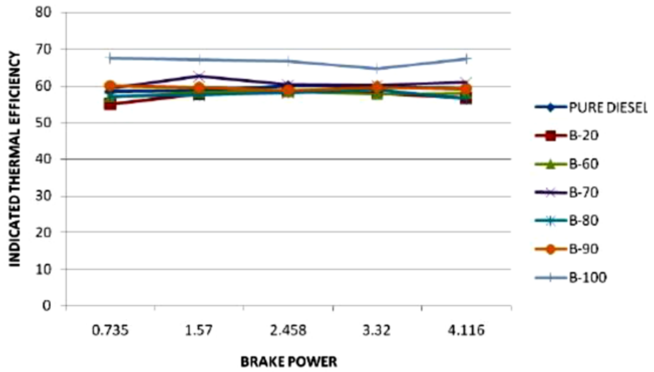

Fig.5. Brake power Vs Indicated Thermal Efficiency

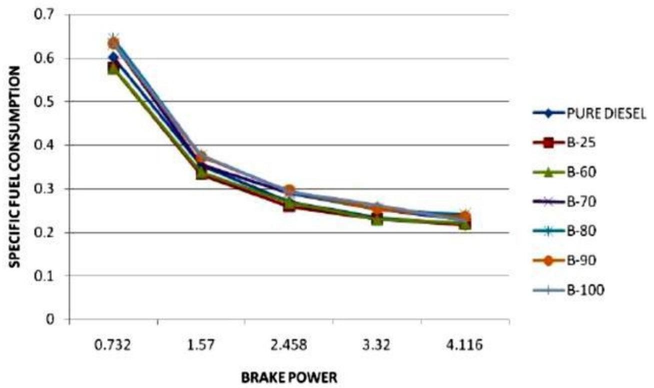

Fig.6. Brake power Vs Specific Fuel Consumption

and lowest bsfc for B 25. Engine load or brake power has much less effect on emissions and hence type of fuel was taken as variable and graphs have been drawn. Emissions with biodiesel operation were less compared to diesel operation. The reasons for all above may be presence of oxygen in the bio diesel which leads to better combustion and fewer emissions

6.1.1. Brake specific fuel consumption

Fig. 7a shows the change in BSFC with respect to brake power for various blend fuels and diesel. It is clearly evident from the figure that BSFC of B25 blend is akin to that of diesel whereas; B75 and B100 blends show some discrepancies. BSFC of the engine depends upon the relationship between the amount of fuel injected and the calorific value of the fuel . As BDM has a lower calorific value, in order to produce the same power output, the TFC as visualized from Fig. 7 b, is more for BDM and its blends, thereby resulting in a higher BSFC. However, lower blends such as B25 show good agreement with diesel at most of the loads. The reason behind the comparable BSFC for B25 with diesel is that although the calorific value of B25 is slightly lower than that of diesel, the improved combustion due to the presence of inbuilt oxygen in it compensates the reduced energy. Moreover, the viscosity of B25 is comparable to diesel, while on the other hand, the higher blends such B75 and B100, experiences less complete combustion, due to lower calorific value and higher viscosity of BMD. In compliance with these findings, Raheman et al. conceded increased BSFC with the increase in biodiesel proportion.

6.1.2. Brake thermal efficiency

The thermal efficiency of the engine relies on the extent to
which the fuel is burnt inside the combustion chamber .
Fig. 7c shows the BTE of the engine fuelled by various blend fuels and diesel. It can be seen from the figure that B25 has a better efficiency than diesel and other blend fuels under different loading conditions. For instance, the BTE of B25 was increased by 8.6% at lower load and 4% at higher load in comparison to diesel. This is due to the fact that KME has a higher cetane number and the presence of oxygen in the fuel is favourable for combustion. However, with the increase of KME blend ratio, there is a slight drop in BTE. This is mainly due to the combined effects of the increased viscosity of the fuel and the presence of inbuilt oxygen. The lower blends of BMD have a lower viscosity and experience better atomization relative to higher blends; as a result, their thermal efficiencies are higher. However for higher blends of BMD, the increased viscosity of the blend fuel affects the fuel atomization and predominate the combustion process, causing the efficiency to drop.

6.1.3. Heat release rate and cumulative heat release rate

Cetane number of the fuel is primarily responsible for the ignition process and therefore, the SOC (start of combustion) is little bit earlier for BDM and its blends as their cetane number is higher than that of diesel (Table 1). It can also be observed from Fig. 8a that the peak heat release rate for B25 lie in close agreement with diesel at maximum load of the engine. Nonetheless, the other blends such as B75 and B100 show a progressive decrease in peak heat release rate. For example, the peak heat release rate of B100 is 33% lower than that of diesel. This is because with the increase of
BDM percentage, the calorific value of the blend decreases, while the viscosity of the blend increases, affecting the fuel atomization and the ensuing combustion process, resulting in a lower peak heat release rate. Similar to this, Muralidharan and Vasudevan pointed out a decrease in peak heat release rate of biodiesel blends than diesel on account of higher viscosity and poor spray characteristics. Further, the reduced premixed combustion has had its impact on diffusion combustion as the accumulated heat release happens to get reduced for higher blends of BDM. For better clarity
and understanding, cumulative heat release rate curve has been drawn and is shown in Fig. 8b.

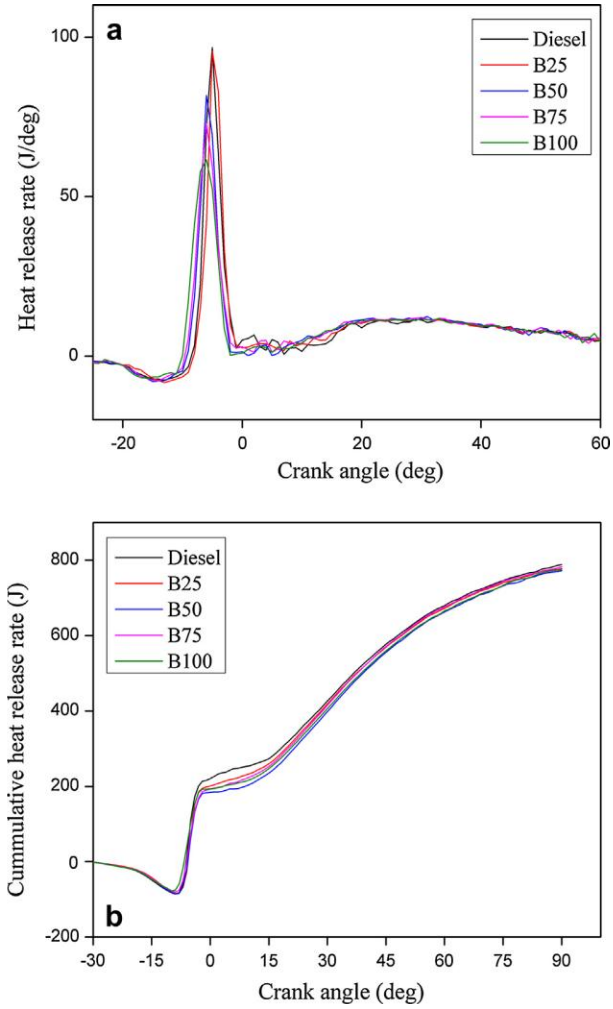

Fig. 8. Variation of combustion parameters with crank angle for maximum engine power output (a) heat release rate and (b) cumulative heat release rate.

6.2.1 CO emission

Fig. 9a shows the CO emission for various blend fuels and diesel. It is noted that all the blend fuels emit higher CO emission, except B25, especially at full load condition, despite the presence of inherent oxygen within BDM. This is due to the fact that more fuel is injected into the engine to produce the same power output as diesel (Fig. 7b), which increases the fuel/air ratio, resulting in incomplete combustion. At the same time, the increased viscosity of BDM further deteriorates the combustion process resulting in more CO emission. However, for B25, the CO emission was observed to be in par with diesel, with a slight increase at full load condition. Since B25 does not confront with poorer atomization, and the presence of inbuilt oxygen has supported enhanced combustion, the results are in agreement with diesel. There are varied results with the CO emission for biodiesel, as Sahoo et al. , when comparing the emission of jatropha and karanja biodiesel, showed increased and decreased CO emission for jatropha and karanja, respectively. These distinctions might have arisen on account of feedstock type, biodiesel synthesis methodology and others. As a matter of fact, most of the researchers tend to report higher CO emission mainly because of the higher viscosity of biodiesel, like the one presented here with BDM.

6.2.2. NOX emission

Diesel engine are prone to more NOX emission due to higher heat release rate and rapid rise of temperature inside the combustion chamber . The NOX emission for various blends of BDM increases with the increase in load due to the increased quantity of fuel injection, which when being burnt elevates the in-cylinder temperature. Apparently, from Fig. 9b, the NOX emission for B25 blend is noticed to be slightly higher than diesel. The magnitude of peak heat release rate for B25 is almost similar to diesel and this accompanied by presence of excess oxygen paves way for the reaction of nitrogen molecules with oxygen at the temperature of burnt gas mixture, resulting in small increase in NOX emission than diesel at higher loads. However, B100 and other higher blends shows slightly reduced NOX emission than that of diesel since the combustion of B100 is predominated by the significant increase in viscosity and thereby, affecting the combustion process. In justification with this, Labeckas et al. indicated lower NOX emission for pure biodiesel, Rapeseed methyl ester in their case, due to lower calorific value and slower evaporation of high viscous biodiesel.

6.2.3. Smoke and exhaust gas temperature

The variation of smoke emission with respect to brake power for different blend fuels is shown in Fig. 10a and it is found to increase with the increase in blend ratio. The smoke value of B25 happens to be in par with diesel. For all other BDM blends, the smoke value is higher than diesel, with B100 blend reporting a 31.2% increase at full load condition. It is well known that soot precursors are formed during premixed combustion phase and if the premixed combustion phase is more pronounced, there is more time available for carbon particles to combine with oxygen and combust properly . But in this case, the premixed combustion phase is less pronounced for higher blends of BDM on account of shorter ignition delay and lower calorific value, which in effect, has caused for liberation of more smoke. The other potential reasons may include increased fuel/air equivalence ratio and viscosity of higher blends of BDM. The deterrence’s in combustion, resulting in increased smoke emission for biodiesel, has been remarked by Agarwal and Agarwal , which conforms the results of present study.

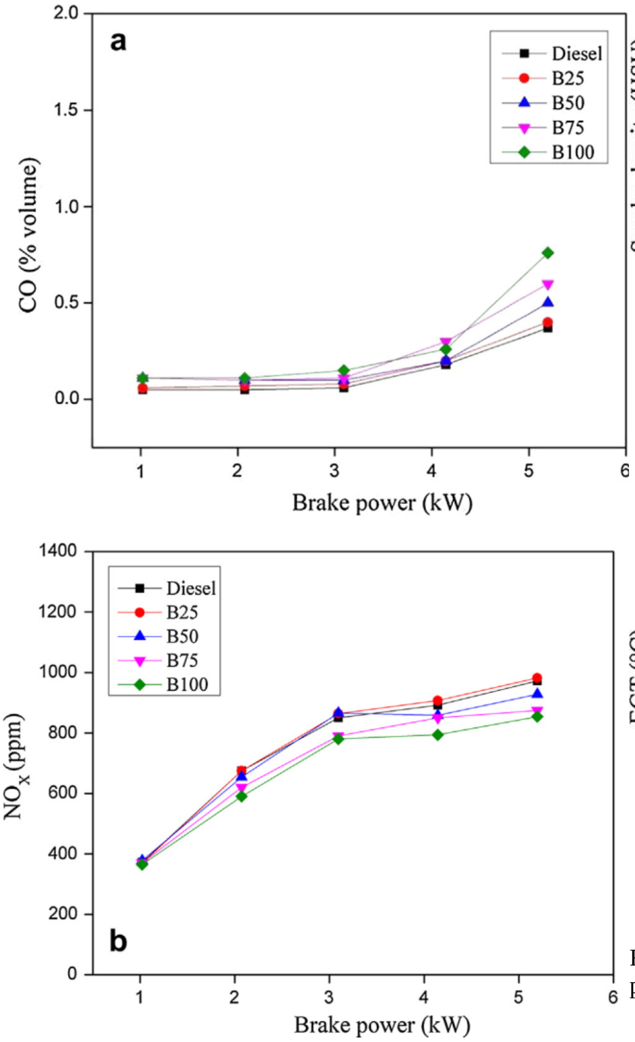

Fig. 9. Variation of emission parameters with brake power (a) CO (carbon monoxide) and (b) NOX (nitrogen oxides).

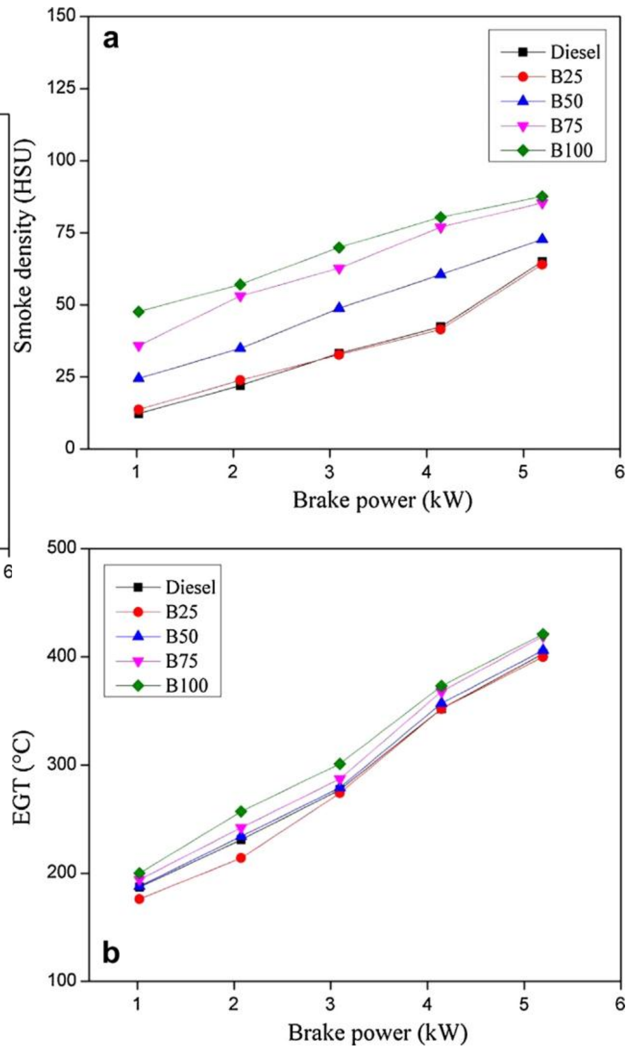

Fig. 10. Variation of emission parameters with brake power (a) smoke and (b) EGT(exhaust gas temperature)

The EGT of B25 is slightly lower than that of diesel as shown in Fig. 10b. Notably, higher ignition delay results in a delayed combustion and higher EGT . For B25, SOC happens to be a bit earlier than diesel, inciting low temperature to the exhaust gases. This also explains the slightly increased efficiency of B25 compared to diesel. However, the EGT of higher blends of BDM were noticed
to be slightly higher than diesel, despite the higher cetane number of BDM and excess oxygen within BDM, as the combustion is deterred by the higher viscosity of BDM, paving way for late combustion in the tail pipe.

5. Conclusion

The potential benefits of Sesame oil, neem oil, groundnut oil, coconut oil and Sunflower oil mixture (BDM) as source for fuel in diesel engine has been tapped by utilizing BDM as an energy source. These five different oil, extracted by steam treatment process followed by mechanical crushing, underwent alkali trans-esterification and was tested for the first time in diesel engine. Systematic characteristic study of the fuel, in-order to identify the properties of the biodiesel, was done . Among the various blends tested in a single cylinder diesel engine, B25 blend claims a 4% increase in BTE than diesel and comparable emissions of HC, CO, NOX and smoke with diesel. It is believed that the kapok oil would garner much attention and would be a congenial source of fuel among the other alternate fuels in the near future.

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