International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 04 | Apr -2017 www.irjet.net p-ISSN: 2395-0072

Experimental investigation of performance and emission characteristics of Palm oil

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Abstract: *Today the world is at the state of war of consuming the fossil fuel. The developed countries are trying to capture the reservoirs of fossil fuel because they are nothing but zero without the fuel. Another problem with the petro diesel fuel is that the level of pollution is increasing day by day due to excess use in vehicle and machinery. The fossil fuels are available in limited amount to the world. The scientists are trying to find alternative sources of fossil fuel that are effective, environmental friendly and economically functional.This experiment is basically testing the performance and emission characteristics of biodiesel. This paper deals with the same thing. Basically this paper deals with finding of performance characteristics and emission characteristics of engine running with biodiesel and its various blends [B10, B20 and B30] at various conditions. Average brake thermal efficiency of the diesel is higher than biodiesel. There is an increase in brake thermal efficiency (BTE) with increase in load. CO emission by blends of biodiesel is higher than diesel [7]. There is relation between density and atomization. HC emission formed by the blends of biodiesel is greater than that of the diesel. There is less production of NOx from engine running with diesel and on the other hand the engine produces higher NOx running with Palm biodiesel.*

Keywords – **Bio-diesel, Parameter Design, Taguchi Methodology, Trans-esterification**

1. INTRODUCTION

It is unanimously accepted truth that the fossil fuel reservoir is depleting day by day and in coming generation certainly this reservoir will not be able to supply our demand. In view of this, the researchers have put their focus in search of the renewable energy sources. Out of the list of plenty renewable sources of energy, biodiesel is one of the important [1, 2]. Biodiesel may be categorized under the heading of renewable energy sources arguing that as it is mostly sourced from plants and the amount of carbon dioxide produced after burning of the biodiesel derived from a plant is almost less than that of the amount of the carbon dioxide required to nurture that plant from where that amount of biodiesel has been produced [4,5]. In this light, the biodiesel is a renewable source of energy. Further, researchers have been reported that the biodiesel can directly be used as fuel without any major modification in the modern CI (compression Ignition) engines either in pure form (100 % biodiesel) or mixing it with the existing diesel. Furthermore, the pollutants resulting from biodiesel combustion in CI engines are comparatively less harmful to environment and human health [9, 10] than that of the traditional diesel oil. Additionally, emissions from road vehicles are major contributors to air pollution, which is a nagging issue of China regarding environmental point of view [6].

In the contemporary field of research, increased number of researchers has shown their interest in establishing the facts related to the use of biodiesel. In this regard Ramesh D et al. have reported the many facts after synthesizing a great number of publication related to the performance and emission characteristics of biodiesel (derived from various sources) which when used in an engine. They particularly mentioned that the parameters (content of biodiesel, properties of biodiesel and its feed stock, engine type, operating conditions and additives) are bitterly influences the engine power, fuel economy and emission characteristics[11].

A critical review of literature may revels that the biodiesel obtained from different feedstock yields different performance and shows different emission characteristics under different conditions. Noteworthy remarks remarked by the contemporary authors related to performance and emission characteristics of biodiesel sourced from different feed stocks is as follows.

Considering the viewpoint presented by the aforementioned authors, in this paper report their findings after analysis of the data pertaining to the performance and emission characteristics which has been obtained by running an IC engine using biodiesel harnessed from palm.

K. Suresh kumar et al. [15] put forward the investigated the performance and emission characteristics when diesel engine run using Pongamiapinnata methyl ester (PPME) and its blends with diesel. The conclusions came were that blends of PPME with diesel up to 40% by volume (B40) yields better Brake Specific Fuel Consumption and improved emission characteristics. Similarly, **S. Godiganur et al. [16]** used blends of methyl ester obtained from mahua oil and studied performance and emission characteristics in a cummins 6BTA 5.9 G2- 1, 158 HP rated power, turbocharged, DI, water cooled diesel engine. For this case, authors have observed a significant reduction in CO, HC emissions and fuel consumption with slight increase in NOx emission with increased in blend percentage but in contrast, brake specific energy consumption decreases and thermal efficiency of engine marginal increases at the specific operating condition when working with 20% biodiesel blend. For other authors for example **S. Puhan et al. [19]** (mahua oil), **XiangmeiMenget al. [29] (**waste cooking oil)and**Haiter Lenin A et al. [37]** (mahua oil)have carried out the similar experiments but with bio diesel obtained from diversified feed stoke.

2. METHODOLOGY

2.1 Fuel Properties

The role of properties of biodiesel on performance and emission characteristics have discussed by various authors [4]. It is noteworthy that the important properties parameters such as viscosities, flash point, cloud point, cetane number, ash content and chain of aromatic rings dictates the performance and emission characteristics and value of these parameters of a biodiesel is solely depends on the sources (feed stock) with which it is obtained. For example, viscosity, cetane number and flash point of Palm oil is very higher than petro diesel. Also, it contains less percentage amount of ash and sulphur content. The cetane number is volume percent of n-hexadecane in the blend of n-hexadecane and 1-methylnaphthalene [4, 10].

2.2. Experiment Setup and Procedure

The experimental set up used in this work is shown in Figure 1 and with is set up there is also a provision to note the emission related data (CO, HC and NO_X) by attaching an extra set up as shown in Figure 2. Here, CO is expressed in terms of percentage whereas the HC and NO_X is presented in terms of ppm Basically, the set up used in this work is four strokes, four cylinders, Tata Indica, Diesel engine with eddy current dynamometer, Piezo sensor, engine cooling and calorimeter. The details of the specifications of engine set up and smoke analyzer parameters are presented in Table 1 and Table 2 respectively. The experiments are conducted at varying load conditions. Here, the load refers to the BHP. While taking the data, after starting the engine at a particular load is then set by gradually regulating the throttle valve. For a combination of load and blend, the corresponding value of CO, HC and NO_X is directly noted whereas, SFC, BTE is calculated using equation (1) and (2) by noting the fuel flow. Reading has been taken at the steady state condition. The level of load and blend is considered in this work as 10, 15, 20, 25, 30 KW and B0 (only Diesel), B10, B20, B30 respectively.

$$\text{Brake Specific fuel consumption}\left(\frac{\text{Kg}}{\text{kWh}}\right) = \text{BSFC}$$

$$\text{BSFC} = \frac{\text{fuel flow}\left(\frac{\text{kg}}{\text{h}}\right)}{\text{Brake power (kW)}} \qquad (1)$$

$$\text{Brake Thermal Efficiency (\%)} = \text{BTE}$$

$$\text{BTE} = \frac{\text{Brake power (kW)} \times 3{,}600 \times 100}{\text{fuel flow}\left(\frac{\text{kg}}{\text{h}}\right) \times \text{calorific value(kj/kg)}} \qquad (2)$$

Here,

Brake power (kW) = (2×π × Speed × Torque) / (60×1,000)

And

Torque (Nm) = Load (N) × Arm length (m)

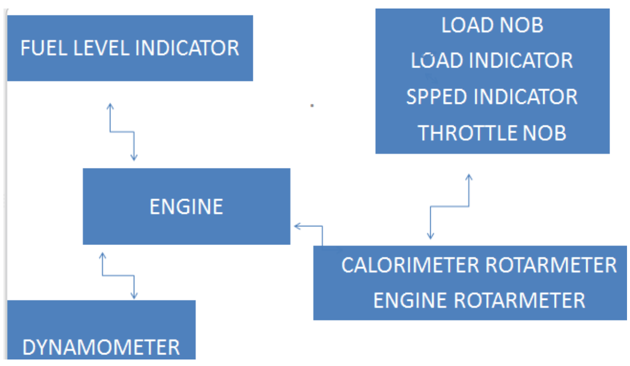

Figure 1. Engine Test Rig

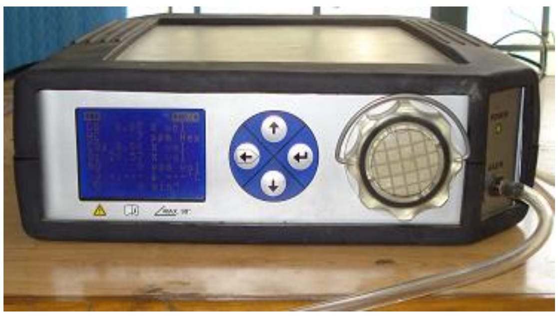

Figure 2.AVL GAS Analyzer (AVL DIGAS 444)

Table 1.Technicalspecificationofthe testengine

Particulars	Specification
Make	TelcTel. Telco
Model	TataIndica,
Type	FourFourcylinders,fourstroke,dieselwater cooled
Ratedpower	39kWat5,000rpm,
Torque	85Nmat2,500rpm
Cylindervolume	1,405cc
Compressionratio	22:1
Dynamometer	Type eddy current, water cooled, with loading unit
Air box	M S fabricated with orifice meter and manometer
Fuel tank	Capacity 15 lit with glass fuel metering column
Calorimeter	Type Pipe in pipe
Piezo sensor	Range 5000 PSI, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 550 RPM
Digital milivoltmeter	Range 0-200mV, panel mounted
Temperature sensor	Type RTD, PT100 and Thermocouple, Type K
Load indicator	Digital, Range 0-50 Kg, Supply 230VAC
Load sensor	Load cell, type strain gauge, range 0-50 Kg
Fuel flow transmitter	DP transmitter, Range 0-500 mm WC
Air flow transmitter	Pressure transmitter, Range (-) 250 mm WC
Rota meter	Engine cooling 100-1000 LPH; Calorimeter 25-250 LPH
Data acquisition card	Resolution12 bit, 8/16 input, mounting PCI slot
Software	"Engine soft" performance analysis software
Overall dimensions	W 2000 x D 2750 x H 1750 mm

Table 2: TechnicalspecificationofALV Analyser

S.NO.	PARAMETER	MEASURMENT	RESOLUTION
1	CO	0-10%	0.01% Vol
2	CO2	0-20%	0.1% Vol
3	HC	0-20000 ppm Vol	1 ppm
4	NOx	0-5000 ppm Vol	1 ppm
5	O2	0-25% Vol	0.01% Vol

2.3 Observation

Following the procedure mentioned in the Section 2.2, the data pertaining to the Brake thermal efficiency, Brake specific fuel consumption, CO %, HC, and $NO_x$are noted for different loading condition and are summarized in Table 4, 5, 6 and 7 for different blends of biodiesel. Also, for better visualization of the trends of the variation, the data is depicted graphically.

In order to have better visualization of the important trends regarding BSFC, BTE and emission related characteristics for each blends, using the data obtained from the experimental investigation are plotted for increasing load condition. These plots are depicted in Figure 3, 4, 5 and 6. Also, the average of each performance (considering all load together) is plotted for all blends so as to visualize the trends of the average performance. This plot is depicted in Figure 8.

Results have been after carrying out the analysis considering variations depicted in Table 4 to Table 7 and graph plotted is displayed in Figure 3 to Figure 7. The important points of the analysis are elaborated in the subsequent subsection 2.4.

Table 3: Properties of biodiesel [14]

Name of oil	Kinematic viscosity (mm^2/s)	Cetane no.	Lower heating value (MJ/kg)	Cloud point (°C)	Pour point (°C)	Flash point (°C)	Density (kg/l)
Palm	5.7	62	33.5	13	-	164	0.88
Diesel	3.06	50	43.8	-	-16	76	0.855

Table 4: Observation Table for B0

LOAD	BTE	SFC	CO %	HC(PPM)	NO_x(PPM)
10	12.0	0.79	0.01	2.0	096
15	16.0	0.47	0.01	1.8	120
20	19.0	0.43	0.02	1.0	140
25	21.0	0.40	0.05	2.1	150
30	22.2	0.38	0.12	4.2	160
Average	18.0	0.49	0.04	2.2	133

Table 5: Observation Table for B10

LOAD	BTE	SFC	CO%	HC(PPM)	NO_x(PPM)
10	10.0	0.86	0.01	1.8	095
15	16.0	0.50	0.01	2.0	130
20	18.4	0.42	0.03	2.1	140
25	20.4	0.37	0.06	6.0	150
30	22.2	0.38	0.11	8.0	160
Average	17.4	0.51	0.04	4.0	135

Table 6: Observation Table for B20

LOAD	BTEE	SFC	CO%	HC(PPM)	NO_x(PPM)
10	10.0	0.86	0.01	1.8	096
15	15.8	0.50	0.02	2.3	135
20	18.5	0.43	0.04	2.0	155
25	20.0	0.40	0.06	4.1	175
30	21.8	0.38	0.13	6.2	160
Average	17.4	0.51	0.04	4.0	135

Table 7: Observation Table for B30

LOAD	BTE	SFC	CO%	HC(PPM)	NO_x(PPM)
10	08.8	0.97	0.01	2.0	095
15	16.0	0.57	0.01	2.0	125
20	18.0	0.43	0.04	4.0	145
25	19.6	0.41	0.05	5.1	165
30	21.2	0.40	0.11	5.8	155
Average	17.4	0.51	0.04	4.00	135

2.4 Discussion

Variation in brake thermal efficiency vs load

From the Figure 3 it can be noted that the brake thermal efficiency of pure diesel is better than bio diesel at respective loads. In contrast, irrespective of load that is average of the brake thermal efficiency has an improved value for all blends and this value (17.4) which is not much less than that of the pure diesel. This fact is displayed in Figure 8. It can also be noted that the maximum thermal efficiency is obtained at maximum loading condition irrespective of the type of blend.

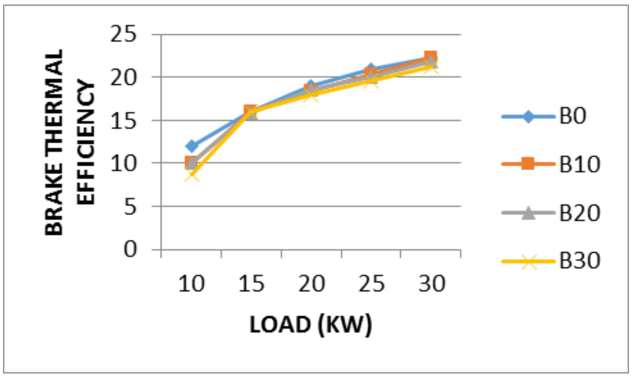

Figure: 3 BRAKE THERMAL EFFICIENCY Vs LOAD (KW)

Brake specific fuel consumption vs load

The comparison of specific fuel consumption for various blends of palm oil and diesel fuel is shown in Figure 4. The pure diesel yields the lowest fuel consumption at all loads. However, it is bit higher than palm oil blends at 25 kW and 30 kW. It seems that the combination effect of density and calorific value has led to this situation. In contrast, the average of the brake specific fuel consumption (Figure 8) is same for all blends of biodiesel and pure diesel.

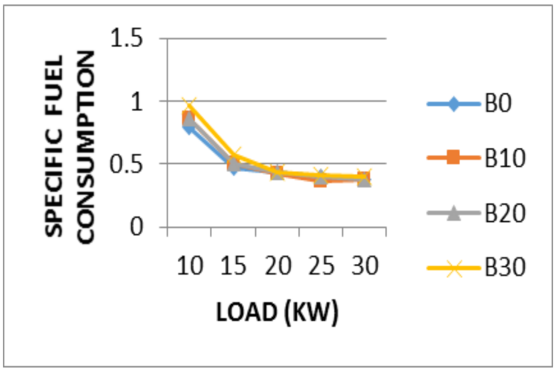

Figure: 4 SPECIFIC FUEL CONSUMPTION Vs LOAD (KW)

Variation of CO vs load

From the Figure 5, it may be noticed that carbon Monoxide emissions for B10, B20 and B30 are comparatively higher than diesel over a broad range. At high load (25 KW), the CO emission for is highest one. However, at the highest load, it has the lowest value. This situation reveals the fact of better combustion at the highest load condition. At low speed, the CO emission was almost equal for all the blends. If it is looked from the perspective of average (Figure 8), the CO emission has the same value for all blends.

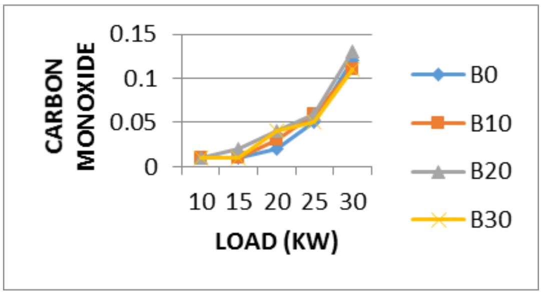

Figure: 5 CARBON MONOXIDE Vs LOAD (KW)

Variation in unburnt hydrocarbon vs load

Unburnt Hydrocarbon consists of incomplete combustion comprising of actual carbon and product of complex reaction. The variation in concentration of HC is shown Figure 6. Palm biodiesel blends produce higher HC emission release compared to the diesel fuel at higher load (25 and 30 KW). It gives clear indication that HC emissions for blends are lower at partial engine load, however, higher at higher engine load. The highest HC emission is found with B10 at high loading condition. From Figure 8, it can be noticed that the HC emission is comparatively lower for the pure bio diesel.

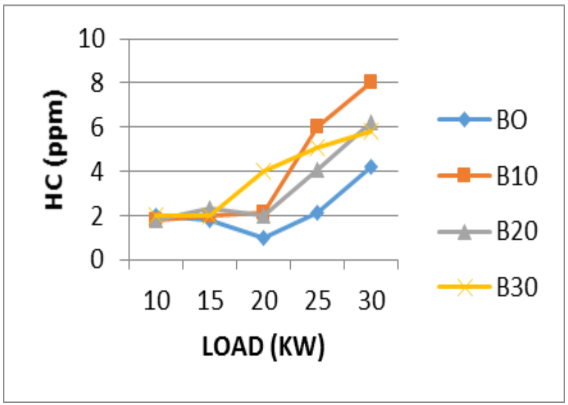

Figure: 6 HYDRO CARBON Vs LOAD (KW)

Variation of NO_xvs load

Figure 7 reveals that emission of NOx increases with increasing load due to higher combustion temperature, hence increase thermal efficiency and NOx emissions. The NOx emission for B20 and B 30 is much more than that of the diesel fuel. The NOx emission for B10 is slightly higher than that of diesel. However, the average, emission has of the blends of biodiesel is not much higher. This fact can be seen from Figure 8.

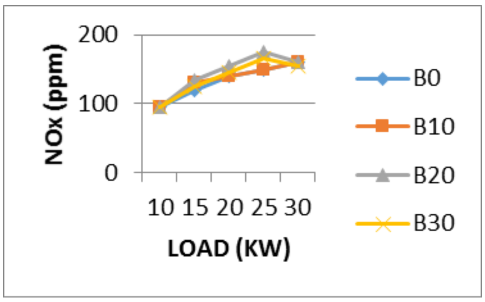

Figure: 7 OXIDES OF NITROGEN Vs LOAD (KW)

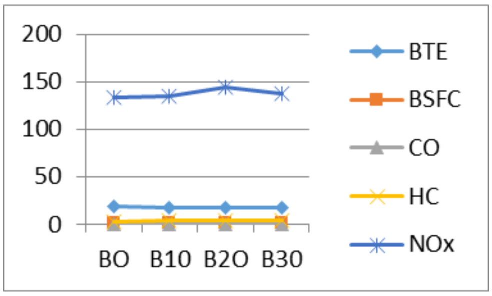

Figure: 8 AVERAGE OF PERFORMANCES AND EMISSIONS Vs LOAD (KW)

3. CONCLUSIONS

In the light of discussion made in aforementioned section the following conclusions can be made. The pure diesel performs well on almost all performance (brake thermal efficiency and specific fuel consumption) and emission characteristics (CO, HC and NO_x) at most of the loading conditions. However, the blend B10 has comparable performance and emission characteristics as that of pure diesel under varying loads and thus can be recommended as an alternative fuel for the CI engines. It may also be noted that the almost all blends yield a comparable performance and shows almost similar emission characteristics from the perspective of the data pertaining to the average of all the loads. Exceptionally, the B10 yields marginally better than that of the other blend.

1. Brake thermal efficiency increases with the increase in load and average brake thermal efficiency of the pure diesel is greater than for all most all blends of palm biodiesel.
2. Specific fuel consumption of pure diesel is less as compared to various blends of biodiesel at all loads. At high load the diesel gives low fuel consumption as compared to the other biodiesel blends.

3. CO emission for all types of blends is higher than diesel. The CO emission data shows correlation between density and atomization process.
4. HC emission produced by the blends of biodiesel is higher than that of the diesel. At low loads, the emission is close to the diesel. However at high load, the emission is much high.
5. Emission of NOx for pure diesel is lesser than Palm biodiesel and its blends. NOx emission increases with the increase of blend.

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