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Experimental Investigation of Single & Twin Cylinder C.I. Engine Performance and Emission Characteristics by Using Hybrid Biodiesel Pongamia Pinnata & Bombax Ceiba

Akshay kumar Shetty[1], Lohith N[2]
[1]M.Tech Student, Sri Siddhartha Institute of Technology, Maralur, Tumakuru
[2]Assistant Professor, Dept of Mech, Sri Siddhartha Institute of Technology, Maralur, Tumakuru

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ABSTRACT: In this research paper the experimentation of performance & emission characteristics of hybrid biodiesel blends on a single and twin cylinder C.I engines are done without any modification. The transesterification process is carried out to get hybrid biodiesel of PBC (mixed Pongamia Pinnata and Bombax Ceiba methyl ester) from mixed oil of pongamia and bombax ceiba is explained. From the experimentation it was found that PBC20(Mixed Pongamia And Bombax Ceiba oil methyl ester 20%+ Diesel 80%) blend gives high brake thermal efficiency compared to neat diesel, brake specific fuel consumption reduces compared to neat diesel fuel and hybrid biodiesel PBC blends reduces HC and CO but slight increase in CO_2 and NO_X compared to diesel fuel . So, it is concluded that PBC20 can be used as an alternative fuel for unmodified C.I Engines.

KEYWORDS: Transesterification, Hybrid-Biodiesel, Fuel properties, Single cylinder diesel engine, Twin cylinder diesel engine.

I. INTRODUCTION

Petroleum energy resources are getting depleted. So there is an important need to investigate renewable, non-polluting and efficient fuels for transport sectors and other fuel using sectors for their future needs [1]. The worldwide growing trends towards many alternatives diesel fuels that show better exhaust emission compared to traditional diesel fuel. Biomass energy is considered as the one of the renewable energy among these alternatives. Biomass energy includes liquid biofuels derived from vegetables oils with low environmental pollution impact, to replace traditional diesel fuels. Some of the liquid biofuels are ethanol for gasoline engines and biodiesel for C.I (compression ignition) or diesel engines [2].biodiesels are one of the alternative fuels to fulfil this need. These fuels have been in use since 1930s. Biodiesels are appealing substitutes for diesel because these fuels can be produced from a variety of renewable and sustainable feedstock's ranging from edible oils such as soya bean, sunflower and corn oils to non edible oils such as Jatropa curacas, Moringa oleifera and Calophyllum inophyllum oils. Biodiesels can also be produced from animal fats and waste cooking oils. More importantly biodiesel can be used directly in diesel engines without modifications and it is easily blended with other fuels to improve the physicochemical properties of the fuel [3].

Nowadays trend of hybrid biodiesel is started to increase the performance and to reduce the emissions, some of the research papers are.

S. Debbarma et al., He has investigated the performance of twin cylinder C.I. engine by using Neem-Karanja hybrid biodiesel blends as a fuel. From the experimental results, He got that BTE of hybrid biodiesel is slightly higher than neat diesel and also hybrid biodiesel blend gave lower HC, CO and NOx than neat diesel. Therefore he concluded that using Neem-Karanja hybrid biodiesel blend (KNB20) can be used as alternate fuel for diesel feuel in unmodified diesel engine [4].

Dilip Kumar Bora et al., He has investigate the performance of single cylinder C.I engine by using polanga, karanja and jatropha hybrid biodiesel blends as a fuel. from the experimental analysis he concluded that using hybrid biodiesl (polanga,karanja and jatropha oils) B20 Blend, performance characteristics are slightly increased compared to diesel fuel and emission characteristics are reduced when compared to neat diesel fuel [5].

S.Arunaprasad et al., conducted experiments on C.I Engine by using Jatropha and Pongamia mixed biodiesel. by making a different blends MB25,MB50,MB75 and MB100 he has performed performance and emission characterssitics, from the results he concluded that BTE higher for M25 blend,BSFC reduced nearer to diesel fuel and reduction of HC and CO and NO_X is slightly increased when compared to neat diesel fuel [6].

R.subramanian, G.Rajendiran, R.venkatachalam, N.Nedunchezhian,K.Mayilsamy et al., studied the performance and emission characteristics of multicylinder C.I engine by using hybrid biodiesel blends as fuel. from the experimentation,they founded that BTE of D10P80E10(Diesel 10%+Pongamia methyl ester80%+ethanol 10%) is 2% higher than diesel, addition of ethanol in diesel reduces NO_X and increases HC Emissions, CO and CO_2 Emissions is lower compared to conventional diesel fuel [7].

N.Balajiganesh,Dr.B Chandra mohan reddy et al., conducted experimental investigation on multi cylinder engine by using mixed oils of cashew nut and cottonseed oil. by preparing a different blends such as B10(Cashew nut oil 5% and Cottonseed oil 5%+90% diesel) and similary B20,B30 and B40. From the experiment he concluded that the BTE, Mechanical efficiency and value for blend B20 is better than diesel and other blends over the entire load range [8].

G. Sulochana,CH.Venkata prasad , P.Kumaran et al., performed experiments on single cylinder C.I. Engine by using fry oil and canola oil mixed biodiesel. With different blends of B20, B40 and B60 conducted performance, combustion and emission characteristics, from the results, they concluded that fry oil and canola oil mixed biodiesel can replace diesel up to some extent. BTE higher for blend 20 compared to diesel, CO and HC emissions are reduced compared to diesel [9].

From the above research work hybrid biodiesel blends increases the combustion, performance and reduces the emissions is concluded. So, in this present work we are going to study the performance and emission characteristics of single and twin cylinder water cooled C.I. engines by using hybrid biodiesel of Pongamia pinnata and Bombax ceiba.

II. MATERIALS AND METHODS

Transesterification:

Transesterification of mixed oils of pongamia and bombax ceiba in equal volume ratio is considered. Transesterification is classified into two types based on FFA (free fatty acid) content, single stage catalyzed transesterification (base catalyzed transesterification, FFA< 4%) and two stage catalyzed transesterification (both acid and base catalyzed transesterification, FFA> 4%). The FFA of mixed oil was 5.53%, hence two stage catalyzed transesterification process is preferred. Initially esterification has done by adding H_2SO_4 1.5ml with 150ml Methanol per litre of mixed oil at required RPM for 1-2 hours in magnetic stirrer at 60°C. After the chemical reaction, it is kept in separating funnel for 1-2 hours to separate the acid layer in separating funnel. Now once again calculated FFA of the separated oil (if it is less than 2% proceed to next step otherwise repeat the acid catalyzed transesterification until FFA $\leq$ 2%) is 1.74%. hence, base catalyzed transesterification is carried out to get Hybrid biodiesel, by adding 5.5gm of NAOH with 150ml of methanol in the reaction vessel with separated oil from acid layer, for 1 to 1½ hours at 60°C in a magnetic stirrer equipment. After the reaction it is transferred into separating funnel for settlement of glycerol by transesterification process then, glycerol is separated and methanol is recovered. Finally it is washed with warm water until the ph value of biodiesel reaches 7, drying is carried out to evaporate the water content in the biodiesel at 100°C with the help of magnetic stirrer.

Preparation of Blends:

The various blends of Hybrid Biodiesel were prepared on simple volumetric ratios. Various Hybrid Biodiesel blends are PBC10 (10% hybrid biodiesel+90% diesel), similarly PBC20 and PBC30 Likewise different blends are prepared as shown in the Table 1 below. The properties of the hybrid biodiesel blends are tabulated in the Table 2.

Table 1: Composition of fuel blends

VARIABLES	DIESEL (%)	PBC (%)
PBC10	90	10
PBC20	80	20
PBC30	70	30

Table 2: Properties of the fuel blends

BLENDS	Density (kg/m^3)	Kinematic Viscosity (mm^2/sec at 40°C)	Calorific Value (kJ/kg)
DIESEL	0.820	2.6	45500
PBC	0.885	5.49	39366
PBC10	0.826	3.6	44887
PBC20	0.833	3.81	44273
PBC30	0.839	4.02	43659

III. EXPERIMENTAL SETUP

Single cylinder:

Experimental research is conducted in a 4 stroke single cylinder water cooled diesel engine with load arrangement of eddy current dynamometer. Detailed specification of the engine is shown in the table 3. AVL DIGAS 444N gas analyzer is used to test the emissions from the test engine. The fuel consumption, speed and exhaust gas temperature were recorded during experiment. By varying loads for different blends the performance and emission is calculated without any modification of the engine throughout the experiment. Where the load is varied in terms of torque from 0-26Nm with a step of 6.5Nm, the performance and emission characteristics is studied with load in terms of percentage from 0-100% with a step of 25%.

Table 3: Specification of a Single cylinder C.I. Engine

Engine	Vertical 4 Stroke water cooled Diesel Engine
Company	Kirloskar
No of Cylinder	01
Rated Output	5 HP
Engine Speed	1500 RPM
Cylinder Bore	80 mm
Stroke Length	110 mm
Compression Ratio	17.5 : 1
Dynamometer	Eddy Current Type(Powermag Make)
Excitation Voltage	0 – 90 Volts (No Load)
Load Voltage	45 Volts (Maximum)
Load Current	3.5 Amps (Maximum)

Twin cylinder:

Experimentation is carried out in a 4-stroke twin cylinder water cooled C.I. Engine with load arrangement of eddy current dynamometer. The detail specification of the twin cylinder C.I engine is shown in the table 4. AVL DITEST gas analyzer is used for checking the emissions in the test engine. Initially the engine is runned in a zero load condition for steady operation. Speed, fuel consumption and exhaust gas temperature were recorded during experiment. By varying load for different blends the performance and emission characteristics are calculated without any modification of the engine throughout the experiment. Whereas the load is varied in terms of torque from 0-60Nm with a step of 15Nm; the performance and emission characteristics is studied with load in terms of percentage from 0-100% with a step of 25%.

Table 4: Specification of a twin cylinder C.I Engine

Manufacturer	Kirloskar oil Engines Ltd.
Model	TV-2
No of Cylinder	Two
Type of Engine	Vertical, 4-Stroke Cycle, Single Acting
Cooling	Water
Fuel	Diesel
Speed	1800 RPM
HP	16 HP
Starting	Hand Cranking
Bore	87.5 mm
Stroke	110 mm
Cubic Capacity	1322cc
Compression ratio	17.5 : 1

IV. RESULTS AND DISCUSSION

Single Cylinder:-

Performance Characteristics:-

Performance of the engine is defined as the degree of success in assigned work i.e., the conversion of heat energy into mechanical energy. The performance of the engine is measured by the terms called parameters. The performance characteristics of the engine are the very important criterion for selection and suitability of alternate fuels. This study evaluates BTE and BSFC of Biodiesel blends.

The variation of brake thermal efficiency with load for diesel and Hybrid Biodiesel blends is obtained as shown in the Fig 1. The brake thermal efficiency increased with load for all fuels mode. The reason for higher brake thermal efficiency may be due to the extended ignition delay and the leaner combustion of hybrid biodiesel. The BTE for PBC10, PBC20 & PBC30 is less than that of conventional diesel fuel by 8.89%, 5.78% and 14.92% respectively. The maximum brake thermal efficiency was observed with PBC20 for all loading condition as compared to other hybrid biodiesel blends with conventional diesel fuel.

[1] Brake Thermal Efficiency (BTE):

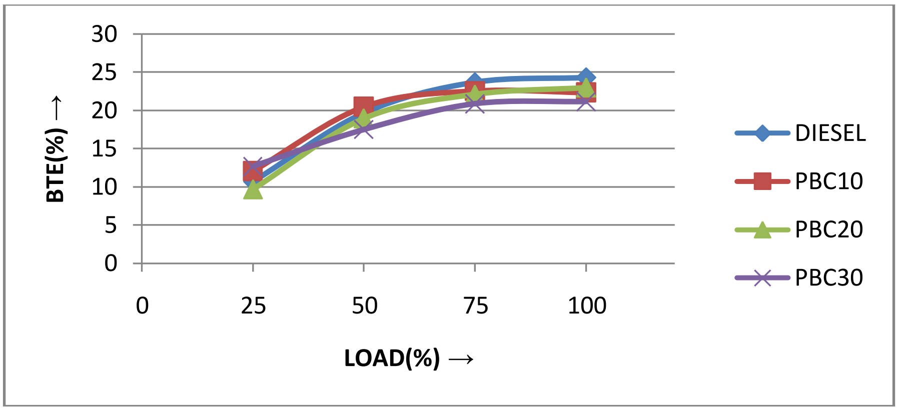

Fig 1: Brake thermal efficiency V/s load

[2] Brake Specific Fuel Consumption (BSFC):

The variation of brake specific fuel consumption with load for different fuel blends is as shown in Fig 2. The BSFC was slightly increased with loads for Hybrid-biodiesel blends of all the fuel modes. The BSFC of PBC10 is 12.42% higher than that of the diesel fuel at maximum load of the engine. The BSFC was higher by 3.40% and 22.39% respectively with the blends PBC20 and PBC30 as compared to diesel fuel. It is due to the lower heating values of hybrid biodiesel compared with diesel fuel.

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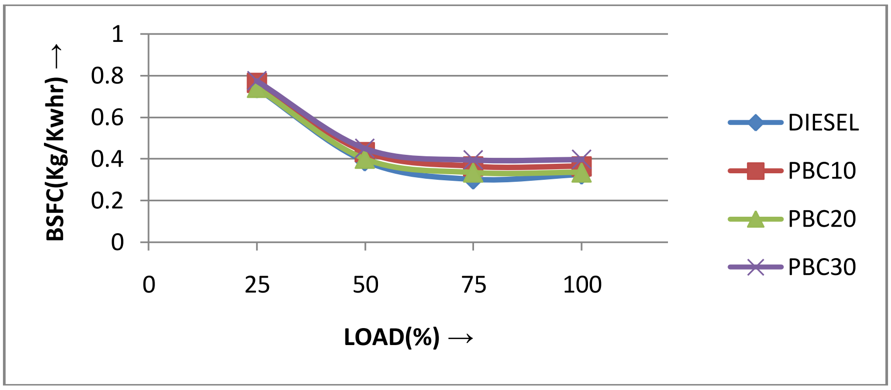

Fig 2: Brake specific fuel consumption V/s load

Emission Characteristics

1) Carbon-dioxide (CO_2) emissions:

The variation of carbon dioxide with load for diesel fuel and hybrid biodiesel blends as shown in the Fig 3. The CO_2 emissions decreased with load for all the fuel modes. The CO_2 emissions of PBC10, PBC20 and PBC30 were slightly lesser than those of diesel fuel from 50% load to maximum load. The Diesel-Hybrid Biodiesel blended fuels shows lower CO_2 emissions at full load conditions due to the oxygen rich in the biodiesel. Where hybrid-biodiesel blends PBC10, PBC20 and PBC30 has decreased emissions by 1.66%, 4.84% and 5.66% respectively as compared to fossil diesel.

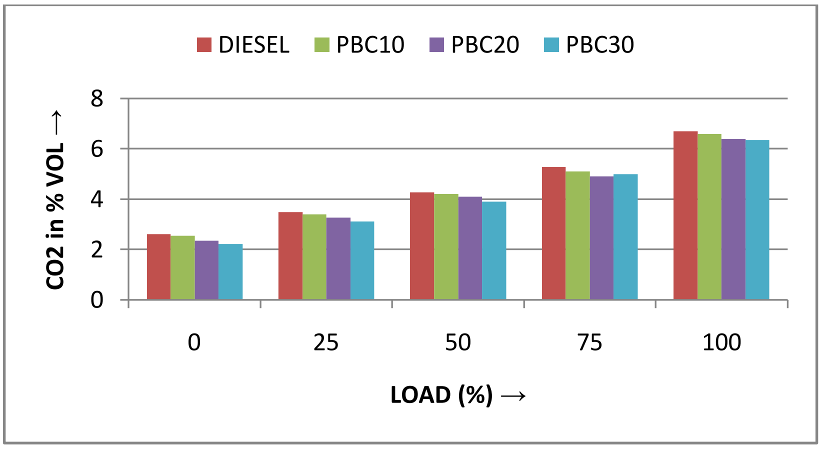

Fig 3: CO_2 V/s load

2) Hydro-Carbon (HC) emissions:

The variation of hydro-carbon emissions with load for diesel fuel and hybrid biodiesel blends PBC10, PBC20 and PBC30 is as shown in the Fig 4. The HC emissions were decreases gradually by increasing load as shown in the fig above for all fuel modes. The HC emissions of the hybrid biodiesel blends were lower than those of diesel fuel at all load conditions. It is due to the better combustion achieved at a medium to maximum loading conditions. The HC emissions of PBC10, PBC20 and PBC30 were 6.77%, 10.52% and 8.62% lesser than that diesel fuel respectively at full load of the engine.

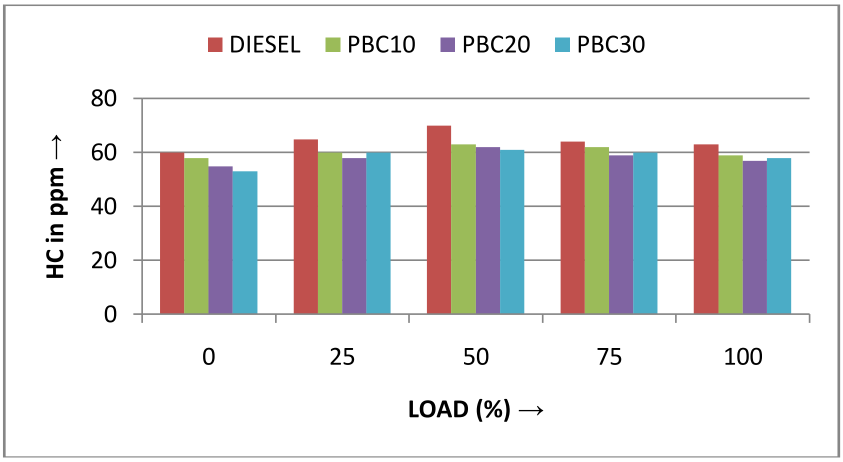

Fig 4: Hydro-carbon V/s Load

3) Carbon-monoxide (CO) emissions:

The variation of carbon-monoxide with load for diesel fuel and hybrid biodiesel blends PBC10, PBC20 and PBC30 is as shown in the Fig 5. The CO emissions slightly increased at low and medium loads and decreased significantly at higher loads with all the fuel modes. The CO emissions of the Biodiesel blends were not much different from that of conventional diesel at low loads as shown in fig. However, the CO emissions of these blends decreased significantly from 50% load as compared to conventional diesel up to full load. The CO emission's reduced by 4.34%, 9.09% and 20% than the conventional diesel at maximum load condition.

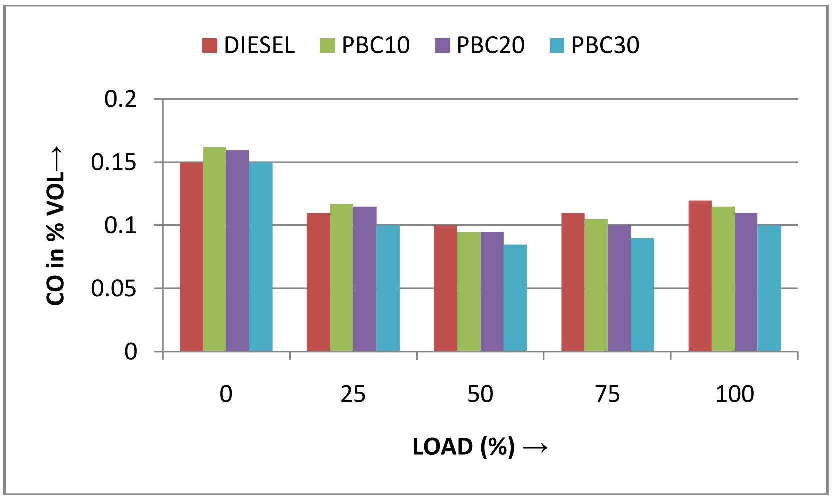

Fig 5: carbon monoxide V/s Load

4) Oxides of nitrogen (NO_X) emission:

The variation of NO_X with load for diesel fuel and hybrid biodiesel blends PBC10; PBC20 PBC20and PBC30 is as shown in the Fig 6. The NO_X emissions of biodiesel blends goes on increasing and it is more at high loads than that of diesel fuel. It is due to the higher oxygen content and combustion temperature of the biodiesel blend at medium to high loads. The NO_X emissions of PBC10, PBC20 and PBC30 were 6.15%, 14.64% and 17.83% greater than diesel at full load condition compared to diesel.

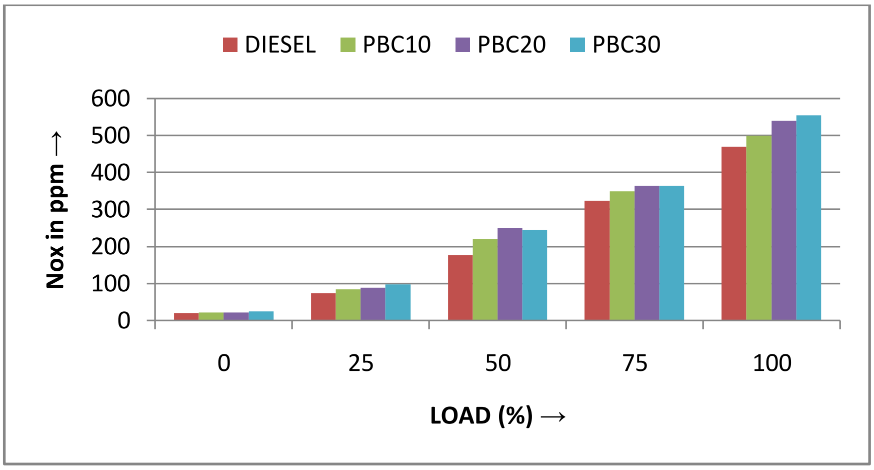

Fig 6: oxide of nitrogen V/s Load

Twin Cylinder:-

Performance Characteristics

1. Brake Thermal Efficiency

The variation of Brake thermal efficiency with load for Diesel, PBC10, PBC20 and PBC30 blends is shown in Fig 7. It is observed that the brake thermal efficiency of all fuel blends are slightly lesser than that of conventional diesel fuel by 4.60%, 2.78% and 4.85% for PBC10, PBC20 and PBC30 blends respectively compared to fossil diesel.

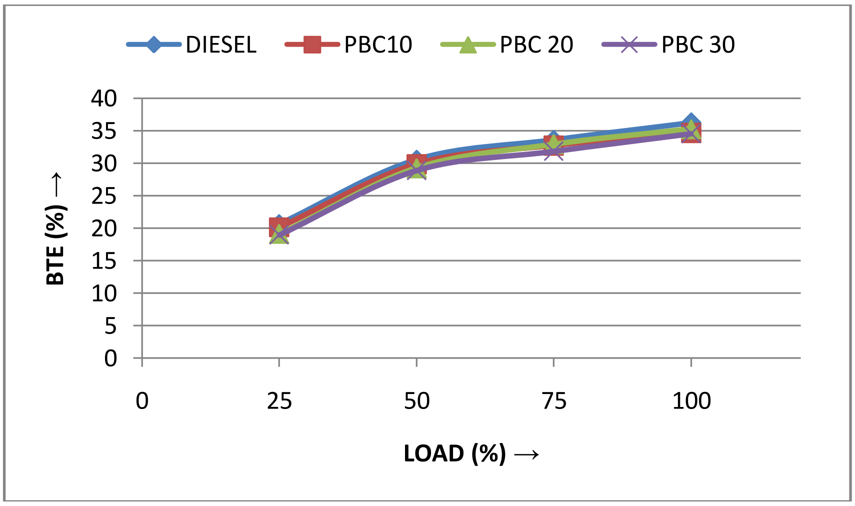

Fig 7: Brake Thermal Efficiency V/s Load

2. Brake Specific Fuel Consumption

The variation of BSFC with load for Diesel, PBC10, PBC20 and PBC30 blends is shown in Fig 8. The BSFC was slightly increased with Hybrid Biodiesel blends at all loading conditions of the engine with load for all the fuel modes. The BSFC was higher by 8.51%, 9.17% and 13.53% with the blends PBC10, PBC20 and PBC30 respectively as compared with diesel. It is due to the lower heating values of hybrid-biodiesel blends compared with diesel fuel.

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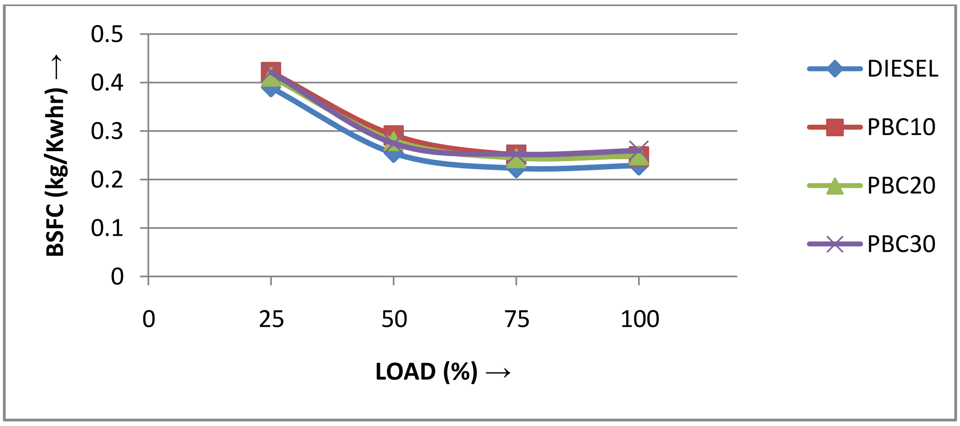

Fig 8: BSFC V/s Load

Emission Characteristics

1. Carbon-dioxide (CO_2) emission:

The emissions of carbon dioxide with load for diesel fuel and hybrid biodiesel blends PBC10, PBC20 and PBC30 is as shown in the Fig 9. The CO_2 emissions increased with load for all fuel modes. The emissions of CO_2 were increased by 5.81%, 3.07% and 0.76% for PBC10, PBC20 and PBC30 respectively for hybrid biodiesel blends as compared with diesel at full load condition.

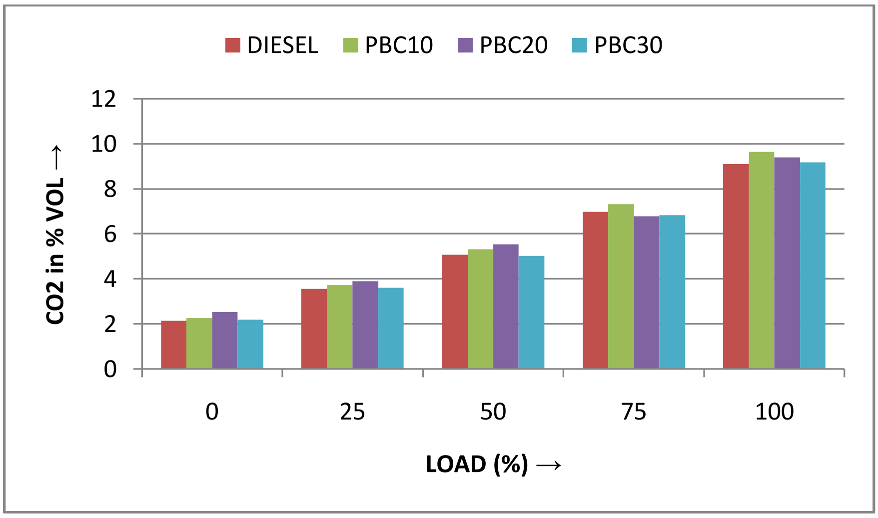

Fig 9: CO_2 V/s Load

2. Hydro-Carbon (HC) emissions:

The emissions of hydro-carbon with load for diesel fuel and biodiesel blends PBC10, PBC20 and PBC30 is as shown in Fig 10. The HC emissions were lower than diesel throughout the entire loading conditions for all the fuel modes. The HC emissions of the hybrid biodiesel blends are slightly lesser than that of conventional diesel fuel. It is due to the better combustion achieved from 0-100% load. The HC emissions decreased with increase in blends ratio. The HC emissions were 4.47%, 7.69% and 6.06% lesser than that of diesel fuel at full load condition for PBC10, PBC20 and PBC30 respectively.

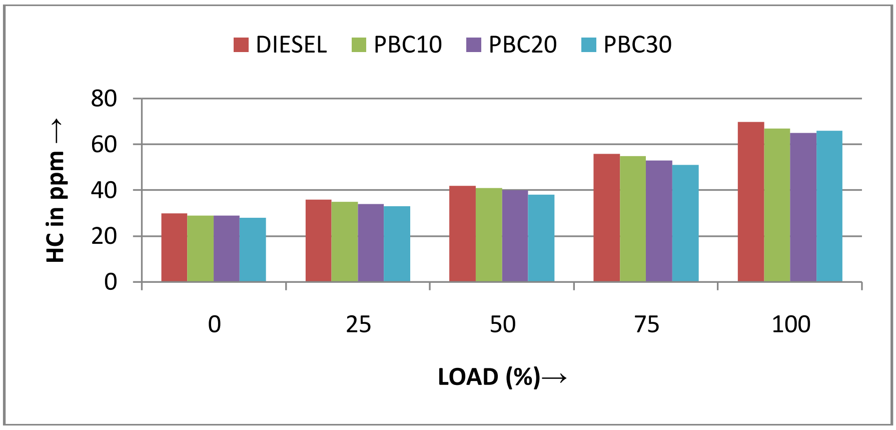

Fig 10: Hydro-carbon V/s Load

3. Carbon-monoxide (CO) emissions:

The variation of Carbon-monoxide emissions with load for diesel fuel and biodiesel blends PBC10, PBC20 and PBC30 is as shown in Fig 11. The CO emissions slightly decreased at low load to full load with all the fuel modes. The CO emissions significantly decreases as compared to conventional diesel, the percentage of decrease is 1.12%, 3.44% and 12.5% for PBC10, PBC20 and PBC30 respectively as compared to diesel. This is due to the better combustion of fuel blends.

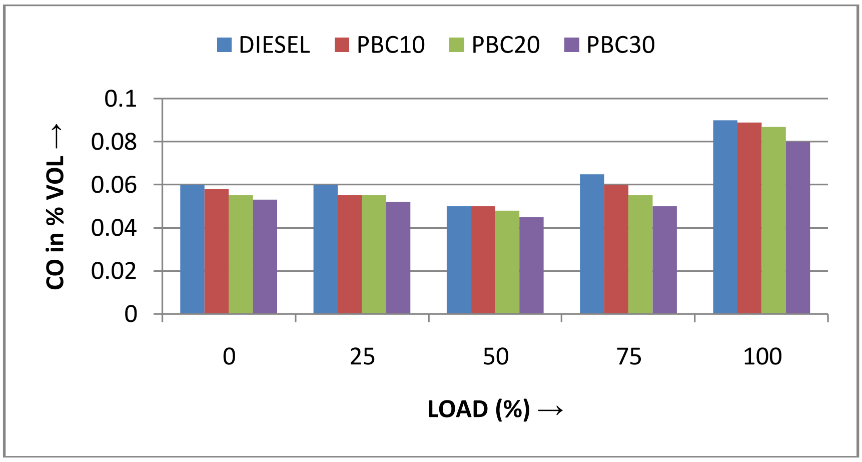

Fig 11: Carbon monoxide V/s Load

4. Oxides of nitrogen (NO_X) emission:

The variation of Oxides of nitrogen with load for diesel fuel and hybrid biodiesel blends PBC10, PBC20 and PBC30 is as shown in Fig 12. The NO_X emissions of biodiesel blends goes on increasing and it is more at medium and high loads than that of diesel fuel. It is due to the higher oxygen content and combustion temperature of the biodiesel blends at medium and high loads. The NO_X emissions of PBC10, PBC20 and PBC30 were 8.11%, 7.08% and 12.03% respectively at full load as compared to conventional diesel fuel.

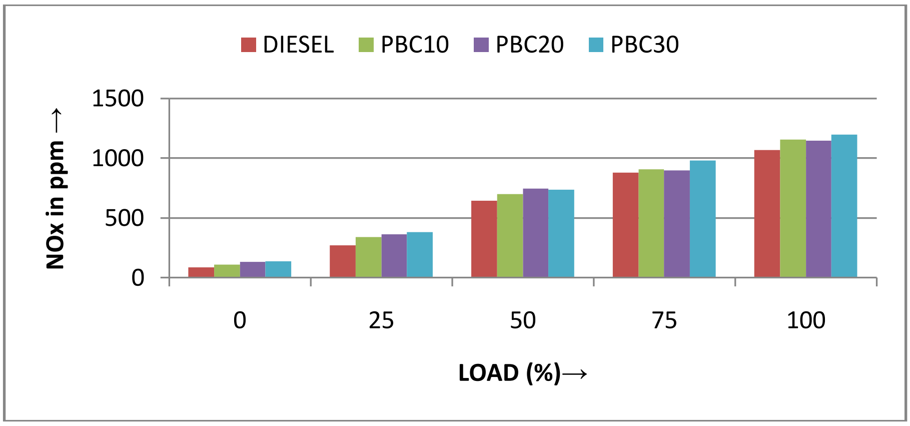

Fig 12: Oxide of nitrogen V/s Load

V. CONCLUSION

A. Conclusion from Performance and Emission Characteristics of Single Cylinder C.I. Engine:

1. The brake thermal efficiency of PBC20 is 5.78% lesser as compared to diesel at maximum load and BTE curve of Hybrid Biodiesel PBC20 is same as neat diesel throughout the different loading condition.
2. The brake specific fuel consumption of all hybrid biodiesel blends has higher fuel consumption, but the PBC20 blend shows BSFC curve nearer to conventional diesel with 3.40% increase in BSFC at full load as compared to diesel.
3. The emissions such as HC, CO_2 & CO reduced gradually as compared to diesel for different loads by using Hybrid Biodiesel blends.
4. The NO_X have been increased slightly throughout different loading condition. Due to the rich oxygen content of hybrid biodiesel blends.

B. Conclusion from Performance and Emission Characteristics of Twin Cylinder C.I. Engine:

1. The Brake Thermal Efficiency of all hybrid biodiesel blends have lesser than that of diesel. Where the BTE of blend PBC20 is 2.78% lesser as compared to diesel at full load, and shows similar BTE curve for different loads as diesel.
2. The brake specific fuel consumption of hybrid biodiesel blends has increased as compared to diesel, but PBC20 blend shows nearer BSFC curve to fossil diesel.
3. The emissions such as HC & CO of Hybrid biodiesel blends decreased gradually as compared to fossil diesel for different loads.
4. The NO_X and CO_2 emissions of hybrid biodiesel blends increased as compared to diesel throughout the different loading condition due to the presence of oxygen content in hybrid biodiesel blends.

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