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Performance and evaluation of VCR diesel engine using deodorizer distillate oil based and additised biodiesel

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Abstract

The present study of oxidation stability and NO_X emission of biodiesel is a challenge to adopt biodiesel. Experimental investigation of deodorizer distillate oil biodiesel with antioxidant (pyrogallol) has been carried out to analyze performance, combustion and emission, characteristics in diesel engine with blends in the diesel (0%, 10%, 20%) by changing compression ratio and engine load. An addition of antioxidant in the biodiesel proved improvement in the oxidation stability. The oxidation stability increases with increasing in antioxidant proportional.The deodorizer distillate oil has to be converted to biodiesel in two step process because deodorizer distillate oil containing high FFA. The emissions from the diesel engine calculated with the help of smoke meter & gas analyzer. NO_X emission from the engine reduced at all load conditions and different compression ratio.

Keywords: *Biodiesel, Antioxidant, Oxidation stability, performance, Emission*

1. Introduction

In recent years, the consumption of petroleum products in India has been increased significantly. As far as India is concerned the need to search an alternative fuels argent to meet the demand for transportation, agricultural sector. All the investigations carried out Biodiesel, an alternative diesel fuel, comprising of alkyl monoesters of fatty acids obtained from contemporary feedstocks such as vegetable oils, animal fat and waste cooking oil, etc. In the recent past, fatty acid methyl esters, produced from different feedstocks have been used as an alternative fuel for conventional diesel in compression ignition engines. Due to its biodegradability and nontoxic nature, biodiesel attracted the attention of global researchers. However, the first generation biodiesel produced from the edible oil encountered the issues of food versus fuel along with its higher feedstock cost and energy policies. On the other hand, the production of biodiesel from the non-edible feedstocks, such as Jatropha, Pongamia Mahua, Neem was found to be more expensive compared to petrodiesel. The biodiesel production cost includes about 85% feedstock price, which results in higher cost of biodiesel (Cunshan et al.,2011). However, the production of biodiesel from deodorizer distillate feedstock oil was found to be lower compared to petrodiesel (Sorate and Bhale,2014) .

In addition to oxidation stability, the effects of antioxidant on engine performance and emission have been presented. In this investigation, oxidation stability of biodiesel derived from non-edible feedstocks such as Neem, Karanja, and Jatropha, stabilized with antioxidant pyrogallol (PY) was studied by Rancimat test. It was found that stability increases with increasing the dosage of antioxidants (Khurana and Agarwal,2011).

Effect of antioxidant additives on the performance and emission characteristics of a DICI engine using neat lemongrass oil–diesel blend the effect of antioxidant additives on the performance and the exhaust emissions has been studied. The test fuel used in this study was neat lemongrass oil (LGO)–diesel blend. The emission results showed a significant reduction of NOx (Sathiyamoorthi et al.,2016).

Emission like HC,CO, and smoke reduced while using biodiesel and its blends due to presence of oxygen in biodiesel but NOx emission increases and increase in peak temperature in combustion (Selvan and Nagarajan, 2012).

The main objective of this work is to analyze the oxidation stability, engine performance, combustion and emission characteristics of diesel engines fuelled with biodiesel produced from deodorizer distillate oil blends with antioxidant with diesel which will help in the direction of controlling stability, emission problems of biodiesel and search of alternative fuel for diesel engine.

2. Materials and Methods

2.1 Deodorizer distillate oil

Deodorizer Distillate oil is by-product of vegetable oil. Oil containing high viscosity (31.46mm2). The higher viscosity of oil leads to the poor atomization of fuel and mixing it with air when used directly in a diesel engine. Deodorizer distillate oil containing high FFA i.e 51.6% FFA. To overcome this limitation, the deodorizer distillate oil has to be converted to biodiesel in two step i.e.

esterification followed by transesterification. After the conversion, the viscosity value of deodorizer distillate oil biodiesel is reduced as per standard.

2.2 Materials

Deodorizer distillate oil used in the present study was obtained from M/s Ghodhawat Foods International Private Limited, Kolhapur, a nearby medium scale vegetable oil refining industry. The unit processes about 20,000 tones of soybean oil and produces about 1000 tones of deodorizer distillate oil per annum as a byproduct. All chemicals used in the experiments such as 99.8% methanol/ethanol, sodium hydroxide, and 98% sulfuric acid were of analytical reagent grade are available at chemistry lab RSCOE, Pune.

2.3 Methods

2.3.1 Preheating

The deodorizer distillate oil was preheated to a 120oC temperature in open cauldron to remove moisture. When the temperature falls to 600C, it is poured into the glass reactor for esterification.

2.3.2 Acid-catalyzed esterification

The acid-catalyzed esterification reaction was conducted in a laboratory-scale experiment. The apparatus used for the experiment contained of round bottom reaction flask and hotplate with a magnetic stirrer. The volume of the reaction flask capacity was 1 liter and contained of two necks, one for a condenser, and the others for a thermometer. A known amount of preheated deodorizer distillate oil feedstock was poured into the reaction flask. The 0.35 v/v of methanol/ethanol was added to the preheated deodorizer distillate oil and stirred for a few minutes. The sulphuric acid (0.7 % v/v of oil) was then added as a catalyst to the mixture and the reaction was carried out at 60oC for 60 minutes (Nakpong and Wootthikanokkhan,2010, Sorate and Bhale,2014). After this reaction, the mixture was allowed to settle for 4 hours in the separating funnel and the methanol-water fraction at the top layer was removed. The lower layer consisted of deodorizer distillate oil having a lower content of FFA and impurities were purified by washing gently with hot distilled water at 55oC until the washing water had a pH value that was similar to that of distilled water. The deodorizer distillate oil layer was then dried at 110oC by the hot air temperature oven.

2.3.3 Alkali-catalyzed transesterification

The alkali-catalyzed transesterification reaction was carried out by using the same experimental setup of acid-catalyzed esterification step. The oil product from the pretreatment step was preheated to the 60 oC temperature in the reaction flask. Methanol to oil ratio of 0.4 v/v, catalyst concentration of 1.5 % w/v was used at the reaction temperature of 60oC and reaction time of 60 minutes (Sorate and Bhale,2014, Nakpong and Wootthikanokkhan,2010).The solution of sodium hydroxide in methanol/ethanol was prepared freshly in order to avoid the moisture absorbance and maintain the catalytic activity. The methanolic/ethanolic solution was then added to the heated oil in the reaction flask. After the reaction, the mixture was allowed to separate into two layers by settling overnight in the separating funnel. The upper layer consisted of methyl/ethyl esters, whereas the lower layer contained a mixture of glycerol and impurities. The methyl/ethyl ester layer was purified by washing gently with hot distilled water at 55oC until the washing water had a pH value that was similar to that of distilled water. The methyl/ethyl ester layer was then dried at 110oC by the hot air temperature oven. The biodiesel properties were determined by using standard test methods.

3. Test procedure and test setup

Test fuel blend was prepared by blending deodorizer distillate oil biodiesel with antioxidant pyrogallol (ppm). Experiments are conducted in kirloskar engine by using biodiesel blended with diesel and with an antioxidant by volume as B10, B20 by changing compression ratio and engine load.

Table 1Engine specification

Make & model TYPE	Kirloskar SV1 single cylinder, 4stroke, DI, water cooled, Diesel Engine
Power (hp)	5.7
Speed (rpm)	1500
Bore (mm)	87.5
Stroke length (mm)	110
Injection bar (bar)	210
load type	Eddy current dynamometer
Compression ratio	16,17,18

After start engine is run on diesel for 15 min to remove out carbon particle present inside cylinder block. Here test is taken at a constant speed of 1600 rpm with varying compression ratio from 16 to 18 in step of one. At the same time, different loads are applied on the engine using dynamometer. The range selected here is 0 to 9 in a step of 3. Software used is “EnginesoftLV” for Engine performance analysis. Test engine coupled with an electrical dynamometer to apply load to the engine. Electrical Dynamometer consists of electrical power bank which applies loads in the range of 0 to 50 kg loads on an engine and it is controlled with the aid of ammeter and voltmeter. The engine is connected to the computer to record and analyze the output data. The performance analysis combustion parameters such as cylinder

pressure, instant heat release rate, mean gas temperature and rate of pressure rise are evaluated. Exhaust gas analyzer is used to measure engine emissions such as NOx, unburnt hydrocarbon (HC), carbon monoxide(CO) and Carbon dioxide(CO2).

Fuel properties

Table 2 Physical properties of test fuels.

Properties	Limit	B100	Diesel
Density at 15 0C, kg/m3	860-900	869	820
Kinematic Viscosity At 40 0C, mm2/s	1.9-6.0	4.63	2.5
Acid value, mg KOH/g	Max.0.5	0.35	-
Calorific value, MJ/kg	-	37.5	42.5
Flash point , 0C	Min 130	174	55
Cloud point, 0C	Report	6	-18
FAME content, %	Min 96.5	98.3	-
Pour point, 0C	-25	2	-23
Cetane number	Min. 51	49	-
Oxidation stability at 110 0C,h	Min. 6	2.6	-

Nikhil analytical & research Pvt. Ltd, laboratories Test Report No: Ch7/L1708 from Sangli.

4. Results and discussions

4.1 Oxidation stability

Oxidation stability of biodiesel was lower than the standard limit because of deodorizer distillate oil containing high FFA. Pyrogallol a suitable antioxidant was selected based on the previous experimental work reported by the authors (Dwivedi and Sharma, 2016; Tang et al 2010; Obadiah et al., 2012; Chen et al., 2011; Kivevele et al.,2011; Chakraborty and Baruah,2012; Jain and Sharma,2010). The biodiesel (B100) samples was dosed with an antioxidant (pyrogallol) in the concentration of 1000, 2000 ppm and stored at room temperature. For reference, the biodiesel (B100) sample without an antioxidant was stored for the same period under similar conditions. Samples were stored in bottles. During the storage period, the room temperature was noted to be within the range of 18°C to 44°C. Check the oxidation stability for different ppm.

4.1.1 Rancimat test

The oxidative stability (EN 14112) was determined by the Rancimat method. As per standard biodiesel, manufacture to have at least 6 h of induction period at 110°C Oxidation stability was found to be only 2.6 h at 110°C as determined by Rancimat apparatus. The presence of polyunsaturated and unsaturated fatty acid derivatives are the important factor for the biodiesel. To improve oxidation stability of biodiesel, it is dosed with pyrogallol in concentration, i.e. 1000, 2000 ppm. This study reveals the best improvement in oxidation stability of deodorizer distillate oil biodiesel (B100) is 8 h at a concentration of 2000 ppm of pyrogallol. The addition of antioxidant increases the oxidation stability.

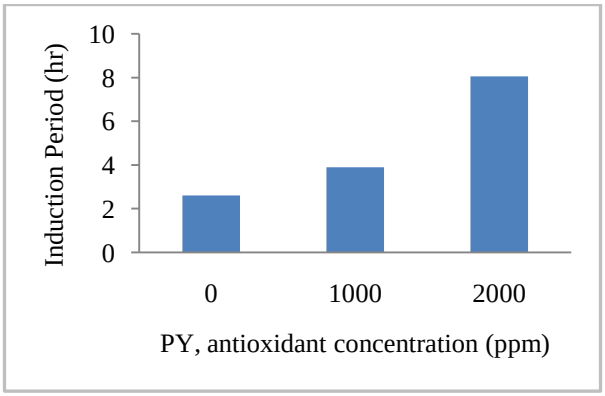
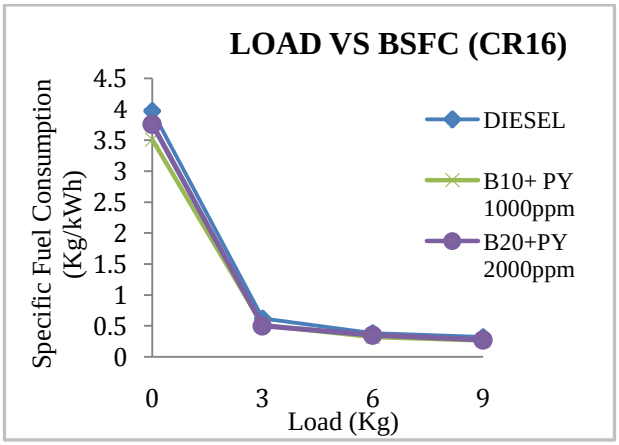


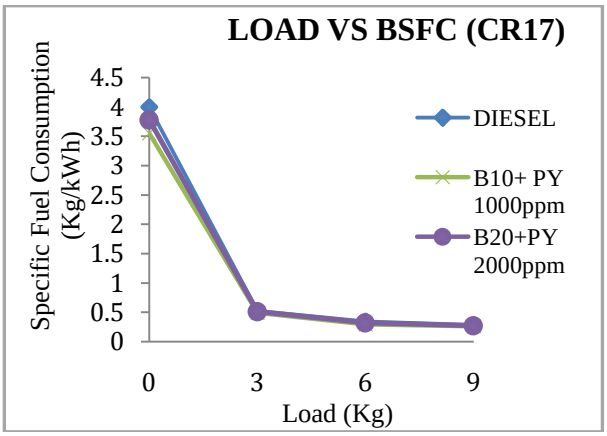
Fig.1.Effect of pyrogallol on the stability of biodiesel.

4.2 Performance characteristics

4.2.1. Brake specific fuel consumption

The variation of brake specific fuel consumption (BSFC) with respect to load at various compression ratio & various load is shown in Fig .2. The BSFC was found higher at low loads and lower at higher loads. It was found that specific fuel consumption decreases with an increase in loads. Also, it was observed that BSFC for biodiesel with antioxidant is decreased than diesel fuel.





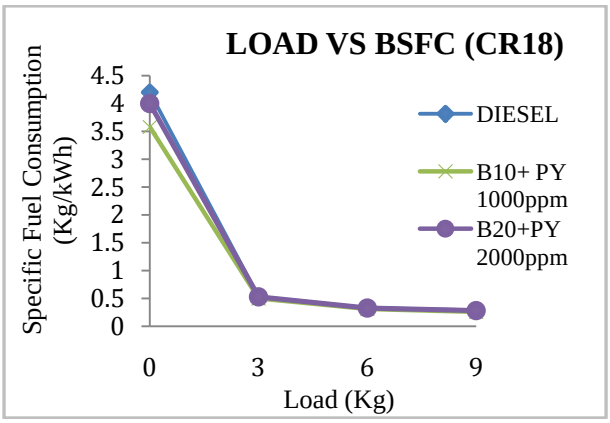
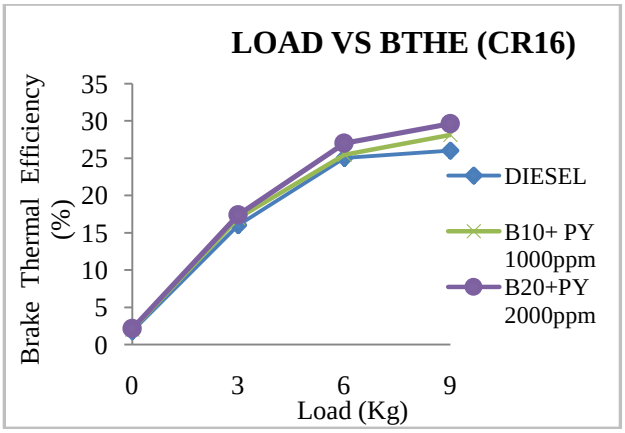
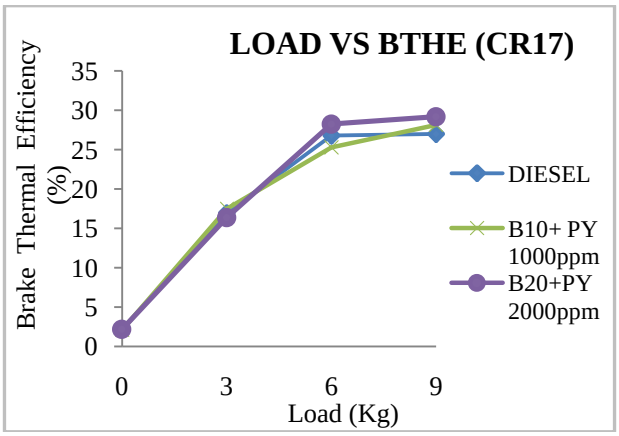


Fig.2. Variation of BSFC with respect to Load

4.2.2. Brake thermal efficiency

The variation of brake thermal efficiency with load is shown in Figure 3. From the test results, it was observed that the brake thermal efficiency of biodiesel with antioxidant increases gradually. Also, it was observed that BTE for biodiesel with antioxidant is increased than diesel fuel.





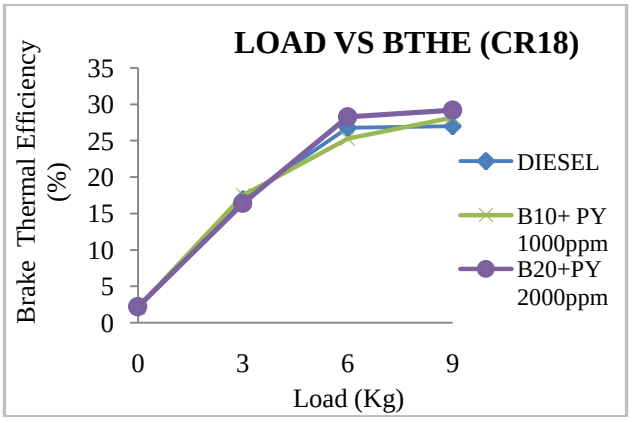


Fig.3. Variation of BTE with respect to Load

4.3 Combustion characteristics

4.3.1 Cylinder pressure and peak pressure

The pressure generated for diesel and biodiesel with antioxidant shown in figure 4. It was clear that maximum cylinder pressure is lower for biodiesel with antioxidant at all engine loads. In CI engine, the peak pressure depends on combustion rate in initial stages.

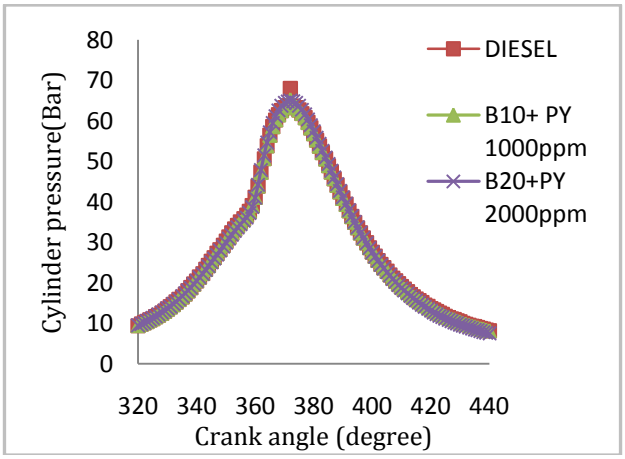


Fig. 4. Variation of cylinder pressure with crank angle

4.3.2 Net heat release rate (NHRR)

The net heat release rate is shown for diesel and biodiesel with an antioxidant in figure 5. The NHRR curves show the potential availability of heat energy which can be converted into useful work. It can be observed from figure 5 that the NHRR for biodiesel with an antioxidant is lower than diesel.

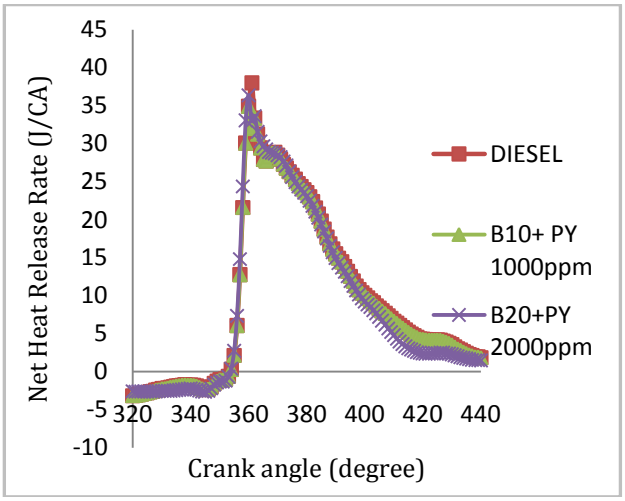
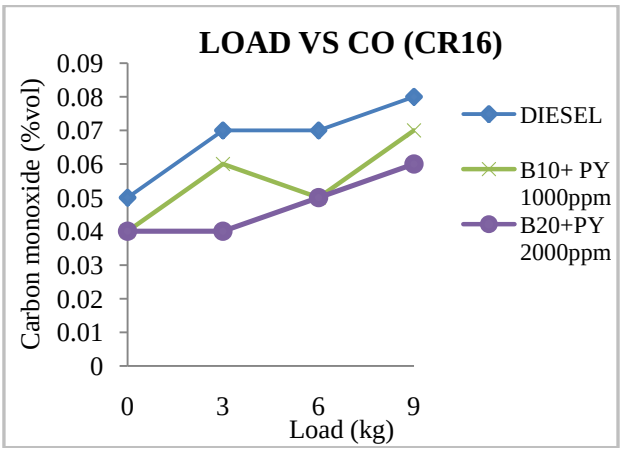


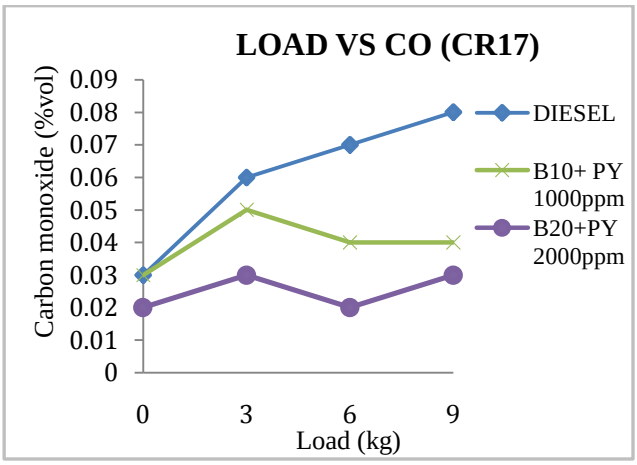
Fig.5. Variation of net heat release rate with crank angle

4.4 Emissions characteristics

4.4.1 Carbon monoxide emission (CO)

The variation of CO emission with load is shown in Fig. 7. It can be observed from Fig.7 that the CO emission for biodiesel with antioxidant is lower than diesel fuel at various compression ratio and engine load due to the presence of an antioxidant.





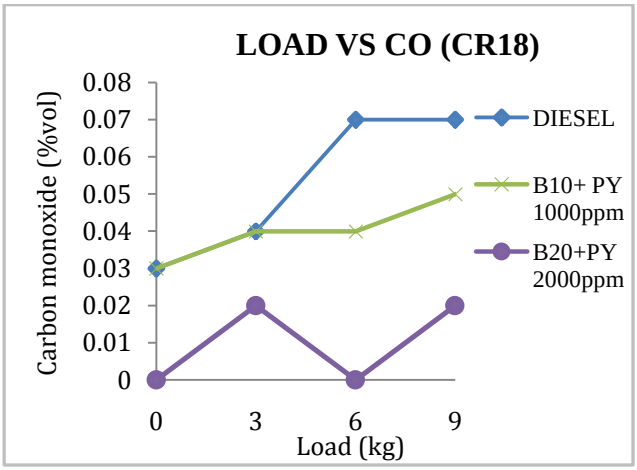
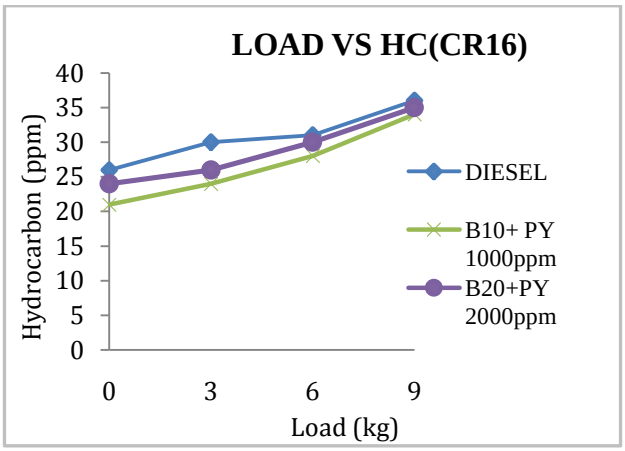
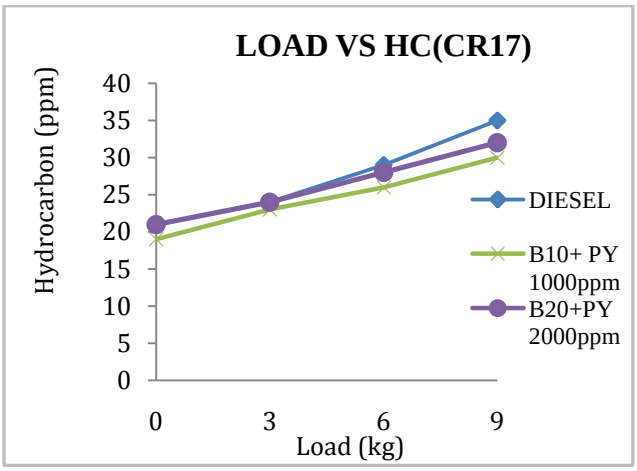


Fig.7. Variation of carbon monoxide with load

4.4.2 Hydrocarbon emission (HC)

The variation of HC emission with load is shown in Fig. 8. It can be observed from Fig.8 that the HC emission for biodiesel with an antioxidant is lower than diesel fuel at various compression ratio and engine load due to the presence of oxygen in biodiesel and higher cetane number.





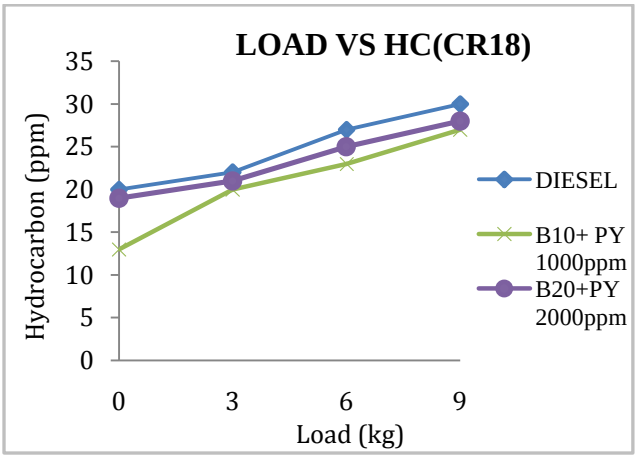
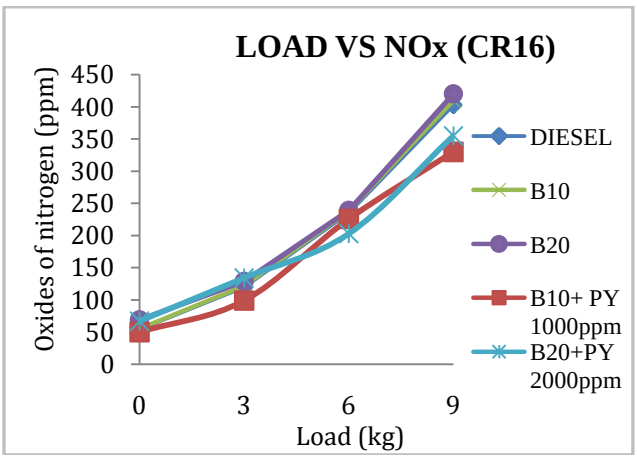
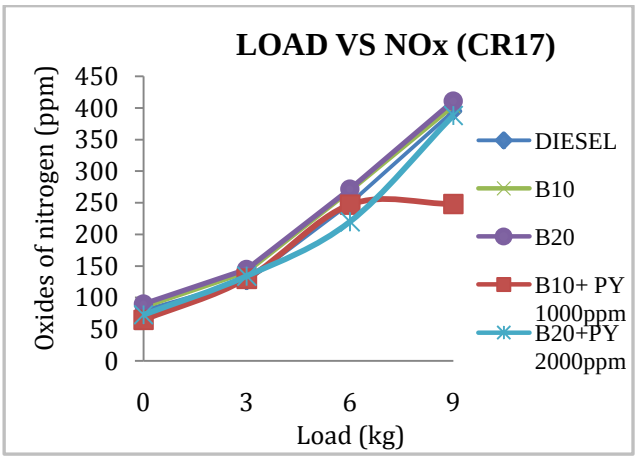


Fig. 8. Variation of hydrocarbon with load

4.4.3 Oxides of nitrogen emission (NOX)

Temperature plays main role in NOx formation. When combustion temperature exceeds 1500°c in the combustion chamber will lead to NOx formation. The variation of NOx emission with load is shown in Fig. 9. It can be observed from Fig. 9 that the NOx emission for biodiesel with an antioxidant is lower than diesel fuel at various compression ratio and engine load due to addition of an antioxidant.





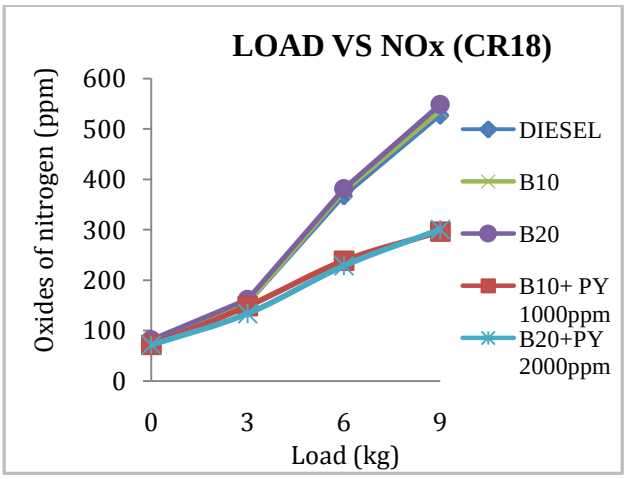


Fig. 9. Variation of oxides of nitrogen with load

5. Conclusion

Test were conducted in diesel engine, with diesel, deodorizer distillate oil with antioxidant and the following conclusion were arrived.

1. On the basis of experiment work, it is observed that viscosity of biodiesel is close to diesel.
2. In the present study, of deodorizer distillate biodiesel has poor oxidation stability. It has been found that using antioxidant (pyrogallol) improve the oxidation stability.
3. NOX emission from the engine reduced at all load conditions and different compression ratio when compared to that of pure diesel.
4. Hence it is concluded that, pyrogallol can be used as a renewable replacement for synthetic fuel additive while using biodiesel blend in the diesel.

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