Renewable Bio-fuel Emission Characteristics and Performance of a Diesel Engine

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Abstract

Biodiesel derived from waste cooking oil or vegetable oil, obtained from a renewable sources which play as an important alternative to petroleum derivatives because of its capability to produce clean environment. Several research works carried out on Biofuel research were based on edible vegitable oils or non-edible oils. But the number of investigations on crude rice bran oil(CRBO) consisting of free fatty acids (FFA) is very limited.. High free fatty acids in CRBO can be utilized as a good source for biodiesel production. In this work, rice bran oil methyl ester (RBME) is produced by transesterification processes and the biodiesel and its blends with diesel are tested for emission and performance in a compression ignition (CI) direct-injection engine of 5.8 kW, four-stroke and water-cooled.The experimental results show that for RBME the emission of Hydrocarbon, smoke density and nitrogen oxides (NOx) are reduced but the carbon monoxide (CO) emission is slightly increases as compared with pure diesel. The brake-thermal efficiency is not affected by the biodiesel blends.The different blends with varying percentages of Bio-fuel is tested and the characteristic currrves for performance of the engine and emission are plotted. From the observed results, it can be considered as an alternative to diesel as it posses better performance characteristics. As the biofuel, CRBO with high FFA is generated from renewable green sources its use creates a cleaner environment.

Keywords: *Biofuel, esterification, renewable fuel, rice bran oil*

1. Introduction

Sundar.K et al. were evaluated the biodiesel blends at different loads from 0 to 12 kg and at compression ratios(CR) from 15 to 18. The performance test was conducted using Kirloskar, four-stroke, single-cylinder, CI engine.The results show that the brake thermal efficiency for 20% biofuel blends of Methyl ester rice bran oil and cotton-seed oil gives less Brake Power and more Break Specific Fuel Consumption values than diesel.But the CO emission is decreased by 18.4% and 17.5% and the HC emission by 3.86% and 3.13% respectively as compared to that of diesel.[1]

Burhani M et al. determined the performance of industrial oil burner uning rice bran oils. The emission characteristics of the oil biodiesel and compared with conventional diesel fuel. The experiment was carried out in an Industrial Light Oil Burner. It was observed that rice bran oil has better emission characteristics compared to diesel.[2] Prabakaran Balasubramanian et al.tested ethanol based Biodiesel blends containing 30% of ethanol in compression ignition engine for performance.The combustion phenomena and emission characteristics under compression ratios 17:1 and 18.1, under the various loading conditions are analysed. The test results recommended compression ratio 18:1 as it produces performance parameter values and emission values comparable with diesel. However,NOx emission and ignition delay of these Biofuel blends were slightly higher than diesel.[3]

M.Arunkumar et al. studied the castor biodiesel for use as an alternate energy source with reduced carbon monoxide of 9% ,HC by 8.8% and a considerable reduction in NOx. Eventhough there was a reduction of 2.2% in thermal efficiency and an increase of 4% in SFC the increase in cultivation of castor plant makes the castor biofuel as better choice for several industrial sectors.[4]

Mayank Chhabra et al. were conducted experiments on a Single cylinder 4-stroke, water-cooled Kirloskar engine using different crude rice bran oil(RBO) blends at compression ratios of 12 to 14 and compared with the results of conventional diesel. The various blends of RBO showed better emission in the case of CO_2 and CO but the NO_X emission is slightly more than diesel. Hence they concluded that crude methyl ester rice bran oil and their blends without modification can be successfully used as an alternative CI engine fuel.[5]

Gund M.D et al.conducted experiments on AV1model of Kirloskar single cylinder CI engine. The fuel used was biogas ,diesel and Biofuel mixture. The results of this experiments are used to study the performance and emission levels of the Biofuel blends.. [6] J.Jayaprabakar et al.worked at reducing the cost of biodiesel using a catalyst which is derived from lipase by reducing the number of washing cycles. Four different blends of oil and diesel were tested on a Kirloskar ,four-stroke, air cooled CI Engine with 23° ignition time . For 20% biofuel blends the Thermal Efficiency is high with low SFC and emission values of CO_2, CO and HC are less as compared to diesel.[7]

Mohit Vasudeva et al. carried out two-step esterification for producing FFA crude RBO. Crude rice Bran biodiesel is tested in a 4-stroke ,Single cylinder CI engine at a compression ratio of 15 to 18. This results in 18.6 % decrease of BSFC and 14.66 % increase in BTE. At this compression ratio, except NOx emission other emissions such as HC,CO_2,CO etc. were decreased. The crude RBO blends show better characteristics compared to that of diesel. [8] Ch.Narasimha et al. carried out an experimental study of single-cylinder, four stroke CI engine having compression ratio 17.5 using Biofuel blends along with EthylHexyl Nitrate and Ethanol as additives. The Biofuel blends with 10% Ethanol by volume produced better performance and reduced emission in comparison with diesel.[9]

The presence of high FFA in the tobacco seed needs two step processing to produce fatty-acid methyl esters (FAME). At first, the esterification process with acid catalyst is done to reduce the FFA level for 18:1 molar ratio in 25 min.Then by the methanolysis process glycerol and FAME yield of 91% occurs in 30 min from the products of esterification. The properties of the Biofuel are within the guidline range of American and and European standards. Thus, the agricultural waste tobacco seeds may be considered as an excellent raw material for the Biofuel production from renewable sources.[10] A.A.Refaat et al. studied the feasibility of producing biofuel from recycled oils to reduce the cost of fuel and to control pollution caused by such wastes..From their results it was identified that if the methanol/oil ratio is 6:1 and at 65°C,1% potassium hydroxide treated for 1 hour produced yield comparable to neat vegetable oil.[11]

From the literature it is evident that not much work performed in producing Biofuel from waste cooking oils obtained from plant sources. Hence,This work focuses on studying such fuels and its blends to identify the blend mixture which produces optimum performance and emission characteristics.

2. Materials and Methods

The alternative fuel to be developed must be accepatable for the environment without posing any pollution and it should be acceptable technically and economically.The viable alternative sources such as triglycerides and its derivatives obtained from animal fats or vegetable oils may be used for biodiesel production. The use of triglycerides for biofuels generation is associated with problems of high viscosity, low volatility and polyunsaturation. These problems are overcomed by developing derivatives of vegetable oil with properties closely matching with diesel and compatible with the diesel fuels.The raw material source of Cashewnut shell is available in plenty near Panruti in Cuddalore District .This oil purchased for cooking,and the waste oil after cooking may also be used for conducting experiments.

A. Biodiesel from CRBO by double-step transesterification

The esterification processes is done in two steps as it is required to convert esters of crude rice bran oil (CRBO).The high level of FFA content is the reason for selecting two step process.The acid esterification is done with the presence of catalyst before carrying out base esterification process. The CRBO is having acid value 32 and posses FFA of 16. The primary objective of the esterification with acid catalyzed process is to bringdown the acid value less than or equal to 4. The various steps of the transesterification process are given in figure 1.

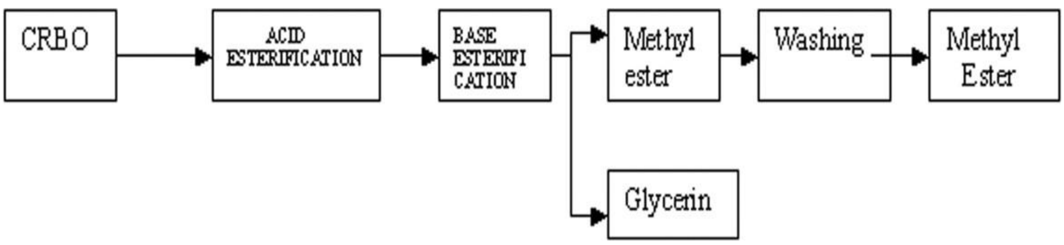

Figure 1.Esterification process

B. Base Esterification

The KOH(Potassium hydroxide) solution is the base catalyst used for the reduction in the viscosity of the CRBO by the process called Base esterification. In this process the following steps are involved. At first, Oil of 500 ml is taken in a reactor vessel. This is heated up to 60°C.100 ml methanol and 5 grams of KOH is taken and methoxide solution is prepared. The prepared solution is added to the oil. The heating is continued and the mixture is stirred well. The temperature is maintained between 55 to 65°C and the speed is maintained at 500 RPM. The processing time given is 1 hour within which it is allowed to settle down. There is a separation of two layers. Biodiesel is normally the upper layer and the lower layer is glycerol. This biodiesel is collected in a separate beaker. The biodiesel is washed with distilled water to free from alkali and then it is dried in hot air oven to get biodiesel free from moisture.The properties of the Biofuel prepared is tested in a laboratory and the properties are shown in table 1.

Table 1. Test Properties of the Bio-fuels

Parameters	Diesel	RBME
Density @ 30°C (kg/m^3)	811	890
Kinematic Viscosity @ 30°C (cSt)	3.39	5.64
Specific gravity	0.811	0.89
Calorific Value (kJ/kg)	42210	38853
Fire Point (°C)	70	143
Boiling point (°C)	190-280	317
Iodine value (Wij's)	-	110
Sulphur (%)	2.0	0.010
Acid value as mg of KOH/gm	-	0.45
Conradson carbon residue (%)	0.35	0.23

C.Experimental Setup and Procedure

Experiments are conducted in a vertical, single-cylinder, four-stroke, water-cooled, direct injection engine. The experimental setup in which the tests are conducted is given in figure 2.

Figure 2.Experimental setup

D.Engine specification

The specification of the diesel engine used in this experiment is given below.

Type	: 4 stroke, direct injection
No. of cylinder	: Single cylinder
Power	: 5.8 KW
Stroke length	: 11cm
Bore Diameter	: 8.75 cm
Loading type	: Eddy current-Dynamometer
Method of cooling	: Water cooling
Rated speed	: 1500 rpm

E. Precaution

Fuel level in the tank, Lubricating oil level, Cooling water supply and Load condition are checked before regularly as a precaution before starting the engine and after the end of the experiment

F. Test procedure

At first, the diesel fuel is placed in the fuel tank and necessary things like water flow, lubricating oil level, etc were checked. Once the preliminary checking is over the Engine is started and then it is allowed to stabilize under the condition of no-load. The time elapsed for 10cc consumption of fuel from the burette is observed and noted using the stopwatch. The temperature of the exhaust gas is noted down by using a thermometer. Finally, note down the exhaust emission temperature values using the Gas Analyzer. This procedure is repeated for different load conditions and the readings were recorded.The above experimental procedure is repeated for oil blends B0D100, B20D80, B40D60, B60D40, B80D20 and B100D0 as fuel and the readings are recorded.

3. Results and Discussion

It is observed that, the engine is running smoothly when operated with different blends of biodiesel at every loading condition. The performance parameters such as brake-thermal efficiency (BTE), specific-fuel consumption (SFC) and total-fuel consumption (TFC) are presented and analysed for different loading conditions. Similarly the various emission characteristics are also presented for diesel and biodiesel blends. The list of Engine performance tests and emission tests are performed in the Kirloskar comet single-cylinder engine with diesel fuel and biodiesel blends and obtained the following characteristics curves.

i) SFC Vs Brake power(BP) ii) Total fuel consumption vs BP iii) BTE vs BP iv) Exhaust gas temperature vs BP v) CO emission vs BP vi) NOx emission vs BP vii) HC emission vs Brake power

Performance characteristics

Figure 3.1 shows how the consumption of the total fuel varies with respect to Engine brake power. The TFC keeps on increasing with the increase of brake power or load. At higher levels of loads, the TFC of biodiesel blends are higher compared to that of the diesel. The increase in TFC is caused by low volatility, higher viscosity and high density of biodiesel. The temperature of exhaust gas with respect to the load applied for diesel and biodiesel blends tested are shown in Figure.3.4. The temperature of exhaust gas is high when the load increases and the gradient is high in biodiesel blends compared to diesel particularly at higher loads. The oxygen in the ester molecule causes enhancement in the combustion process which inturn increases the temperature of the exhaust gas.

The distribution of SFC to BP is shown in Figure 3.2. The SFC keeps on decreasing with an increase of load values or BP. But when the load value increases, the SFC of biodiesel blends is higher compared to the diesel. Since the low volatility, high viscosity and high density affects the formation of biodiesel blends or mixture of the fuel it leads to slow combustion.

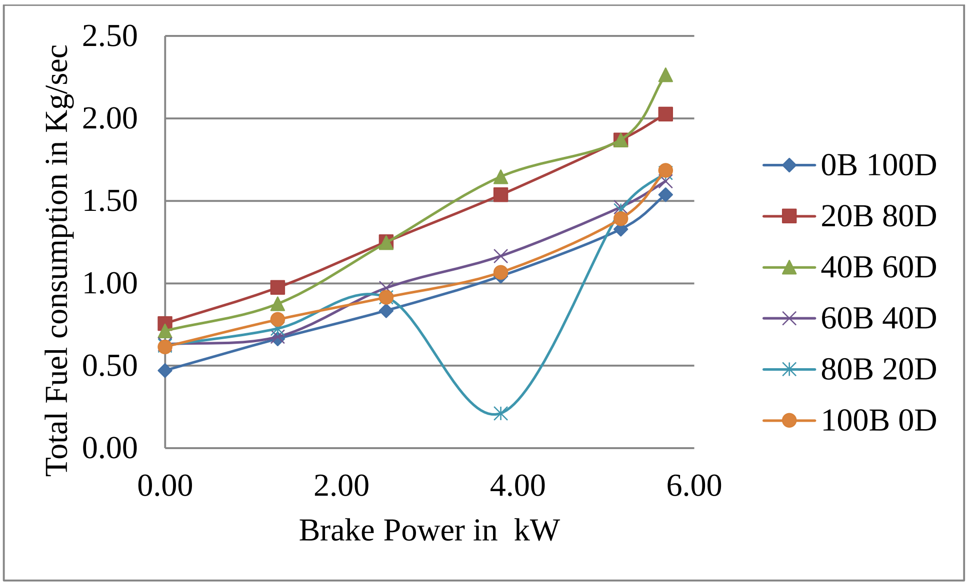

Figure 3.1 Variation of TFC with BP

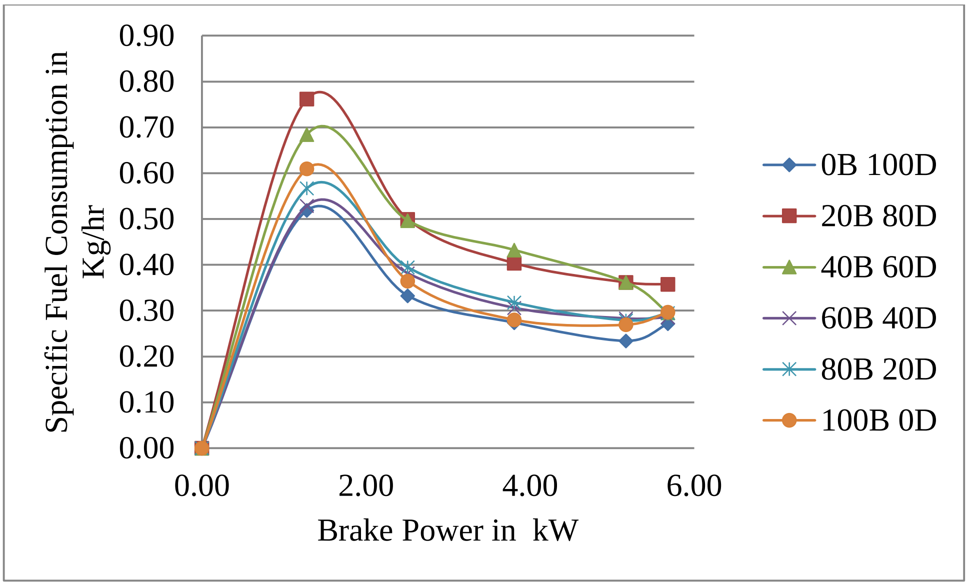

Figure 3.2 Variation of SFC with BP

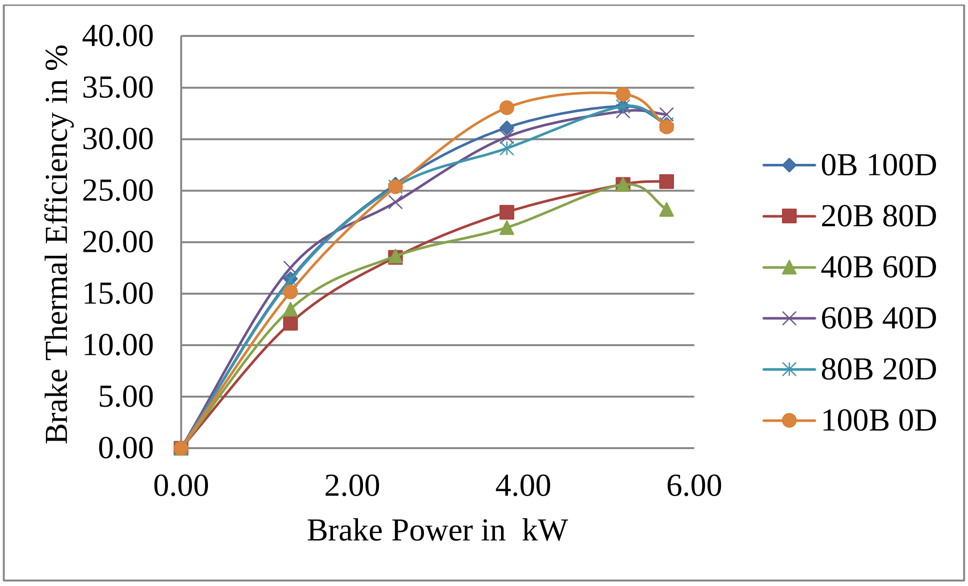

Figure 3.3 Variation of BTE with BP

Figure 3.3 shows the variation of BTE for different brake power values. The BTE increases with the increase of load. The increase in the biodiesel blend percentage with the diesel causes a nominal decrease of BTE values. This is accepted because the energy content in the biodiesel is not as efficient as that of diesel.

Emission characteristics

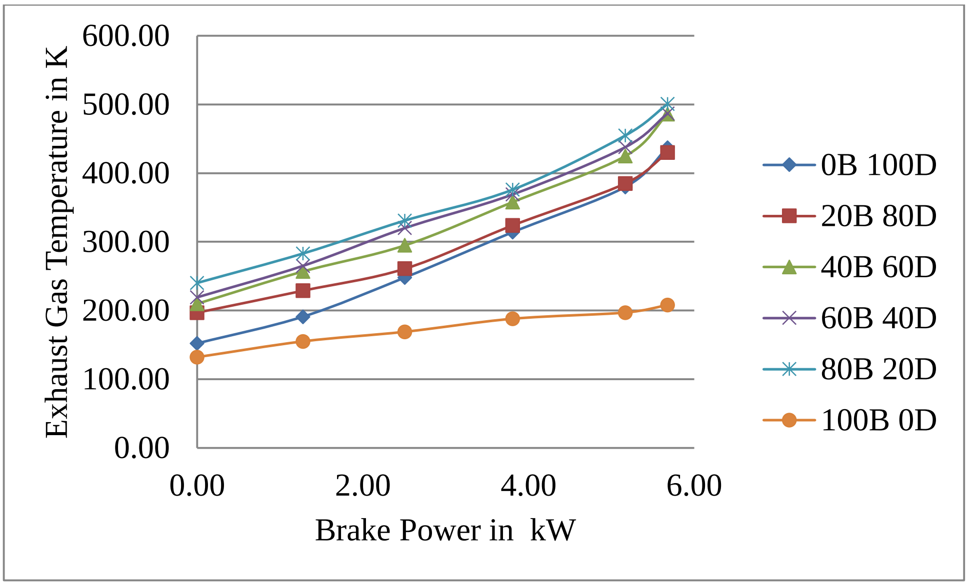

Figure 3.4 Exhaust Temperature Vs BP

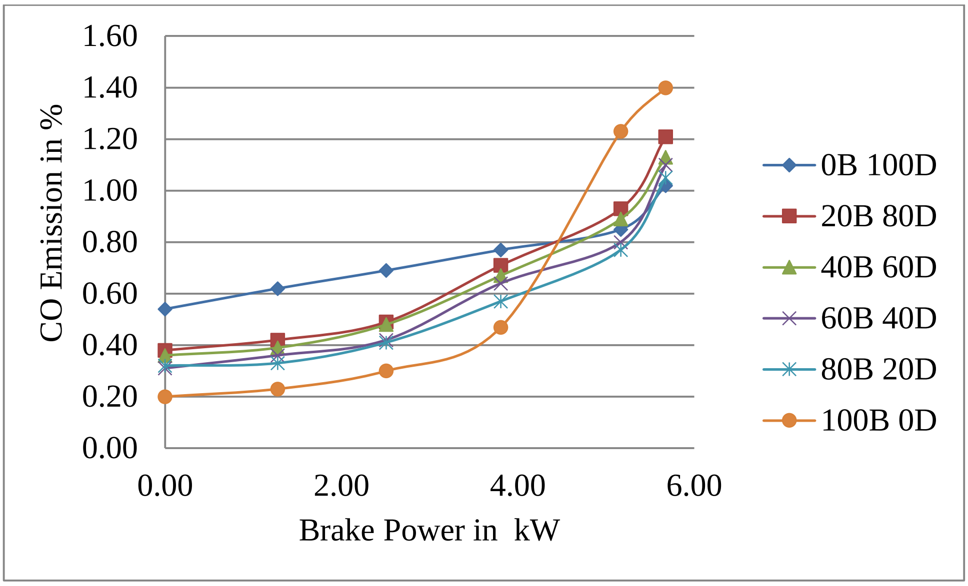

Figure 3.5 CO Emission Vs BP

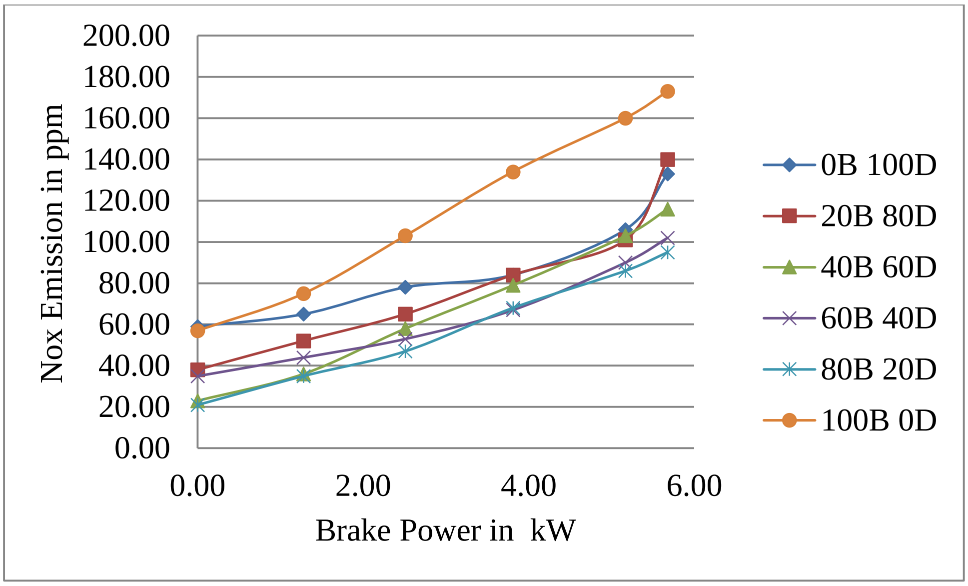

Figure 3.6 NOx Eission Vs BP

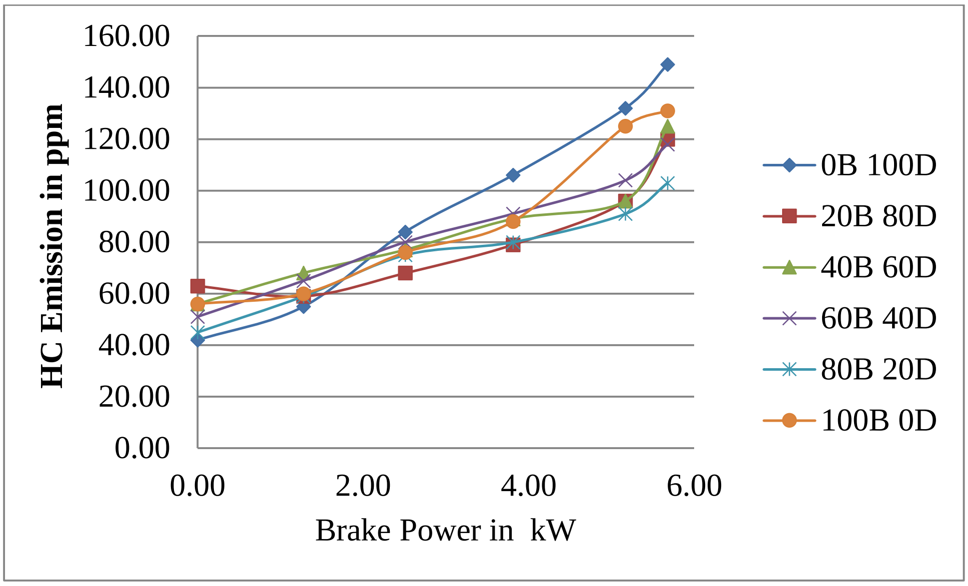

Figure 3.7 HC Emission Vs BP

The CO emissions of biodiesel developed is compared with diesel and is presented in figure 3.5. The amount of CO emission from the biodiesel blends are low compared to that of diesel. The emissions are found to be increasing at higher loading conditions. This is common in all internal combustion engines, because if the load increases the fuel-air ratio decreases. It is significant to observe that the CO emission is more for diesel than biodiesel blends for all load conditions.

The variation of NOx emission to the load applied for different Biofuel blends and diesel tested is given in Figure.3.6. If the load in the engine increases then the NOx emission also increases for all the biodiesel blends tested. As the NOx emission depends on the temperature, it increases upon combustion chamber temperature increase because of increasing the load. The variation of HC emission with respect to the load applied for different Biofuel blends tested is shown in Figure.3.7. It is seen from the figure that the biodiesel produce low hydrocarbon emissions as compared to diesel fuel. It is due to better combustion of biofuels and blends due to smaller delay period of the ester-based fuel because of the higher value of cetane number than diesel. The inherent oxygen enclosed in the biodiesel may be responsible for the decrease in Hydro Carbon emission.

From the experimental results it is observed that 80% Biodiesel blended with 20% diesel gives optimum performance with minimum emission as compared to other blends tested.However pure Biodiesel can be used for maximum efficiency with slight increase in SFC. But the NOx emission is increased.

4. Conclusion

The single-cylinder water cooled CI engine is used for conducting experiments. The experiment is conducted using pure diesel and with various blends of Biofuel, diesel.The observed values are tabulated and the performance analysis and emission calculations are carried out. It was observed that the performance of the Engine is not affected by the biodiesel and its blends with diesel.But,at higher loads the brake thermal efficiency of the engine is slightly lower when compared to pure diesel fuel. The higher ignition-lag at high loads may be the reason for this phenomena and it leads to reduction in smooth operations.

The observed cylinder temperature of the engine is high at all loads when biodiesel and its blends are used. The biodiesel blends produces exhaust gas at a higher temperature as the temperature of the Exhaust gas is a function of temperature of the cylinder. It is evident from the NOx emissions chart that biodiesel and its blends blends with diesel produces increased NOx emission which leads to increase in the cylinder temperature and exhaust gas temperature for pure biodiesel and its blends.

But, the oxygen content in Biodiesel and its blends is high compared to diesel. This causes reduction in the HC emissions of biodiesel and its blends in addition to reduced CO release. The higher molecular weight ,low cetane number of biofuels and the burning in the final stage of combustion are the reason for lesser release of CO. So, by using the RBME as an alternate fuel, the country can save a huge amount of foreign exchange by avoiding the import of crude oil products and can attain self-sufficiency in energy needs.

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