© July 2016 | IJIRT | Volume 3 Issue 2 | ISSN: 2349-6002

PERFORMANCE AND EMISSION CHARACTERISTICS OF CI DI ENGINE USING BLENDS OF TWO BIODIESEL (SIMAROUBA BIODIESEL AND PONGAMIA BIODIESEL) AND DIESEL FUEL

Amareshwarayya Hiremath[1], B. R. Hosamani[2] , P.S.Kori[3]

[1]*PG Student, Thermal Power Engineering, Department of Mechanical Engineering,*

[2,3]*Associate professor, Department of Mechanical Engineering, B.L.D.E.A's PGHCET VIJAYAPUR 586103, Karnataka. India*

***Abstract*—The rapid depletion of fossil fuels and environmental concerns make alternative fuels such as biodiesel more attractive. Biodiesel has properties similar to pure diesel. However certain properties of biodiesel such as viscosity, calorific value, density and volatility differ from pure diesel. These properties strongly affect injection, air-fuel mixing and there by combustion and performance characteristics of biodiesel in a diesel engine. The current work has carried out on vertical single cylinder 4-stroke compression ignition (CI) diesel engine, to investigate the performance and emission characteristics of diesel engine using two bio-diesels namely Simarouba bio-diesel and Pongamia bio-diesel in the ratio of (S50+P50), (S75+P25) and (S25+P75). In this study blends B0, B20, B40, B60, B80 and B100 at an engine speed of 1500rpm has tested. It has shown that there is a marginal increase in BSFC and decrease in BTE, in blending bio-diesel at constant injection pressure. Emission of CO, UBHC and NO_x are lowered in bio-diesel and diesel blends. The blend (S50+P50) has shown the superior performance than (S75 +P25) and (S25+P75) blends.**

Index Terms- **50% Simarouba and Pongamia (S50+P50), 75% Simarouba and 25% Pongamia (S75+P25), 25% Simarouba and 75% Pongamia (S25+P75).**

I.INTRODUCTION

In the year 1892 Diesel engine is invented by a German engineer Rudolf Diesel (1858-1913). The subsequent growth in diesel engine technology headed to widespread utilization of the oil reserves and they are in a state of depletion because of continuous refining and will definitely result in complete extinction of these reservoirs in future days[1]. presently a substitute to diesel that is bio diesel is inspecting to use in diesel engine with proven results and added potential chances to energy efficiency and reduced exhaust emissions[2]. Improvement in bio diesel will directly effect on economic growth and poverty drop in the whole world as these provide energy security[1]–[3]. Many energy fuels are being investigated as potential substitutes for the current high pollutant diesel fuel derived from bio seeds and diminishing commercial sources[2]–[5]. There are many tree breeds which bear seeds, rich in oil. Some of the important varieties are Pongamia, Jatropha, Rubber, Neem, Mahua, Sal, Undi, Pilu etc.[5]–[9] For CI engine fuelled with jatropha biodiesel and its blends with diesel BSFC is increased in case of biodiesel, CO emission is reduced whereas NOx is increased, observed similar brake thermal efficiency as that of diesel at low and medium engine loads.[2]. Mahua is perhaps the second most widely known tree in India after mango. With the use of mahua biodiesel with additives in CI engine it is noticed that brake thermal efficiency increases with the percentage of additive in all the test fuels. The brake specific fuel consumption decreases with increase in additive percentage. Exhaust gas temperature increases almost linearly with load for all test fuels and decreases with increase in additive percentage. It is also seen from the results that both

CO and HC emissions tend to decrease with increase in additive percentage in biodiesel.[10]. Use of bio-fuel requires very little or no modification of engine when blended with diesel. As a renewable and oxygen-containing biofuel, ethanol is a prospective fuel for vehicle, which can be blended with diesel or be injected into cylinder directly[11].

II. OBJECTIVES

In this paper, Simaoruba and Pongamia biodiesels are used in interaction with the diesel fuel. In this paper the best possible blend results are presented for good performance and lowered engine emissions at constant speed of 1500rpm. However the main objectives are highlighted as follow.

- Getting detailed information about bio plants, there plantation, different uses of those plants.
- Gathering fundamental concept of biodiesel and its characteristics.
- Preforming performance test of mixed oil blended with diesel and analysing the results.
- Recording the emissions liberated during the test and comparing the result with diesel in order to know its impact on environment.
- Creating awareness about usage of these bio fuels in urban and rural life and it is necessary in today's life style.
- Knowing the different procedures and rules concerned with the bio diesel and there usage.
- Obtaining most suitable blend ratio which can meet the neat diesel characteristics.

III. BIODIESEL EXTRACTION

Direct use of vegetable oils can clogs diesel engines due to its high viscosity; the oil needs to be chemically modified into mono-alkyl esters whose properties resemble those of fossil fuels. Transesterification process is the universal method used for extraction of biodiesel.

Fig 1.1 compare the effect of addition of simarouba and pongamia mixuture biofuels that is (S50+P50), (S25+P75), (S75+P25) in diesel on density. With the addition of biofuels in diesel, the density goes on increasing and it has been observed that B100 of S25+P75 has highest density that is 890 Kg/m^3 whereas density of pure diesel is 830 Kg/m^3. The fuel mixture containing 50% simarouba and 50% pongamia shows higher density values compared to other fuel mixture blends. Increased density of blended fuels reflects its unsuitability as diesel fuel in cold climatic conditions. In general, the injection pressure required will be more and its penetration is also deeper. It may cause problems in fuel atomisation[1]. It should be considered that the density of biodiesel is affected from the sources of raw material in their productions.

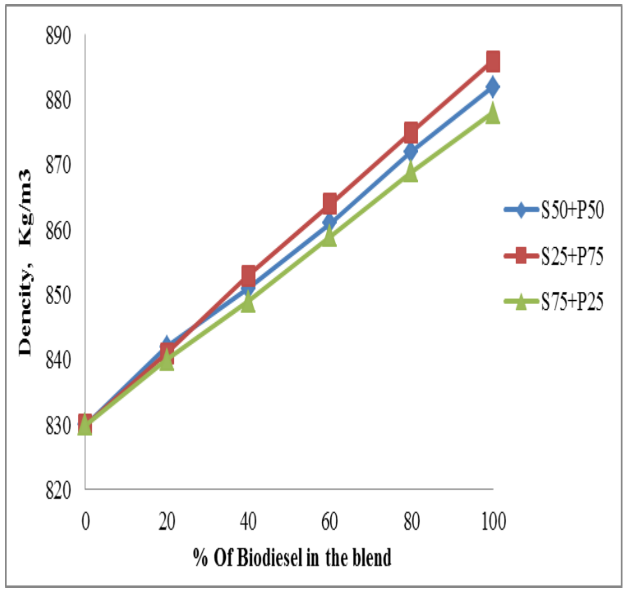

Fig 1.1 Change in Density with increase in % of biodiesel

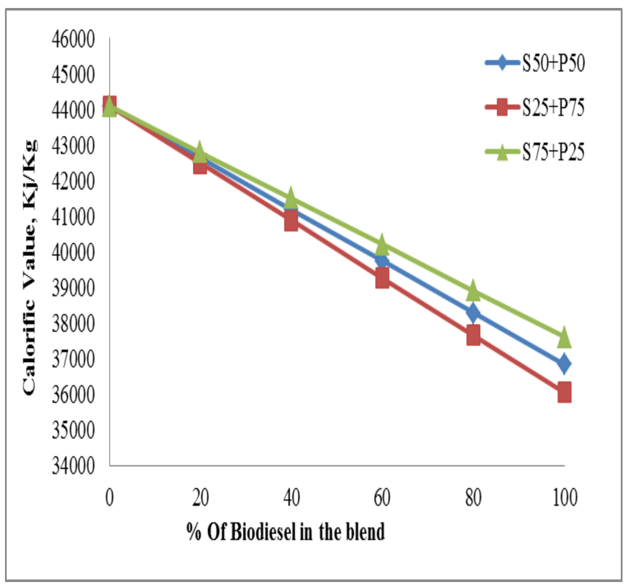

Fig 1.2 Change in CV with increase in % of biodiesel

Fig 1.2 shows the effect of addition of biodiesel in diesel on calorific value. The calorific value of S25+P75 mixture biodiesel was found less than those of calorific value of S50+P50 and S75+P25 biofuel. The decrease in CV of biofuel compared to diesel is due to lower hydrocarbon to carbon ratio and presence of chemically bonded oxygen in biodiesel blended fuel. The lowest CV found is 36000 KJ/Kg for the blend B100 of S25+P75 mixture fuel. Lower calorific value causes the percentage increase in specific fuel consumption with increased amount of biodiesel fuel in blend. This also leads to lower brake thermal efficiency of the engine[8].

IV. EXPERIMENTAL SETUP AND METHODOLOGY

The experiments are conducted on compression ignition direct injection; single cylinder 4-stroke Kirloskar diesel engine. The layout of experimental test rig and its instrumentation is shown in fig. 2. It is a water cooled engine with a rated power of 5.2 kW at 1500 rpm having bore 87.5 mm and stroke 110 mm, compression ratio of 17.5, and constant injection pressure of 205bar at 23˚bTDC injection time. It consists of a test bed, a diesel engine with an eddy current dynamometer, a computer with a software called engine soft, an AVL 444 make (5-gas analyzer) exhaust gas analyzer, AVL437 make smoke meter, a pressure sensor to measure the cylinder pressure, TDC sensor records pressure for every two degrees of crank rotation, with which P - θ curve is plotted.

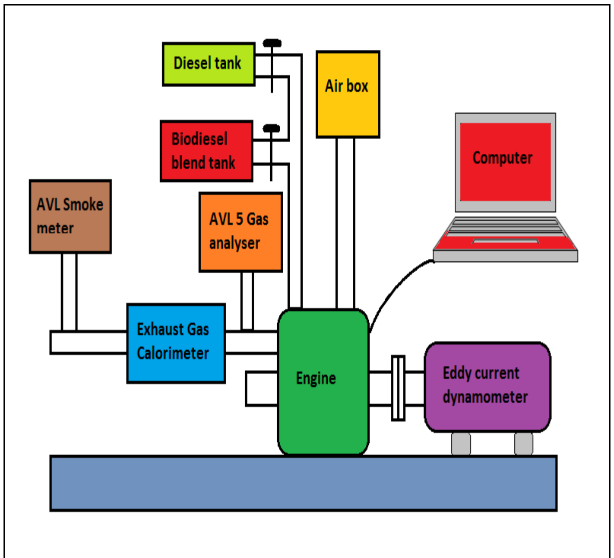

Fig. 2. Line diagram of experimental Setup

The eddy current dynamometer is mounted on base frame and connected to engine. The engine is subjected to different loads with the help of dynamometer. A rotameter is provided for engine cooling water flow measurement. A pipe in pipe type calorimeter is fitted at the exhaust gas outlet line of the engine. The calorimeter cooling water flow is measured and adjusted by the rotameter. Temperature sensors are fitted at the inlet and outlet of the calorimeter for temperature measurement. The pump is provided for supplying water to eddy current dynamometer, engine cooling and calorimeter. A fuel tank is fitted inside control panel along with fuel measuring unit. An air box is powered for damping pulsation in airflow line. An orifice meter with manometer is fitted at the inlet of air box for flow measurement. Piezo-electric type sensor with water cooled adapter is fitted in cylinder head for combustion pressure measurement. This sensor is connected to an engine indicator fitted in control panel, which scans the pressure and crank-angle data is interfaced with computer through COM port. An encoder is a device, circuit, transducer, software program, algorithm that converts information from one format to another. Rotary encoder is an optical sensor used for speed and crank angle measurement. The sensor is mounted on dynamometer shaft and connected to engine indicator. Thermocouple type temperature sensors measure cooling water inlet, outlet and exhaust temperatures. These temperatures are digitally indicated on indicator situated on control panel. Smoke opacity meter is distributary sample type. It equips gas temperature pressure and distributor control cell in order to ensure metrical stability and repeat. It measures the whole burthen opacity smoke degree continuously and free speed up opacity smoke degree. The exhaust gas analyzer is used to measure the relative volumes of gaseous constituents in the exhaust gases of the engine. Indicators on the test bed show the following quantities which are measured electrically: engine speed, brake power and various temperatures. The computer is interfaced with engine. The PCI 1050 IC card is connected to COM port of CPU.

Table 1.4 Engine Specifications

Make	Kirloskar Engine
Bore & stroke	87.5mm x110mm
Type of cooling	Water cooled
Speed	1500 rpm

Compression ratio	17.5.1
Number of cylinder	1
Rated power	5.2 kW
Start of injection	23˚ bTDC
Injection pressure	205 bar

Engine soft is the software used to control the entire engine readings. It is lab view based software. The engine is tested at constant rated speed of 1500 rpm throughout its power range using B0, B20, B40, B60, B80 and B100 blends. Experiments are conducted on the engine at different loads from 0 kg to 18 kg at an interval load of 3kg (rated load). Blends B0, B20, B40, B60, B80 and B100 are tested for 23˚bTDC and at an injection pressure 200bar.

V. RESULTS AND DISCUSSIONS

Thermal performance on vertical single cylinder, 4-stroke direct ignition (DI) and compression ignition (CI) Kirloskar diesel engine is carried out using the blends of two biodiesel namely Pongamia and Simarouba biodiesels with diesel for their varied different volume fraction at 200bar injection pressures (IP) are presented below.

1. Thermal performance parameter characteristics for (S50+P50) blend at 200bar IP:

1.1.1 (BSFC) Brake specific fuel consumption for (S50+P50) blend at 200bar IP:

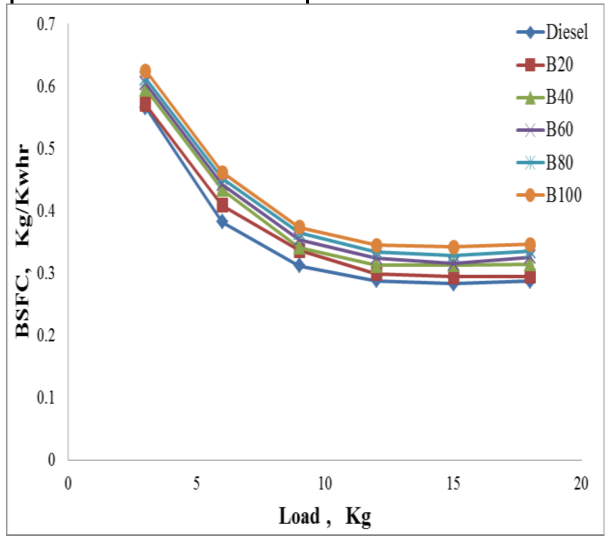

Fig 1.1.1 Change in BSFC with Load for (S50+P50)

From fig 1.1.1 shows the variation of BSFC with change in load for the different blends of biodiesel and diesel and neat diesel. BSFC for diesel fuel is lesser than the all the blends of biodiesel and diesel. Higher BSFC for Biodiesel and diesel blends may be due to the lesser energy content of biodiesel fuel. To get same power output from as that of diesel fuel for the biodiesel blends, more fuel is to be supplied compared to that of diesel fuel. As the volume percentage of biodiesel in the blend of biodiesel and diesel increases there is an increase in BSFC. The higher BSFC for biodiesel and diesel blend may be also due to the slower burning of biodiesel and diesel blend. This may be due to the higher viscosity of biodiesel fuel that may give the larger atoms of fuel during injection that may take more time for evaporation and mixing with air and burning that may be another reason for higher BSFC. The blend B20 and B40 are closer to that of diesel fuel. For other blends BSFC is increasing as the percentage of biodiesel in the blends increases.

The percentage increase in fuel consumption for different blends in comparison with neat diesel, that is B0 blend at full load are 2.61%, 9.65%, 13.51%, 16.59%, 20.71%.for B20, B40, B60, B80, B100.At higher loads cylinder wall temperature increases which intern reduces ignition delay which improves the fuel combustion process due to the presence of oxygen in the biodiesel.

1.1.2. (BTE) Brake thermal efficiency for (S50+P50) blend at 200bar IP:

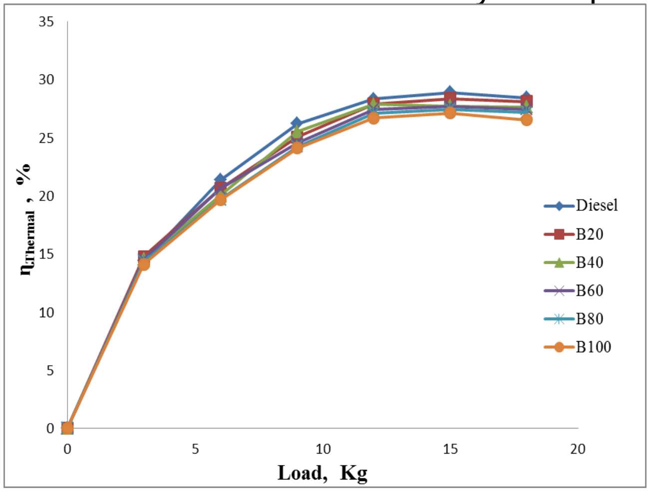

Fig. 1.1.2 Change in BTE with Load for (S50+P50).

This is one parameter gives clear idea about the fuel performance, from this efficiency the idea about how efficiently the chemical energy of the fuel is utilised or the energy content in the fuel is used and get converted in to heat energy by the engine.

The fig.1.1.2 is presenting the variation of thermal efficiency with change in loads for different biodiesel and diesel blends and neat diesel fuel. At the lower loads it is observed that the thermal efficiency of all the blends of biodiesel and diesel are seems to be same. The same thermal efficiency at the lower loads may be due the lean mixture supplied to the engine. This may be due to lean mixture supplied at lower loads may burn slower for all the biodiesel and diesel blend and pure diesel fuel may produce same thermal efficiency. As the load on the engine increases there is increased thermal efficiency, this may be due to the increased fuel supply with increase in loads.

Due to the increased fuel supply there is an increased heat release rate that may be the reason for increased thermal efficiency with increasing load for all the fuels. It is observed from the figure that thermal efficiency for the diesel (B0) fuel is the highest and that of 100% biodiesel (B100) fuel is the least. For other biodiesel and diesel blends are between the pure diesel (B0) and 100% biodiesel (B100).The lower thermal efficiency for biodiesel fuel may be due to the lower heating value of biodiesel fuel. Another reason may be due the higher viscosity and density of biodiesel fuel compared to diesel. Higher viscosity and density will progress the combustion at the slower rate compared to that of diesel fuel. As the load on the engine increases the thermal efficiency increases this is due to the more quantity of fuel supplied and burned at higher loads. The curves for all other blends shows decrease in efficiency compared to diesel. The reason for this result is because of existence of higher unsaturation caused by mixing of different heating value fuels, lower calorific value of the biodiesel fuel and higher viscosity and density observed in the fuel during the property test. At 18Kg load the percentage decrease is as fallows 1.08%, 2.72%, 3.48%, 4.49%, 6.63% for blends B20, B40, B60, B80 and B100.The poor combustion observed at the higher load with the use of biodiesel is characterised by lower instability of the fuel. Among these blend the B20 blend shows only 1% decrease in efficiency which is acceptable in turn doesn't sound large difference compared with all other blends, the pure biodiesel (B100) shows 6.63% decrease in efficiency which is not reliable. The blend B40 is acceptable in some circumstances provided full efficiency is not more concerned at this blend usage. It has been observed in certain papers that the viscosity of these blends can be reduced by preheating the biofuel improve the spray characteristics of the fuel during the combustion process and decreases the wall impingement of biofuel on combustion chamber walls which results in improved combustion process and thermal efficiency increases, it has been stated by some research scholars that optimising the injection timing and pressure will help in improved thermal efficiency of the fuel.

1.1.3. (EGT) Exhaust gas temperature for (S50+P50) blend at 200bar:

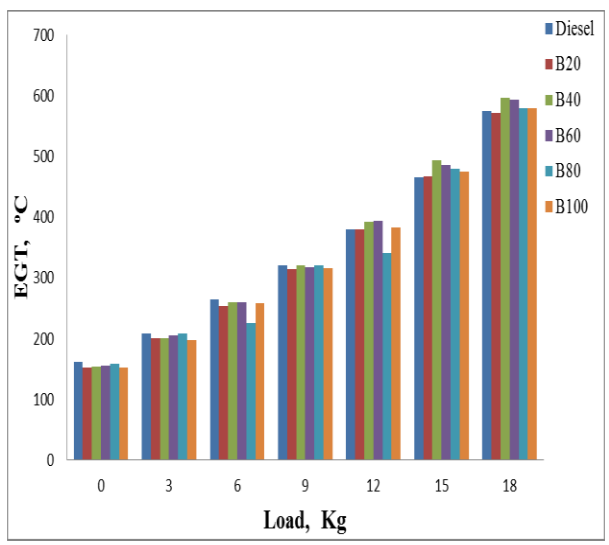

Fig.1.1.3 Variation of EGT with Load for(S50+P50)

Figure 1.1.3 shows the variation of exhaust gas temperature with change in load. Exhaust gas temperature indicates the utilization of heat energy in to mechanical efficiency. It is observed from the figure that for initial loads exhaust gas temperature for biodiesel and diesel blends are lower compared to that of diesel fuel. This may be due to the initiation of early combustion in biodiesel and diesel blends compared to diesel fuel. It indicates that heat energy is converted to mechanical energy with biodiesel and diesel blends are better than diesel. As the load on the engine increases beyond 15 kg the exhaust gas temperature is higher for biodiesel and diesel blends compared to that of diesel. The higher exhaust gas temperature may be due to the slower combustion of biodiesel and diesel blends compared diesel. The reason for slower combustion may be due to the more amount of fuel is supplied to take up higher loads. And due to the higher viscosity and density of biodiesel fuel will reduce the flame speed and decreases the combustion rate and increases the combustion duration. However EGT increases with increase in biodiesel percentage in the diesel fuel and load on diesel engine. Increased percentage of biodiesel at higher loads are calculated by using the results, it has been seen that there is decrease in exhaust gas temperature by 0.52% for B20 compared to diesel and there after it is increased by 3.65%, 3.30%, 0.86% and 0.85% for blends B40, B60, B80 and B100 respectively higher temperature recorded is for blend B40 and is 596 ºC.

1.2. b. Emission Characteristics for blend (S50+P50) at 200bar:

1.2.1 Carbon monoxide (CO) for blend (S50+P50) at 200bar:

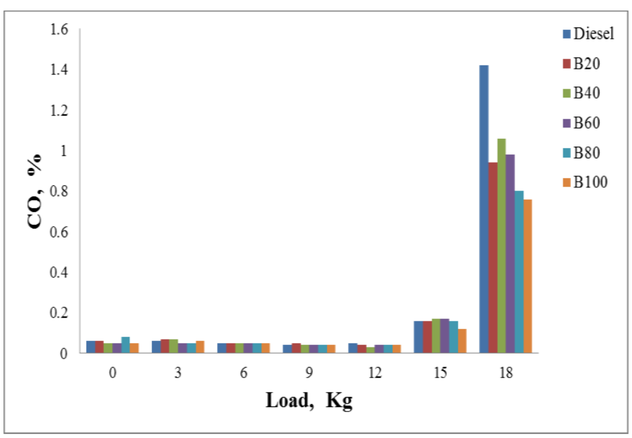

Fig. 1.2.1 Variation of CO with Load for (S50+P50)

Figure 1.2.1 shows the variation of carbon monoxide emission with change in load for the blends of biodiesel and diesel. CO emissions are formed due to the incomplete combustion. Incomplete combustion may be due to the insufficient oxygen availability. Due to incomplete combustion, energy available in the fuel may not be completely utilised, there is loss energy through the exhaust. It is observed from the above figure that carbon monoxide emission is negligible. In every cycle of operation of engine, quantity of air taken in to the engine cylinder is same and the fuel supplied is changing depends on loads. It is observed from the above the figure that carbon monoxide emissions are less up to 15 Kg. Load. At the rated load CO emission is increased may due to the incomplete combustion for all the biodiesel and diesel blends and also for pure diesel fuel. It is observed from the above figure that CO emission for biodiesel and diesel blends are lower for biodiesel and diesel blends compared to diesel. The lower emission of CO for blends may be due to the oxygen present in the biodiesel in its molecular structure may help in better combustion and converts CO to CO_2.The foremost reason for CO emission is incomplete oxidisation of hydro carbon fuels during exhaust. The graphs show decrease in CO emission compared to diesel this is because the presence of oxygen (O_2) content in the biodiesel which causes oxidisation throughout exhaust emissions. In some papers it is mentioned that CO emissions are lessened with rise in injection timing the factors which are possible causes of reduced emission are atomisation, evaporation of fuel droplet, complete combustion. Influence of atmospheric pressure is less on CO emission is observed while carrying out the test. the B20 blend shows consistency fallowing the diesel column and even at higher loads it is decreased by 33.3, 25.3%, 30.9%, 43.6% and 46.4% for blend B20, B40, B60, B80 and B100 respectively which is very good sign of controlled emissions. On higher load that is 18Kg it is observed that far decrease in emission which is because of rich fuel mixture or increased density of fuel and better air fuel ratio is observed, for the period of combustion when chemical equilibrium, unhurried recombination with oxygen reasons CO stages to get freeze through expansion and exhaust strokes.

1.2.2 Hydro carbons (HC) for (S50+P50) blend for 200bar:

Figure 1.2.2 shows the variation of HC emissions with change in load for biodiesel and diesel blends and pure diesel. It is observed from the figure that at no load there is more HC emissions for biodiesel and diesel blends compared diesel. This may be due to lean mixture available for the combustion. As the load on the engine increases there is decrease in HC emissions, this may be due to the increased fuel supply with increase in load may improve the combustion of mixture.

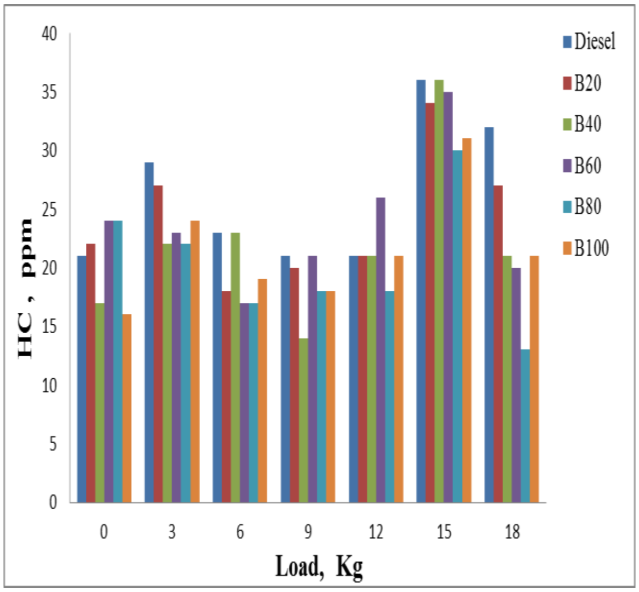

Fig. 1.2.2 Variation of HC with Load for (S50+P50)

The lower emission of HC may be due to the better combustion for biodiesel and diesel blend compared to diesel fuel. The oxygen present inherently in the biodiesel fuel may help in combustion. The inherent oxygen in the biodiesel fuel will make the combustion better compared to oxygen supplied from outside source. As the load on the engine increases there is an increase in HC emissions this is due to the more quantity fuel supplied to take higher load. With rise in load and at load 18kg B80 is the least (59%) HC emitting blend showing best result in concerned to environment however considering the efficiency parameters B20 will be suitable to diesel fuel the percentage decrease in HC emission at full load condition by different blends are 15.625%, 34.375%, 37.5%, 59.37% and 34.37% for B20, B40, B60, B80 and B100 respectively. During the increased load on the engine at a constant speed of 1500rpm the temperature of engine inner cylinder is found to be increased which intern increases the gas mixture creation and then the burning of fuel is initiated; due to slow down in ignition delay lessening the gas temperature resulting in momentous increase in HC emission.

1.2.3 Nitrogen oxides (NOx) for (S50+P50) blend at 200bar:

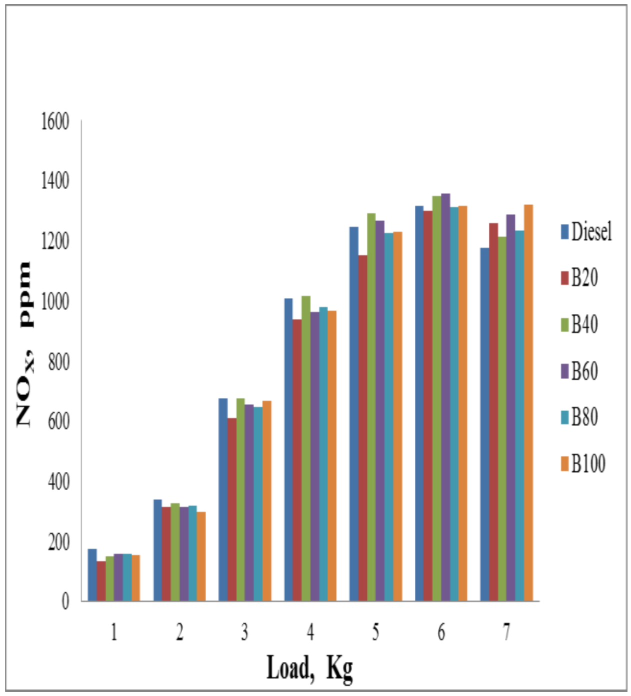

Fig 1.2.3 Variation of NO_X with Load for (S50+P50)

Figure 1.2.3 shows the variation of NO_x emissions with change in load for the blends of biodiesel and diesel and pure diesel. The main requirements for NOx formation are oxygen availability and higher temperature; if these are available formation of NOx takes place. Out of these two even any one is not available the NOx formation may not be taking palace. It is observed from the above figure that for initial load NO_x emissions are less because quantity of fuel supplied at lower load is less. As the load on the engine increases there is an increased fuel supply, increases the NOx emissions. It can be observed that NOx emissions are less for all the biodiesel; and diesel blends compared to diesel fuels. The lesser NOx emissions may be due to the absence of aromatics in biodiesel. Aromatics are the main component of the fuel causes the NOx formation. Due to the absence of aromatics and lower combustion temperature may reduce the NOx emissions for biodiesel blends. Due to lesser ignition delay higher part of ignition takes place earlier to TDC for biodiesel compared to diesel. “Higher peak cycle temperature is observed compared to diesel”.However all blends have shown moderate increase the blend B20 and B40 are near close diesel in every increase of load there by showing suitability as fuel in engine however percentage rise in emission for load 18kg compared to diesel has calculated, 6.9%, 3.0%, 9.2%, 4.8% and 12% for blends B20, B40, B60, B80 and B100 respectively among these B40 have shown least difference compared to other blends however in concerned with efficiency and other factors the emission of B20 is acceptable.

2. Pressure variation with changeable crank angle:

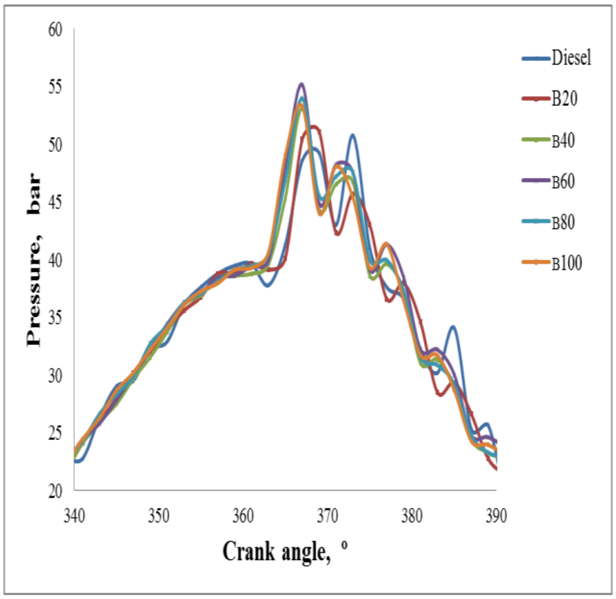

Fig. 2. P-Ɵ diagram at 12 Kg for (S50+P50)

The figure2 is presenting the variation pressure with change in crank angle for all the blends of biodiesel and diesel for 12.5 Kg. loads. It is observed from the figure that pressure biodiesel and diesel blends are higher compared to diesel fuel. The higher pressure for the blends may be due higher density of biodiesel fuel, produces more products of combustion. Products of combustion are depends on the density of the fuel, if the density is higher the products are more. It is also observed from the figure that ignition delay for biodiesel blends is lesser compared to diesel. The lesser ignition delay period in for biodiesel and diesel blends may be due to the higher Cetane number of biodiesel. Peak pressure for B80 is the highest and for diesel fuel it is comparable with biodiesel. Pressure for diesel fuel is more, for lesser degree of crank angle. This may be due to the faster burning of diesel compared to biodiesel blends.B80 blend is 9º after TDC with 69.5bar peak cyclic pressure whereas for diesel it is 7º after TDC is 66.13bar which indicates peak pressure is increased with biodiesel B80 by 5% which indicated delay in ignition period during biodiesel compare to diesel B20 is just above the diesel which is 66.47bar as per the above graph 4.8.

VI. CONCLUSIONS

The conclusions or results of suitability of biodiesel fuel mixed in different ratios with diesel are listed below:

- Break specific fuel consumption is increased for all the biodiesel blends compared to diesel.
- Brake thermal efficiency for all the biodiesel blends are less compared to diesel. Exhaust gas temperature increases with increase in load on the engine.
- Emission of CO and HC are reduced with the use of biodiesel in the engine, with increase in biodiesel content in the diesel reduction of emissions is observed during the test, for B80 and B100 up to 50% reduction in emission is observed, for B20 (S50+P50) has shown considerable reduction, that is 33.3% and 15.625% for CO and HC respectively.
- NO_X emission is lesser at lower loads. With the increase of biodiesel concentration in the diesel B20 and B40 of (S50+P50) have shown minimum increase that is 6.9% and 3% respectively.
- Based on the performance and emission characteristics tests the blend prepared by mixed oil (50% Simarouba and 50% Pongamia) and Diesel by blending them in the ratio B20 and B40 seems to be suitable for long-term usage.

REFERENCES

[1] Institute of Electrical and Electronics Engineers, Ed., 2012 International Conference on Advances in Engineering, Science and Management (ICAESM 2012): Nagapattinam, Tamil Nadu, India, 30 - 31 March 2012. Piscataway, NJ: IEEE, 2012.

[2] A. Datta, S. Palit, “An experimental study on the performance and emission characteristics of a CI engine fuelled with Jatropha biodiesel and its

blends with diesel," J. Mech. Sci. Technol., vol. 28, no. 5, pp. 1961–1966, May 2014.

[3] A. Datta, S. Palit, and B. K. Mandal, "An experimental study on the performance and emission characteristics of a CI engine fuelled with Jatropha biodiesel and its blends with diesel," J. Mech. Sci. Technol., vol. 28, no. 5, pp. 1961–1966, May 2014.

[4] K. N. Pethani, N. K. Patel, and R. K. Bumataria, "An Experimental Study on the Performance and Emission Characteristics of Single Cylinder Compressed Ignition Engine Using Mahua Biodiesel with Additives," 2015.

[5] B. Tesfa, R. Mishra, C. Zhang, F. Gu, and A. D. Ball, "Combustion and performance characteristics of CI (compression ignition) engine running with biodiesel," Energy, vol. 51, pp. 101–115, 2013.

[6] A. M. Liaquat, H. H. Masjuki, M. A. Kalam, I. M. R. Fattah, M. A. Hazrat, M. Varman, M. Mofijur, and M. Shahabuddin, "Effect of Coconut Biodiesel Blended Fuels on Engine Performance and Emission Characteristics," Procedia Eng., vol. 56, pp. 583–590, 2013.

[7] M. U. Ravi, C. P. Reddy, and K. Ravindranath, "Experimental Investigations on Conventional and Semi-Adiabatic Diesel Engine Using Simarouba Biodiesel as Fuel," J. Inst. Eng. India Ser. C, vol. 94, no. 2, pp. 165–174, Apr. 2013.

[8] M. H. mat Yasin, R. Mamat, A. F. Yusop, R. Rahim, A. Aziz, and L. A. Shah, "Fuel Physical Characteristics of Biodiesel Blend Fuels with Alcohol as Additives," Procedia Eng., vol. 53, pp. 701–706, 2013.

[9] T. R. Reddy, M. M. Krishna, C. K. Reddy P. V. K. Murthy, "Performance, Exhaust Emissions and Combustion Characteristics of Mohr Oil Based Biodiesel in A Medium Grade Low Heat Rejection Diesel Engine," Int. J. Automot. Eng. Technol., vol. 2, no. 2, pp. 70–84, 2013.

[10] K. N. Pethani, N. K. Patel, and R. K. Bumataria, "An Experimental Study on the Performance and Emission Characteristics of Single Cylinder Compressed Ignition Engine Using Mahua Biodiesel with Additives," 2015.

[11] J. Lei, Y. Bi, "Performance and Emission Characteristics of Diesel Engine Fueled with Ethanol-Diesel Blends in Diesel" J. Biomed. Biotechnol., vol. 2011, pp. 1–10, 2011.