EFFECT OF CHANGE OF COMPRESSION RATIO ON THE PERFORMANCE OF CI ENGINE FUELED WITH VARIOUS BIODIESEL – DIESEL BLENDS – A REVIEW

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Abstract - This work indicates the effects of change of compression ratio on the performance of CI engine fueled with various biodiesel-diesel blends. Various performance parameters like Brake Specific Fuel Consumption (BSFC), Brake Thermal Efficiency (BTE), Brake Power (BP) and emission parameters like Carbon monoxide (CO), Hydrocarbon (HC), Nitrogen oxides (NOx) compared for various compression ratios with various biodiesel - diesel blends. It is found that around 30% reduction in Brake Specific Fuel Consumption (BSFC) was observed and Brake Thermal Efficiency (BTE) is improved by 13% for diesel fuel at full load on increasing the compression ratio from 16 to 18. At the same time, Hydrocarbon (HC) emission reduced by 25%, Carbon monoxide (CO) emission reduced by 20.5% and NOx emissions increases from 165 ppm to 220 ppm for diesel fuel at full load on increasing the compression ratio. Rise in compression ratio also results in increase of Brake Thermal Efficiency (BTE) from 31.41 % to 31.67% for diesel - biodiesel blends at compression ratio of 19.5:1 which is due to fact that increase in compression ratio ensures more complete combustion of fuel and improved performance of engine.

Keywords: Compression ratio, BSFC, BTE, BP, CO, HC, NOx

Nomenclature

BSFC	***Brake Specific Fuel Consumption (kg/kWh)***
BTE	***Brake Thermal Efficiency (%)***
BP	***Brake Power (kW)***
CO	***Carbon monoxide (%)***
HC	***Hydrocarbon (ppm)***
NOx	***Nitrogen Oxide (ppm)***
CI	***Compression Ignition***
CR	***Compression Ratio***
B0	***Pure Diesel***
B10	***90% Diesel 10% Jatropha Biodiesel***
B20	***80% Diesel 20% Jatropha Biodiesel***
B30	***70% Diesel 30% Jatropha Biodiesel***

I. INTRODUCTION

Diesel engines find more application in the current world compared to SI engines. The higher torque and efficiency due to increased compression ratio enable the human favoring the diesel engines for variety of applications. Day by day very strict emission regulations have been imposed on the vehicles and constant speed engines marking various technological advancements. The engine operating parameters play a key role in tuning the engine conforming to the better performance and emission standards. The effect of varying the compression ratios has more impact on the performance, emission and combustion parameters. The effect of variation in the compression ratio on brake thermal efficiency indicated that higher compression ratios improve the engine efficiency. The specific fuel consumption of the A20 blend at the compression ratio of 19.5:1 is 0.30 kg/kWh and for diesel it is 0.32 kg/kWh. This is due to fact that increase in compression ratio reduces BSFC due to reduction in dilution of charge by residual gases which result in better BTE and lower BSFC [1]. The BTE was higher by almost 13% at full load when CR was increased from 16 to 18. This is due to the fact that increase in compression ratio ensures more complete combustion due to injection of fuel in higher temperature and pressure compressed air, better air - fuel mixing and faster evaporation [2]. The maximum brake power obtained for O20 and diesel is 3.9927 kW and 3.9339 kW for compression ratio 20:1 at full load. This may be due to better improvement of fuel spray characteristics, proper mixing of fuel - air ratio and complete combustion of fuel [3]. The CO emission reduced by 37.5% when compression ratio was increased from 14 to 18 for the blend B30. The possible reason for this trend could be that the increased compression ratio actually increases the air temperature inside the cylinder consequently reducing the delay period causing better and more complete burning of the fuel and so lower CO emission [4]. The NOx emission for diesel and blend B40 for compression ratio 21 is 621 ppm and 640 ppm respectively. This may be due to the fact that increase in compression ratio increases the combustion pressure and temperature which accelerates the oxidation of nitrogen to form oxides of nitrogen [5]. The maximum brake thermal efficiencies obtained for B0, B50 and B70 is 7.25%, 6.59% and 5.41% respectively. This lower brake thermal efficiency obtained for these blends than diesel could be due to a reduction in the calorific value and an increase in fuel consumption as compared to B0 [6]. The CO emission reduces 20.5% at high compression ratio 18 and full load condition because combustion is much better than lower compression ratio good diffusion flame combustion [7]. The brake specific fuel consumption for diesel is 0.531 kg/kWh and for jatropha biodiesel is 0.73 kg/kWh. This was due to the higher density and viscosity of Jatropha oil biodiesel. The net calorific value of the Jatropha oil biodiesel is about 14.88% lower than that of diesel fuel. This may explain the increase in fuel consumption [8]. The maximum brake power of the engine was 4.06 kW, 3.87 kW and 3.70 kW for B0, B10 and B20 respectively. The reason for the lower brake power of biodiesel compared to diesel can be attributed to their lower calorific values and higher viscosities [9].

II. BIODIESEL PROPERTIES

Vegetable oil is converted into biodiesel through a chemical process that trans-esterification and produces methyl ester or ethyl ester. Here, various kinds of biodiesel and their properties shown in below table.

Table 1 Different properties of biodiesel fuels

Test	**Unit**	**Diesel**	**Palm**	**Jatropha**	**Sunflower**	**soya**	**Coconut**
Density	kg/m^3	820	873	876	878	882	874
Viscosity @ 40℃	mm^2/s	2.2	4.61	4.75	4.42	4.26	2.75
Flashpoint	℃	66	163	152	175	159	113
Cetane number	-	52	61.9	55.7	51.1	51.3	59.3
Higher heating value	Mj/kg	42	40.6	40.7	40.6	41.1	38.1

III. LITERATURE REVIEW

Senthil Ramalingam studied the effects of the engine design parameters viz. compression ratio (CR) and fuel injection timing (IT) jointly on the performance with regard to specific fuel consumption (SFC), brake thermal efficiency (BTE) and emissions of CO, HC, Smoke and NOx with Annona methyl ester (A20) as fuel. Compression ratio of 19.5 along with injection timing 30° bTDC will give better performance and lower emission which is very close to diesel. It is found that the combined increase of compression ratio and injection timing increases the BTE and reduces SFC while having lower emissions.

For all tested values A20 provide best results in terms of BTE, higher heat release rate and lower emissions of HC, CO and NOx. Blend A20 can be effectively used as an alternative biodiesel with injection timing of 30° bTDC along with compression ratio of 19.5 in tested engine. Only 20% of Annona methyl ester is added with 80% pure diesel, will meet to a certain extent the shortage of availability of pure diesel.

The HC emission of A20 blend at the compression ratio of 19.5:1 is 26 ppm whereas for diesel it is 29 ppm. The CO emission of the A20 blend at the compression ratio of 19.5:1 is 0.05 ppm whereas for diesel it is 0.06 ppm. The NOx emission of the A20 blend at the compression ratio of 19.5:1 is 515 ppm whereas for diesel it is 510 ppm. The specific fuel consumption of the A20 blend at the compression ratio of 19.5:1 is 0.30 kg/kWh whereas for diesel it is 0.32 kg/kWh.

The BTE of A20 blend at the compression ratio of 19.5:1 is 31.67% and for neat diesel fuel it is 31.41%. This is due to the fact that increase in compression ratio ensures more complete combustion due to injection of fuel in higher temperature and pressure compressed air, better air- fuel mixing and faster evaporation.

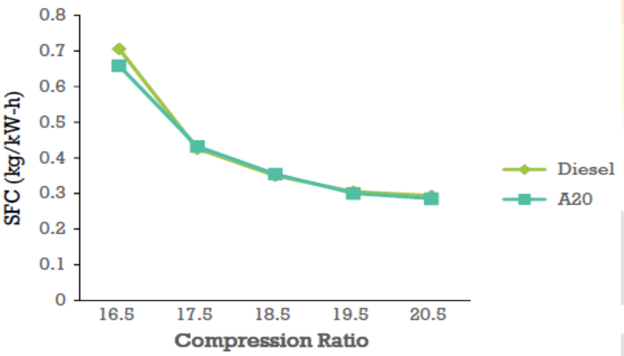

Fig. 1 Compression Ratio vs. Specific Fuel Consumption

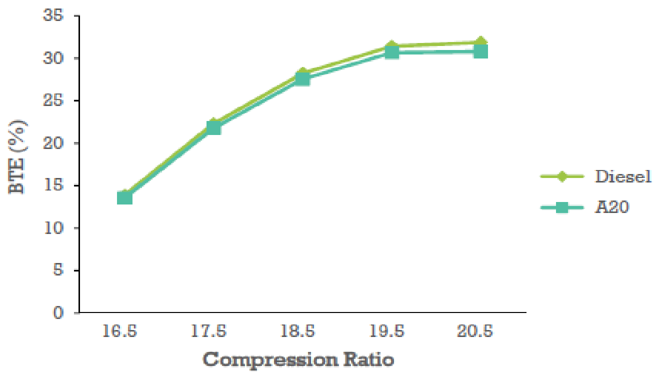

Fig. 2 Compression Ratio vs. Brake Thermal Efficiency

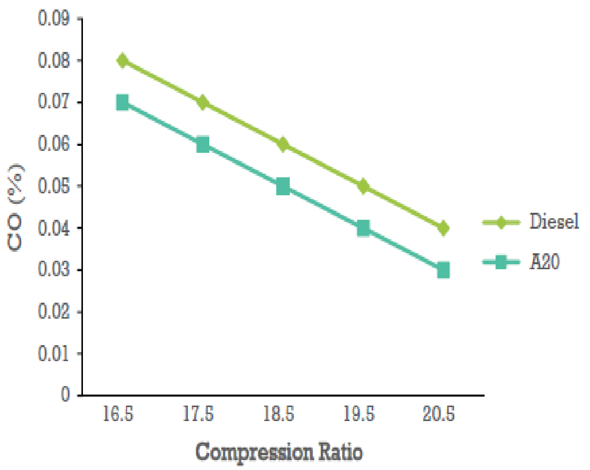

Fig. 3 Compression Ratio vs. Carbon monoxide emission

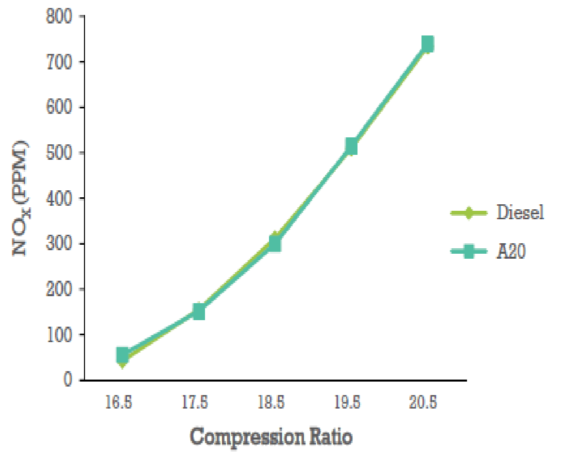

Fig. 4 Compression Ratio vs. Nitrogen oxide emission

V.Hariram studied a single cylinder direct injection CI engine was tested on varying the compression ratios of 16, 17 and 18 at varying loads. The combustion and performance variation on increasing the compression ratios were investigated clearly. Increase in brake thermal efficiency and reduce in exhaust gas temperature were observed when compression ratio was increased from 16 to 18. The brake specific fuel consumption was reduced on increasing the compression ratio. Increase of peak cylinder pressure was observed on increase of compression ratio and the ignition delay period reduced on increasing the compression ratio. The rate of pressure rise was also investigated and showed maximum of 5.38 bar/°CA and minimum of 0.78 bar/°CA on above compression ratios. Cumulative heat release was also evaluated in this study showing higher heat energy for higher loads and compression ratios.

Reduction in BSFC of about 30% was observed when CR was increased from 16 to 18 and BTE improved by 13% at full load on increasing the CR. The exhaust gas temperature showed a slight reduction when CR was increased from 16 to 18 and a peak pressure showed increase of about 10%, 17% and 21% when CR was increased from 16 to 18 at no load, 50% load and full load respectively. The minimum delay was observed at full load at maximum CR of 18 and overall reduction of about 9% was observed in the delay period on increasing CR from 16 to 18. Compression ratio of 18 was considered to be useful CR without knocking with better BTE and BSFC compared to both CRs 16 and 17.

S. Nagaraja studied the performance and emission characteristics of a direct injection variable compression ratio engine when fueled with pre heated palm oil and its 5%, 10%, 15%, 20% blends with diesel are investigated and compared with standard diesel. The suitability of raw palm oil using pre heated in temperature range of 90°C as a fuel has been presented. Experiments were conducted at constant speed of 1500 rpm, full load and at compression ratios of 16:1, 17:1, 18:1, 19:1 and 20:1. The effect of compression ratio on brake power, mechanical efficiency, indicated mean effective pressure and emission characteristics has been investigated and presented. The blend O20 is found to give maximum mechanical efficiency at higher compression ratio 20:1 and it is 14.6% higher than diesel. The break power of blend O20 is found to be 6% higher than diesel at higher compression ratio 20:1. Exhaust gas temperature is low for all the blends compared to diesel.

The emission of CO, HC dropped with an increase in blending ratio and compression ratio of maximum load. The engine performance was found to be optimum when using O20 as fuel at compression ratio 20:1 during full load condition. From the observation of this study while increasing the compression ratio of the engine the mechanical efficiency was increased at full load condition. This may lead to better thermal efficiency of the engine. There is a significant reduction in CO and unburned Hydrocarbon for all blends of preheated palm oil at higher compression ratio and full load. The HC emissions of blend O20 is found to be 24.2% lower than standard diesel at higher CR 20:1.

Mohammed EL_Kassaby studied the effect of blending ratio and compression ratio on a diesel engine performance. Wasted cooking oil from restaurants was used to produce neat (pure) biodiesel through transesterification and then used to prepare biodiesel/diesel blends. Emission and combustion characteristics was studied when the engine operated using the different blends (B10, B20, B30 and B50) and normal diesel fuel B0 as well as when varying the compression ratio from 14 to 16 to 18. The result shows that the engine torque for all blends increases as the compression ratio increases. The BSFC for all blends decreases as the compression ratio increases and at all compression ratios BSFC remains higher for higher blends as the biodiesel percent increase. The change of compression ratio from 14 to 18 resulted in 18.39%, 27.48%, 18.5% and 19.82% increase in brake thermal efficiency in case of B10, B20, B30 and B50 respectively. The HC emission reduced by 52%, CO emission reduced by 37.5% and NOx emission increased by 36.84% when compression ratio was increased from 14 to 18.

Biodiesel could be safely blended with diesel fuel up to 20% at any of compression ratio and speed tested for getting almost the same performance and emission as that with diesel fuel. The delay period decreased by 13.95% when compression ratio was increased from 14 to 18. Increasing the compression ratio improved the performance and cylinder pressure of the engine and had more benefits with biodiesel than with high pure diesel.

At partial load or low engine speed operation, small differences in power output was found, since an increase in fuel consumption in the case of biodiesel would compensate its reduced heating value. At full load or high engine speed conditions, the observed maximum torque values of the biodiesel fuel blends operations were less than the diesel fuel value for each fuel. The engine torque for all blends increases as the compression ratio increases.

K. Muralidharan investigate the performance, emission and combustion characteristics of a single cylinder, four stroke, variable compression ratio engine fueled with waste cooking oil methyl ester and its 20%, 40%, 60% and 80% blends with diesel and compared results with standard diesel. Biodiesel produced from waste sunflower oil by transesterification process. Experiment has been conducted at a fixed engine speed of 1500 rpm and at compression ratios of 18:1, 19:1, 20:1, 21:1 and 22:1. The impact of compression ratio on fuel consumption, exhaust gas emissions has been investigated. BTE of standard diesel and blend B40 for compression ratio 21 is 26.08% and 31.48% respectively. By increasing the compression ratio, brake thermal efficiency increased for all the fuel types tested. The specific fuel consumption of the blend B40 at compression ratio of 21 is 0.259 kg/kWh whereas for diesel it is 0.314 kg/kWh. This is due to as compression ratio increase, the combustion temperature and pressure increase so ignition delay period decrease and fuel ignite rapidly. The maximum brake power obtained for B40 and diesel at compression ratio 21 is 2.12 kW and 2.07 kW respectively. Blends B20, B60 and B80 produce less hydrocarbon emissions at high compression ratio 21 than standard diesel because ignition delay is short and oxygen required for complete combustion easily. The NOx emission for diesel and blend B40 for compression ratio 21 is 621 ppm and 640 ppm respectively. The reason for higher NOx emission for blends is due to higher peak temperature as the compression ratio increase.

Jagannath Hirkude studied the work that aim is to experimentally investigate the effect of compression ratio on performance of compression ignition engine operated with waste fried oil methyl ester (WFOME) blended with mineral diesel. The work discusses the results of investigations carried out on a single cylinder, four stroke, direct injection diesel engine operated on WFOME blended with mineral diesel. Compression ratios considered for this analysis were 14.5, 16.5 and 17.5. All tests with different fuels were conducted for constant speed (1500 rpm) and with varying loads (0.5 kW to 4 kW) on the engine. Comparative measures brake thermal efficiency, brake specific fuel consumption, exhaust gas temperature, particular matter, NOx, CO and HC emissions. Engine performance in terms of higher brake thermal efficiency and lower emissions with different blends of biodiesel (B0, B50 and B70) at higher CR 17.5. The performance parameters for different WFOME blends were found to be very close to diesel and emission characteristics of engine improved significantly.

It was observed that an increase of load leads to a significant increase of brake thermal efficiency and decrease in BSFC. The effect of variation in the compression ratio on brake thermal efficiency indicated that higher compression ratios improve the engine efficiency. The best results for BSFC were obtained at increased CR 17.5. The results showed that CO and particular emissions decreased while nitrogen oxide emission increased with an increase in CR from 14.5 to 17.5.

For all tested fuels an increase in compression ratio leads to an increase in exhaust gas temperature. The reduction in exhaust emissions and brake specific fuel consumption together with increased brake power and brake thermal efficiency made the WFOME from waste fried oil a suitable alternative fuel for diesel at higher compression ratio 17.5. With the increase in CR from 16.5 to 17.5 the mean BSFC reduced by 5.69%, 4.40% and 3.89% for B0, B50 and B70. With the increase in CR from 16.5 to 17.5 the mean BTE increased by 7.25%, 6.59% and 5.41% for B0, B50 and B70.

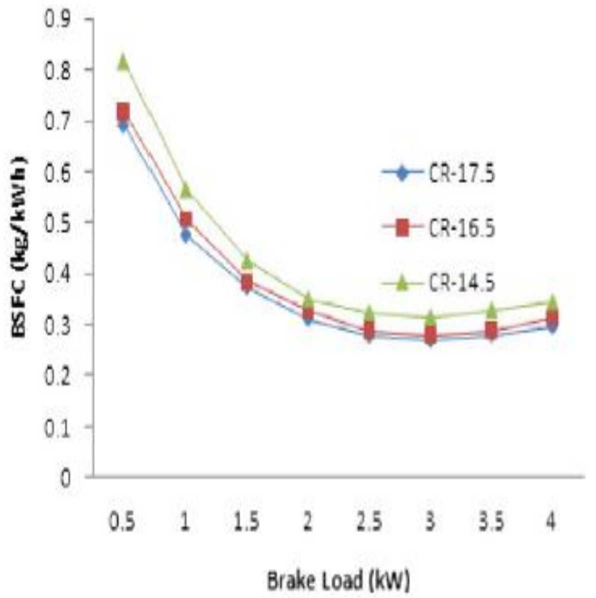

Fig. 5 Variation of BSFC with load and compression ratio for diesel

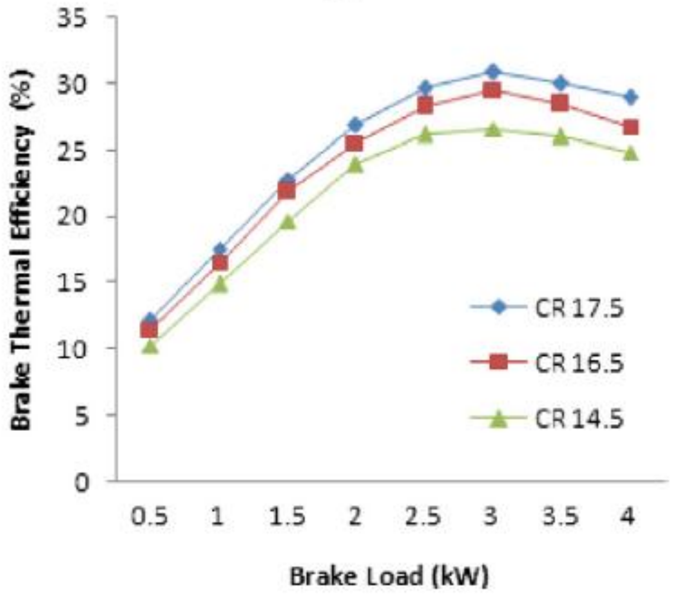

Fig. 6 Variation of BTE with load and compression ratio for diesel

S. Jindal investigate the effect of compression ratio and injection pressure in a direct injection diesel engine running on Jatropha methyl ester. For small sized direct injection constant speed engines used for agricultural applications (3.5 kW). The engine was tested at no load and at 25%, 50%, 75% and 100% loads and three different compression ratios 16, 17 and 18. At the compression ratio of 18, the BTE improves by 8.9%. This can be attributed to better combustion and higher lubricity of biodiesel. The BSFC reduced from 0.39 to 0.36 kg/kWh at high compression ratio 18 and full load condition. The decrease in BSFC can be attributed to the more efficient utilization of the fuel at high compression ratio because of better atomization associated with slight ignition delay.

The HC emission reduces 25% at high compression ratio 18 and full load condition. This is mainly due to the fact that biodiesel has about 10-11% oxygen contents which help in better combustion of fuel inside the cylinder. The CO emission reduces 20.5% at high compression ratio 18 and full load condition because combustion is much better than lower compression ratio good diffusion flame combustion. NOx emission increases from 165 ppm to 220 ppm at high compression ratio 18 and full load condition.

The change in NOx emission corresponds up to some extent to combustion temperature which tends to increase with increase in compression ratio. With increase in compression ratio facilitates combustion of larger droplets because of high temperature of combustion. The high compression ratio 18 improve BTE and reduces BSFC because of better combustion of fuel.

Gaurav Paul studied the effect of addition of jatropha biodiesel to mineral diesel on the performance and emission characteristics of a conventional compression ignition engine have been experimentally investigated and compared with simulated data using Diesel-RK software. The experiments were carried out using pure diesel (B0) and pure jatropha biodiesel (JB100) as fuels. The performance characteristics shows that brake specific fuel consumption (BSFC) increases and brake thermal efficiency decreases with the use of jatropha biodiesel. Experimentally pure has maximum efficiency 29.6%, whereas pure biodiesel has maximum efficiency of 21.2%. In the simulation the pure diesel has maximum efficiency 30.3% whereas pure jatropha biodiesel has the maximum efficiency of 27.5%. NOx emission is found to increase with load as well as use of biodiesel in both experimental and simulation study. After the successful validation of the numerical study with the experimental another simulation was done where the performance, combustion and emission characteristics of the same engine fueled with pure diesel (B0), pure jatropha biodiesel (JB100) and 50% jatropha blend (JB50) were derived.

In the numerical study it is found that with the use of jatropha biodiesel the BSFC increases whereas BTE decreases. Combustion characteristics show an increase in peak cylinder pressure and a decrease in ignition delay period with the increase in biodiesel share in the blends; whereas the emission of NOx increases; smoke and PM emission decreases for the same.

M.Mofijur showed the paper that aim is to study the feasibility of jatropha as a potential biodiesel feedstock for Malaysia. Physico-chemical properties of jatropha biodiesel and its blends with diesel B0, B10 and B20 followed by engine performance and emission characteristics were studied. The results show that viscosities of B10 and B20 are closer to diesel. Therefore, B10 and B20 have been used to evaluate engine performance and emission. Compared to B0 the average reduction in brake power (BP) is 4.67% for B10 and 8.86% for B20. It was observed that brake specific fuel consumption (BSFC) increases as percentage of biodiesel increase. Compared to B0, a reduction in hydrocarbon (HC) emission of 3.84% and 10.25% and carbon monoxide (CO) emission of 16% and 25% was observed for B10 and B20. However, the blends give higher nitrogen oxide (NOx) emission of 3% and 6% for B10 and B20. The viscosities of B10 and B20 (3.7135 mm^2/s and 3.7878 mm^2/s) are almost closer to diesel fuel. The flash point results of all blends are considered to be safe to store and to be used in diesel engines. Calorific value decreased as the amount of jatropha biodiesel increased in blends.

The average BSFC for B10, B20 (278.46 g/kWh and 281.9 g/kWh) were found to be higher compared to B0 (273.5 g/kWh). These results show that Jatropha biodiesel-diesel blends (B10 and B20) can be used in diesel engines without major modification. The reduction in brake power (BP) was found to be 3.87 kW and 3.70 kW for blends B10 and B20 as compared to pure diesel 4.06 kW.

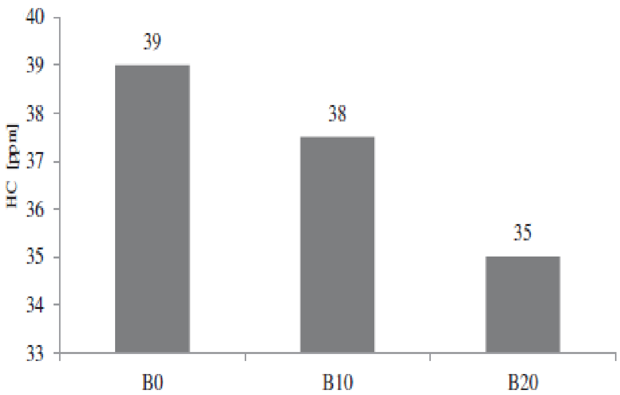

Fig. 7 Comparison of HC emissions for various blends of Jatropha biodiesel and pure diesel

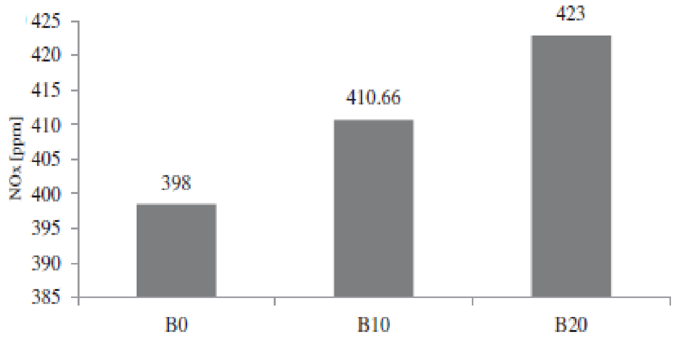

Fig. 8 Comparison of NOx emissions for various blends of Jatropha biodiesel and pure diesel

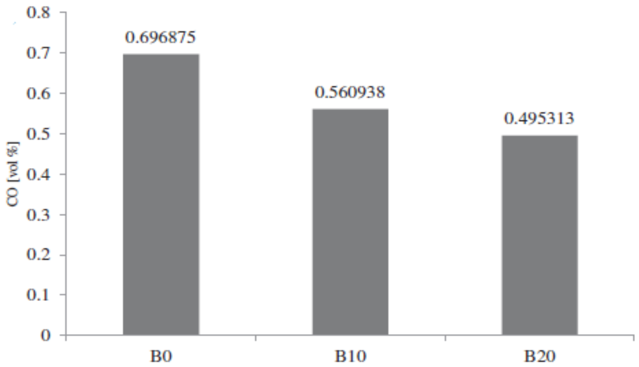

Fig. 9 Comparison of CO emissions for various blends of Jatropha biodiesel and pure diesel

IV. CONCLUSION

From above investigation carried by various researchers conclude that as the compression ratio increase emissions of CO, HC decrease because combustion temperature increase so delay period of fuel burning decrease and for complete combustion oxygen required easily.
As the compression ratio increase NOx emissions increase because combustion temperature increase so delay period of fuel burning decrease so for NOx generation oxygen required easily.

As the compression ratio increase brake power (BP), brake thermal efficiency (BTE) increases and brake specific fuel consumption (BSFC) decreases because as the compression ratio increase combustion temperature and pressure increase so delay period decrease so fuel ignite fast and produce more power in small time.

Different kinds of biodiesel like Jatropha, Palm and other vegetable oils etc. are the best alternative fuel for engine.

The ratio of biodiesel-diesel blends increase the emissions of CO, HC decrease and NOx emissions increase because 10-11% more oxygen available in biodiesel for complete combustion.

The ratio of biodiesel-diesel blends increase brake power (BP), brake thermal efficiency (BTE) decreases and brake specific fuel consumption (BSFC) increases because density and viscosity of biodiesel is high so volume of ignition of fuel increase in less time so ignition delay period increase and calorific value of biodiesel is less compared to diesel.

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