Experimental Analysis of Diesel Engine Using Biofuel at Varying Compression Ratio

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Experimental Analysis of Diesel Engine Using Biofuel at Varying Compression Ratio

Major Project Report

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By

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Declaration

This is to certify that

1. The thesis comprises my original work towards the Degree of Master of Technology in Thermal Engineering at Nirma University and has not been submitted elsewhere for a degree.

2. Due acknowledgement has been made in the text to all other material used.

- Parth Panchal

Certificate

This is to certify that the Major Project entitled " Experimental Analysis of Diesel Engine Using Biofuel at Varying Compression Ratio" submitted by **Panchal Parth Rajeshkumar(09MMET08)**, towards the partial fulfillment of the requirements for the Degree of Master of Technology in Mechanical Engineering (Thermal Engineering) of Institute of Technology, Nirma University, Ahmedabad is the record of work carried out by him under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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Abstract

Environmental concern and availability of petroleum fuels have caused interest in the search for alternative fuels for internal combustion engine. Many alternate fuels are tried by various researches. Based on literature review it is found that for diesel engine Bio Diesel is most promising fuel. In this project works prospects and opportunities of increasing biodiesel-diesel blend ratio as fuel in diesel engine is going to be studied by varying compression ratio. Also based on experimentation an optimum blend and engine parameters are to be suggested for obtaining better performance and emission control.

Biodiesel present a very promising scenario of functioning as alternative fuels to fossil diesel fuel. The properties of these can be compared favorably with the characteristics required for internal combustion engine fuels specially diesel engine. Preliminarily to compare performance of biodiesel-diesel blend with base cases i.e. performance of engine using diesel as a fuel, experiments were performed to study effect of variation of compression ratio on brake power, brake specific fuel consumption and brake thermal efficiency of diesel engine using diesel as a fuel at various loads ranging from 0.5% to 100%. Out of three compression ratio that is 14, 16 and 18, 18 compression ratio results of brake thermal efficiency, brake specific fuel consumption and brake power , is better results compared to other. In diesel-biodiesel blend as percentage of biodiesel increase emission of carbon monoxide (CO), carbon dioxide (CO_2), unburned hydro carbon (HC) and oxides of nitrogen (NOx) decrease. As per the literature survey B20 (20%biodiesel and 80% diesel) is best in performance compare to other blends.

Key words: Biodiesel, Biodiesel-Diesel blend, Varying Compression Ratio

Contents

List of Figures

List of Tables

Nomenclature

BTHE	Brake Thermal Efficiency
BP	Brake Power
BSFC	Brake Specific Fuel Consumption
EGT	Exhaust Gas Temperature
CO	Carbon Monoxide
HC	Hydrocarbons
NOx	Nitrogen Oxide
CO_2	Carbon Dioxide
B0	Pure Diesel
B10	10% Biodiesel mix with Diesel
B20	20% Biodiesel mix with Diesel
B30	30% Biodiesel mix with Diesel
B40	40% Biodiesel mix with Diesel
B60	60% Biodiesel mix with Diesel
B80	80% Biodiesel mix with Diesel
B100	Pure Biodiesel
CR	Compression Ratio
IT	Injection Timing
bTDC	Before Top Dead Centre
HSD	High Speed Diesel

Chapter 1

Introduction

Diesel engines are attracting greater attention due to higher efficiency and cost effectiveness, because of that they have been widely used as a power of engineering machinery, automobile and shipping equipment. Oil provides energy for 95% of transportation. All countries including India are grappling with the problem of meeting the ever increasing demand of transport fuel within environment concerns and limited resources.

So, the most attentive question arise in our country and at world level is "How long we can use this petroleum fuels?" The solution of this question is in three words 'Reduce',' Reuse' and 'Recycle'. But another solution is also there in only one word that is 'Replace'.

That's why this is high time for India that the use of Biofuel is seriously considered.

Biofuel are renewable liquid fuels coming from biological raw material and have been proved to be good substitutes. As such biofuel ethanol for blending with petrol and biodiesel for blending with diesel are gaining worldwide acceptance as a solution for problems of environmental degradation and agricultural economy.

Biodiesel can be used in the pure form, or blended in any amount with diesel fuel for use in compression ignition engines. Biodiesel is composed of long-chain fatty acids with an alcohol attached, often derived from vegetable oils. It is produced through the reaction of a vegetable oil with methyl alcohol or ethyl alcohol in the presence of a catalyst. Animal fats are another potential source. Commonly used catalysts are potassium hydroxide (KOH) or sodium hydroxide (NaOH). The chemical process is called transesterification which produces biodiesel and glycerin. Chemically, biodiesel is called a methyl ester if the alcohol used is methanol. If ethanol is used, it is called an ethyl ester. They are similar but currently, methyl ester is cheaper due to the lower cost for methanol.

Biodiesel is attractive as an alternative fuel source because its emissions profile is cleaner than that of diesel fuel. Biodiesel can be used in diesel engines without modification, and can be blended with petrol-diesel fuel effectively. A blend of 20 % biodiesel and 80 % diesel fuel, called B20, is currently the most widely used form of biodiesel. If not used as a total replacement for Diesel in I.C.Engine it's got good prospect as using as an additives that improve diesel fuel properties which can be sold for a price above that of the diesel fuel.

Biodiesel can be stored just like the petroleum diesel fuel and hence does not require separate infrastructure. It can be stored for long periods in closed containers but the container must be protected from direct sunlight, low temperature and weather. The biodiesel-diesel blends should be stored at temperature at least higher by 15 deg C that the pour point of the fuel.

IIndia stands to benefit from the use of biodiesel through improving air quality with the reduction of harmful vehicle (trucks, busses and cars) emissions. These emissions are costly in that there is an apparently causal relationship between illnesses such as asthma and an increased the risk of life threatening diseases. The prominent use of biodiesel in Auto's is another use where biodiesel can reduce petroleum emissions and dependence. Many farms have disappeared in recent years and could produce soy for biodiesel.

1.1 Benefits of biodiesel as an alternative fuel

- Higher cetane number which have shorter ignition delays provide more time for the fuel combustion process to be completed. Hence, diesel engine operates more effectively with higher cetane number fuels. Biodiesel have high cetane number in the range of 48 to 60 compare to diesel having in the range of 42 to 45.

- The use of biodiesel can extend the life of diesel engines because it is more lubricating.

- Studies conducted with bio diesel on engine have shown substantial reduction in Particulate matter (25-50%). HC and CO emissions were also reported to be lower.

- Blends of 20% biodiesel with 80% petroleum diesel can be used in unmodified diesel engines.

- It was stated that about half of the biodiesel industry can use recycled oil or fat, the other half being soybean, or rapeseed oil according to the origin of these feed stocks.

- Biodiesel is nontoxic, biodegradable. It reduces the emission of harmful pollutants (mainly particulates) from diesel engines (80% less CO2 emissions, 100% less sulfur dioxide) but emissions of nitrogen oxides (precursor of ozone) are increased.

- Biodiesel replaces the exhaust odor of petroleum diesel with a more pleasant smell of popcorn or French fries.

1.2 Challenges of biodiesel as an alternative fuel

- At high temperatures, biodiesel can oxidize if air is present, causing the formation of acids and solids, which can corrode and plug fuel system components. Additives can help prevent this deterioration.

- Much as vegetable oils become cloudy in the refrigerator, biodiesel will form wax at cold temperatures. These wax crystals plug fuel filters, so flow-improving additives are necessary in cold weather.

- Biodiesel crops yield comparatively less energy per unit of crop area than that available for ethanol crops.

1.3 Organization of Report

The report has been organized in five chapters. The abstract of the thesis and the Key words have been presented before the contents of the thesis.

Chapter one is introduction to the project work. This covers the overall picture of using biofuel in diesel engine.

In chapter two, literature review regarding the different strategies for reducing the use of fossil fuels which shall be immensely helpful for the further research work in the direction.

In chapter two, literature review regarding the different strategies for reducing the use of fossil fuels which shall be immensely helpful for the further research work in the direction.

Chapter three includes the discussion about different physicochemical properties of diesel, biodiesel, diesel-biodiesel blend followed by instrumentation of the test rig used for the experimentation and methodology of experiments have been discussed.

In chapter four all the results obtained during the experimentation have been discussed in detail.

Chapter five is where concluding remarks are given. The scope and motivation for the future work in the direction are also elaborated

At last the report also includes resource of the references.

Chapter 2

Literature Review

Based on problem definition, before carrying out a project, it is required to know the work carried out by different researchers nationally and internationally. Number of journals and conference papers were reviewed, out of which papers with concern topic are briefly summarized as under.

A. Murugesan etal[2] worked on suitability of biodiesel as a fuel in diesel engine. They presented a very promising scenario of functioning a biodiesel as an alternative fuel. The properties of these biodiesel can be compared favorably with the characteristics required for internal combustion engine fuels. Fuel-related properties are reviewed and compared with those of conventional diesel fuel. Peak pressure development, heat release rate analysis, and vibration analysis of the engine are discussed in relation with the use of bio-diesel and conventional diesel fuel. Optimization of alkali-catalyzed transesterification of Pungamia pinnata oil for the production of bio-diesel is discussed. Use of bio-diesel in a conventional diesel engine results in substantial reduction in unburned hydrocarbon (UBHC), carbon monoxide (CO), particulate matters (PM) emission and oxide of nitrogen (NOx).

Ekrem Buyukkaya[3] used biodiesel as a renewable fuel in numerous studies evaluating its potential use in diesel engines. These studies were investigated to evaluate the performance, emission and combustion of a diesel engine using neat rapeseed oil and its blends of 5%, 20% and 70%, and standard diesel fuel separately. The results indicate that the use of biodiesel produces lower smoke opacity (up to 60%), and higher brake specific fuel consumption (BSFC) (up to 11%) compared to diesel fuel. The measured CO emissions of B5 and B100 fuels were found to be 9% and 32% lower than that of the diesel fuel, respectively. The BSFC of biodiesel at the maximum torque and rated power conditions were found to be 8.5% and 8% higher than that of the diesel fuel, respectively. From the combustion analysis, it was found that ignition delay was shorter for neat rapeseed oil and its blends tested compared to that of standard diesel. The combustion characteristics of rapeseed oil and its diesel blends closely followed those of standard diesel.

N. Stalin and H. J. Prabhu[4] carried out an experimental work in this field.They presents a review of the alternative technological methods that could be used to produce this fuel. Performance of IC engine using karanja biodiesel blending with diesel and with various blending ratios has been evaluated. The engine performance studies were conducted with a prony brake-diesel engine set up. Parameters like speed of engine, fuel consumption and torque were measured at different loads for pure diesel and various combinations of dual fuel. Brake power, brake specific fuel consumption and brake thermal efficiency were calculated. The test results indicate that the dual fuel combination of B40 can be used in the diesel engines without making any engine modifications. Also the cost of dual fuel (B40) can be considerably reduced than pure diesel.

H. Raheman , S.V. Ghadge[5] reviwed the effect of different compression ratio on engine performance using biodiesel as a fuel. The brake specific fuel consumption (BSFC) and exhaust gas temperature (EGT) increased, whereas brake thermal efficiency (BTE) decreased with increase in the proportion of biodiesel in the blends at all compression ratios (18:1–20:1) and injection timings (35˙−45˙ before TDC) tested. However, a reverse trend for these parameters was observed with increase in the compression ratio (CR) and advancement of injection timing (IT). The BSFC of

B100 and its blends with high speed diesel reduced, whereas BTE and EGT increased with the increase in load for the range of CR and IT tested. The differences of BTEs between HSD and B100 were also not statistically significant at engine settings of ‘CR20IT40’ and ‘CR20IT45’. Thus, even B100 could be used on the Ricardo engine at these settings without affecting the performance obtained using high speed diesel (HSD).

S. Jindal etal[6] worked on diesel engine using biofuel. This study targets on finding the effects of the engine design parameters viz. compression ratio (CR) and fuel injection pressure (IP) jointly on the performance with regard to fuel consumption (BSFC), brake thermal efficiency (BTHE) and emissions of CO, CO2, HC, NOx and Smoke opacity with jatropha methyl ester (JME) as fuel. Comparison of performance and emission was done for different values of compression ratio along with injection pressure to find best possible combination for operating engine with JME. It is found that the combined increase of compression ratio and injection pressure increases the BTHE and reduces BSFC while having lower emissions. For small sized direct injection constant speed engines used for agricultural applications (3.5 kW), the optimum combination was found as CR of 18 with IP of 250 bar.

M. Mani, G. Nagarajan[7] worked on diesel engine using waste plastic oil. As an alternative, non-biodegradable, and renewable fuel, waste plastic oil is receiving increasing attention. The waste plastic oil was compared with the petroleum products and found that it can also be used as fuel in compression ignition engines. In the present work, the influence of injection timing on the performance, emission and combustion characteristics of a single cylinder, four stroke, direct injection diesel engine has been experimentally investigated using waste plastic oil as a fuel. Tests were performed at four injection timings (23˚, 20˚, 17˚and 14˚ bTDC). When compared to the standard injection timing of 23˚ bTDC the retarded injection timing of 14˚ bTDC resulted in decreased oxides of nitrogen, carbon monoxide and unburned hydrocarbon while the brake thermal efficiency, carbon dioxide and smoke increased under all the test conditions.

Kanok-on Rodjanakid etal[8] show the performance of engine using biodiesel made from Refined Palm Oil Stearin and Crude Coconut Oil. Neat vegetable oil poses some problems when subjected to prolong use in CI engines. The problems are attributed to its high viscosity and low volatility. These problems can be minimized by the process of transesterification. In this study thetransesterification reaction of refined palm oil stearin and crude coconut oil were carried out with methanol and ethanol using potassium hydroxide as a catalyst to yield biodiesels, methyl ester from refined palm oil stearin and ethyl ester from crude coconut oil. The products were evaluated by comparing physical characteristics of biodiesels to conventional diesel oil. These characteristics included specific gravity, density, viscosity, pour point, flash point, fire point, heating value, copper strip corrosion etc. The biodiesels were then tested in a diesel engine to observe their actual performance and emissions. The fuel spray of biodiesels was also compared with the conventional diesel oil.

Magın Lapuerta etal[9] worked on emission analysis using biodiesel in diesel engine. Experiments were carried out on diesel engine using biodiesel fuels as opposed to conventional diesel fuels. Since the basis for comparison is to maintain engine performance, the first section is dedicated to the effect of biodiesel fuel on engine power, fuel consumption and thermal efficiency. The highest consensus lies in an increase in fuel consumption in approximate proportion to the loss of heating value. In the subsequent sections, the engine emissions from biodiesel and diesel fuels are compared, paying special attention to the most concerning emissions: nitric oxides and particulate matter, the latter not only in mass and composition but also in size distributions. They analyzed sharp reduction in particulate emissions.

M. Gumus, S. Kasifoglu used biodiesel made from apricot seed kernel oil methyl ester. Apricot (Prunus armeniaca) seed kernel oil was transesterified with methanol using potassium hydroxide as catalyst to obtain apricot seed kernel oil methyl ester. Neat apricot seed kernel oil methyl ester and its blends with diesel fuel were tested in a compression ignition diesel engine to evaluate performance and emissions. Apricot seed kernel oil methyl ester and its blends can be successfully used in diesel engines without any modification. Lower concentration of apricot seed kernel oil methyl ester in blends gives a better improvement in the engine performance and exhaust emissions. Therefore lower percent of apricot seed kernel oil methyl ester can be used as additive.

2.1 Problem Definition

Environmental concern and availability of petroleum fuels have caused interests in the search for alternate fuels for internal combustion engines. In our country the usage ratio of diesel to gasoline fuel is 7:1[2], depicting a highly skewed situation. Thus, it is necessary to replace fossil diesel fuel by alternative fuels. Vegetable oils present a very promising scenario of functioning as alternative fuels to fossil diesel fuel. The properties of these oils can be compared favorably with the characteristics required for internal combustion engine fuels.

Biodiesel has a high cetane number than diesel fuel, no aromatics, no sulfur and contains 10-12 % oxygen by weight. These characteristics of biodiesel reduce the harmful emissions of unburned hydrocarbon (HC), CO, and particulates than the diesel fuel. Several researchers found increased NOx emission as compare to petrol-diesel and many worked on analyzing the performance of engine using different blends of diesel-biodiesel.

2.2 Objectives of the Project

Most of literature results indicate that the emission of nitric oxide (NOx) is higher when biodiesel introduce in engine as a fuel and few indicates nitrogen oxide (NOx) reduction also.

On the basis of the literature survey, following objectives are decided.

To check feasibility of biodiesel in C.I. engine fuelled with diesel-biodiesel blends with more fraction of biodiesel.

The experimental work under this project includes analyzing the effect on performance and emission engine by changing compression ratio by using different blends of diesel-biodiesel. To suggest best blend based on above results as an optimum blend.

Chapter 3

Methodology of Work

3.1 Plan of the experiments

The main aim of the experimentation is to check feasibility of biodiesel in C.I. engine fuelled with diesel-biodiesel blends with more fractions and 100% biodiesel. The experimental work under this project consists of two parts, initial experimental work to analyze the effect of different compression ratio on engine performance and emission in second phase, optimizing work for finding the optimum diesel-biodiesel blend.

Initial experimental work includes preparation of experimental setup, various biodiesel-diesel blends and measurement of various engine parameters and emission parameters by running the engine on different compression ratio.

Work in line with the actual objective of the project is planned out as follows,

- Generation of base line performance data from the C.I engine fuelled by diesel, Compare different Diesel-biodiesel blends and 100% biodiesel data with base line data for various load.

- Optimize the best blend out of given different blends.

3.2 Variable parameters for experiments

For entire project work, different parameters are varying among their respective range. The variable parameters are fuel, compression ratio and the load condition. Table 3.1 shows all the combination for all the variable parameters. The main parameter is fuel composition. The experiments were carried out with 100% diesel. Diesel-biodiesel blends (B10, B20, B30, B40, B60 and B80) and 100% biodiesel. Also other parameter i.e. loads and compression ratio also varied as mention in Table 3.1 during experimentation. With all the combinations of different load, test fuel and compassion ratio the total number of experiments were 120.

Fuel	Pure Diesel, B10, B20, B30, B40, B60, B80, Pure Biodiesel
Compression Ratio	14, 16, 18
Load (%)	0, 25, 50, 75, 100

Table 3.1: Variable Parameters for Experiments

3.3 Experimental setup

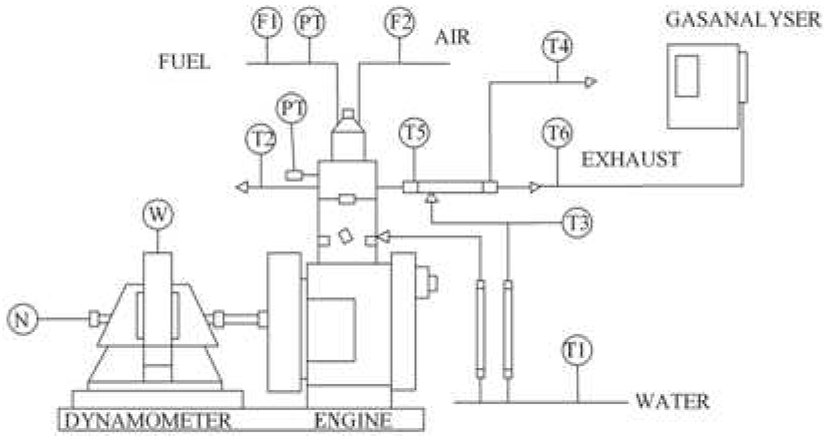

Figure 3.1: Schematic diagram of experimental setup

F1 & F2	Flow sensor for fuel and air
W	Load sensor
N	Engine speed sensor
PT	Cylinder pressure & Injection pressure sensor
T1-6	Temperature sensors

In figure 3.1 Schematic diagram of experimental setup is shown. The setup consists of single cylinder, four stroke, Multi-fuel, research engine connected to eddy current type dynamometer for loading. The operation mode of the engine can be changed from diesel to Petrol or from Petrol to Diesel with some necessary changes. In both modes the compression ratio can be varied without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. Instruments are provided to interface airflow, fuel flow, temperatures and load measurements. Rotameter are provided for cooling water and calorimeter water flow measurement. A battery, starter and battery charger is provided for engine electric start arrangement. Lab view based Engine Performance Analysis software package "Enginesoft" is provided for on line performance evaluation. In Table 3.2 the detailed specification of engine is given.

- **Engine Setup Specifications**

<table>
<tr><td>Engine</td><td colspan="2">1 cylinder, 4 stroke, water cooled, stroke 110 mm, bore 87.5 mm.</td></tr>
<tr><td rowspan="4"></td><td rowspan="4">Diesel mode</td><td>Power 3.5 KW</td></tr>
<tr><td>CR range 12:1-18:1</td></tr>
<tr><td>Speed 1500 rpm</td></tr>
<tr><td>Injection variation 0-25 Deg BTDC</td></tr>
<tr><td rowspan="4"></td><td rowspan="4">Petrol mode</td><td>Power 4.5 KW @ 1800 rpm</td></tr>
<tr><td>Speed range 1200-1800 rpm</td></tr>
<tr><td>CR range 6:1-10:1</td></tr>
<tr><td>Spark variation: 0-70 deg BTDC</td></tr>
<tr><td>Dynamometer</td><td colspan="2">Type eddy current, water cooled, with loading unit</td></tr>
<tr><td>Calorimeter</td><td colspan="2">Type Pipe in pipe</td></tr>
<tr><td>Rotameter</td><td colspan="2">Engine cooling 40-400 LPH; Calorimeter 25-250 LPH</td></tr>
<tr><td>Piezo sensor</td><td colspan="2">Combustion: Range 5000 PSI, with low noise cable</td></tr>
<tr><td>Crank angle sensor</td><td colspan="2">Resolution 1 Deg, Speed 5500 RPM with TDC pulse.</td></tr>
<tr><td>Temperature sensor</td><td colspan="2">Type RTD, PT100 and Thermocouple, Type K</td></tr>
<tr><td>Load sensor</td><td colspan="2">Load cell, type strain gauge, range 0-50 Kg</td></tr>
<tr><td>Fuel tank</td><td colspan="2">Capacity 15 lit</td></tr>
<tr><td>Software</td><td colspan="2">"Enginesoft" Engine performance analysis software</td></tr>
</table>

Table 3.2: Specifications of research engine

- **Gas Analyzer Specifications**

Figure 3.2: Exhaust Gas Analyzer

Figure 3.2 shows the exhaust gas analyzer which was used during experiments to find out exhaust gas like carbon monoxide, carbon dioxide, nitrogen oxide and unburned hydrocarbons. The model of the instrument was 'Emission Tester AVL - 4000 Light'. Instrument was able to give results of emission gases on the screen. In table 3.3 the measurement data of instrument is given.

Emission Parameters	Measurement
Carbon Monoxide (CO)	0-10% vol.
Unburned Hydrocarbons (HC)	0-20000 ppm
Carbon Dioxide (CO_2)	0-20% vol.
Nitrogen Oxide (NOx)	0-5000 ppm

Table 3.3: Measurement Data

3.4 Uncertainty Analysis

The uncertainty in measurement is estimated based on the procedure given by Kline and McClintock (1953). The uncertainty in measurement is defined as

$$\omega_R = \sqrt{\left(\frac{\partial R}{\partial V1}\omega_1\right)^2 + \left(\frac{\partial R}{\partial V_2}\omega_2\right)^2 + ...\left(\frac{\partial R}{\partial V_n}\right)^2}$$

R is the result of which uncertainty is to be estimated. !R is the uncertainty in the result. Vi (i=1 to n) are the variables of which R is a function. Defining the uncertainty in percentage, the equation modifies to

$$\frac{\omega_R}{R} = \frac{1}{R}\sqrt{\left(\frac{\partial R}{\partial V1}\omega_1\right)^2 + \left(\frac{\partial R}{\partial V_2}\omega_2\right)^2 + ...\left(\frac{\partial R}{\partial V_n}\right)^2} \times 100\%$$

The uncertainties in the measurement were estimated by calculation from the above equation or provided by the manufacturer.

- Uncertainty in Engine Parameters

Engine Speed (N)	± 1 rpm
Temperature (t)	± 1˙c
Crank Angle Encoder	± 1˙ angle
Pressure (p)	± 1 bar

- Uncertainty in Calculated Results

Brake Power (BP), kW	± 0.6%
Brake Specific Fuel consumption (BSFC), Kg/kWh	± 1.09 %
Brake Thermal Efficiency (BTHE), %	± 1.41 %
Carbon Monoxide (CO), %vol.	± 0.01 %
Carbon Dioxide (CO_2), %vol.	± 0.1 %
Unburned Hydrocarbons (HC), ppm	± 1 ppm
Nitrogen Oxide (NOx), ppm	± 1 ppm

Chapter 4

Results and Discussion

4.1 Properties of Diesel and Biodiesel

This project is to check the effect of biodiesel and diesel-biodiesel blends on the performance and emission analysis of diesel engine. Biodiesel required for the experiments will be procured from central 'Salt & Marine Chemicals Research Institute (CSMCRI)', Bhavnagar. Properties of the biodiesel were tested at Khushbu Petro-Chem R & D Centre, Ahmedabad. Table 4.1 shows the comparison of the important properties for the Biodiesel and Diesel. From comparison we can identify that the major difference in Viscosity, calorific value and density. The viscosity and density of Biodiesel is higher than Diesel. These are the reason why the conventional diesel engines may not run efficiently on 100% biodiesel without any modification. In figure 4.1 the actual pictorial view of pure diesel and pure biodiesel is shown.

Figure 4.1: Test Fuel Diesel and Biodiesel

Properties	Diesel	Biodiesel
Density @ 27˙c (kg/m^3)	825	870
Viscosity @ 40˙c (cSt)	2.10	2.80
Calorific Value (kJ/kg)	42235	36844
Flash Point (˙c)	40	138
Cetane Number	48	52

Table 4.1: Comparison of Biodiesel and Diesel properties

4.2 Test Fuel

Jetropha biodiesel was used as the test fuel in different proportion with diesel. The biodiesel was blended with commercial diesel in 10% (B10), 20% (B20), 30% (B30), 40% (B40), 60% (B60), 80% (B80) and 100% (B100). Table 4.2 shows the property of all the test fuel.

Fuel Properties	B0	B10	B20	B30	B40	B60	B80	B100
Density @ 27˙c (kg/m^3)	825	829.5	834	838.5	843	852	861	870
Viscosity @ 40˙c (cSt)	2.10	2.17	2.24	2.31	2.38	2.52	2.66	2.80
Calorific Value (kJ/kg)	42235	41695	41156	40617	40078	39000	37922	36844
Flash Point (˙c)	40	49.8	59.6	69.4	79.2	98.8	118.4	138
Cetane Number	48	48.4	48.8	49.2	49.6	50.4	51.2	52

Table 4.2: Properties of Diesel, Biodiesel and Diesel-Biodiesel Blends

4.3 Variation in Compression Ratio

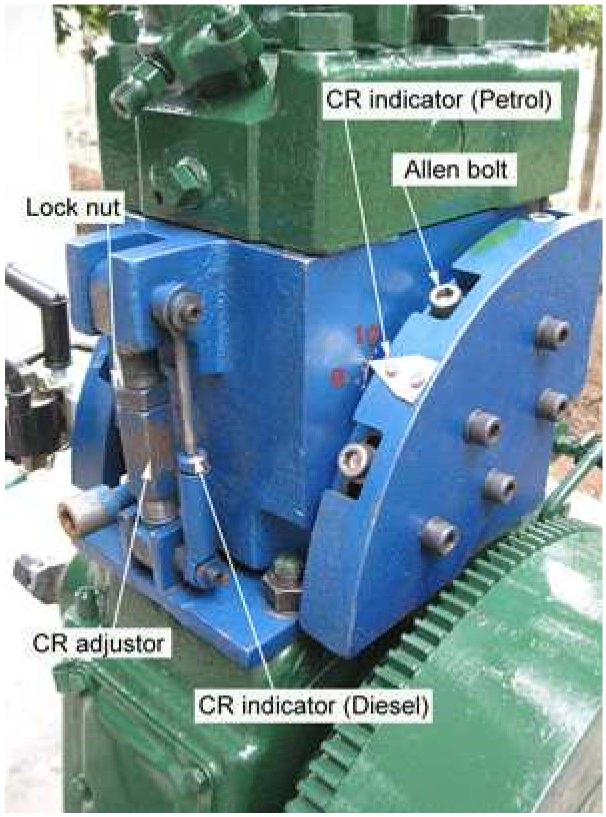

Figure 4.2: Compression Ratio Adjustment

In figure 4.2 the actual arrangement for changing compression ratio is shown. First of all slightly loosen the six Allen bolts than loose the lock nut, rotate and adjust as per the require compression ratio referring the marking on CR indicator. In next step lock the adjuster by the lock nut and tight all the 6 Allen bolts. By following this method compression ratio 14, 16, and 18 were set.

4.4 Test Procedure

Engine tests were carried out at different loads on the engine at different combination of the fuel and compression ratio and the following performance and emission parameters were analyzed.

Performance Parameters

- Brake specific fuel consumption. Kg/kwh
- Brake thermal efficiency, %
- Brake power, kW
- Exhaust Gas Temperature,˙ c

Emission Parameters

- Carbon Monoxide (CO), % vol.
- Carbon Dioxide (CO_2), % vol.
- Unburned Hydrocarbons (UBHC), ppm
- Nitrogen Oxide (NOx), ppm

4.5 Experimental Results

Experiments were conducted for various combinations as data given in Table3.1. Performance and emission data were recorded used for various analysis. First results of pure diesel with pure biodiesel are compared. The effect of compression ratio has been analyzed and finally in third category the analysis of effect of different diesel-biodiesel blends on various parameters has been carried out.

4.5.1 Performance Analysis

4.5.1.1 Brake Thermal Efficiency

- Comparison of BTHE for Pure Diesel and Pure Biodiesel

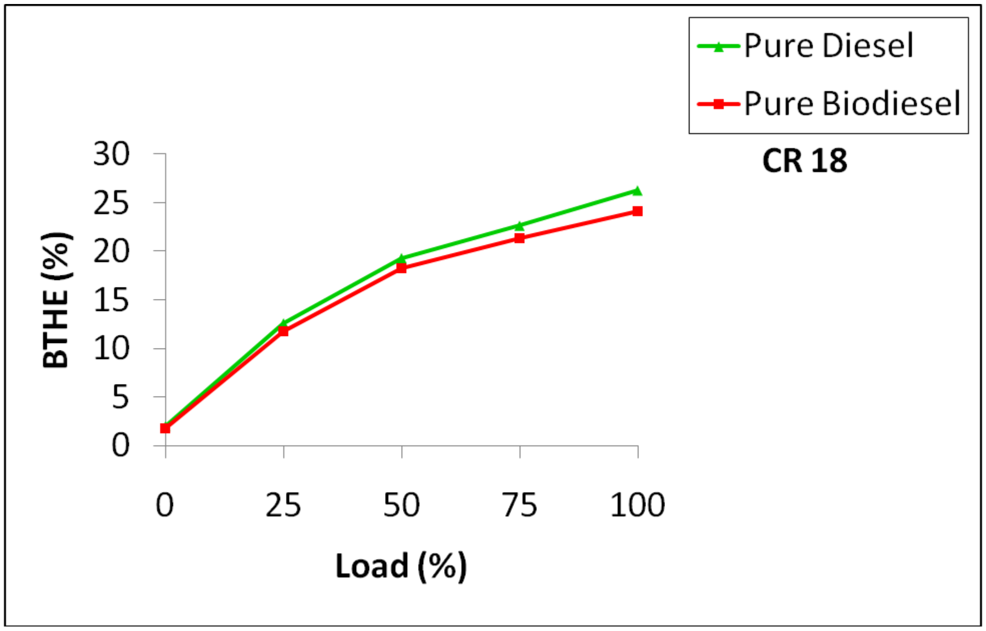

Figure 4.3: Comparison of BTHE for Pure Diesel and Pure Biodiesel

The brake thermal efficiency distribution is shown in Figures 4.3 for diesel and biodiesel at compression ratio 18. At every load we got higher efficiency with diesel compare to biodiesel. The brake thermal efficiency of an engine increases significantly with load. At full load the brake thermal efficiency of biodiesel 8.29 % lower than diesel and at 50% part load it was 5.28% lesser than diesel. This happened because of the lower calorific value of the biodiesel.

- Effect of Compression Ratio on BTHE for all Diesel-Biodiesel Blends

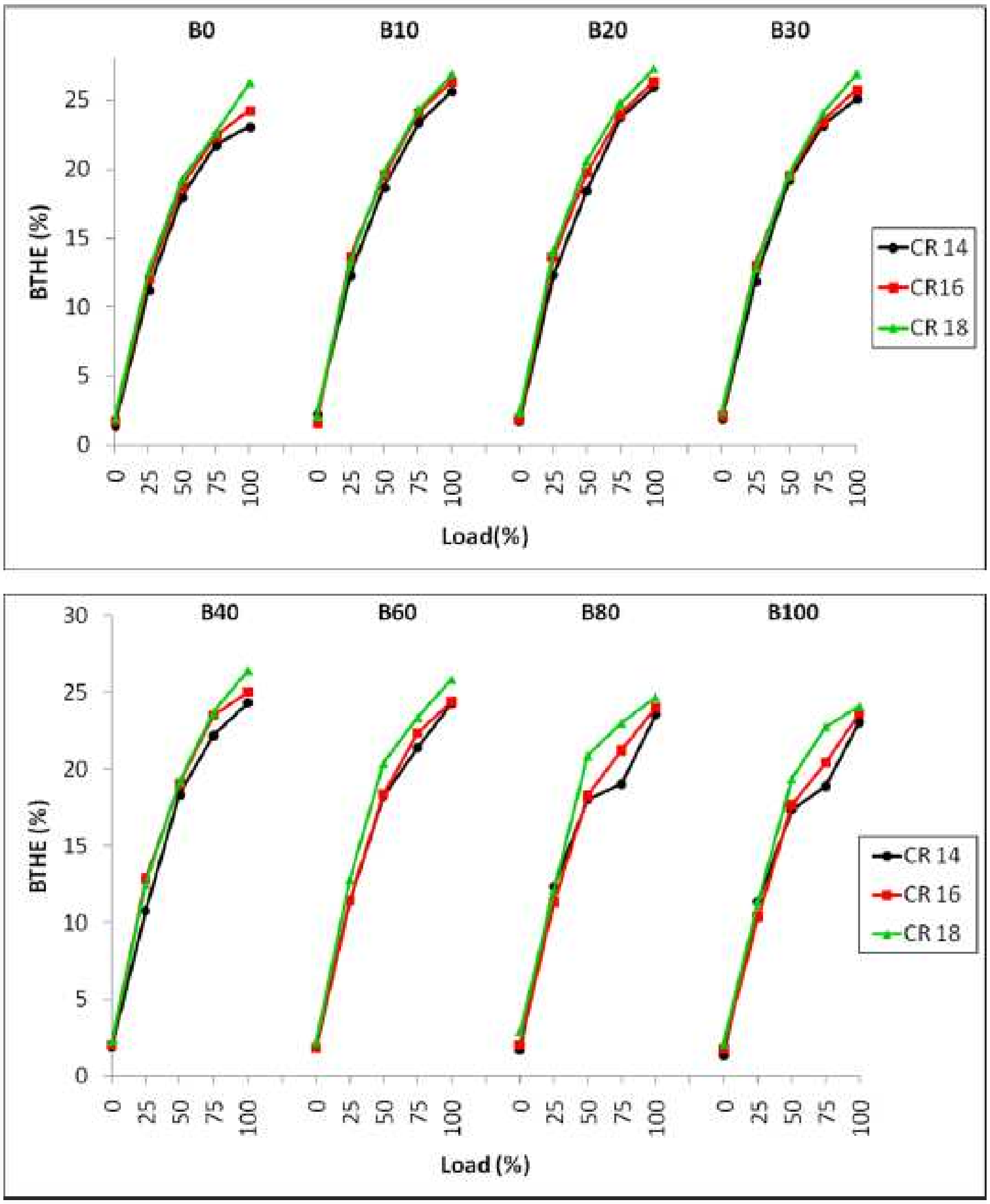

Figure 4.4: Effect of Compression Ratio on BTHE for all Diesel-Biodiesel Blends

In Fig 4.4 the effect of compression ratio on brake thermal efficiency is shown for all the different diesel biodiesel blends. It can be observed that as compression ratio increase brake thermal efficiency was considerably increased for all the blends. This is because as higher compression ratio the combustion was much better compare to lower compression ratio.

- Effect of Different Diesel-Biodiesel Blends on BTHE

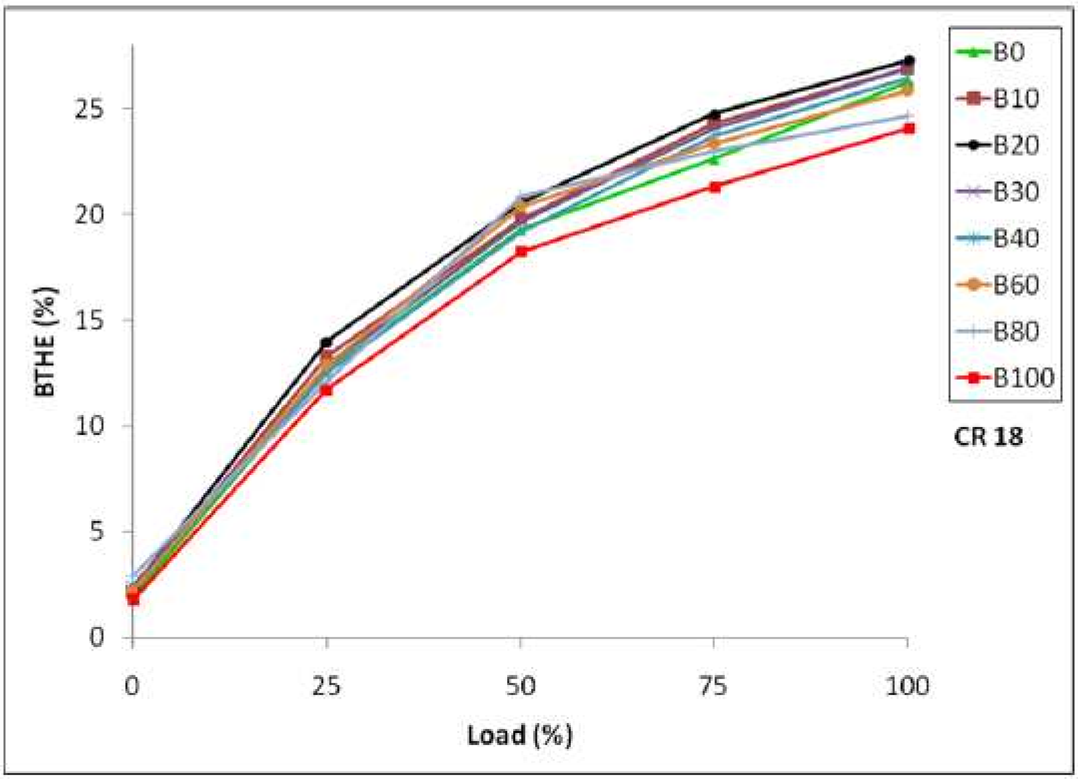

Figure 4.5: Effect of Different Diesel-Biodiesel Blends on BTHE

The brake thermal efficiency distribution is shown in Figures 4.5 for diesel and diesel-biodiesel blends. The results showed that up to 20% biodiesel mix with the diesel the value of brake thermal efficiency increases comparatively by 3.92% compare to pure diesel at full load. This could be attributed to the presence of increased amount of oxygen in biodiesel. For other combination of diesel-biodiesel blends the results were found to be lower compare to base line data.

4.5.1.2 Brake Specific Fuel Consumption

- Comparison of BSFC for Pure Diesel and Pure Biodiesel

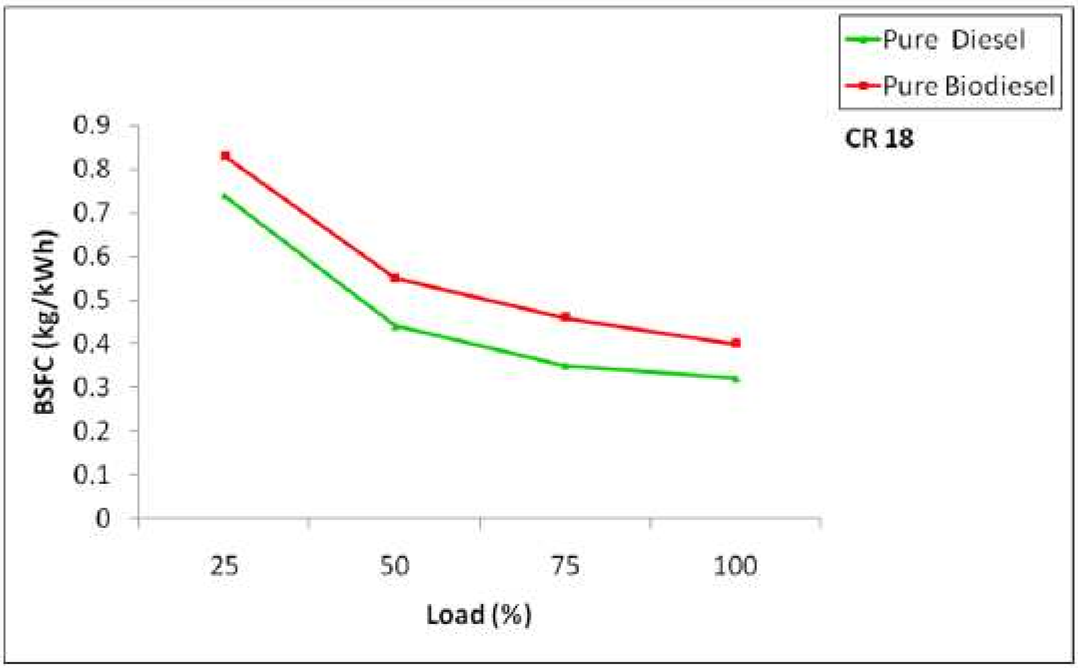

Figure 4.6: Comparison of BSFC for Pure Diesel and Pure Biodiesel

Fig, 4.6 shows the comparison brake specific fuel consumption of pure diesel and pure biodiesel at compression ratio 18. The analysis for both the fuel was found that brake specific fuel consumption decreases as load increases. At full load and part load biodiesel having 20% higher fuel consumption than diesel. The higher fuel consumption was found in biodiesel because of its lower calorific value[2] .

• Effect of Compression Ratio on BSFC for all Diesel-Biodiesel Blends

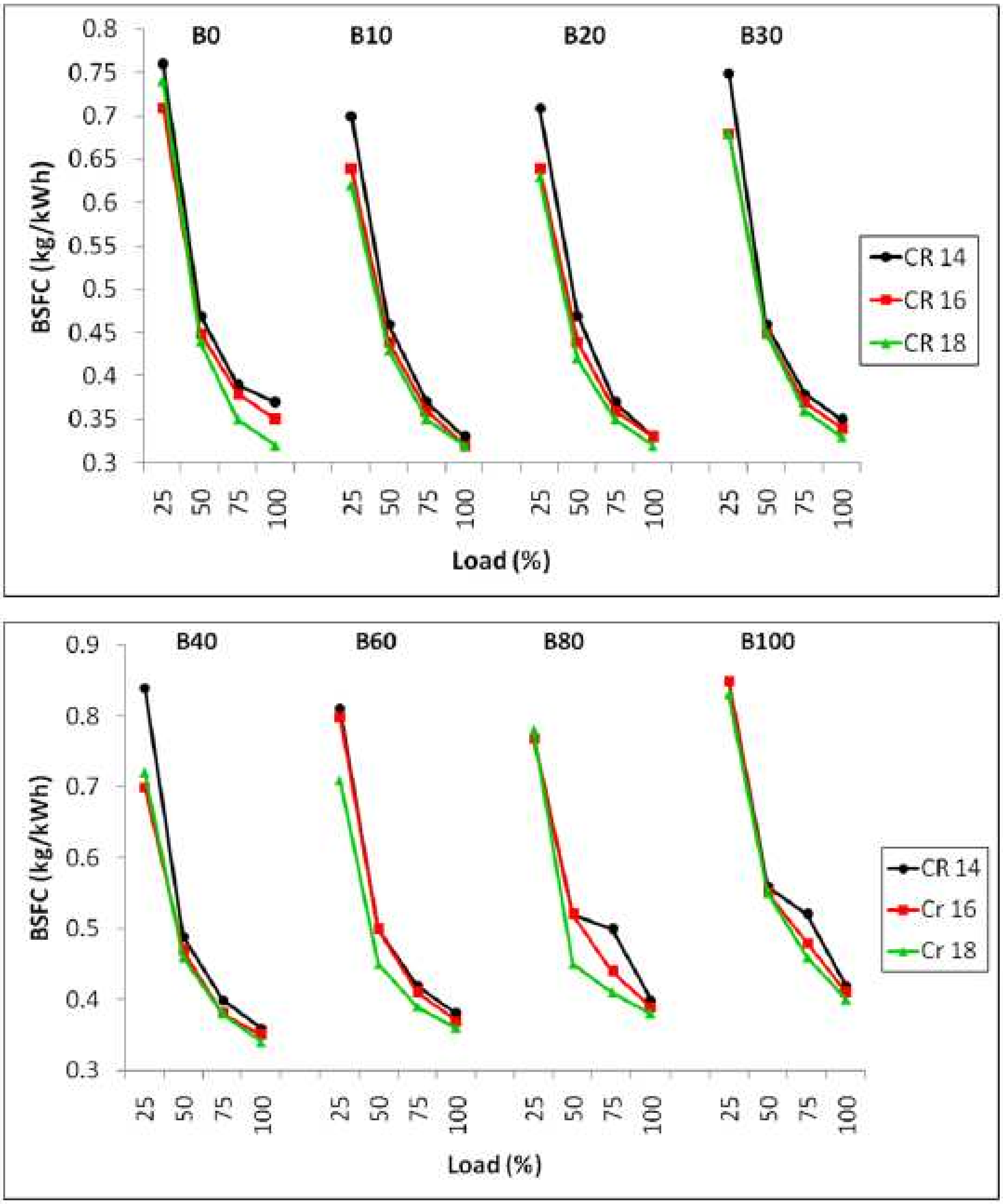

Figure 4.7: Effect of Compression Ratio on BSFC for all Diesel-Biodiesel Blends

The effect of compression ratio on brake specific fuel consumption is shown in the fig. 4.7. The value of brake specific fuel consumption for diesel at full load for compression ratio 14, 16 and 18 was 0.37kg/kWh, 0.35kg/kWh and 0.32kg/kWh respectively. The value of brake specific fuel consumption decreases with the increment of compression ratio. Same approach continues for all the blends. For pure biodiesel due to its low volatility and higher viscosity it might be performing relatively better well at higher compression ratio[5].

- Effect of Different Diesel-Biodiesel Blends on BSFC

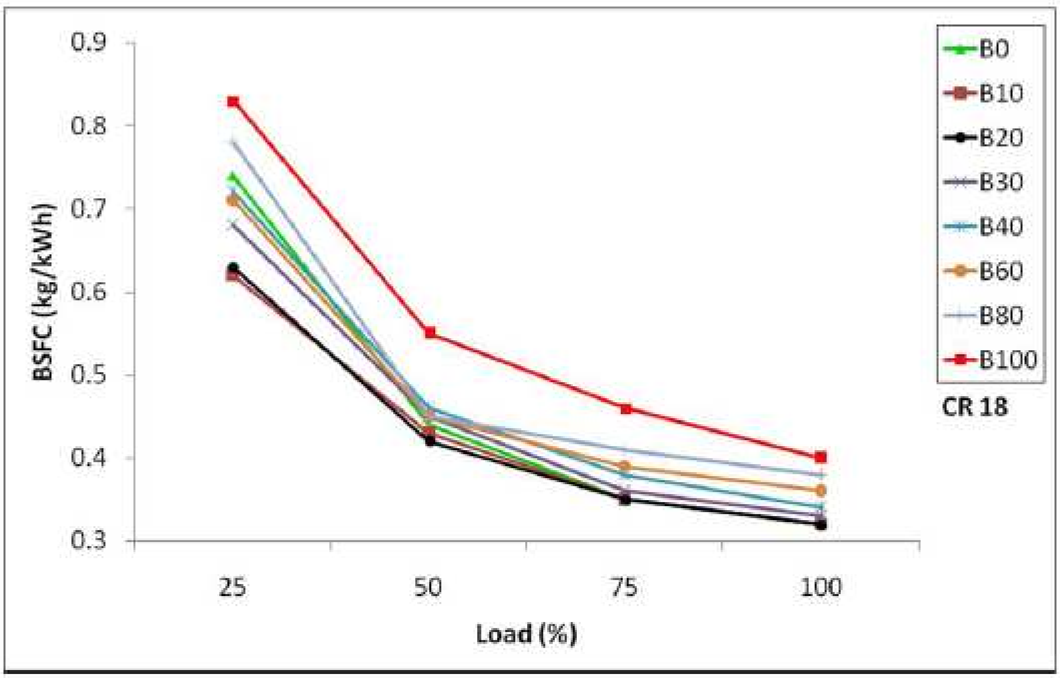

Figure 4.8: Effect of Different Diesel-Biodiesel Blends on BSFC

Fig. 4.8 shows the effect of blend on brake specific fuel consumption. The value of brake specific fuel consumption on compression ratio at full load for B20, B30, B40, B60, B80 and B100 was 0.32kg/kWh, 0.33kg.kWh, 0.34kg.kWh, 0.36kg.kWh, 0.38kg.kWh and 0.40kg.kWh respectively. Such a high value of BSFC for the blends, especially for B80 and B100 may be attributed to the poor combustion characteristics of this blends.

4.5.1.3 Brake Power

- Comparison of BP for Pure Diesel and Pure Biodiesel

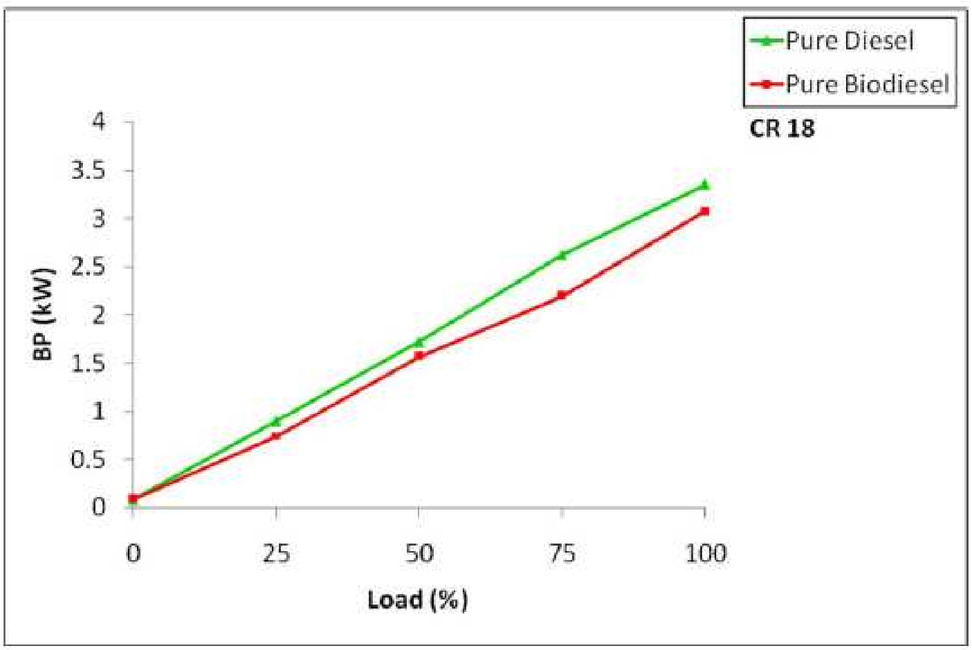

Figure 4.9: Comparison of BP for Pure Diesel and Pure Biodiesel

The brake power distribution is shown in Figures 4.9 for diesel and biodiesel at compression ratio 18. At every load it was observed from the figure that brake power is with diesel compare to biodiesel. The brake power of an engine increases significantly with load. At full load the brake power of biodiesel was comparatively 8.05 % and at part load (50% load) it was 8.27% lesser than diesel because of the higher viscosity and density of the biodiesel.

• Effect of Compression Ratio on BP for all Diesel-Biodiesel Blends

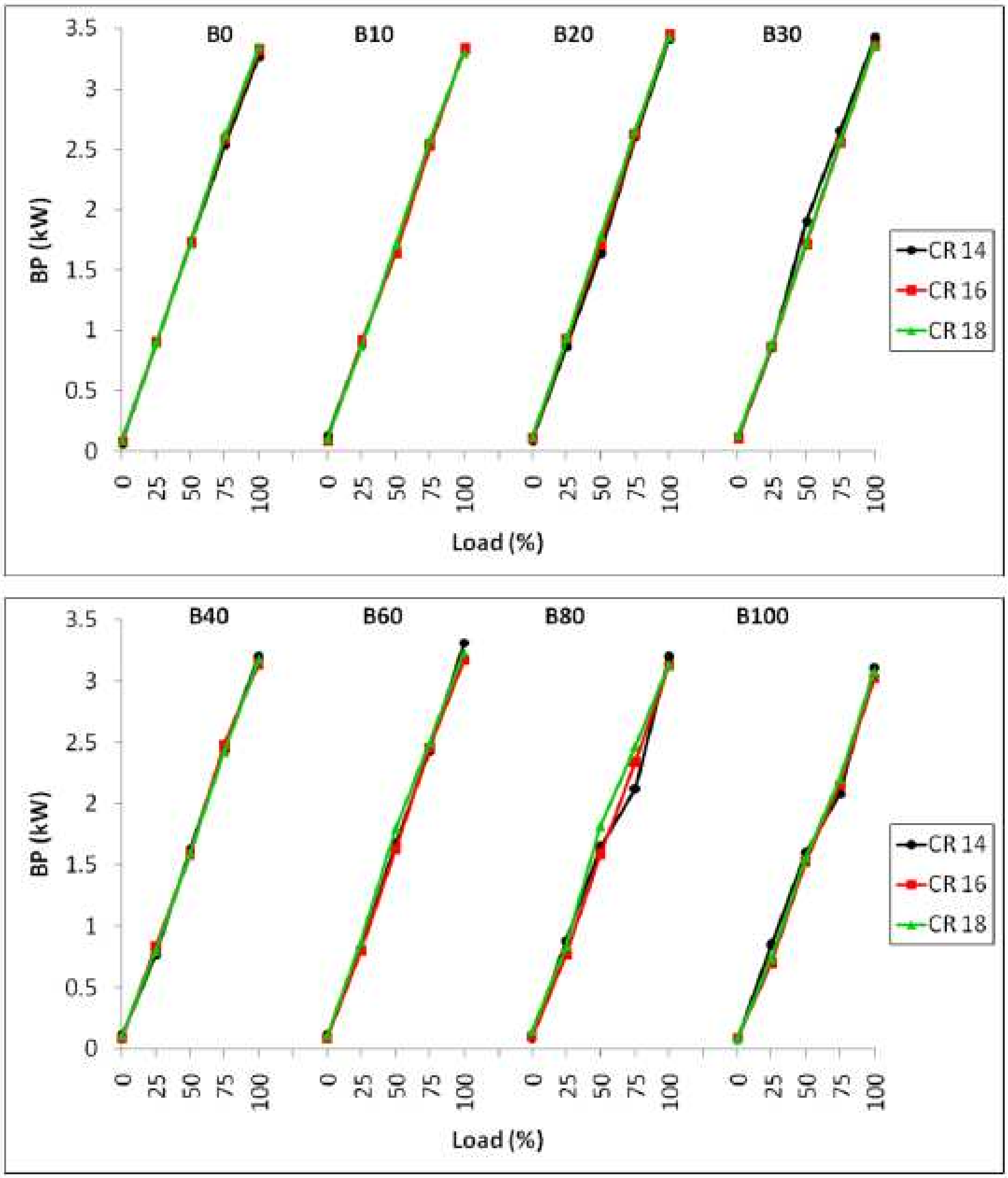

Figure 4.10: Effect of Compression Ratio on BP for all Diesel-Biodiesel Blends

In fig. 4.10 the values of brake power for the entire blends for three compression ratio is plotted. By the It is observed from the figure that there is no considerable effect on brake power. The nature of brake power increase with the increase in load.

- Effect of Different Diesel-Biodiesel Blends on BP

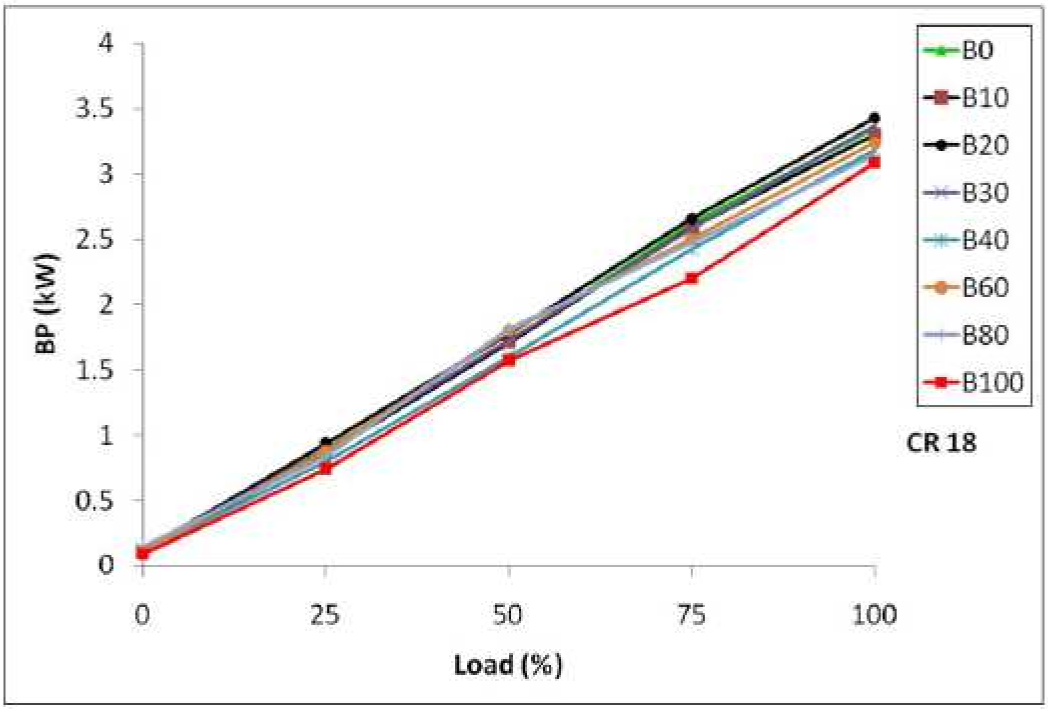

Figure 4.11: Effect of Different Diesel-Biodiesel Blends on BP

The brake power distribution is shown in Figures 4.11 for diesel and diesel-biodiesel blends. The values of brake power at compression ratio 18 full load for B0, B10, B20, B30, B40, B60, B80 and B100 were 3.35kW, 3.30kW, 3.43kW, 3.37kW, 3.18kW, 3.24kW, 3.14kW and 3.08kW respectively. The brake power is higher for B20 and beyond that as percentage of biodiesel increases the value of biodiesel decreases.

4.5.1.4 Exhaust Gas Temperature

- Comparison of Exhaust Gas Temperature for Pure Diesel and Pure Biodiesel

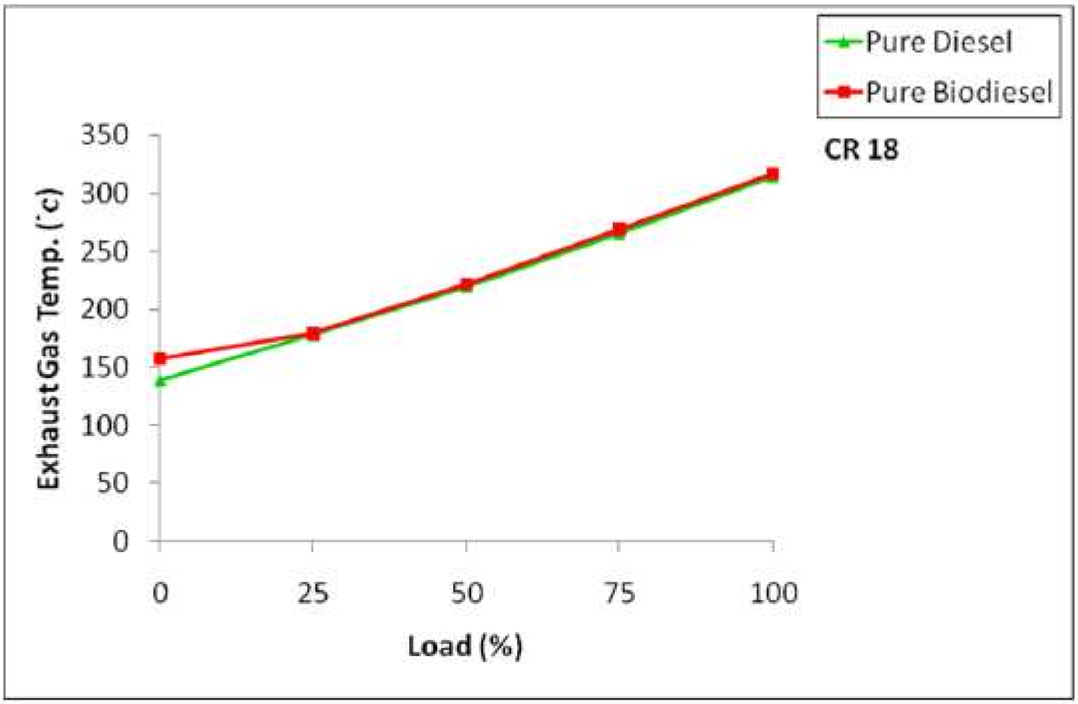

Figure 4.12: Comparison of Exhaust Gas Temperature for Pure Diesel and Pure Biodiesel

In fig 4.12 the comparison of exhaust gas temperature of diesel and biodiesel is shown at compression ratio 18. The temperature increases with the load. Initially it was found that but after it is was found that there is no considerable change in exhaust gas temperature of diesel and biodiesel.

- Effect of Compression Ratio on Exhaust Gas Temperature for all Diesel-Biodiesel Blends

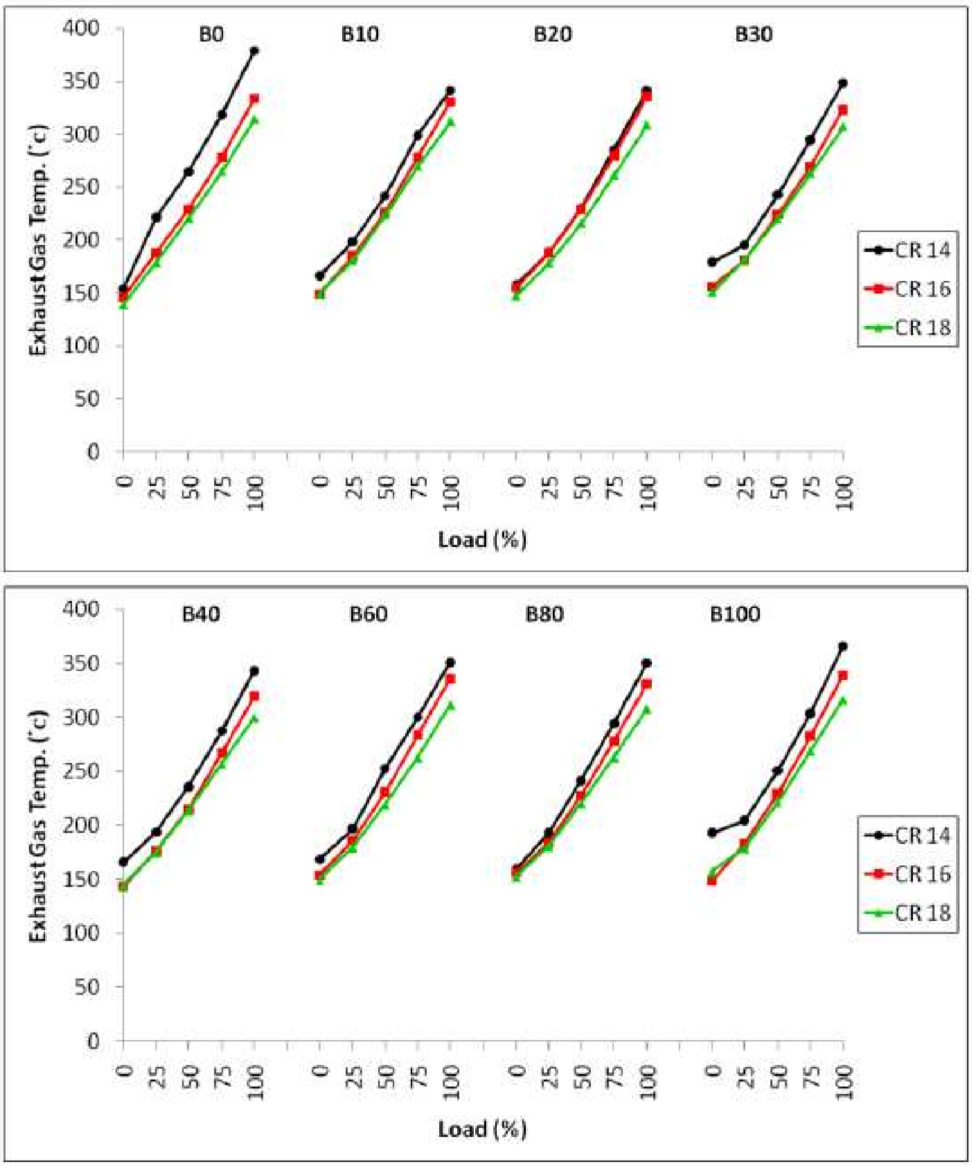

Figure 4.13: Effect of Compression Ratio on Exhaust Gas Temperature for all Diesel-Biodiesel Blends

In fig. 4.13 the effect of compression ratio on exhaust gas temperature for all the blends at the entire load is shown. For pure diesel the value of exhaust gas temperature at compression ratio 14, 16 and 18 was 378.95˙c, 333.56˙c and 314.36˙c respectively. From figure we can observed that the value of exhaust gas temperature decreases with increment of compression ratio.

- Effect of Different Diesel-Biodiesel Blends on Exhaust Gas Temperature

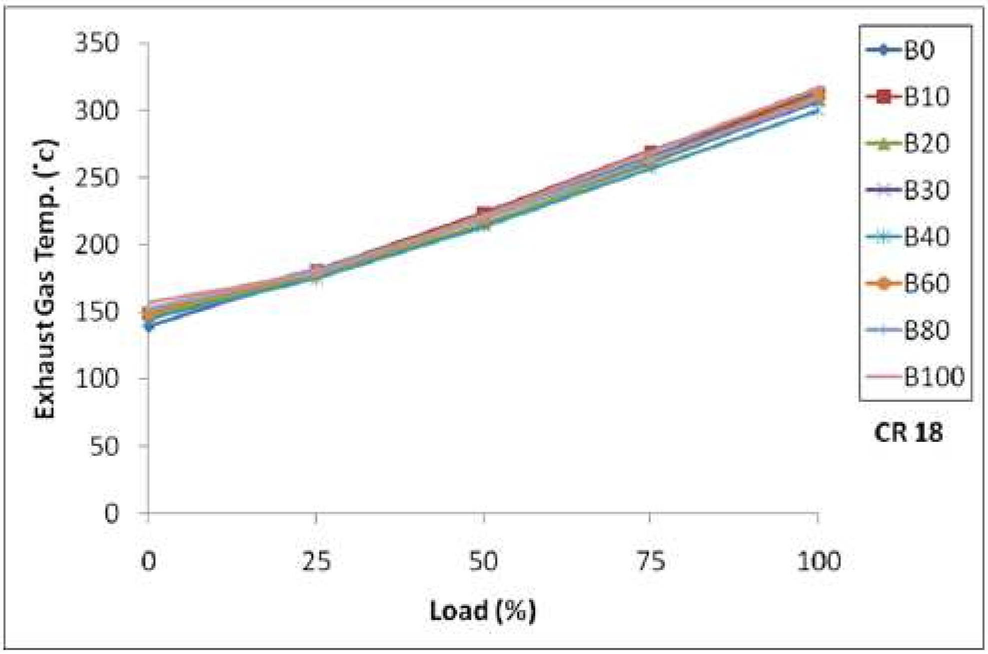

Figure 4.14: Effect of Different Diesel-Biodiesel Blends on Exhaust Gas Temperature

The Fig. 4.14 shows the variation of exhaust gas temperature with percentage of load for different fuels. The exhaust gas temperature rises with the increase of engine load for all the fuels. It was observed that the exhaust gas temperature at different load when using different fuels is nearly the same.

4.5.2 Emission Analysis

4.5.2.1 Carbon Monoxide (CO)

- Comparison of Emission of CO for Pure Diesel and Pure Biodiesel

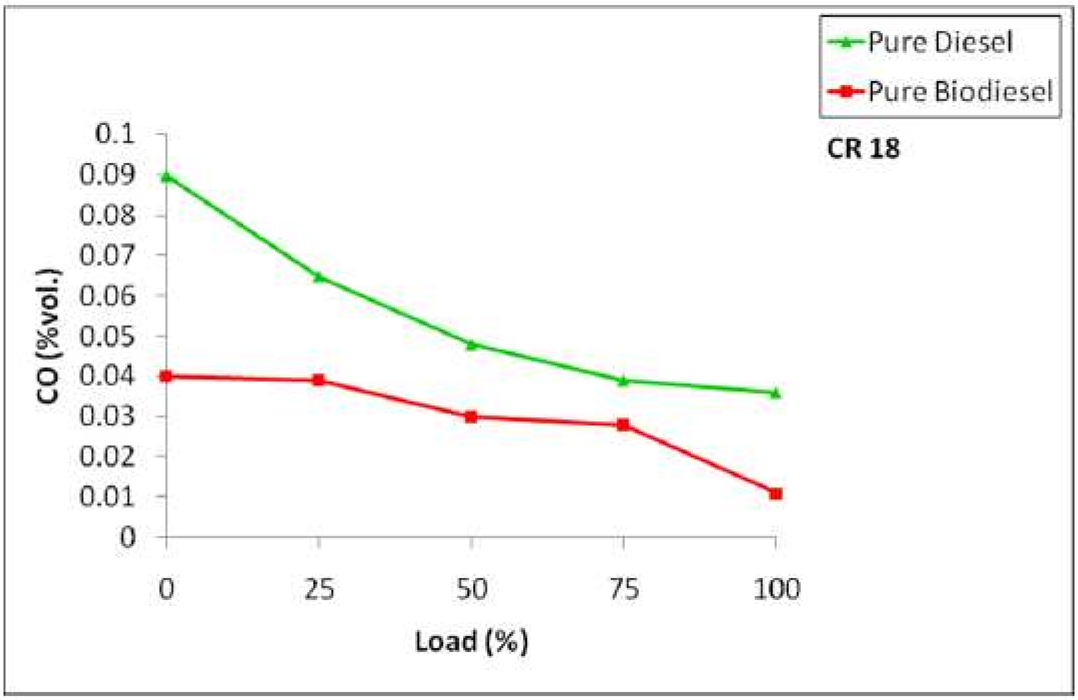

Figure 4.15: Comparison of Emission of CO for Pure Diesel and Pure Biodiesel

In fig4.15 the comparison of emission of carbon monoxide for diesel and biodiesel is shown. At entire load range of including 100% biodiesel had lesser emission of carbon monoxide than diesel. This decrease may be because of higher oxygen content in biodiesel which causes the complete combustion.

- Effect of Compression Ratio on Emission of CO for all Diesel-Biodiesel Blends

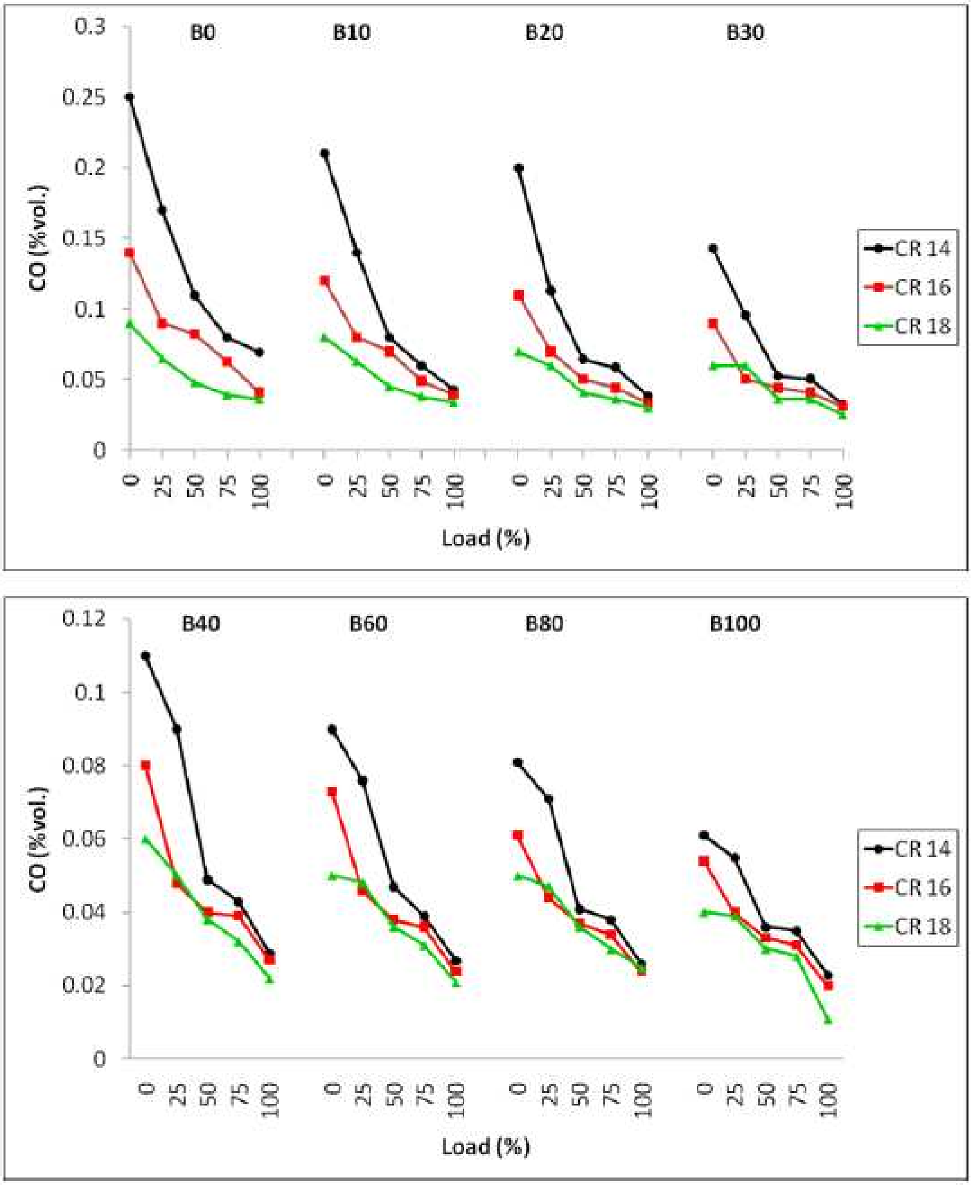

Figure 4.16: Effect of Compression Ratio on Emission of CO for all Diesel-Biodiesel Blends

In fig. 4.16 the effect of compression ratio on emission of carbon monoxide for all the blends at the entire load is shown. It was clear from the figure that as compression ratio increases emission of carbon monoxide decreases. At higher compression ratio the combustion characteristics are good due to that the emission of carbon monoxide is less.

- Effect of Different Diesel-Biodiesel Blends on Emission of CO

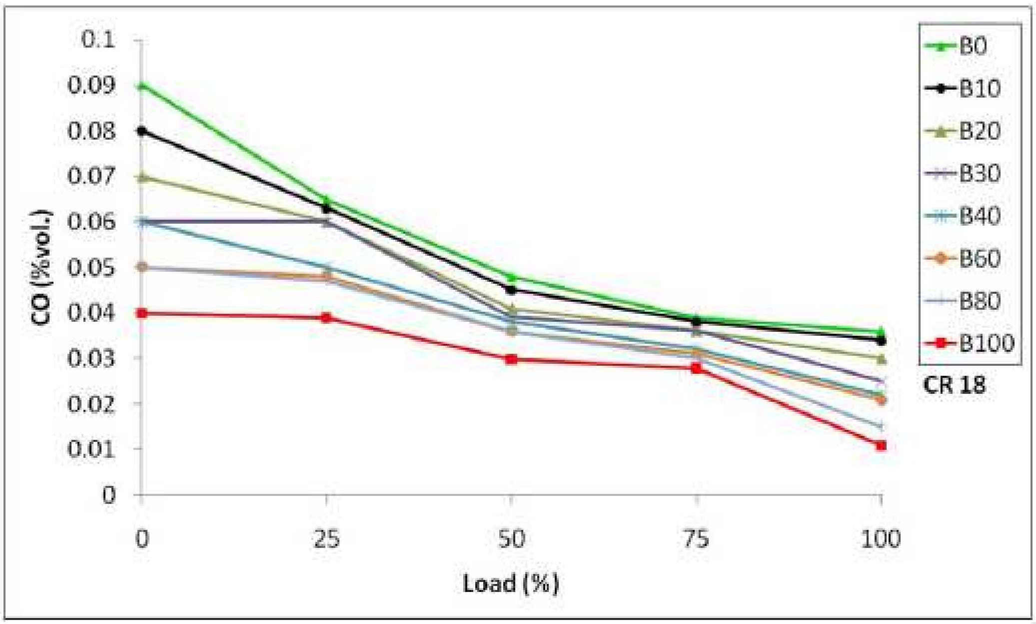

Figure 4.17: Effect of Different Diesel-Biodiesel Blends on Emission of CO

Fig. 4.17 shows the plots for the different blends. It was observed that emission of carbon monoxide decreases with the increase in load. Emission of carbon monoxide of pure diesel was 0.036%vol. and emission of carbon monoxide of B10, B20, B30, B40, B60, B80 and B100 was 0.034%vol., 0.030%vol., 0.025%vol., 0.022%vol., 0.021%vol., 0.025%vol. and 0.011%vol. respectively.

4.5.2.2 Unburned Hydro Carbons (HC)

- Comparison of Emission of HC for Pure Diesel and Pure Biodiesel

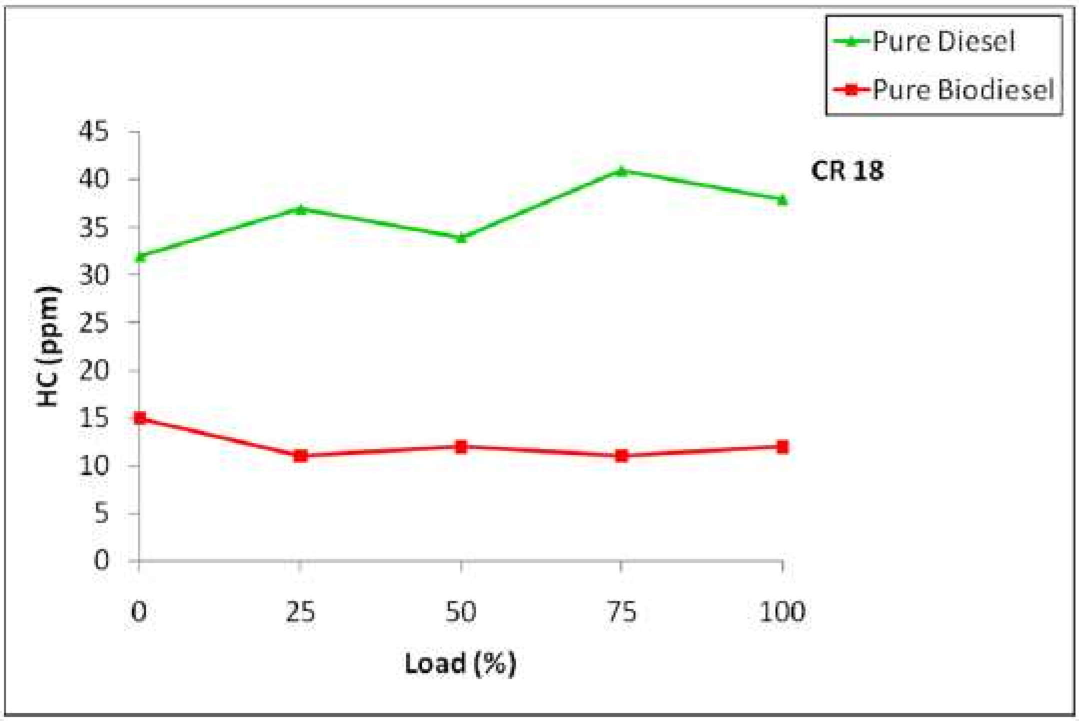

Figure 4.18: Comparison of Emission of HC for Pure Diesel and Pure Biodiesel

In fig 4.18comparison of emission of unburned hydrocarbon of diesel and biodiesel is shown. The emission of biodiesel was considerably less compare to diesel. At compression ratio 18 the emission of hydrocarbon of diesel and biodiesel were 38 ppm and 19 ppm respectively. The higher cetane number of biodiesel and oxygen availability of fuel is responsible for this decrease.

- Effect of Compression Ratio on Emission of HC for all Diesel-Biodiesel Blends

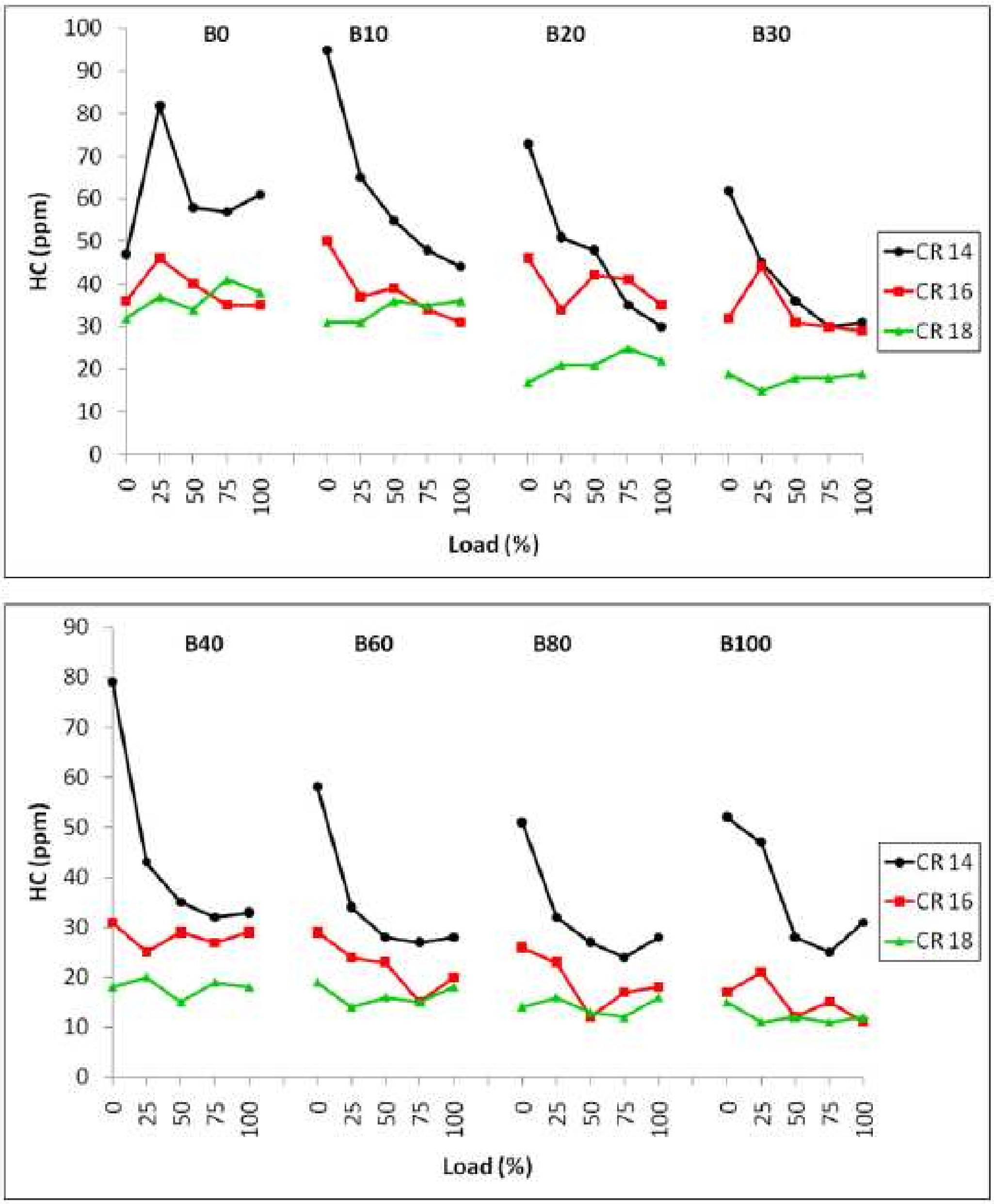

Figure 4.19: Effect of Compression Ratio on Emission of HC for all Diesel-Biodiesel Blends

The effect of compression ratio is shown in figure 4.19 on emission of hydrocarbon. It was found that as the compression ratio increase the results are improved. The emission is considerably lower when compression ratio is 18 compare to compression ratio was set to 14. For every combination of blend the approach was found to be same.

- Effect of Different Diesel-Biodiesel Blends on Emission of HC

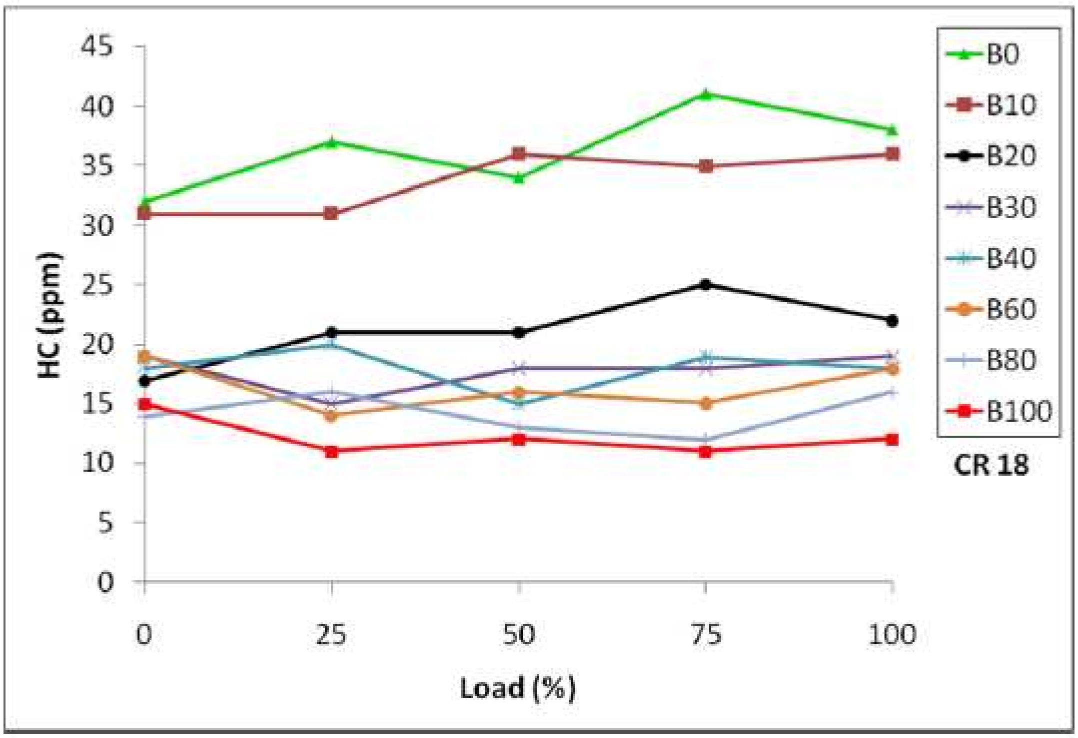

Figure 4.20: Effect of Different Diesel-Biodiesel Blends on Emission of HC

The variation of hydrocarbon emissions for diesel and diesel-biodiesel blends is shown in fig. 4.20. The emission of unburned hydrocarbon is small for all the fuels. The hydrocarbon emission of B20, B30, B40, B60 B80 and B100 were lower than that of diesel fuel. The higher cetane number is responsible for this decrease.

4.5.2.3 Nitrogen Oxide (NOx)

- Comparison of Emission of NOx for Pure Diesel and Pure Biodiesel

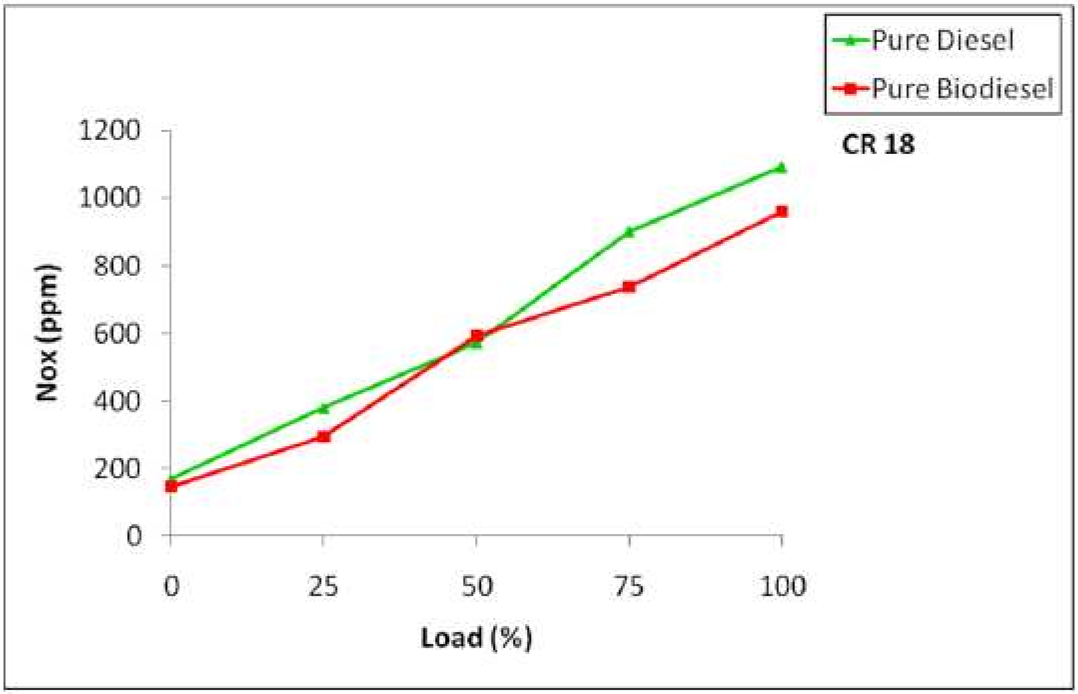

Figure 4.21: Comparison of Emission of NOx for Pure Diesel and Pure Biodiesel

Fig 4.21 shows comparison of nitrogen oxide emission for diesel and biodiesel at compression ratio 18. The emission of nitrogen oxide for diesel and biodiesel 1093ppm and 960ppm.The emission of nitrogen oxide decreases for biodiesel at full load condition but slightly increase at part load condition. During combustion chemical reaction which made nitrogen oxide were takes place at higher temperature. The exhaust gas temperature remains almost same for all the blends.

- Effect of Compression Ratio on Emission of NOx for all Diesel-Biodiesel Blends

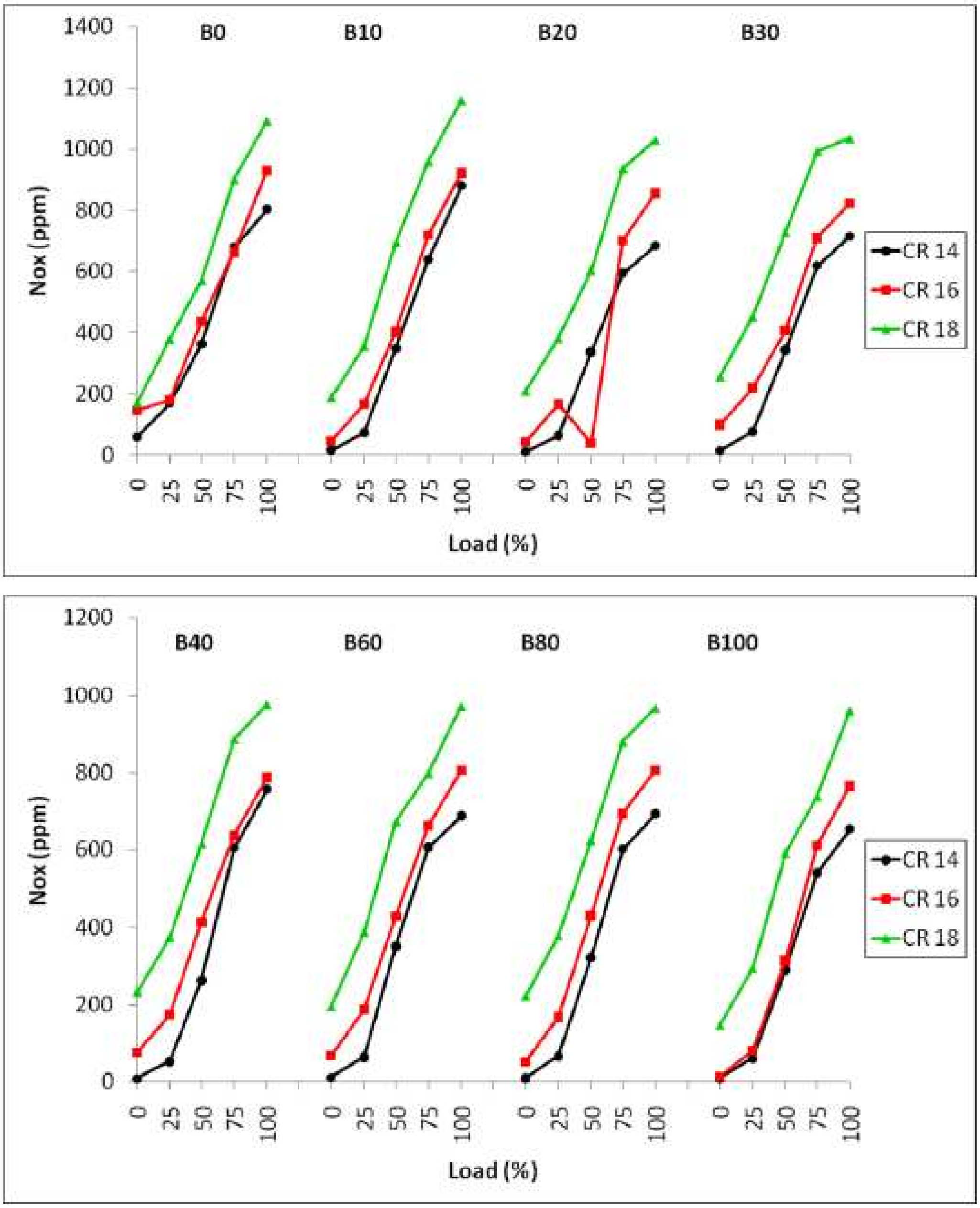

Figure 4.22: Effect of Compression Ratio on Emission of NOx for all Diesel-Biodiesel Blends

The effect of compression ratio on emission of nitrogen oxide is shown in the fig. 4.22. The value of nitrogen oxide emission for diesel at full load for compression ratio 14, 16 and 18 was 804ppm 929ppm, and 1093ppm respectively. The value of nitrogen oxide emission increases with the increment of compression ratio. All the other blends the approach remains same as diesel.

- Effect of Different Diesel-Biodiesel Blends on Emission of NOx

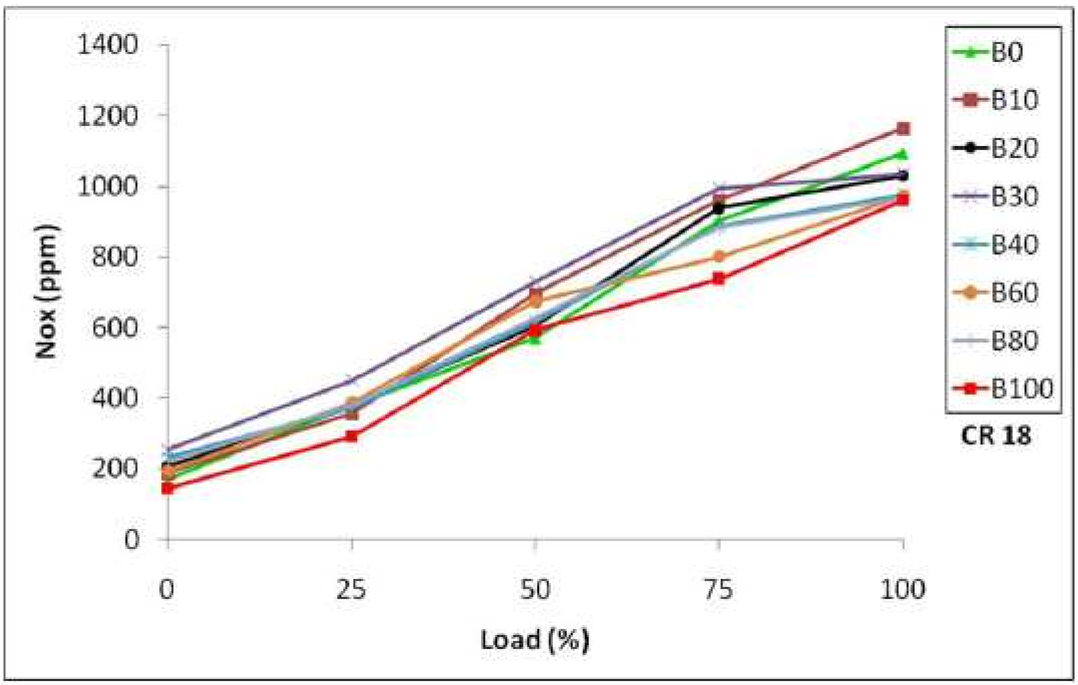

Figure 4.23: Effect of Different Diesel-Biodiesel Blends on Emission of NOx

Fig 4.23 shows the variation of nitrogen oxide emission with percentage of load for different fuels. It is observed that nitrogen oxide emission from the biodiesel and diesel-biodiesel blends are lower than those of diesel fuel. The reduction of the nitrogen oxide emission is possibly due to the lower calorific value of biodiesel and its blends which may leads to lower temperature during combustion.

4.5.2.4 Carbon Dioxide (CO_2)

- Comparison of Emission of CO_2 for Pure Diesel and Pure Biodiesel

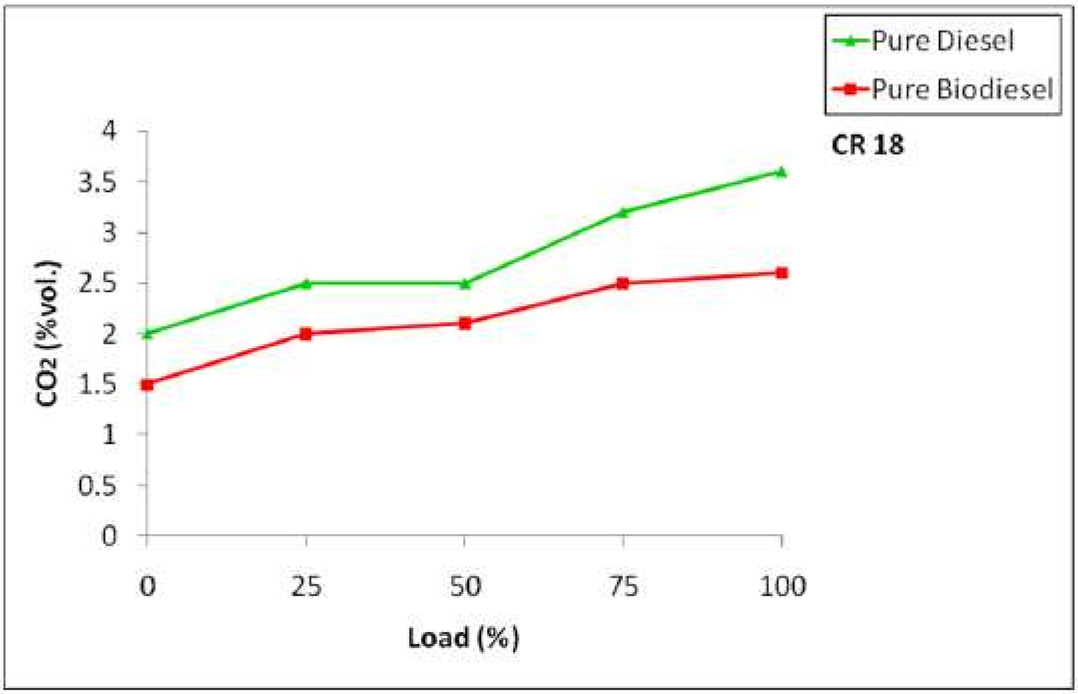

Figure 4.24: Comparison of Emission of CO_2 for Pure Diesel and Pure Biodiesel

The carbon dioxide emission distribution is shown in Figures 4.24 for diesel and biodiesel at compression ratio 18. At every load we got lower emission with biodiesel compare to diesel. The carbon dioxide emission of an engine increases significantly with load. At full load the carbon dioxide emission of diesel and biodiesel was 3.6%vol. and 2.6%vol. respectively.

- Effect of Compression Ratio on Emission of CO_2 for all Diesel-Biodiesel Blends

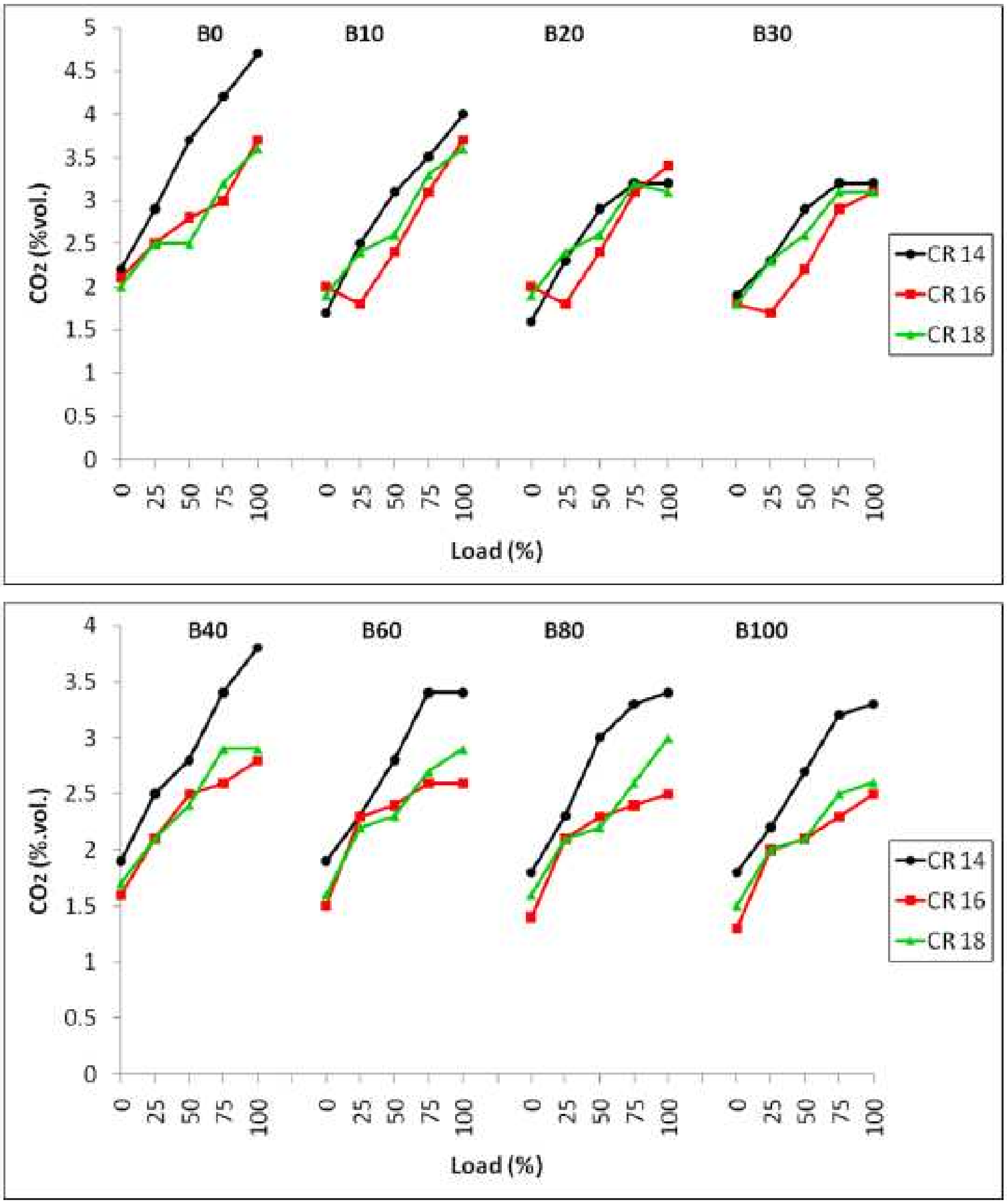

Figure 4.25: Effect of Compression Ratio on Emission of CO_2 for all Diesel-Biodiesel Blends

In Fig 4.25 the effect of compression ratio on carbon dioxide emission is shown for all the different diesel biodiesel blends. From the fig. we can clearly visualized that as compression ratio increase carbon dioxide emission was considerably increased foe all the blends. At higher compression ratio the combustion was much better compare to lower compression ratio.

- Effect of Different Diesel-Biodiesel Blends on Emission of CO_2

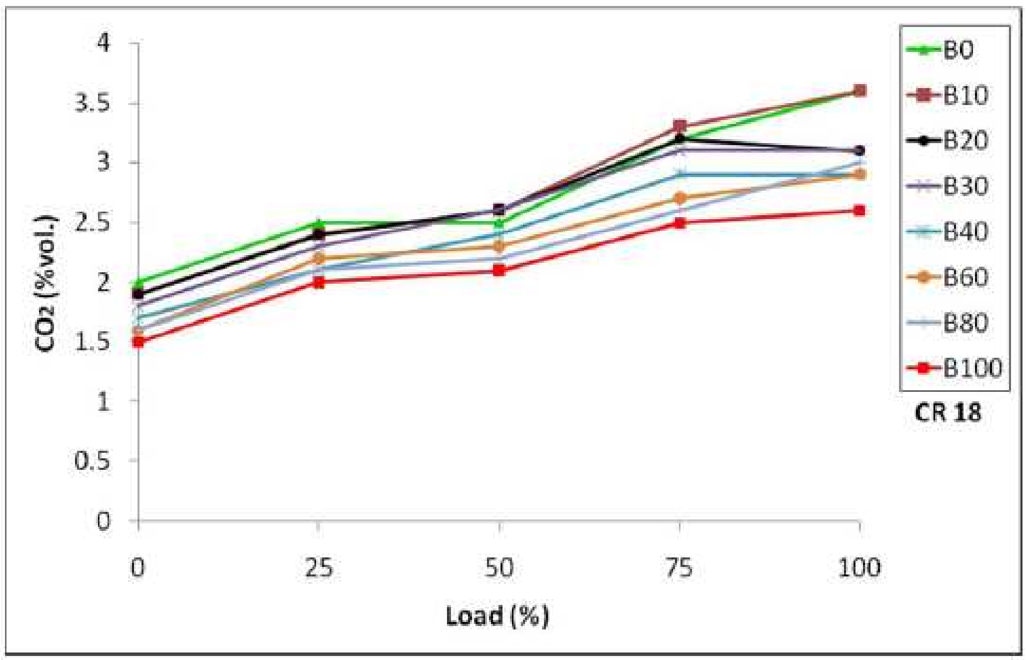

Figure 4.26: Effect of Different Diesel-Biodiesel Blends on Emission of CO_2

Fig. 4.26 shows the variation of carbon dioxide emissions with percentage of load for different fuels. It is observed that all the carbon dioxide emission of diesel fuels is higher than that of the blended fuels. This may be because the biodiesel contains oxygen elements the common context is relatively lower in the same volume of fuel consumed at the same engine load, consequently, the carbon dioxide emissions from the biodiesel and its blends are lower.

Chapter 5

Conclusions

This work is concentrated around the use of biodiesel and diesel-biodiesel blend in diesel engine as much as possible by analyzing the performance and emission of diesel engine.

Calorific value of Biodiesel is less (36844 kJ/kg) as compare to diesel (42235kJ/kg). Decrease in calorific value results in higher consumption of fuel for biodiesel-diesel blend and pure biodiesel as compare to diesel.

Biodiesel is more viscous (2.80cSt) as compare to diesel (2.10cSt).For higher blends of biodiesel, the modification in injection system of engine may be required due to increase in viscosity of fuel.

From performance and emission test analysis, it is found that when compression ratio increases brake thermal efficiency (BTHE) increases and brake specific fuel consumption (BSFC) decreases. The results of brake power remains unaffected by changing compression ratio. In emission parameters with the increment in compression ratio emission of carbon monoxide (CO), unburned hydrocarbons (HC) and carbon dioxide (CO_2) was found to be decrease. Emission of nitrogen oxide (NOx) was increases considerably with the compression ratio increases. This was due to better combustion characteristics with increase in compression ratio.

Engine was running smoothly on pure biodiesel also. If we can agree for slight compromise with the engine performance parameters, we can replace the diesel fuel. In pure biodiesel all the emission parameters found to be lower compared to diesel.

Up to B20 the performance of the engine improve considerably but for more percentage of biodiesel (B30, B40, B60 and B80) it decreases compared to diesel. Based on performance and emission analysis of engine using different diesel-biodiesel blends, optimum blend was found is B20 (20% biodiesel, 80% diesel). B20 having comparatively 3.77% higher brake thermal efficiency than base line data. Brake specific fuel consumption of B20 slightly decrees compare to diesel. Brake power of B20 is also increases comparatively by 5.8%.

In exhaust gas analysis for diesel and B20 emission of carbon monoxide was 0.036%vol. and 0.030%vol., emission of carbon dioxide was 3.6%vol. and 3.1%vol., emission of unburned hydrocarbon was 38ppm and 36ppm, emission of nitrogen oxide was 1093ppm and 1031ppm.

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