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Analysis of Exhaust Gas Emission using Calophyllum Inophyllum Biodiesel in CI Engine with Variation in Load and Compression Ratio

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ABSTRACT

Environment pollution caused by the burning of the conventional fuels from the engines always a challenge to be addressed and a lot of the alternate fuels that can positively replace the conventional fuels used in the engine. Calophyllum Inophyllum biodiesel and its blends is examined as a possible source of alternative fuel in CI engine. Thermal cracking followed by Transesterification is the process the biodiesel is obtained and B20, B40, B60, B80 blends are prepared and emission performance on the DI VCR engine conducted. Analysisof the exhaust emission parameters like NOx, CO, CO2 at a constant speed of 1500rpm, injection timing of 270bTDC and 200bar with variation in load and compression ratio. The regression analysis performed on independent variables or the input variables compression ratio that varied from 15.5 to 17.5 in steps of one, Blends of the biodiesel that varied from 20 % to 100% in the steps of 20%, and the load variation from no load to full load with the incrimination of 25%.

1. Introduction

Modernization has lead to the increased use of energy. Conventional fuel is largely utilized in the transport, agriculture, commercial, domestic, and industrial sector for generation of power. Because of excessive usage of these fuels on large front had lead to the serious shortage of the fossil fuel. A decent amount of research work is done in identifying the alternate source for the possible replacement of the fossil fuels.

Biodiesel stands as a possible source of the alternative fuel obtained from vegetable oils, animal fats, edible and non edible sources .Using biodiesel can help to reduce the world's dependence on fossil fuels and which has significant environmental benefits

Vegetable oils like Sunflower, Cotton seed, Linseed, Sesame, Soybean, Peanut, Palm, etc are taken as an alternative fuel to Diesel fuel, a systematic effort has been taken by to investigate the use of biodiesels made from vegetable oils. Since vegetable oils are edible in nature, their use as a fuel has limited application due to higher domestic food requirement. Non edible oils extracted have been tried on diesel engine, leaving a lot of scope in this area. Non edible oils like Karanja, Jatropha, Rubberseed, Rapeseed, Honne,[1]etc. play a vital role in the biodiesel production are intensively studied to use as biodiesel[2,3]

2. Materials and methods

For the preparation of biodiesel, crude oil will have long chains of Hydrocarbon molecules and high viscosity is first broken down into lower molecular weight product by thermal cracking [4].

The crude oil has some impurities so Hydro Chloric acid (HCl)is added to crude oil as an anti forming agent. A maximum temperature of 250^{o} C heating metal is used for heating the crude oil along with Porcelain bites in order to retain the uniform temperature inside the flask with proper insulation with glasswool. Condensed Vapour that is collected is preceded for transesterification. 5 gm of potassium hydroxide and 180ml of methanol made to react in a round bottomed flask with 1 liter of thermally cracked oil.

A continued 2 hr stirring with magnetic stirrer at a temperature of 65^{0}Cis maintained and glycerol is separated so the entire solution is introduced into a separating funnel and allowed to settle for a period. The prepared Calophyllum oil Methyl is cleaned for the removal of impurities by washing with distilled water until the forming is not seen. Then blends of B20 (20% of Calophyllum Oil Methyl Ester with 80% of diesel by volume), B40, B60, B80 are prepared and conducted experiments

The following are the properties of the oil after preparation through thermal cracking and transesterification method.

Table 2.1: Properties Chart

Properties	IS standards	Diesel	Calophyllum oil	B100	B20
Viscosity at 40^{0}C (cSt)	**IS 1448 P:25**	2.1	33.2	4.3	2.6
Calorific value(Mj/kg)	**IS 1448 P: 6**	42.15	35.12	38.72	41.33
Density **(kg/m^{3})**	**IS 1448 P:16**	790	928	879	832
Flash point(^{0}c)	**IS 1448 P:20**	68	221	152	86

3. Experimental Setup

For the purpose of experimentation Diesel Engine test rig having single cylinder four stroke, D.I. water cooled type diesel engine with Eddy current loading for diverse fuel blends is used. The engine is a variable compression ratio engine.

3.1 Experimental methodology:

All experiment reading is recorded at constant Engine speed 1500 rpm, compression ratio 17.5, injection pressure of 200 bar and injection timing of 27^{O}bTDC. Readings signify the engine parameters recorded are the variation in load and compression ratio with respect to all blends of Diesel-Biodiesel.

The measurands are Exhaust emissions for different Blends of Bio diesel and the Diesel. The gas analyser used is 5-way in nature that can measure oxides of nitrogen, carbon (like CO and $CO_{2,}$) hydrocarbons in PPM or % basis.

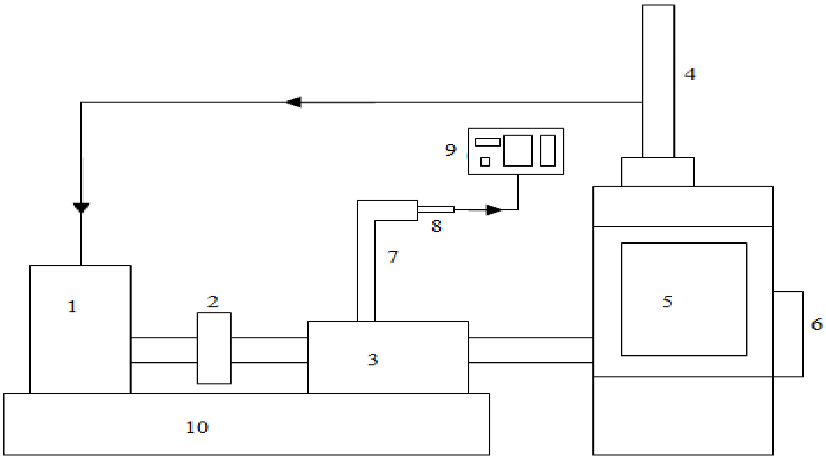

Fig. 3.1 Block diagram of experimental setup

1. Single Cylinder 4-Stroke CI Engine
2. Flywheel
3. Generator
4. Fuel Storage Tank
5. Computer
6. Load Adjusting Panel
7. Exhaust Pipe
8. Gas Analyzer Probe
9. Exhaust Gas Analyzer
10. Engine Bed

Table3.1: Specification of engine

Sr. No.	Description	Specification
1	Make	Rocket EngineeringModel VRC-1
2	Bore, Stroke ,BrakeHorsePower, RPM	80 mm, 110 mm, 5 HP, 1500rpm
3	Compression Ratio	17.5 : 1
4	Fuel Oil	High SpeedDiesel
5	CoefficientofDischarge	0.64
6	Water Flow Transmitter	0 to 10 lit./min.
7	Air Flow Transmitter	0 to 250 cc
8	PiezoSensor	0 to 5000 psi with low noise cable
9	Software	Labview
10	Exhaust Gas Analyser Make	Indus Scientific Pvt.Ltd.
11	Measureable Gases	CO, CO2, NOx and HC

4. Exhaust emissions of various blends with variation of load

4.1 CO_2 emission:

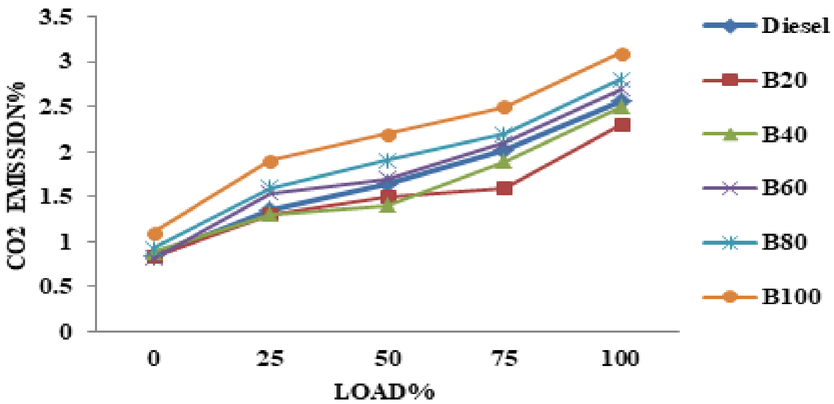

Fig.4.1 Variation of CO_2 to load

Fig 4.1shows the emission of CO_2 with the load incrementation for all the blends. Release of carbon dioxide emission is a sign of cleaner emission. As the amount of the biodiesel percentage increases the CO_2 levels also increases which is good sign for alternate fuel. Even diesel doesn't show the the above statement. When load is increased the fuel consumption increases , the carbon dioxide emmision also shows the result in a linear progressive fashion. The CO_2 emission for B100 is highest and least for diesel. The increase in carbon dioxide emissions for B100 and B20 is 13.5% and 3.8% respectively to diesel.

4.2 Carbon-Monoxide Emission:

Fig 4.2Depicts the variation of CO with the increase in load. The load is incremented by 25% .The CO forms when incomplete burning of fuel takes place. Also flame quenching CO emission also these emissions required the following reasons like oxygen content are lesser than theoretical or time shortage for combustion is lesser.

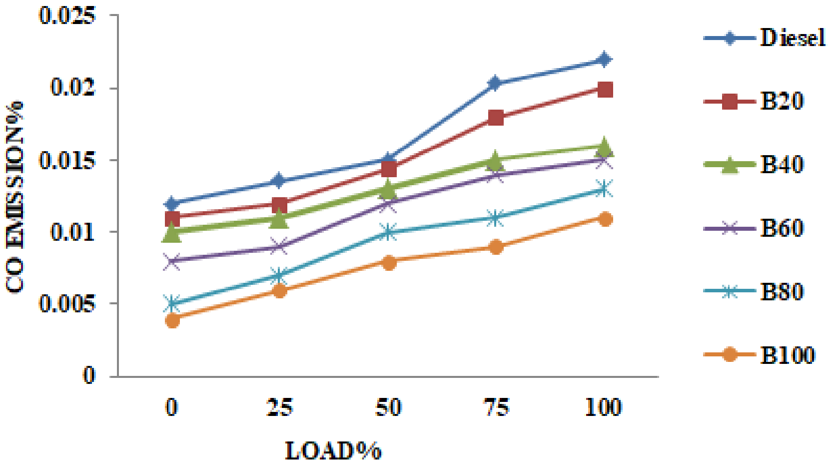

Fig. 4.2 Variation of CO emission to Load

At constant injection timing of 27^{O}bTDC, the CO emissions of Diesel fuel is highest and is measured in %. The B100 blends show a reduction by 52% than that of diesel and B20 by 12% for all loads.

4.3 Nitrogen Oxides emission:

The variation of Nitrogen Oxides with respect to load is plotted graphically in Fig 4.4. The nitrogen oxides (NOx) emission is a direct function of burning temperature of the fuel in the combustion chamber inside the engine. The fluctuation of load and Oxides of nitrogen is showing a linear trend. The NOx produced by B100 is highest as combustion is found to be complete as due to the chemical structure of biodiesel has oxygen impregnated in it and which is absent in diesel. The NOx emission of B100 increased by 23% in comparison to diesel.

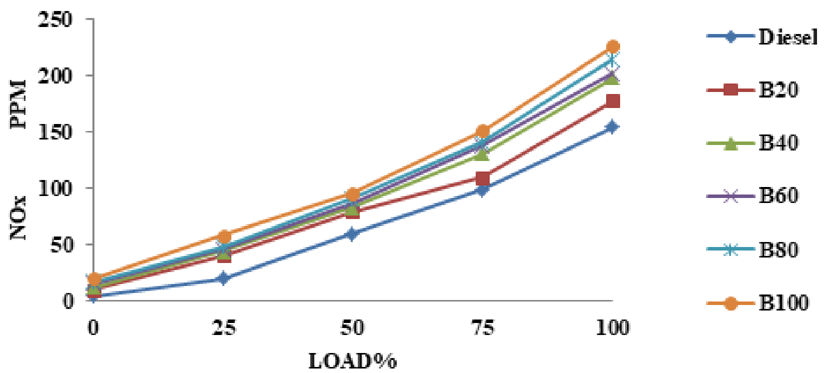

Fig.4.3Variation of Nitrogen oxide emission to Load

5. Exhaust emission of various blends with variation in compression ratio

The below experimental study reveals the variations observed when the Compression ratio is altered for the same blends. The readings are noted at full load or maximum load.

5.1 Carbon dioxide Emission

Fig. 5.1 shows the graphical representation of Carbon dioxide emission of all the blend and diesel with the increase in compression ratio is shows that carbon dioxide emissions of diesel fuel found is very less and as the blend percentage of biodiesel increases the carbon dioxide emission also increases which is adverse fact for CO_2 emission. As the compression ratio is increased from 15.5-17.5 in units of 1CR value. The CO_2 emission decreases slightly. The blending plays an important factor showing that, as the blend percentage increases the CO_2 increases. Diesel shows the lowest readings of CO_2.

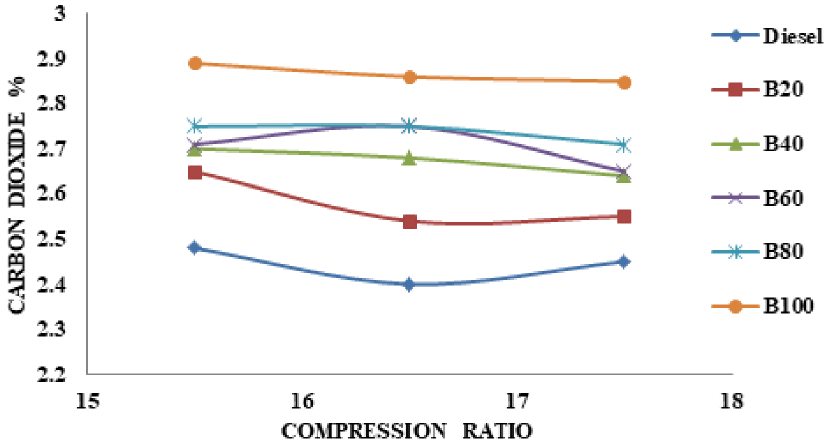

Fig. 5.1Variation of CO_2 to Compression Ratio

5.2 Carbon monoxide Emission:

Fig 5.2 shows the variation of CO with Compression ratio with all the biodiesel blends. The carbon monoxide emission is a derivative of incomplete combustion, either by insufficient oxygen or time lack to undergo complete combustion. At various compression ratios, the CO emission of diesel fuel is in high. But as the percentage of Bio diesel increases in the Blend, the emission of carbon monoxide decreases. It is found that the lowest CO emission is found for B 100. It might be that oxygen molecule present in the fuel which adds up for combustion thereby increasing the combustion efficiency and effective burning of methyl ester as fuel.

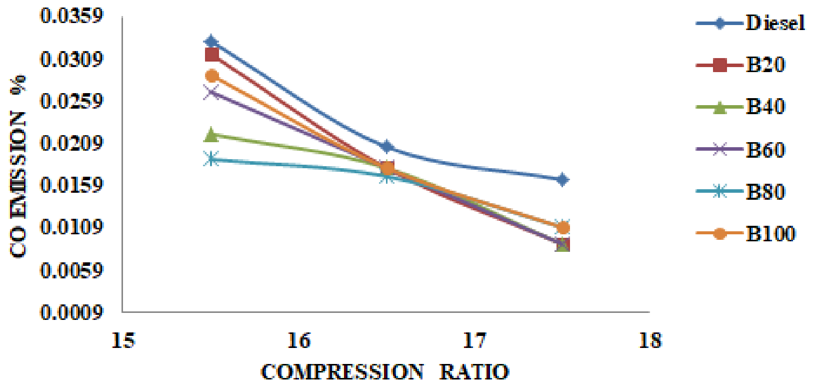

Fig. 5.2 Variation of CO Emissionto Compression ratio

5.3 Nitrogen Oxide Emission:

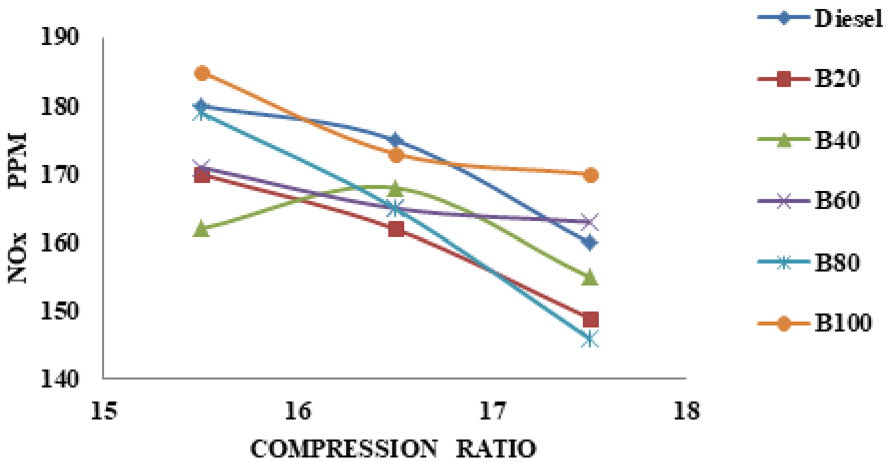

Fig. 5.3 Variation of NOx to Compression Ratio

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Formation of Nitrous Oxides is a function of temperature. It is found that the NOx emission is highest for the B100, which might be due to higher Oxygen presence in structure in chemical structure resulting in higher exhaust gas temperature. As the compression ratio increases the emission of NOx decreases for all the blends and also diesel. The NOx emission for B80 and B20 blend is the very less when compared to the other blend at the maximum compression ratio.

6. Regression Analysis

The regression analysis is one of the predictive modelling techniques that will give the information about how much the dependent or the result will vary if the independent parameter varies. It is an important tool for modelling and analysing the data and then predicting of forecasting the result.

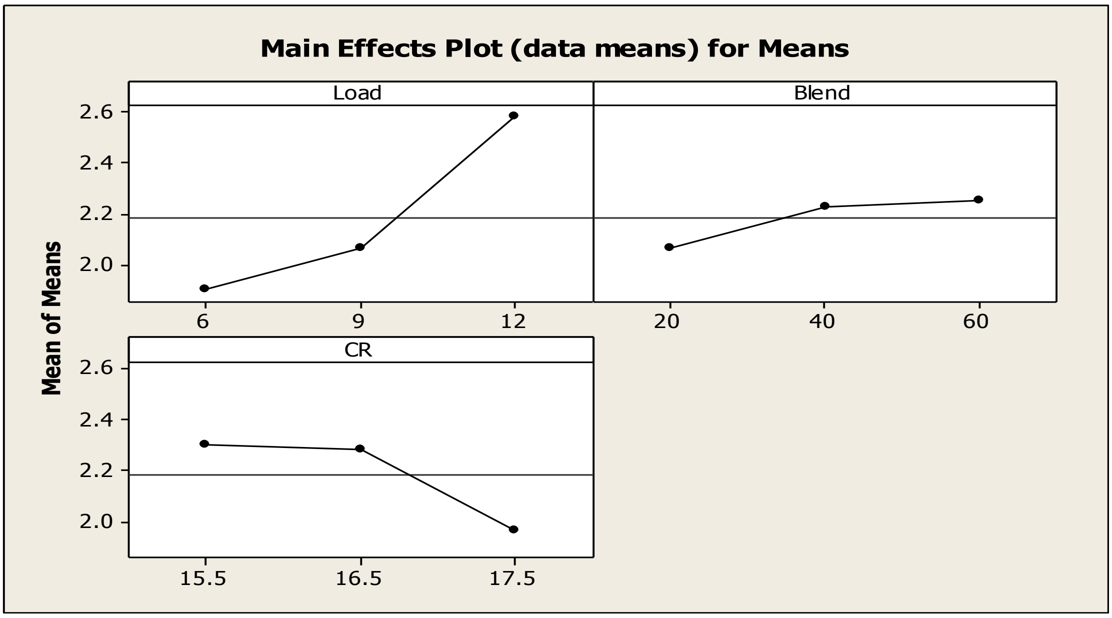
The analysis gives the idea about the impact the independent variable is having the on the dependent variable. It will give the idea about the strength the independent variable is having and then judge if the variable can be included or eliminated for the prediction of the result. [5, 6] In the present work the selection of the dependent variables are considered to be the emission parameters like the CO_2, CO, NOx, HC The independent variables or the input variables are the compression ratio that varied from 15.5 to 17.5 in steps of one, Blends of the biodiesel that varied from 20 % to 100% in the steps of 20%, and the load variation from no load to full load with the incrimination of 25%. Based on the desired output of the emission that is required the design of the experiment is decided over the variation of the load, blend and compression ratio. The analysis on the minitab for the regression equation with the multiple variable input parameters, the values of the R Sq and the adjusted R sq are in the good terms. So the values from the experiments for the emission parameters that are conducted on the single cylinder four stroke VCR diesel engine with the Calophyllum inophyllum biodiesel are validated using the minitab software.

Table 6.1 Regression equation of the emission parameters

Emission parameter	Regression Equation	R Sq	R Sq Adjusted
CO_2	CO_2 = 3.75 - 0.168 CR + 0.00458 Blend + 0.114 Load	87.2%	79.6%
CO	CO = - 0.098 + 0.0193 CR - 0.00190 Blend - 0.0078 Load	83.6%	87.6%
NOx	NOx = 150 - 5.33 CR - 0.225 Blend + 9.78 Load	82.5%	72.0%

There various results that are obtained from the software for the emission are presented

6.1CO_2 Graphs:



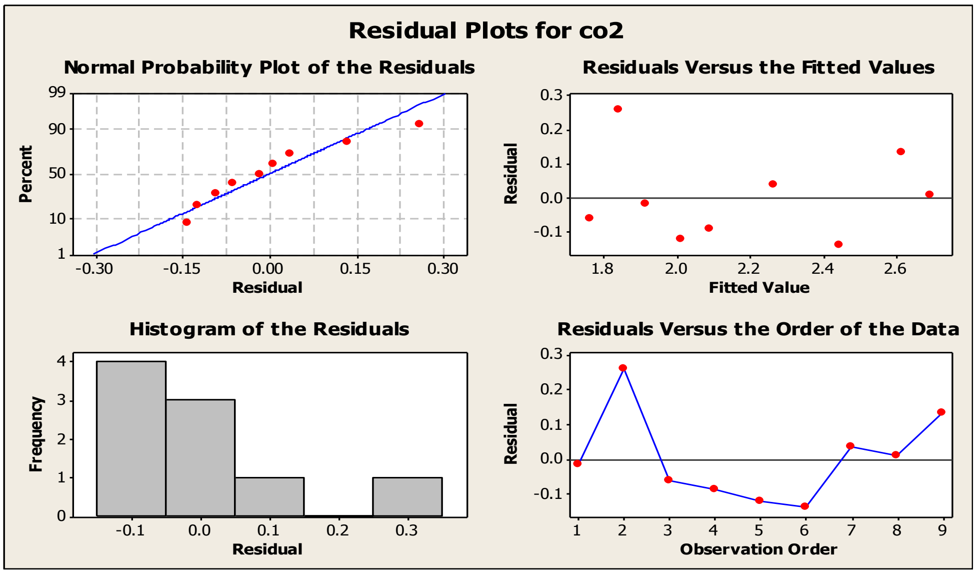
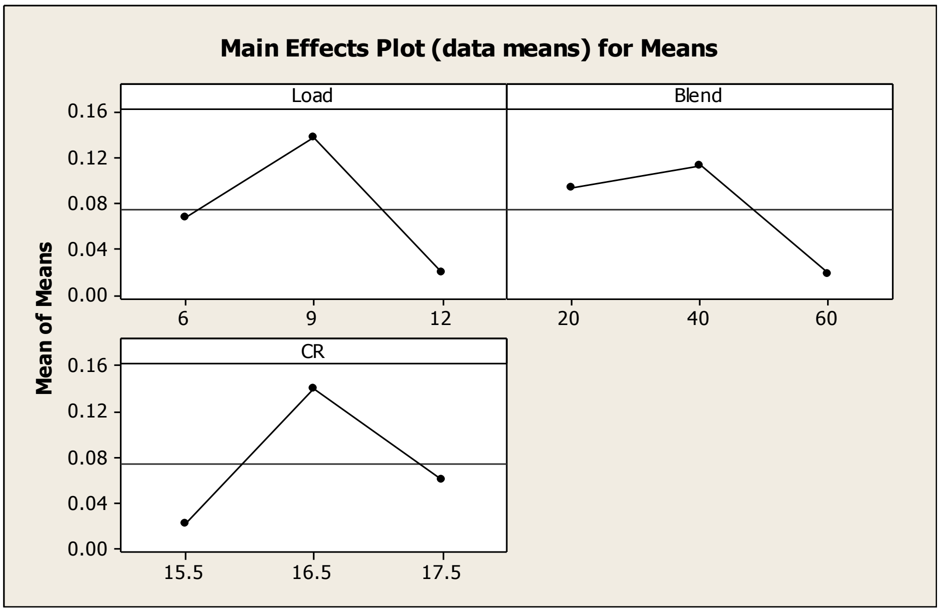


Fig. 6.1 Plots of the graphs for CO_2

6.2 CO Graphs:



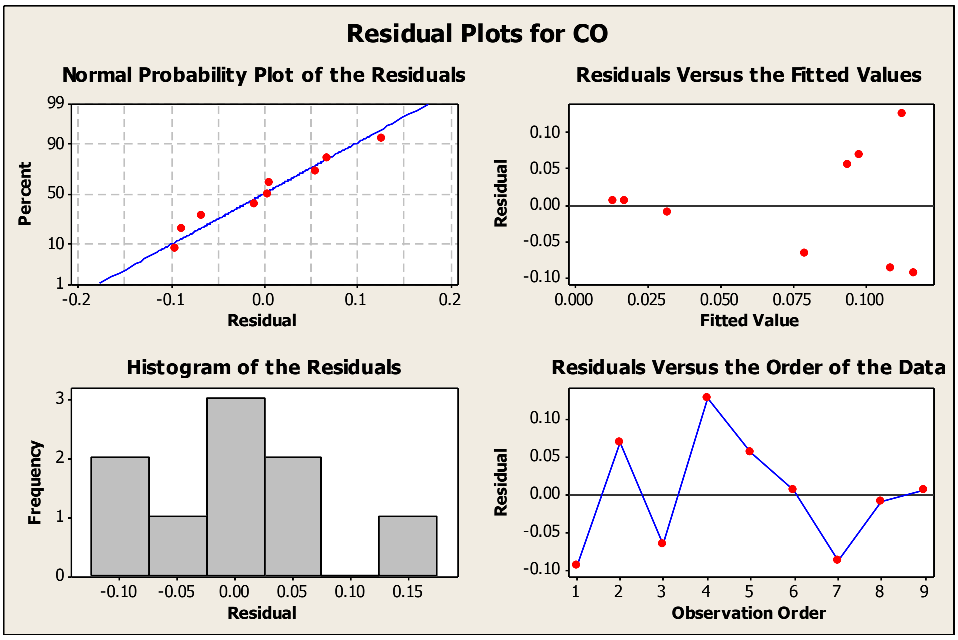
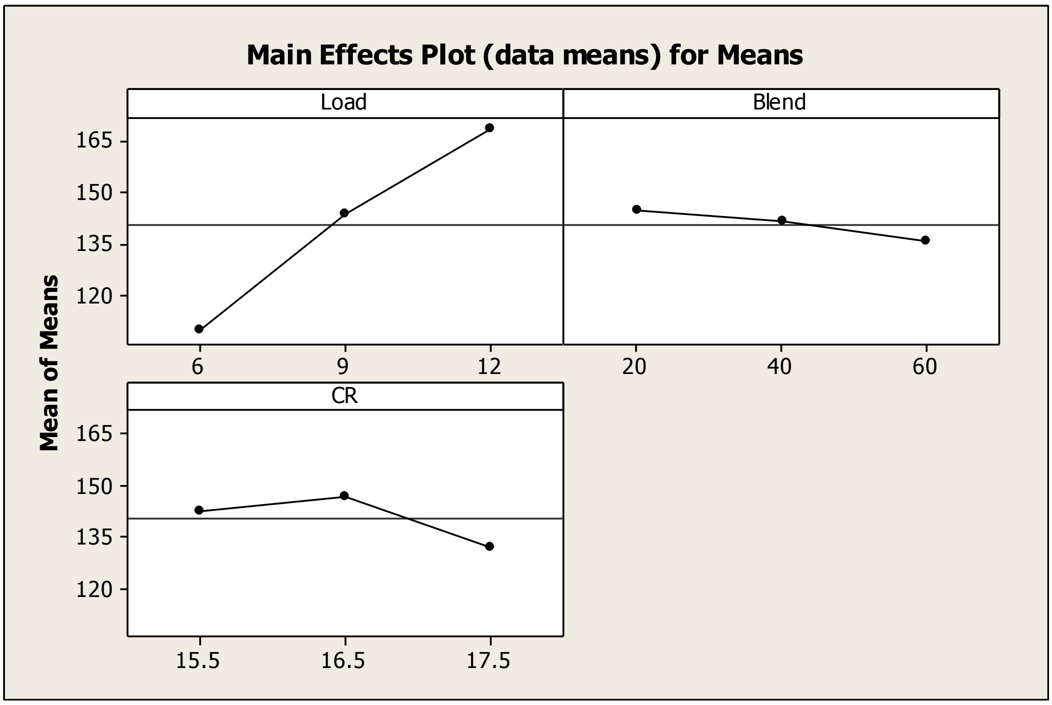


Fig. 6.2 Plots of the graphs for CO

6.3 NOx Graphs:



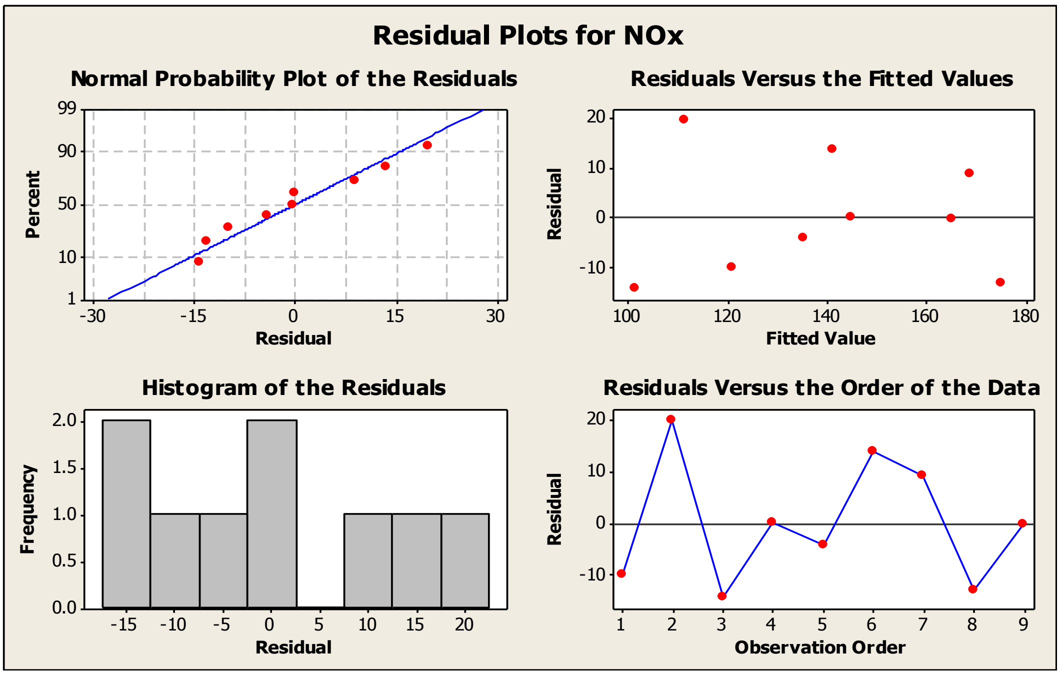


Fig. 6.3 Plots of the graphs for NOx

7. Results and Discussion

1. As compression ratio increased the carbon monoxide emission reduced 17.26% for B100 and 16.5% for B20 with comparison to diesel.
2. When compared to the emission of the CO_2 and NO_x with increase in load and compression ratio B20 is better, and it has least CO emission at maximum compression ratio, B20 can be a possible replacement.
3. At the maximum compression ratio NOx emission for B80 and B20 blend is the very less when compared to the other blend. NOx emission is less for B20 when compared to other blends when the load is maximum.
4. At full load the variation in the blend proves to be an important factor in the CO2 emission as the compression ratio increases.

With the experimental reading that are taken on the diesel engine with the variation of the load, compression ratio and blend the regression equation for the emissions holds good and is valid.

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