# EMISSION ANALYSIS OF BIO-DIESEL BLENDS ON VARIABLE COMPRESSION RATIO ENGINE

**Rupesh L. Raut[1], Babaso N. Naik[2], Shekhar D. Thakare[3], Amol A. Gawali[4]**

[1] *M Tech Scholar, Mechanical Department, Walchand College of Engineering Sangli, Maharashtra, India*
[2] *Assistant Professor, Mechanical Department, Walchand College of Engineering Sangli, Maharashtra, India*
[3] *M Tech Scholar, Mechanical Department, Walchand College of Engineering Sangli, Maharashtra, India*
[4] *M Tech Scholar, Mechanical Department, Walchand College of Engineering Sangli, Maharashtra, India*

## Abstract

*Biodiesel is the first and only alternative fuel to have a complete evaluation of emissions results and potential health effects submitted to the US EPA under the Clean Air Act 211 Both Tier I and Tier II have been completed as per the attached package. A large number of experimental studies are reported to study the thermal performance of biodiesels used in diesel engines operated at constant compression ratio and constant injection pressure. In these studies the effect of load, blend, speed, injection timing, brake power, etc on thermal performance and emission characteristics are studied. The fields of optimization on VCRE performance at various CR have emerged as areas of research in recent times. It is found that very few studies are reported in these areas. Therefore the present work is carried out multi-objective optimization on engine exhaust emissions based on compression ratio, load, and blend to find the optimum operating conditions. Based on experimental study, it can be concluded that with increase in CR, the performance of diesel engine operated using Jatropha blends approach to that operated using Diesel And at higher CR, the thermal performance of Jaropha biodiesel blends is closest to that of diesel compared to operate at other CRs of 14, 15, and 16. Thus, the best combination of input parameter in term of CR will be 17 to 18 when engine is operated at full load. The experiment however can not specify any optimum Jatropha biodiesel blend that will simultaneously maximize thermal performance and minimize emission constituents. Although, B5 and B10 give better performance compared higher blends, it cannot be recommended as it poses problems of higher levels of exhaust emission.*

***Key Words:*** *VCR Engine, CR, HC Emissions, CO Emission, $CO_2$ Emission, $NO_x$ Emission.*

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## 1. INTRODUCTION

World's energy consumption has increased continuously since decades except for a brief period like the oil crisis in 1970's in which the growth slowed down. Energy consumption is not expected to decrease in this century, because the world population is increasing and the economies of developing countries are expanding rapidly. In contrast, the source and supply of primary energy sources like coal, oil and natural gas seem to decrease to a critical point. The petroleum fuels one of the major sources of energy are currently the dominant global source of $CO_2$emissions, greenhouse gases and global warming. Therefore many nations have signed the UN agreement to prevent a dangerous imbalance in the climate system.

Sharp hike in petroleum prices and increase in environmental pollution jointly have necessitated exploring some renewable indigenous alternatives to conventional petroleum fuels. Also, depletion of fossil fuels, vehicular population, increasing industrialization, extra burden on home economy, growing energy demand, explosion of population, environmental pollution, emission norms (Euro I, II, III, IV), etc emphasize on the need for alternative fuels. The possible options we have are renewable energies solar power, Compressed Natural Gas (CNG), alcohols, hydrogen, bio alcohol such as methanol, ethanol, butanol, batteries and fuel cells, propane, non-fossil methanol, non-fossil natural gas, emulsified fuels, biofuels mostly from non-edible seed oils, biodiesels i.e. transesterified form of seed based oils and other biomass sources. For developing countries, fuels of bio-origin, such as alcohol, vegetable oils, biomass, biogas, biodiesels, etc. are becoming important because of their renewable and environmental friendly nature. Some of these fuels can be used directly, while others need some sort of modification before they are used as substitute to conventional fuels.

Bio-diesel which can be used as an alternative diesel fuel is made from renewable biological sources such as vegetable oils and animal fats. It is bio-degradable; non-toxic and possesses low emission profiles. Also, the use of bio-fuels is environment friendly. Biodiesel production is increased by 85%, making it the fastest growing renewable energy source in 2006. Several developed countries have introduced policies encouraging the use of biodiesels.

In a country like India having a huge agricultural potential, vegetable oil proves a promising alternate for petroleum (diesel) fuel. Today, India has 17% of the world's population, and just 0.8% of the world's known fossil fuel and natural gas resources. India‘s annual requirement of oil is 120 million metric tons. India produces only about 25% of its total requirement. The import cost today of oil and natural gas is over Rs. 2, 00,000 cores. We have nearly 60 million hectares of wasteland, of which 30 million hectares are available for energy plantations like Jatropha, Karanja. Each acre will produce about 2 tones of biodiesel at about Rs. 20 per liter.

India being predominantly an agricultural country requires major attention for the fulfillment of energy demands of a farmer. Irrigation is the bottleneck of Indian agriculture, it has to be developed on a large scale, but at the same time Diesel fuel consumption for these sectors must be kept at a minimum level because of the price of Diesel oil and its scarcity due to fast depletion. Finding an alternative fuel for petroleum diesel fuel is critically important for our nation's economy and security. The complete substitution of oil imports by indigenous alternatives for the transportation and agricultural sectors is the biggest and toughest challenge for India.[1]

## 2. EXPERIMENTAL SETUP

The experimental test rig consists of a variable compression ratio engine, eddy current dynamometer as loading system, fuel supply system for both Diesel oil and biodiesel supply, water cooling system, lubrication system and various sensors and instruments integrated with computerized data acquisition system for online measurement of load, air and fuel flow rate, exhaust emissions and smoke opacity. Following fig. gives the information about experimental test rig.

| | |
|---|---|
| **Product** | VCR Engine test setup 1 cylinder, 4 stroke, Diesel (Com.) |
| **Product code** | 234, 234H* |
| **Engine** | Make Kirloskar, Type 1 cyl., 4 stroke Diesel, water cooled, power 3.5kW at 1500rpm, stroke 110mm, bore 87.5mm. 661cc, CR17.5, Modified to VCR engine CR 12 to 18 |
| **Dynamometer** | Product 234: Type eddy current, water cooled, Product 234H: Type Hydraulic |
| **Propeller shaft** | With universal joints |
| **Air box** | M S fabricated with orifice meter and manometer |
| **Fuel tank** | Capacity 15 lit with glass fuel metering column |
| **Calorimeter** | Type Pipe in pipe |
| **Piezo sensor** | Range 5000 PSI, with low noise cable |
| **Crank angle sensor** | Resolution 1 Deg, Speed 5500 RPM with TDC pulse. |
| **Data acquisition device** | NI USB-6210, 16-bit, 250kS/s. |
| **Piezo powering unit** | Make-Cuadra, Model AX-409. |
| **Temperature sensor** | Type RTD, PT100 and Thermocouple, Type K |
| **Temperature transmitter** | Type two wire, Input RTD PT100, Range 0–100 Deg C, Output 4–20 mA and Type two wire, Input Thermocouple, |
| **Load indicator** | Digital, Range 0-50 Kg, Supply 230VAC |
| **Load sensor** | Load cell, type strain gauge, range 0-50 Kg |
| **Fuel flow transmitter** | DP transmitter, Range 0-500 mm WC |
| **Air flow transmitter** | Presure transmitter, Range (-) 250 mm WC |
| **Software** | "EnginesoftLV" Engine performance analysis software |
| **Rotameter** | Engine cooling 40-400 LPH; Calorimeter 25-250 LPH |
| **Pump** | Type Monoblock |
| **Overall dimensions** | W 2000 x D 2500 x H 1500 mm |
| **Optional** | Computerized Diesel injection pressure measurement |

**Fig -1**: Engine Specifications

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. The injection point and spark point can be changed for research tests. Rotameters are provided for cooling water and calorimeter water flow measurement. A battery, starter and battery charger is provided for engine electric start arrangement. The setup enables study of VCR engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio, heat balance and combustion analysis. Lab view based Engine Performance Analysis software package "Enginesoft" is provided for on line performance evaluation. The test engine is manufactured by Apex Innovations, Sangli [10]

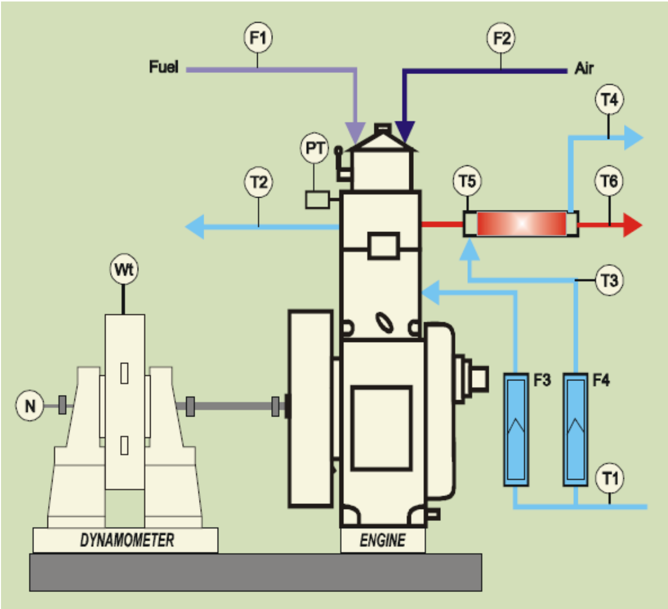


**Fig -2**: Experimental Set up

T1= Temperature of jacket water IN
F1=Flow rate of fuel
T2= Temperature of jacket water OUT
F2= Flow rate of air
T3= Temperature of water Calorimeter IN
F3= Flow rate of engine cooling water
T4= Temperature of water Calorimeter OUT
F4= Flow rate of calorimeter cooling water
T5= Temperature of Exhaust Gas, before calorimeter
Wt=Load cell reading
T6= Temperature of Exhaust Gas, after calorimeter
N=Engine speed Tachometer reading

## 3. RESULTS AND DISCUSSIONS

The emission constituents considered for evaluation and Unburned Hydrocarbon (HC), Carbon monoxide (CO), Carbon dioxide ($CO_2$) and Oxides of Nitrogen ($NO_x$). The variation of the emission constituents with CR is interpreted. For each constituent, the variations for Diesel and blends of Jatropha biodiesel with diesel as fuels are superposed and analyzed. We have taken reading with respect to fix variable compression ratio and load.

### 3.1 Variable Compression Ratio

The variations of exhaust emission constituents at different values of CRs at 14, 15, 16, 17, and 18 with a constant rated load of 100% and 125% is presented in Figures 3 to 10.

### 3.1.1 HC Emissions

The comparison of variation of HC with CR for Jatropha biodiesel and its blends with Diesel at 100% and 125% Load is shown in Figures 3 and 4.

It can be observed from the figure that HC emissions decrease with increase in CR for all the fuels tested. The trend observed may be due to complete combustion of fuel which may be due to high heat of compressed air at higher CR.

It is also observed that HC decreases with the increase in blend proportion. The trend may be due to better combustion of Jatropha biodiesel due to its oxygenated nature. The mean percentage decrease in HC emission with Jatropha biodiesel as compared to Diesel is of the order of 10% to the 75% from B5 to B80 respectively.

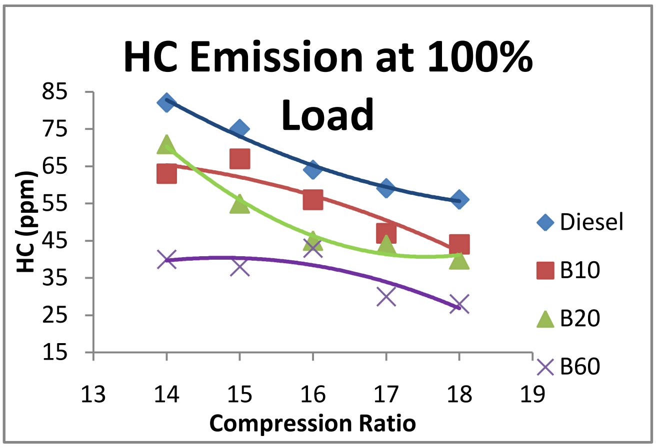


**Fig -3:** Comparison of variation of HC with CR at 100% Load

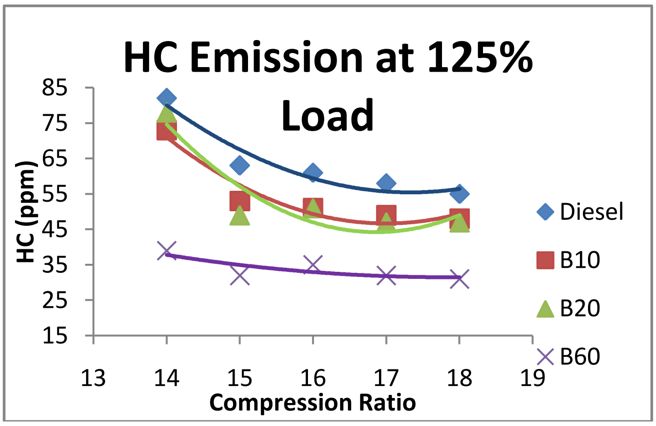


**Fig -4**: Comparison of variation of HC with CR at 125% Load

### 3.1.2 CO Emissions

Figure 5 and 6 represents the comparison of variation of CO with CR for Jatropha biodiesel and its blends with Diesel at 100% and 125% load.

It can be observed that CO emission decreases with increase in CR. The trend may be due to better combustion of fuel at higher CR which in turn is due to high air temperature inside the cylinder. It can also be observed that at low CRs, CO emissions are higher and at higher CRs, it is lesser for blends compared to Diesel. The lower CO emissions for blends may be due to the oxygenated nature of Jatropha biodiesel due to which more of carbon gets oxygenated forming CO. The higher CO emissions for the blends at low CR may be due to higher viscosity of biodiesel which leads to poor atomization and incomplete combustion.

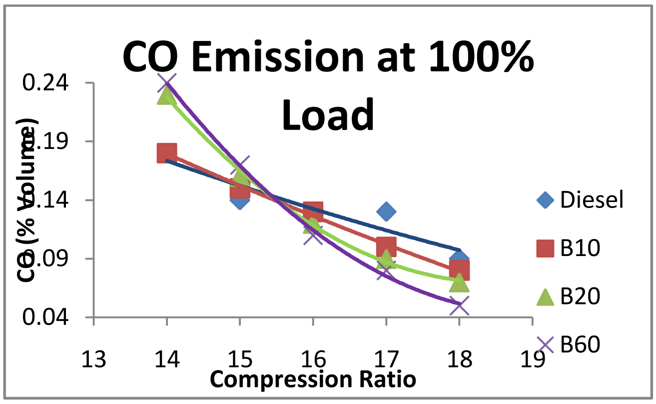


**Fig -5:** Comparison of variation of CO with CR at 100% Load

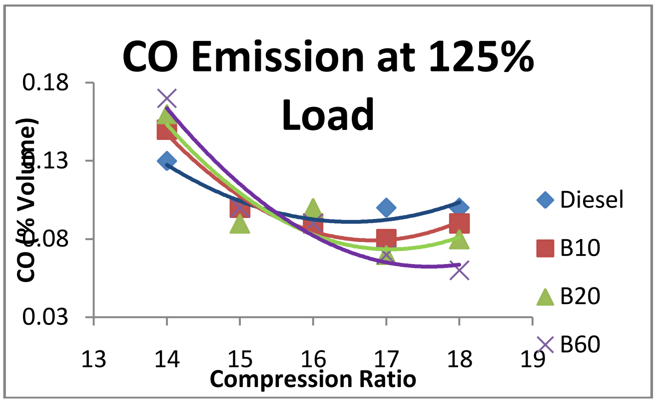


**Fig -6:** Comparison of variation of CO with CR at 125% Load

The mean percentage decrease in CO emission with Jatropha biodiesel as compared to Diesel is of the order of 8% to the 50% from B5to B80 respectively.

### 3.1.3 $CO_2$ Emissions

Figure 7 and 8 represents the comparison of variation of $CO_2$ with CR for Jatropha biodiesel and its blends with Diesel at 100% and 125% load. It can be observed that $CO_2$ emission decreases with increase in CR.

It is observed from the figure that $CO_2$ emission initially decrease, reach the lowest and subsequently increase with the increase in CR for all the fuels tested. It is also observed that $CO_2$ emission is higher for Diesel compared to Jatropha biodiesel at all CRs. The trend may be due to complete oxidation of car bon present in the biodiesel due to its inherent oxygen content. It can be noted that the percentage decrease in CO2 emissions between Jatropha biodiesel and Diesel over the range of CRs is 22%.

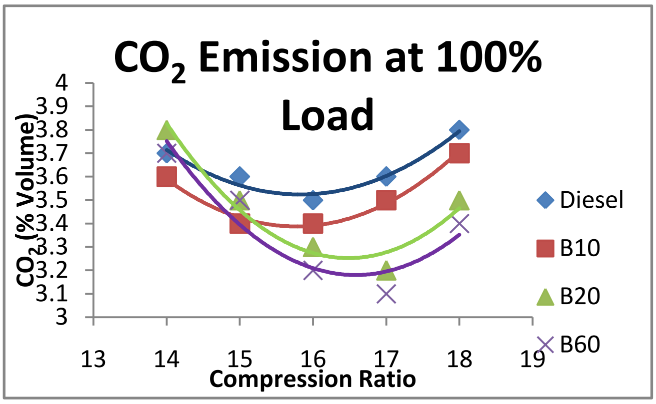


**Fig -7:** Comparison of variation of $CO_2$ with CR at 100% Load

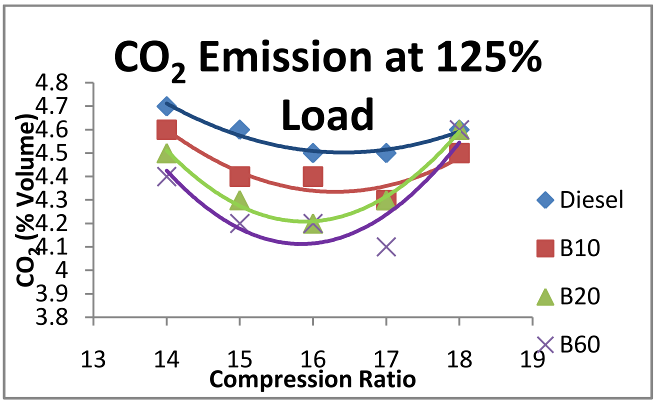


**Fig -8:** Comparison of variation of CO with CR at 125% Load

### 3.1.4 $NO_x$ Emissions

It can be observed from the figure that $NO_x$ emissions increases for blends while it decreases for Diesel oil with increase in CR. The trend observed for blends is because at lower CR, less oxygen is available from blends to form $NO_x$ due to less heat of compressed air, but at higher CR greater availability of oxygen and higher heat of compressed air initiates early combustion ensuring complete oxidation of fuel.

The mean percentage increase in $NO_x$ emission with Jatropha biodiesel as compared to Diesel is of the order of 2% to the 10% from B5 to B80 respectively.

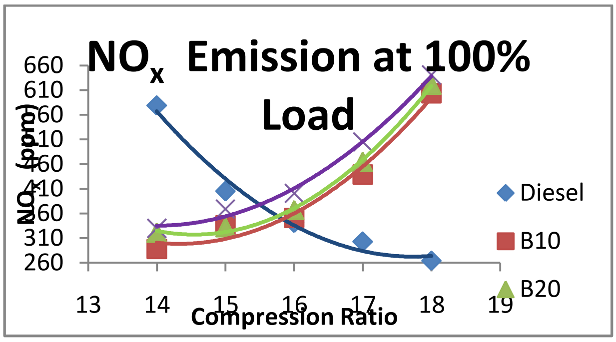


**Fig -9:** Comparison of variation of $NO_X$ with CR at 100% Load

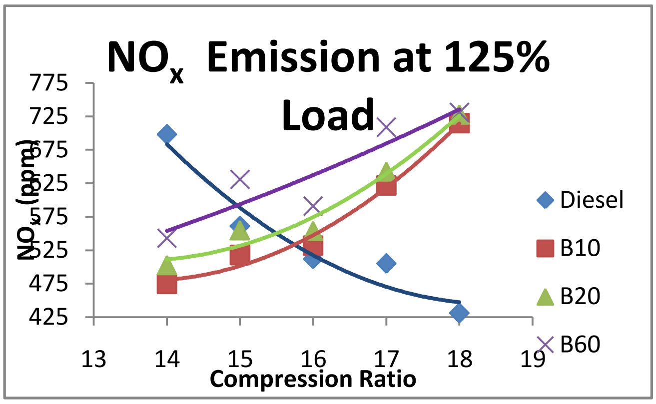


**Fig -10:** Comparison of variation of $NO_X$ with CR at 125% Load

## 3.2 Variable Load

The variations of exhaust emission constituents at different loads from 0% to 125% at a constant CR of 18 are presented in figures 11 to 14.

### 3.2.1 HC Emissions

It can be observed that HC emissions increase with increase in load for all the fuels tested. The increase is steeper at higher loads than at lower loads. The steeper increase at higher loads may be due to the rich fuel air mixture as compared to Stiochometric which leads to improper burning thereby resulting in increase of HC content in the exhaust.It can be observed that HC emissions decrease with increase in blend proportion at a constant load. The trend can be attributed to the higher oxygen content of Jatropha biodiesel due to which complete combustion takes place inside the cylinder. HC emissions increase by 30% to 85% for all blends when load is increased from 0% to 125%. With the increase in blend ratio, up to 67% of reduction is observed in HC emissions for all the loads under consideration.

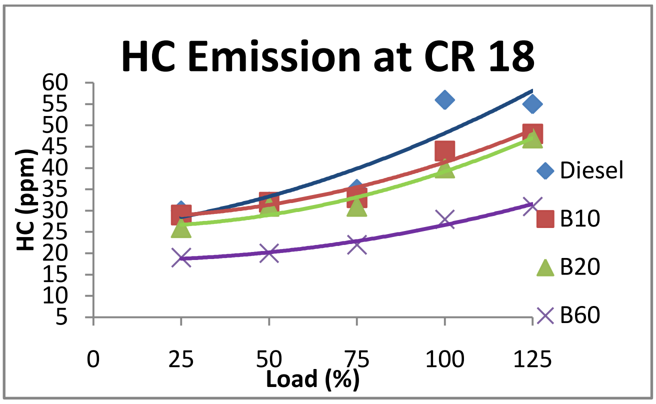


**Fig -11:** Comparison of HC Emissions CR 18

### 3.2.2 CO Emissions

It is observed that CO emissions increase with the increase in load. The trend can be attributed to more fuel being consumed at higher loads which means rich running of the engine and there being insufficient oxygen to convert all the carbon in the fuel to carbon dioxide. It is a well-known fact that the formation of CO as an emission constituent in the exhaust gases is mainly due to incomplete oxidation of carbon constituent in the fuel.

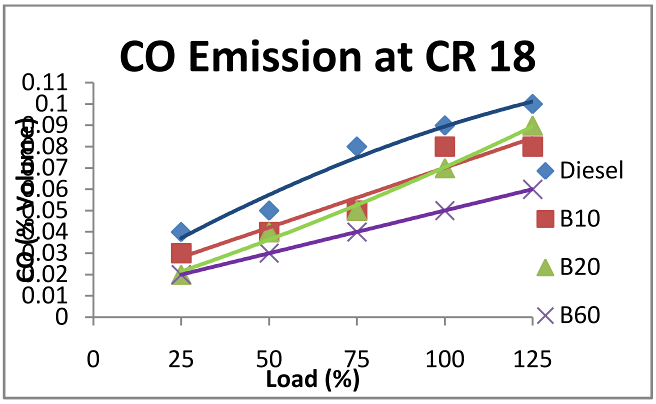


**Fig -12:** Comparison of CO Emissions at CR 18

The increase in blend proportion reduces CO emissions because oxygen promotes complete combustion. It is found that the CO emissions increase up to about 175% from no load to full load condition for all the fuels tested. At full load of 12kg, it is seen that there is a 56% reduction in CO emissions when Jatropha biodiesel is used as compared to Diesel oil.

### 3.2.3 $CO_2$ Emissions

It can be observed that $CO_2$ increases with the increase in load for all fuels tested. The trend observed may be because of more fuel being burnt at higher loads due to which more carbon is available to form $CO_2$.

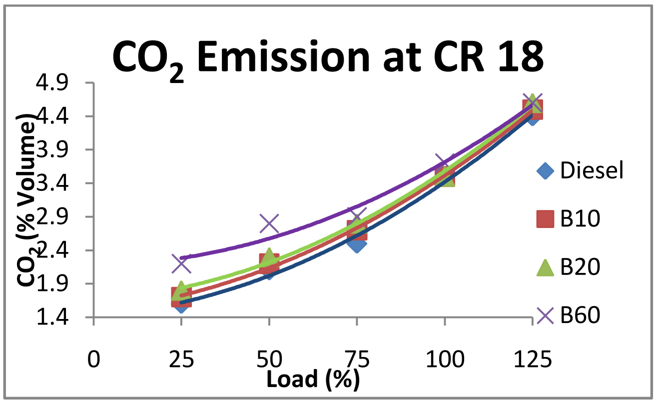


**Fig -13:** Comparison of $CO_2$ Emissions at CR 18

It can also be observed that $CO_2$ emissions are marginally more for Jatropha biodiesel than Diesel oil and it reduces with reduction in blend proportion. The reduction in $CO_2$ emission is because of high oxygen content in the biodiesel due to which more of the carbon gets oxygenated during combustion inside the cylinder which results in higher $CO_2$ emission. The percentage increase in $CO_2$ emissions is about 8.5% for Jatropha biodiesel as compared to Diesel oil at full load of 100%. $CO_2$ emissions increase by 100% to 180% for all blends when load is increased from 0% to 125%.

### 3.2.4 $NO_x$ Emissions

It can be observed from the figure that $NO_x$ emissions increase with increase in load. The trend can be attributed to more temperature with diesel as fuel and higher temperature and inherent oxygen content with biodiesel and its blends.

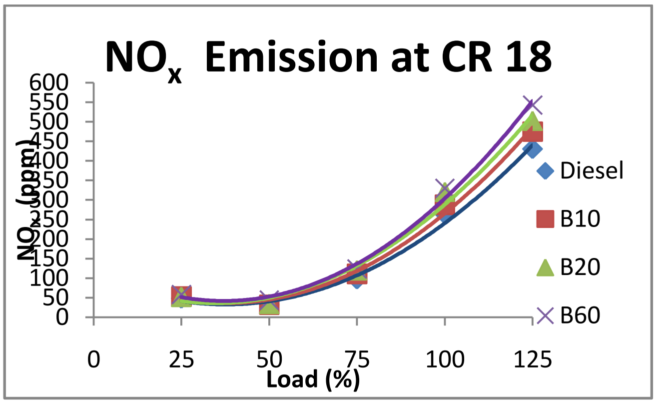


**Fig -14:** Comparison of $NO_X$ Emissions at CR 18

It can be observed that the $NO_X$ emissions are higher for biodiesel blends. The reason for higher $NO_X$ is higher oxygen content of Jatropha biodiesel than Diesel oil. During combustion process of blends, more oxygen is available from fuel and nitrogen from air readily gets combined with oxygen at higher cylinder temperatures and forms compounds like nitrogen dioxide ($NO_2$) and nitric oxide (NO) which constitute NO. The $NO_x$ emissions for Jatropha biodiesel are 30.68% higher than that of diesel at full load 100%.

## 4. CONCLUSIONS

The experimental study is conducted on four strokes, variable compression ratio diesel engine using Jatropha biodiesel blends with diesel. The emission analysis is evaluated by running the engine at different combination of preset CRs and varying load. The emission constituents measured are HC, CO, $CO_2$ and $NO_x$. Based on the experimental studies, following are the important observations made and conclusion drawn thereon.

From the large number of experimental data for emission constituents obtained for various input parameters such as load, CR and blend, picking up an optimum combination of the input parameters manually is not possible. The effect of blend proportion, load and CR create multi-objective scenario. Therefore, there is a need to find optimum conditions considering emission constituents. Genetic Algorithm (GA) is one optimization technique that can help to tackle the multi-objective scenario.

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## BIOGRAPHIES

**Rupesh Laldas Raut**, M Tech (Thermal Engineering) Student, Department of Mechanical Engg, Walchand College of Engineering, Sangli, Maharashtra, India, *rupeshraut992@gmail.com*



**Babaso Naik**,Assistant Professor, Department of Mechanical Engg, Walchand College of Engineering, Sangli, Maharashtra, India, *babasonk@gmail.com*

**Shekhar Dinkar Thakre**, M Tech (Thermal Engineering) Student, Department of Mechanical Engg, Walchand College of Engineering, Sangli, Maharashtra, India, *shekhar10thakre@gmail.com*

**Amol Annasaheb Gawali**, M Tech (Thermal Engineering) Student, Department of Mechanical Engg, Walchand College of Engineering, Sangli, Maharashtra, India, *gawaliamol7@gmail.com*