EXPERIMENTAL STUDIES ON A VCR DIESEL ENGINE USING BLENDS OF DIESEL FUEL WITH JULIFLORA BIO-DIESEL AND CERIUM OXIDE NANO ADDITIVE

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ABSTRACT
Increasing fuel prices and depleting fossil fuel resources in recent years drawn attention towards the use of alternative fuels for diesel engines. The use of vegetable oil is popular, economic and implementable source among the various fuel alternatives. As the petroleum reserves are depleting at a faster rate due to the growth of population and more energy needs, leads to serious search for renewable alternative fuels. A single cylinder computerized variable compression ratio engine was operated successfully using Juliflora bio-diesel and its blends of Juliflora oil methyl ester and Cerium oxide nano additive. The following conclusions are made based on experimental results.
Engine works smoothly on Juliflora oil with performance comparable to neat diesel operation. Mechanical efficiency of the engine is more for the B10 blend of Juliflora oil with neat diesel at all loads. The brake thermal efficiency of the engine with Juliflora methyl ester-diesel blend was marginally better than that with neat diesel fuel. For 17.5:1 compression ratio with B10, a better mechanical efficiency, brake thermal efficiency is observed when compared to diesel and other blends and brake specific fuel consumption for B10 was less. For 19:1 compression ratio with B30, better mechanical efficiency, brake thermal efficiency is observed when compared to diesel and other blends and brake specific fuel consumption for B30 was less. Hence it is concluded that the VCR Diesel engine works efficiently by giving lowest emission values of CO, CO_2 and HC for Juliflora biodiesel blend B10 with cerium oxide as nano-additive at both the compression ratios 17.5:1 and 19:1.
Keywords: VCR engine, Emissions, Combustion, Juliflora bio-diesel, Cerium Oxide Nano additive and Neat diesel

I. Introduction
Fast depletion of the fossil fuels, increasing threat to the environment from exhaust emissions and global warming have generated intense interest in developing alternate fuels for engines all over the world. In the context of fast depletion of fossil fuels and increasing of diesel engine vehicle population, the use of renewable fuels like vegetable oils becomes more important. Among all petroleum based fuels, diesel oil used in a diesel engine that dominates the field of commercial transportation and agricultural machinery due to its ease of operation and higher efficiency. The consumption of diesel oil is several times higher than that of petrol. The increasing number of auto mobiles has lead to increase in demand of fossil fuels. The import bill is directly in proportionate with increasing cost of petroleum and hence a concern for developing countries. Energy security and environmental protection are important. Limited life of Fossil fuels and their ever increasing cost led to the search of renewable fuels for various sectors like transportation, agriculture and industries are using diesel fuel as a major source of power. With ever-in- creasing population, the usage of automobiles also increased, which leads to the consumption of higher amount of fossil fuels. Bio-diesel is a cleaner burning replacement fuel for diesel available from natural sources such as virgin and used vegetable oil, algae and animal fats.Bio-diesel emerges as one of the most energy-efficient environmentally friendly options in recent times to full fill the future energy needs. During the last 15 years, bio-diesel has progressed from the research stage to a large scale production in many

developing countries. In Indian context, non-edible oils are emerging as a preferred feedstock and several field trials have also been made for the production of bio-diesel.The present work studies the results of application of a Juliflora bio- diesel on a practical heavy-duty VCR diesel engine, with the aim of knowing their impact on exhaust emissions and performance. The goal of this experimental study is to analyze the new fuel contributions to potential performance and efficiency loss. An attempt is made to assess the combustion and performance phenomenon of Juliflora bio-diesel fuel. An investigation covering the performance, emissions is dealt with to evaluate the engine under various fuel blend implementations.

II. Literature

Arul, V. et.al[1] carried out an experimental investigation to establish the performance and emission characteristics of a compression ignition engine while using cerium oxide nanoparticles as additive in neat diesel and diesel-biodiesel-ethanol blends. In the first phase of the experiments, stability of neat diesel and diesel-biodiesel-ethanol fuel blends with the addition of cerium oxide nanoparticles are analyzed. After series of experiments, it is found that the blends subjected to high speed blending followed by ultrasonic bath stabilization improves the stability. The tests revealed that cerium oxide nanoparticles can be used as additive in diesel and diesel-biodiesel- ethanol blend to improve complete combustion of the fuel and reduce the exhaust emissions significantly.

Sathasivam et.al[2] investigated the nanocatalyst having cerium oxide on multiwall carbon a nanotube using biodiesel blends at two concentrations (50 and 100 ppm).The results revealed that the high surface area of the nanoparticles and their proper distribution along with catalytic oxidation reaction resulted in significant overall reductions in the emission. More specifically, all pollutants, i.e., CO, HC, and NOx, and smoke opacity were reduced when compared to B20.

P Tamil Selvan et.al [3]research work indicates the results of analysis conducted to investigate the performance, exhaust emission and combustion characteristics of a VCR diesel engine fuelled with non-edible biodiesel at a rated speed of 1500 rpm with 300 bar injection pressure at three compression ratios. The test fuel was derived from Prosopis Juliflora seed oil methyl ester blends15% (B15) and 25% (B25) by volume. Biodiesel was produced by the transesterï¬cation process using methanol along with KOH as catalyst. The combustion characteristics investigated were rise in cylinder pressures, net heat release rate, cumulative heat release rate and mass fraction of fuel burned at all loads using three compression ratios. The emission and performance study was also conducted. The lower heat release rates, increased cylinder pressures were observed for both the blends compared to diesel. Increased brake thermal efficiency observed at higher compression ratio for B25 blend. It has also been observed that the emissions were decrease in trend with increase in compression ratios.

Arockiasamy, P et.al[4] studied the effect of nanoparticle as additive in Jatropha biodiesel and is experimentally investigated in a single cylinder DI diesel engine with the aim of diluting the level of pollutants in the exhaust and for the improvement of engine performance owing to its potential advantage of high surface area to volume ratio, acting as a catalyst for the better combustion. Alumina and Cerium oxide nanoparticles are blended separately with Jatropha biodiesel at 30 parts per million and the engine performance, combustion and emission characteristics are compared with neat diesel and neat biodiesel as base fuels. For alumina blended test fuel, percentage reduction of NOx emission by 9 %, Smoke opacity by 17 %, unburned hydrocarbon by 33 % and carbon monoxide by 20 % are observed along with percentage reduction of NOx emission by 7 %, Smoke opacity by 20 %, unburned hydrocarbon by 28 % and carbon monoxide by 20 % for cerium oxide blended test fuel. 5 % improvement in brake thermal efficiency is observed for both the test fuels, due to its high surface area to volume ratio of nanoparticle promoting better combustion by improved atomization, better mixing of air-mixture and rapid evaporation of the fuel

Rajpoot, A.S et.al [5]study uses a novel binary mixture of Prosopis Juliflora biodiesel (PJB) and 200 ppm of metal-based nanoparticles [cerium oxide (CeO_2), manganese dioxide (MnO_2), and titanium dioxide (TiO_2)], to operate and examine the behaviour of a four-stroke, one-cylinder, naturally aspirated, water-cooled diesel engine.. The adoption of nanoparticle-enhanced biodiesel is not only a promising alternative in the search for cleaner but also more effective energy sources. This study suggests more investigation and development in the areas of alternative fuels, engine optimization, and the development of sustainable energy solutions.

Rajendra Pawar et'al [6]research paper focuses on investigating the performance, combustion, emission, and vibration characteristics of diesel engine fuelled with rice bran biodiesel and n-butanol additive (5% constant) at CR 17.5. The engine characteristics of seven biodiesel blends (B5n5, B10n5, B15n5, B20n5, B25n5, B30n5, and B40n5) were measured at various loads under constant speed and compared with diesel fuel. The performance characteristics were observed in moderate quantities as compared to diesel whereas the emissions were found reduced drastically than diesel fuel except for nitrogen oxide (NOx) emissions. The measured engine cylinder vibration for all blends indicates similar results as diesel fuel hence leading to smooth combustion. The investigation shows that blends from B20n5 to B30n5 have the potential to be used in a diesel engine without any modification

Nagarhalli M. V. et al., [7] have tested KOME and found that HC emission decrease by 12.8% for B20 and 3% for B40 at full load. NOx decreased by 39% for B20 and 20% for B40 at full load. BSFC increased by 7% for B20 and 1.9 % for B40 at full load. A B40 blend has been recommended by the author.

H. Raheman et al.,[8] Emissions and Performance of Diesel Engine from Blends of Karaja Oil Methyl Ester(KOME) and Diesel have used for test. They found the average BSFC was 3% lower than diesel in case of B20 and B40. Maximum BTE was found to be 26.79% for B20 which is 12% higher than diesel. They concluded that B40 could replace diesel.

Sivakumar et al. 2010 [9] in their study titled " Performance and Emission characteristics of a 4 stroke CI engine operated on Honge methyl ester using artificial neural network" bio-diesel was prepared from Honge oil (Pongamia) and used as a fuel in C.I engine. An improvement in BTE was observed for higher compression ratios. Brake specific energy consumption for bio-diesel blends is more than that of diesel and decreases for higher compression ratios.

Exhaust emissions Smoke, CO, HC were reduced for Diesel-bio-diesel blends when compared with diesel values for all compression ratios and higher compression ratios have the advantage further reduction in those emissions.

Gaurav Dwivedi et.al [10]In this study "Performance Evaluation of Diesel Engine Using Bio-diesel from Pongamia Oil" focused on the work done in the area of production of bio-diesel from Pongamia and the characterization of properties of various blends of Pongamia bio-diesel. The work also includes the impact analysis of Pongamia oil and its bio-diesel on engine performance and exhaust emission.

S. K. Acharya et al [11], Investigated the effect of preheated Juliflora and kusum oil on its emission characteristics. Emission characteristics were evaluated by preheating of Juliflora and kusum oil in a shell and tube type heat exchanger. This study was carried out on a single cylinder, four strokes, water cooled engine with constant compression ratio (16.5:1) and 1500 rpm. The emission components such as carbon monoxide (CO), hydrocarbon (HC), carbon dioxide (CO_2) were increased with increase the engine load and oxide of nitrogen (NOx).

Nobukazu Takagi et al [12] conducted experiments on a single cylinder Direct Injection diesel engine with palm oil, rapeseed oil and the blends of palm oil and rapeseed oil with ethanol and diesel fuel at different fuel temperatures. They found that the performance and engine exhaust emission levels were in the acceptable limits for the vegetable oils and their blends. When compared with diesel, the methyl esters of rapeseed oil and palm oil offered lower smoke and lower NOX emission, and engine noise and higher thermal efficiency.

III. Experimentation

3.1 Experimental Setup

"Direct Injection, VCR Diesel engine is utilized for the experimentation. Experimentation is carried out at various engine loads (Engine Loading device is eddy current dynamometer) to record the cylinder pressure and finally to compute heat release rates with respect to the crank-angle. Engine performance data is acquired to study the performance and engine pollution parameters.
The exhaust gas analysis of different components of exhaust gas are measured and compared and engine performance is analyzed for the parameters mentioned above with the implementation of blends of neat diesel with Juliflora bio- diesel at different compression ratios. The engine setup is shown in Figure.1 and 1a.

Figure1: Computerized VCR Engine Test Rig

Figure1a : Dynamometer

Table 1, Specification of the Di-Diesel Engine

No of cylinders	1
No of strokes	4
Cylinder diameter	87.5mm
Stroke length	110mm
Connecting rod length	234mm
Orifice diameter	20mm
Dynamometer arm length	185mm
Power	3.5kw
Speed	1500RPM
CR range	12:1 to 18:1
Injection point variation	0 to 25^0 BTDC
Compression ratio	17.5:1 and 19:1

This experimental investigation were carried out on a Kirloskar made VCR engine. It was connected with the control panel unit which consist rotameter, water temperature indicator, loading switch, speed indicator and fuel flow transmitter etc. The engine performance and combustion parameters such as brake power (BP), brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), mechanical efficiency (MEFF), heat balance, cylinder pressure and heat release rate were determined by engine performance analysis software.

3.2 Multi Gas Analyzer

A multi gas analyser is a device that detects the presence of gases in an area, often as part of a safety system. This type of equipment is used to detect a gas leak or other emissions and can interface with a control system so a process can be automatically shut down. It can also be used to detect combustible, flammable and toxic gases, and oxygen depletion. The gas analyser measures the

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exhaust emissions such as Carbon Monoxide (CO), Carbon Dioxide (CO_2), Hydro Carbon (HC), Oxygen (O_2) by means of Non-Dispersive infrared (NDIR) measurement

Figure.2: Multi Gas Analyzer

3.3 Transesterification Process

Transesterification of natural glycerides with methanol to methyl esters is a technically important reaction that has been used extensively in the soap and detergent manufacturing industry worldwide for many years. The transesterification process is the reaction of a triglyceride with an alcohol to form esters and glycerol. During the transesterification process, the triglyceride is reacted with alcohol in the presence of a catalyst, usually a strong alkaline like sodium hydroxide. The alcohol reacts with the fatty acids to form the mono-alkyl ester, or bio-diesel, and crude glycerol.

1. Production of Juliflora oil Methyl ester

Juliflora oil is a bio-diesel produced by using raw Juliflora seed oil. Due to high content of FFA of Juliflora oil, the objective has been achieved in two steps namely (i) acid esterification, (ii) alkaline esterification.

2. Acid esterification

The acid esterification was carried out at 4:1-6:1 molar ratio with varied H_2SO_4 (0.5- 2.0%) at 50-60°C and 60-90 min reaction time. Preheated oil, methanol and acid H_2SO_4 were mixed together as per desired proportion and stirred at 200 rpm. After completing the acid esterification reaction, treated was taken into beaker (Figure. 3 (a)) and heated up to 60°C.

3. Alkaline esterification

After acid treatment, 50 g oil was taken in a 250 ml flask and preheated up to 100°C to eliminate dissolved moisture content in the Juliflora oil. The required amount of methanol (4:1, 6:1, 8:1) was mixed with distinct percentage of KOH catalyst concentration (0.5, 1.0, and 1.5). This homogeneous mixture of methanol and catalyst KOH was mixed with the Juliflora oil and stirred with 200 rpm at varied reaction temperature 50-60°C. The reaction was stopped after 60, 75 and 90 min. After completion of trans esterification reaction, Juliflora oil methyl ester was separated from glycerol by separating funnel (Figure.(3b)) and then the separated methyl ester was washed with hot distilled water. At last bio-diesel was heated in the hot air oven to remove excess water content, and collected in jar as shown in the Figure 3(c).

Figure 3a: Acid Estirification

Figure3b: Alkaline Esterification

Figure 3c: Juliflora Biodiesel

3.4 Cerium Oxide Nanopartcle as Additive

The use of nano-particles as additives to diesel fuel is a promising method for improving the efficiency and improving the exhaust emissions of a CI engine. The cerium oxide acts as an oxygen donating catalyst and provides oxygen for the oxidation of CO or absorbs oxygen for the reduction of N0x. The activation energy of cerium oxide acts to burn off carbon deposits within the engine cylinder at the wall temperature and prevents the deposition of non-polar compounds on the cylinder wall results reduction in HC emissions as shown in Figure 4..

Figure 4: Cerium Oxide Nanoparticle

An experimental investigation is carried out to establish the performance characteristics of a compression ignition engine while using cerium oxide nano-particles as additive in neat diesel and diesel-biodiesel blends.In the first phase of the experiments, stability of neat diesel and diesel-biodiesel fuel blends with the addition of cerium oxide nano-particles is analyzed. After series of experiments, it is found that the blends subjected to high speed blending followed by ultrasonic bath stabilization improves the stability.

In the second phase, performance characteristics are studied using the stable fuel blends in a single cylinder four stroke engine coupled with an electrical dynamometer and a data acquisition system.The cerium oxide acts as an oxygen donating catalyst and provides oxygen for combustion. The activation energy of cerium oxide acts to burn off carbon deposits within the engine cylinder at the wall temperature and prevents the deposition of non-polar compounds on the cylinder wall results reduction in HC emissions. The tests revealed that cerium oxide nanoparticles can be used as additive in diesel and diesel-biodiesel blends to improve complete combustion of the fuel significantly. However thermal efficiencies are higher for neat diesel than the fuel mixed with nano-particle. There is a significant improvement in the exhaust emissions while using diesel mixed with cerium oxide nano-particle.

3.5.Ultraprobe Sonicator

Sonication is the act of applying sound energy to agitate particles in a sample, for various purposes such as the extraction of multiple compounds from plants, microalgae and seaweeds. Ultrasonic frequencies (>20 KHz) are usually used, leading to the process also being known as ultrasonication or ultra-sonication. Sonication is commonly used in nanotechnology for evenly dispersing

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nanoparticles in liquids. Additionally, it is used to break up aggregates of micron-sized colloidal particles as shown in Figure 5.

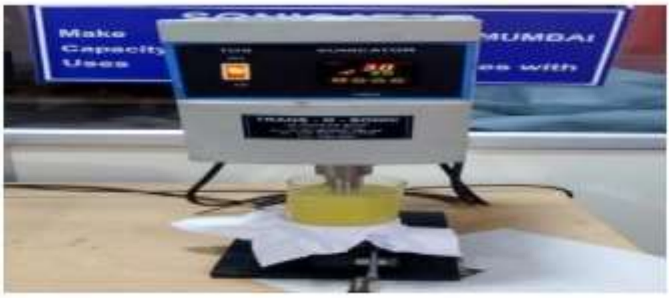

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Figure 5: Ultra Probe Sonicator

3.5 Experimental Procedure

The experimentation is conducted on a single cylinder direct injection VCR diesel engine operated at normal room temperatures of 28^0C to 33^0C.

IV Results and Discussions

4.1 Mode of Experimentation

Series of exhaustive engine tests were carried out on a compression ignition diesel engine using diesel and Juliflora oil biodiesel blends several blends of varying concentration of Juliflora oil methyl ester (biodiesel) with diesel were prepared as follows:

➢ B10 : This is the blend containing 10% bio-diesel and 90% neat bio-diesel

➢ B30 : This is the blend containing 30% bio-diesel and 70% neat bio-diesel Performance and emission tests were conducted under different loading condition on these various diesel biodiesel blends. The optimum blend was found out from the graphs based on the maximum thermal efficiency, minimum brake specific energy consumption and safe emission at all loads.

4.2 Calorific Values For Diesel and Biodiesel Blends

Net C.V Diesel (Calorific value of diesel) = 42,500 kJ/kg
Net C.V B10 (Calorific value of B10) = 42,250 kJ/kg
Net C.V B30 (Calorific value of B30) = 41,015 kJ/kg
The series of exhaustive engine tests were carried out on a compression ignition diesel engine using diesel and Juliflora oil bio-diesel blends. Several blends of varying concentration of Juliflora oil methyl ester (bio-diesel) with diesel were prepared as follows:

4.3 Performance Analysis

Brake power, fuel consumption, brake specific fuel consumption (B.S.F.C), Brake thermal efficiency , Indicated thermal efficiency for both diesel and Juliflora biodiesel blended with nano additive are calculated at different loads using model calculation and are tabulated below. The comparison graphs for diesel and biodiesel blends.

4.3.1 For Compression Ratio 17.5:1 at B10

4.3.1.1 IP,BP&FP

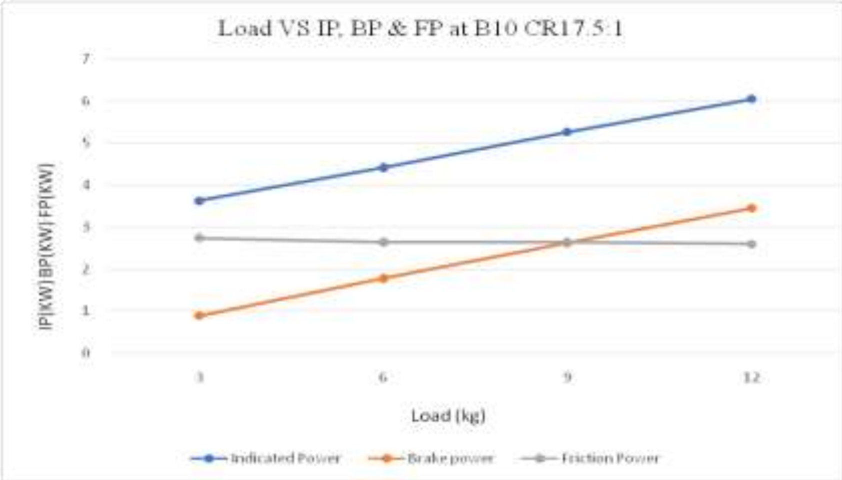

Figure 6: Load Vs IP, BP, FP

The maximum indicated power of the engine was 6.05 for Juliflora bio diesel at 12.01kg load.
The maximum break power of the engine was 3.45 for Juliflora bio diesel at 12.01kg load.
The maximum friction power of the engine was 2.60 for Juliflora bio-diesel at 12.01 kg load.

4.3.1.2 IMEP,BMEP&FMEP

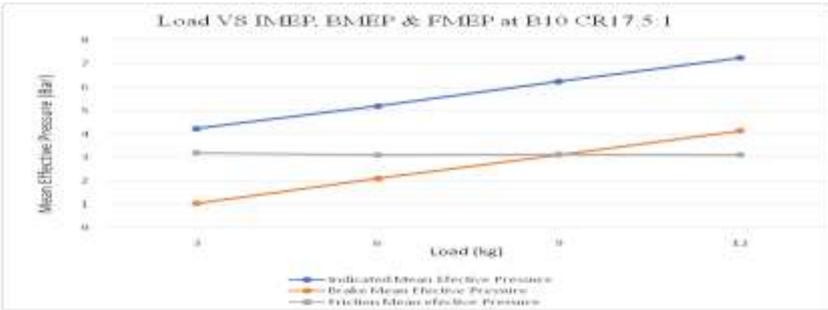

Figure 7: Load Vs IMEP,BMEP,FMEP

The indicated mean effective pressure of the engine was 7.26 for Juliflora bio-diesel at 12.01 kg load.
The Break mean effective pressure of the engine was 4.14 for Juliflora bio-diesel at 12.01 kg load.
The Fraction mean effective pressure of the engine was 3.12 for Juliflora bio-diesel at 12.01 kg load.

4.3.1.3 Air & fuel flow

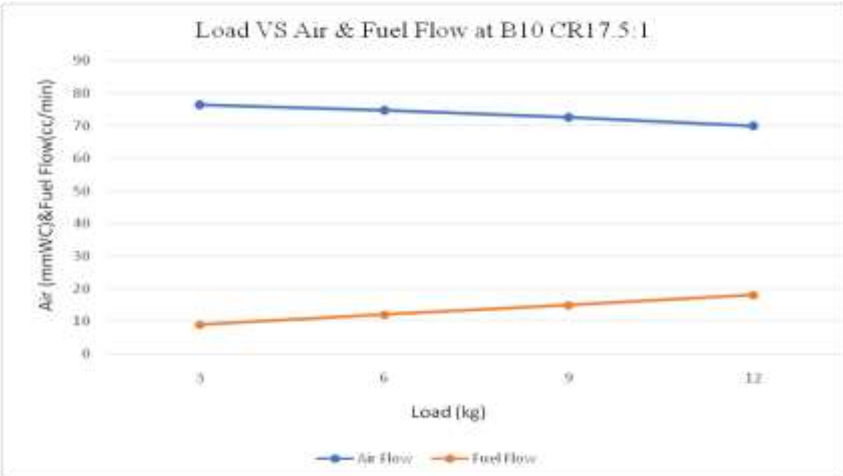

Figure 8: Load VS Air Flow &Fuel Flow

The Air flow of the engine was 78.61mmwc for Juliflora bio-diesel at 0.02 kg load.
The Fuel flow of the engine was 18.00cc/min for Juliflora bio-diesel at 12.01 kg load.

4.3.1.4 Indicated & Brake Thermal Efficiency

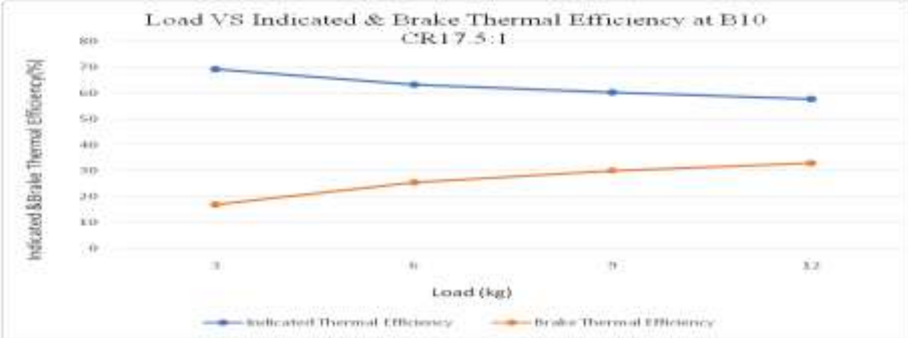

Figure 9: Load Vs ITE & BTE

The Indicated Thermal Efficiency of the engine was 69.31% for Juliflora bio-diesel at 3.01 kg load.
The Brake Thermal Efficiency of the engine was 32.96% for Juliflora bio-diesel at 12.01 kg load.

4.3.1.5 SFC & Fuel Consumption

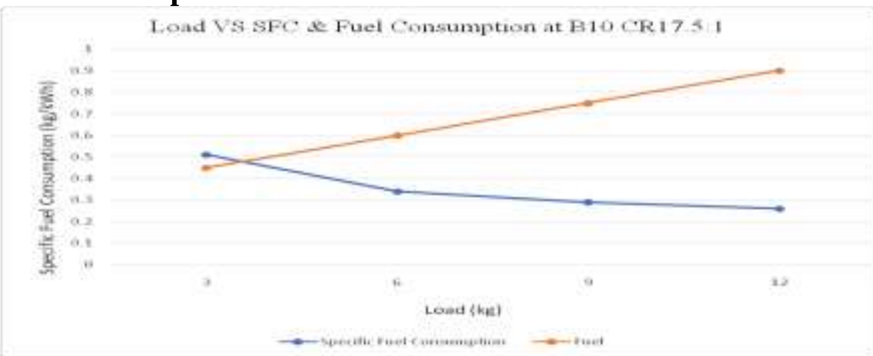

Figure 10: Load Vs SFC & Fuel Consumption

The Specific Fuel Consumption of the engine was 0.52kg/kwh for Juliflora bio-diesel at 0.02 kg load.
The 0.90 Fuel Consumption of the engine was 0.52kg/h for Juliflora bio-diesel at 12.01 kg load.

4.3.1.6 Torque, Mechanical& Volumetric Efficiency

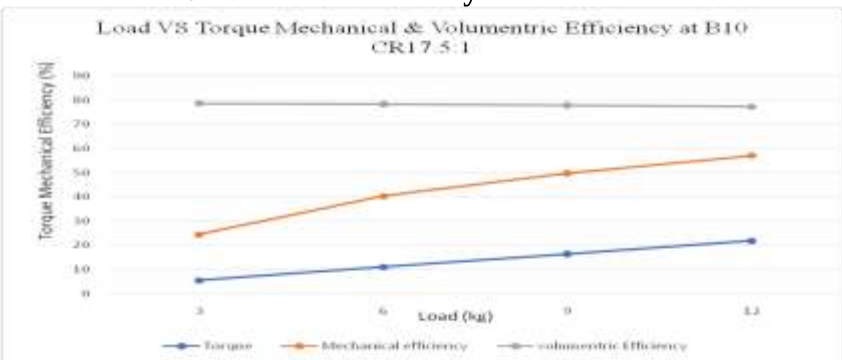

Figure 11: Load Vs Torque, Mechanical & Volumetric efficiency

➢ The Torque of the engine was 21.80nm for Juliflora bio-diesel at 12.01 kg load.
The Mechanical Efficiency of the engine was 57.04% for Juliflora bio-diesel at 12.01 kg load.
The Volumetric efficiencyof the engine was78.80% for Juliflora bio-diesel at 0.02 kg load.

4.3.2 For Compression Ratio 17.5:1 at B30

4.3.2.1 IP,BP&FP

Figure 12: Load Vs IP,BP,FP

The maximum indicated power of the engine was 5.82kw for Juliflora bio diesel at 12.02 kg load.
The maximum break power of the engine was 3.45 for Juliflora bio diesel at 12.02kg load
The maximum friction power of the engine was 2.49kw for Juliflora bio-diesel at 3.01 kg load.

4.3.2.2 IMEP,BMEP&FMEP

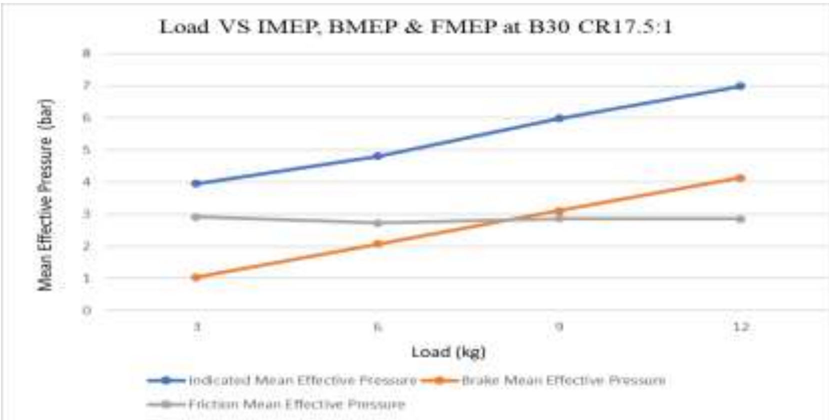

Figure 13: Load Vs IMEP,BMEP,FMEP

The indicated mean effective pressure of the engine was 6.99 bar for Juliflora bio-diesel at 12.01 kg load.

The Break mean effective pressure of the engine was 4.14bar for Juliflora bio-diesel at 12.02 kg load.

The Fraction mean effective pressure of the engine was 2.92bar for Juliflora bio-diesel at 3.01 kg load.

4.3.2.3 Air& Fuel flow

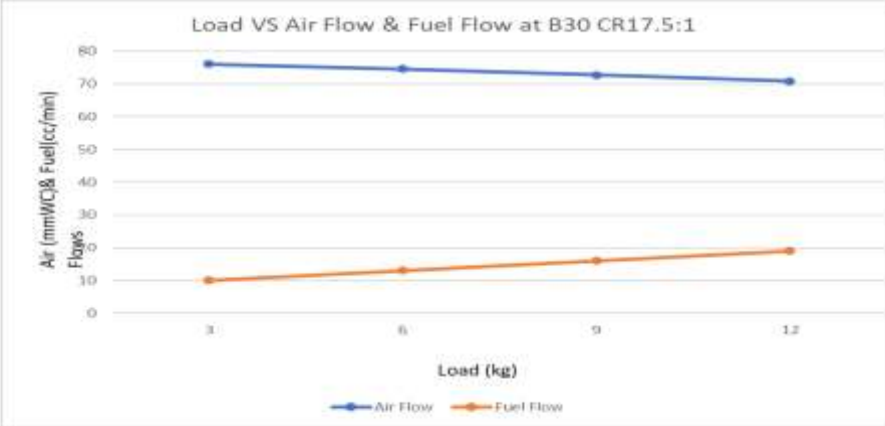

Figure 14: Load Vs Air Flow & Fuel Flow

The Air flow of the engine was 78.05mmwc for Juliflora bio-diesel at 0.03 kg load.
The Fuel flow of the engine was 19.00cc/min for Juliflora bio-diesel at 12.02 kg load.

4.3.2.4 Indicated &Brake Thermal Efficiency

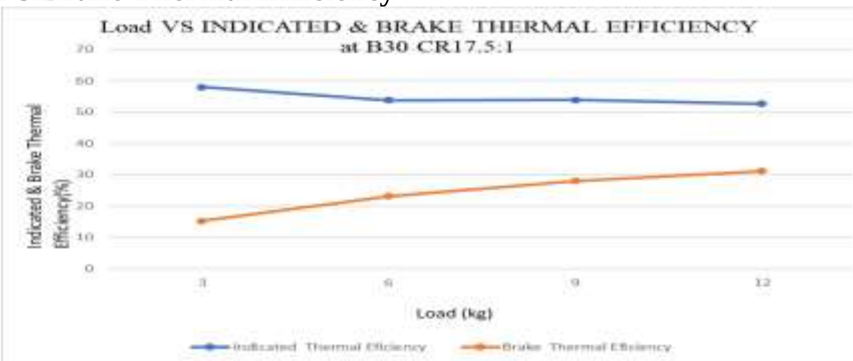

Figure 15: Load Vs ITE& BTE

The Indicated Thermal Efficiency of the engine was 68.71% for Juliflora bio-diesel at 0.03 kg load.
The Brake Thermal Efficiency of the engine was 31.24 %for Juliflora bio-diesel at 12.02 kg load.

4.3.2.5 SFC & Fuel Consumption

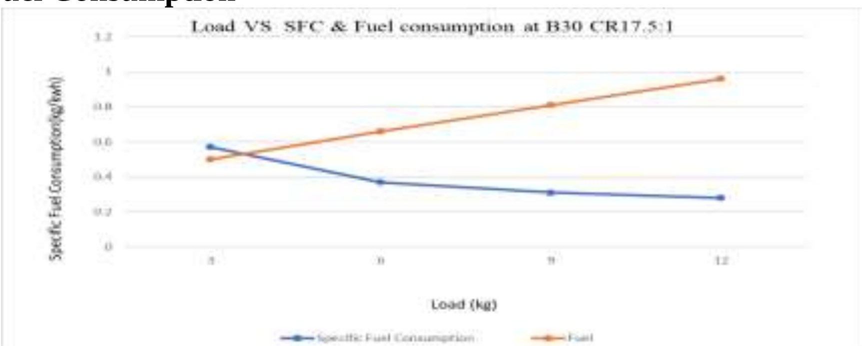

Figure 16: Load Vs SFC Fuel Consumption

The Specific Fuel Consumption of the engine was 31.77 kg/kwh for Juliflora bio-diesel at 0.03 kg load.
The Fuel Consumption of the engine was 0.96 kg/h for Juliflora bio-diesel at 12.02 kg load.

4.3.2.6 Torque, Mechanical & Volumetric Efficiency

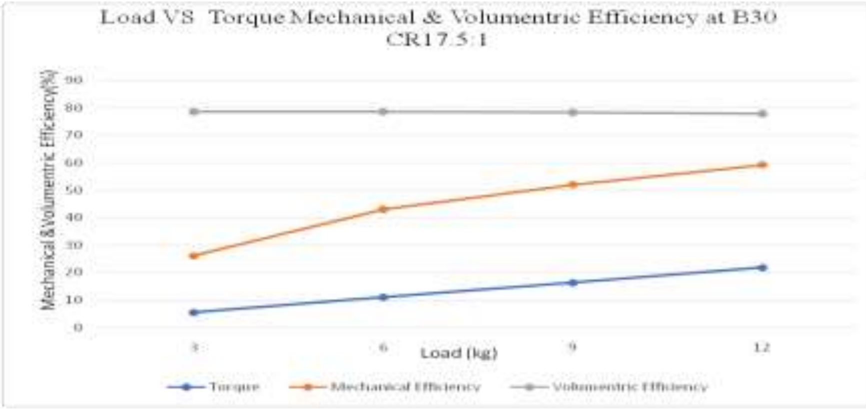

Figure 17: Load Vs Torque, Mechanical & Volumetric Efficiency

The Torque efficiency of the engine was 21.82Nm for Juliflora bio-diesel at 12.02 kg load.
The Mechanical Efficiency of the engine was 59.26% for Juliflora bio-diesel at 12.02 kg load.
The Volumetric efficiencyof the engine was78.82 for Juliflora bio-diesel at 0.03 kg load.

4.3.3 For Compression Ratio 19:1 at B10

4.3.3.1 IP,BP&FP

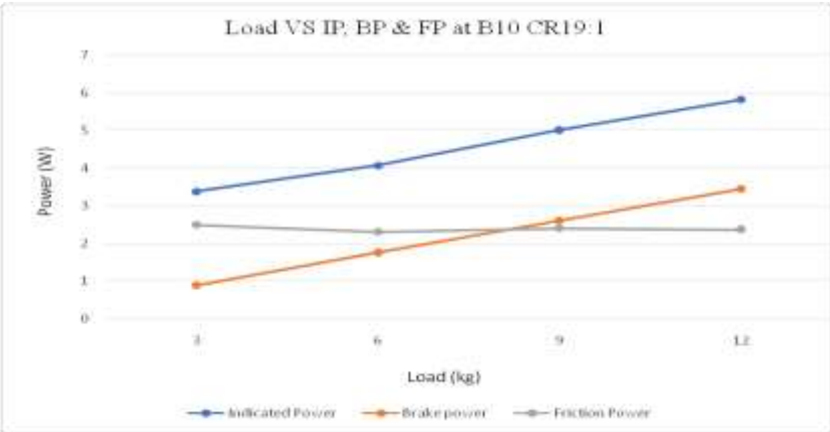

Figure 18: Load Vs IP, BP,FP

The maximum indicated power of the engine was 5.85 kw for Juliflora bio diesel at 12.02 kg load.
The maximum brake power of the engine was 3.45 kw for Juliflora bio diesel at 12.02 kg load.
The maximum friction power of the engine was 2.89 kw for Juliflora bio diesel at 0.02 kg load.

4.3.3.2 IMEP ,BMEP&FMEP

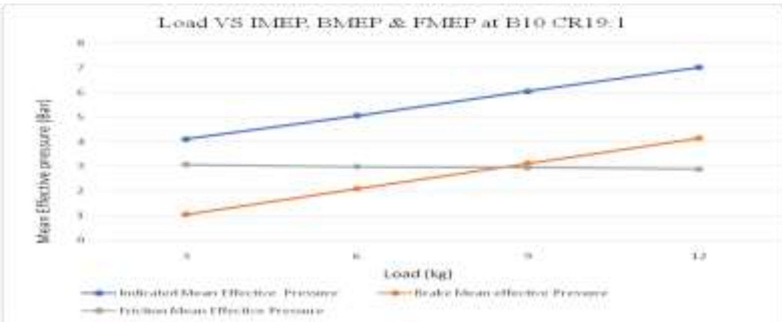

Figure 19: Load Vs IMEP,BMEP,FMEP

The maximum indicated mean effective pressure of the engine was 7.02 bar for Juliflora bio diesel at 12.02kg load

The maximum brake mean effective pressure of the engine was 4.14 bar for Juliflora bio diesel at 12.02 kg load.

The maximum friction mean effective pressure of the engine was 3.76 bar for Juliflora bio diesel at 0.02 kg load.

4.3.3.3 Air &Fuel Flow

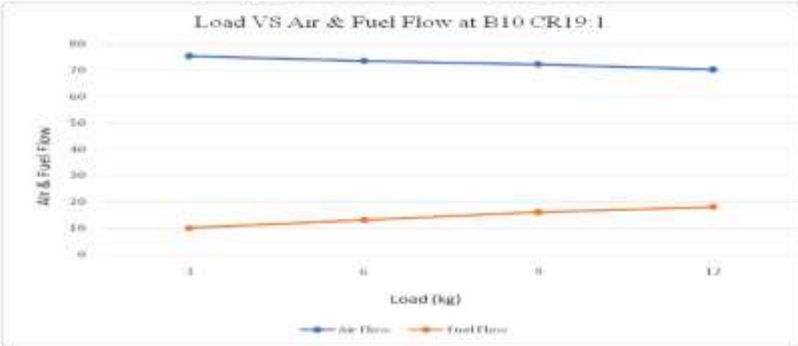

Figure 20: Load Vs Air Flow &Fuel Folw

The maximum air flow of the engine was 77.66 mmWC for Juliflora bio diesel is at 0.02kg load.
The maximum fuel flow of the engine was 18.00 CC/min for Juliflora bio diesel is at 12.02kg load.

4.3.3.4 Indicated & Brake Thermal Efficiency

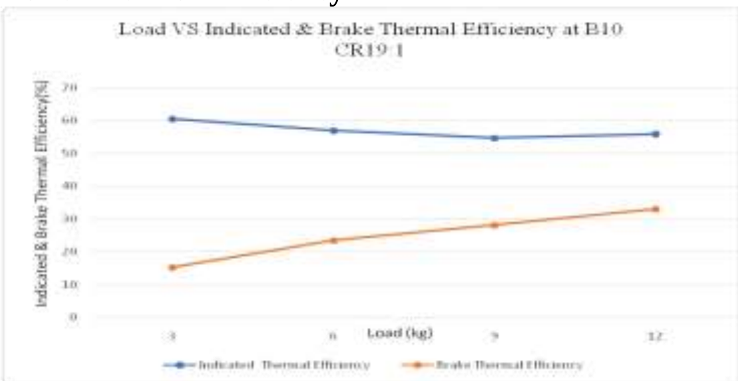

Figure 21: Load Vs ITE & BTE

The maximum indicated thermal efficiency of the engine was 68.63% for Juliflora bio diesel at 0.02 kg load.
The maximum brake thermal efficiency of the engine was 32.93 % for Juliflora bio diesel at 12.02 kg load.

4.3.3.5 SFC& Fuel Consumption

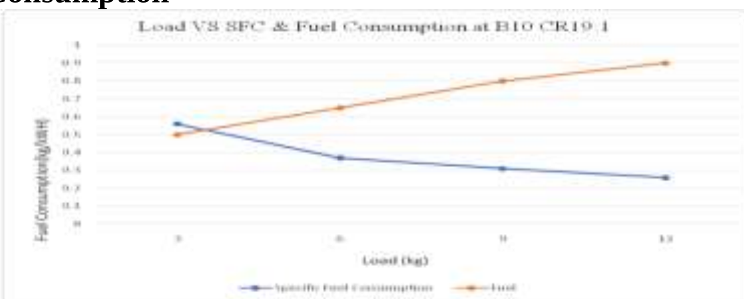

Figure 22: Load Vs SFC & Fuel Consumption

The maximum specific fuel consumption of the engine was 0.6 kg/kwh for Juliflora bio diesel at 0.02 kg load.
The maximum fuel of the engine was 0.90 kg/h for Juliflora bio diesel at 12.02 kg load.

4.3.3.6 Torque, Mechanical & Volumetric Efficiency

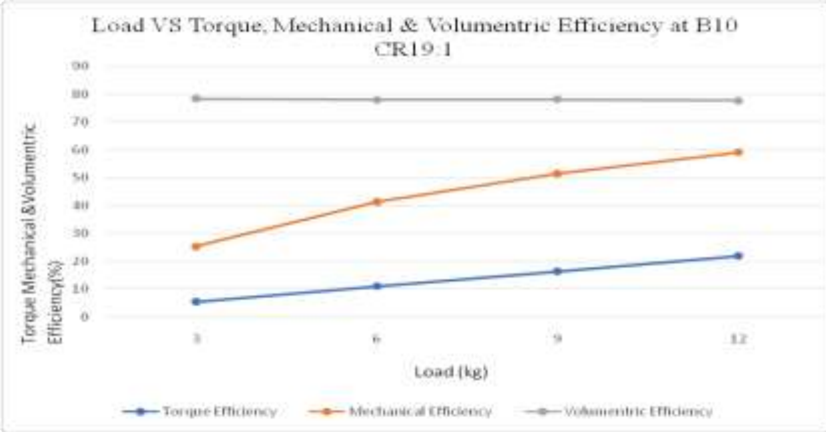

Figure 23: Load Vs Torque, Mechanical & Volumetric Efficiency

The maximum torque efficiency of the engine was 21.82% for Juliflora bio diesel at 12.02 kg load.
The maximum mechanical efficiency of the engine was 59.0% for Juliflora bio diesel at 12.02 kg load.
The maximum volumetric efficiency of the engine was 78.47% for Juliflora bio diesel at 0.02 kg load.

4.3.4 For Compression Ratio 19:1 at B30

4.3.4.1 IP,BP&FP

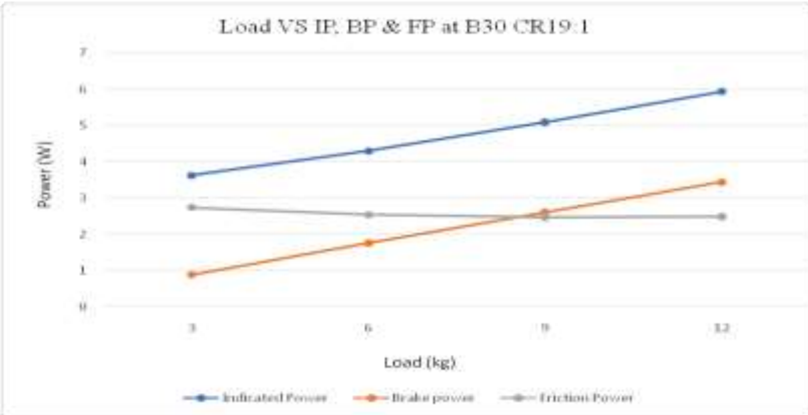

Figure 24: Load Vs IP,BP,FP

The maximum indicated power of the engine was 5.94 kw for Juliflora bio diesel at 12.02kg load.
The maximum brake power of the engine was 3.44 kw for Juliflora bio diesel at 12.02 kg load.
The maximum friction power of the engine was 2.88 kw for Juliflora bio diesel at 0.02 kg load.

4.3.4.2 IMEP,BMEP&FMEP

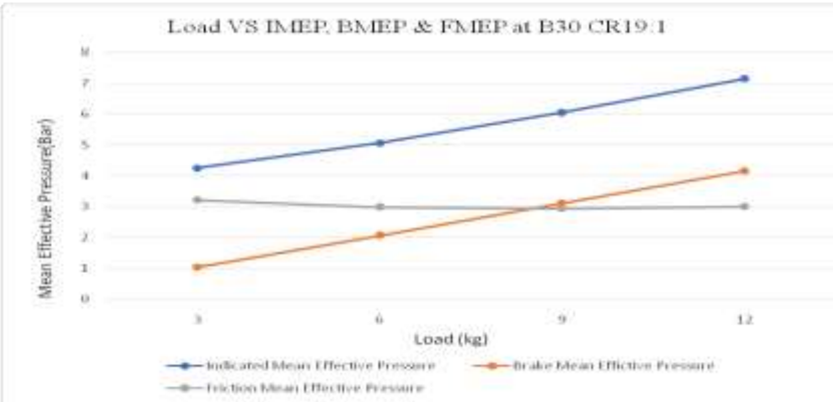

Figure 25: Load Vs IMEP,BMEP, FMEP

The maximum indicated mean effective pressure of the engine was 7.15 bar for Juliflora bio diesel at 12.02kg load.

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The maximum brake mean effective pressure of the engine was 4.15 bar for Juliflora bio diesel at 12.02 kg load.
The maximum friction mean effective pressure of the engine was 3.63 bar for Juliflora bio diesel at 0.02 kg load.

4.3.4.3 Air &Fuel Flow

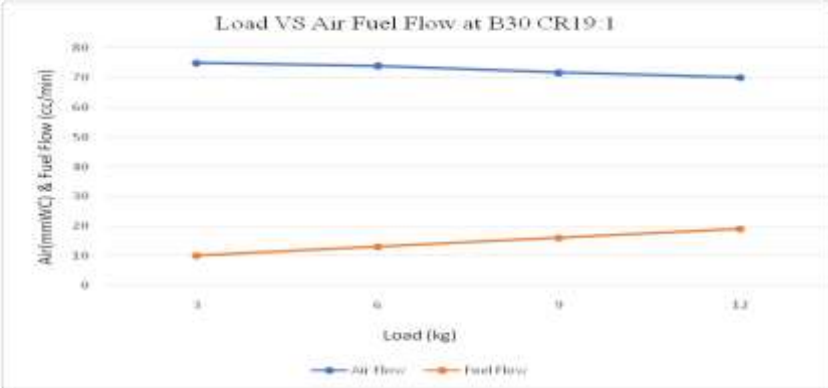

Figure 26: Load Vs Air Flow & Fuel Flow

The maximum air flow of the engine was 77.79 mmwc for Juliflora bio diesel at 0.02kg load.
The maximum fuel flow of the engine was 19.0 cc/min for Juliflora bio diesel at 12.02kg load

4.3.4.4 Indicated& Brake Thermal Efficiency

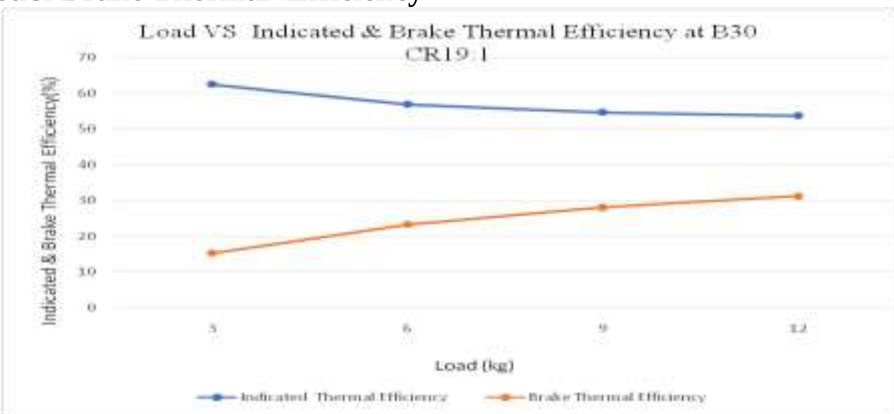

Figure 27: Load Vs ITE &BTE

The maximum indicated thermal efficiency of the engine was 53.78% for Juliflora bio diesel at 12.02 kg load.
The maximum brake thermal efficiency of the engine was 31.19% for Juliflora bio diesel at 12.02 kg load.

4.3.4.5 SFC& Fuel Consumption

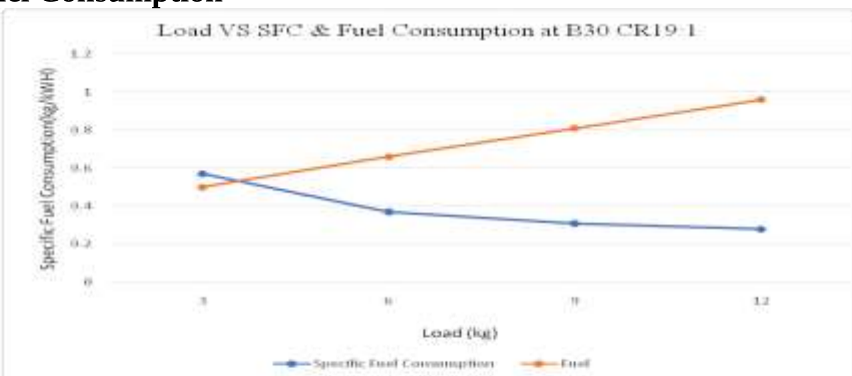

Figure 28: Load Vs SFC & Fuel Consumption

The maximum specific fuel consumption of the engine was 0.6 kg/kwh for Juliflora bio diesel at 0.02kg load.

The maximum fuel of the engine was 0.96 kg/h for Juliflora bio diesel at 12.02kg load.

4.3.4.6 Torque, Mechanical & Volumetric Efficiency

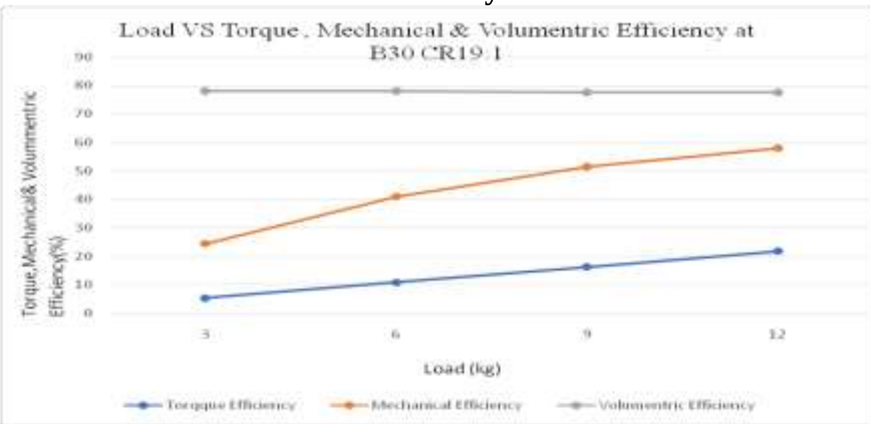

Figure 29: Load Vs Torque, Mechanical, Volumetric Efficiency

The maximum torque efficiency of the engine was 21.82%for Juliflora bio diesel at 12.02kg load.

The maximum mechanical efficiency of the engine was 57.99% for Juliflora bio diesel at 12.02 kg load.

The maximum volumentric efficiency of the engine was 77.65% for Juliflora bio diesel at 12.02 load.

4.4 Combustion Graphs

4.4.1 Pressure Vs Crank Angle

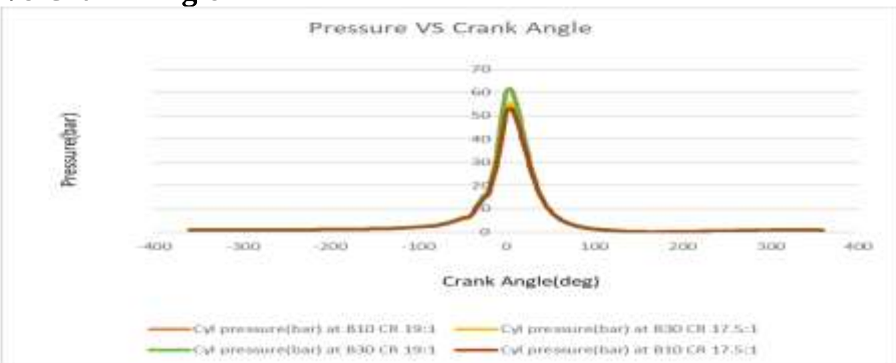

Figure 30: Pressure Vs Crank Angle

4.4.2 Crank Angle Vs Net Heat Release

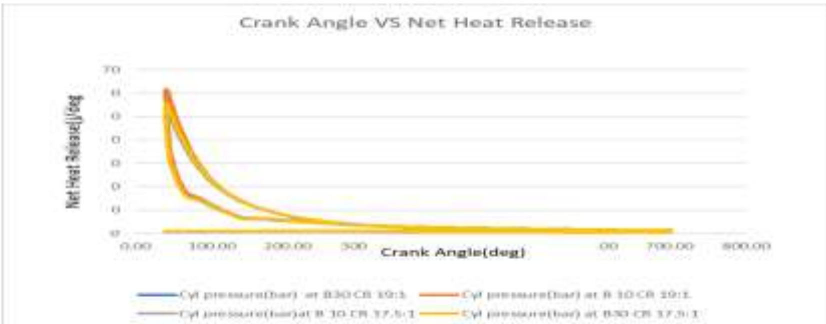

Figure 31: Crank Angle Vs Net Heat Release

4.4.3 Crank Angle Vs HeatRelease

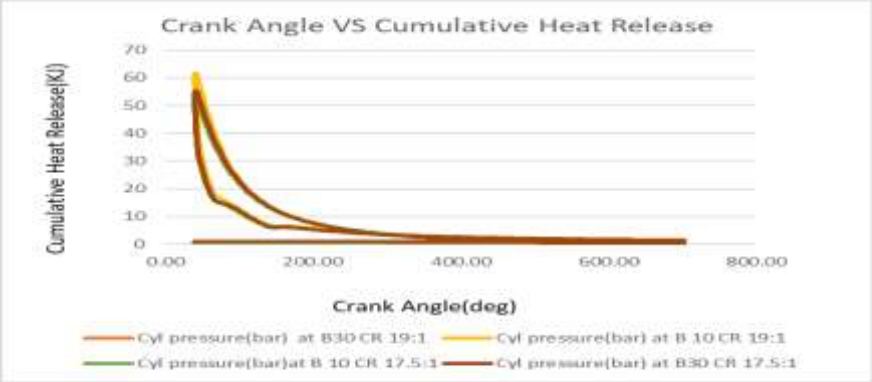

Figure 32: Crank Angle Vs Cumulative Heat Release

4.4.4 Crank Angle Vs Fraction Burned

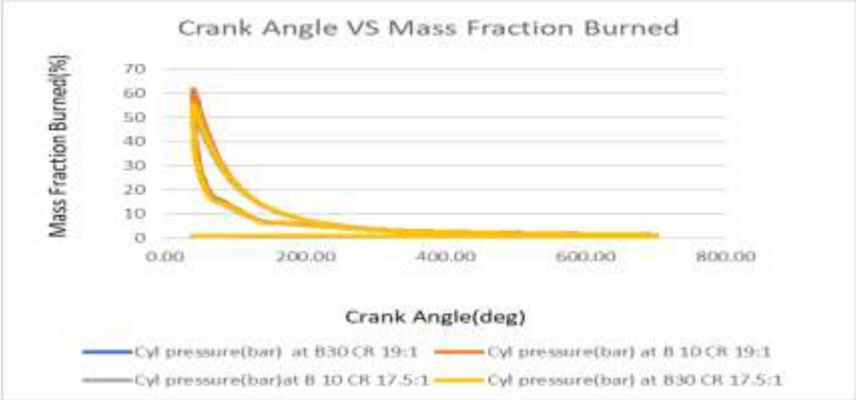

Figure 33: Crank Angle Vs Mass Fraction Burned

4.4.5 Pressure Vs Volume

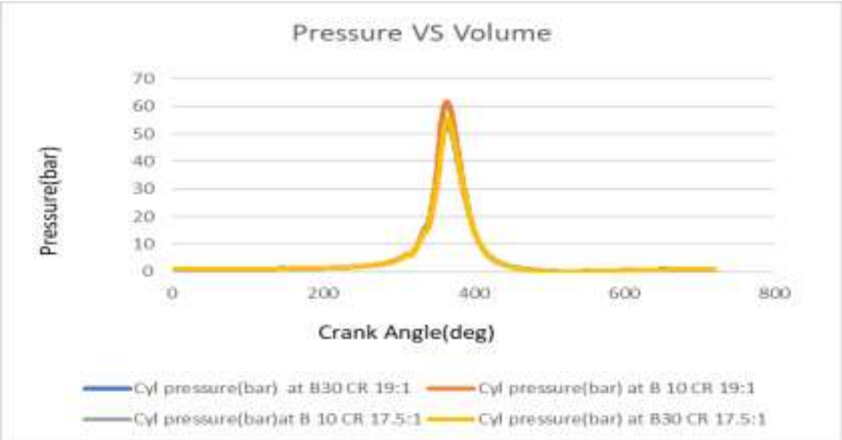

Figure 34: Pressure Vs Volume

4.4.6 Log Pressure Vs Log Volume

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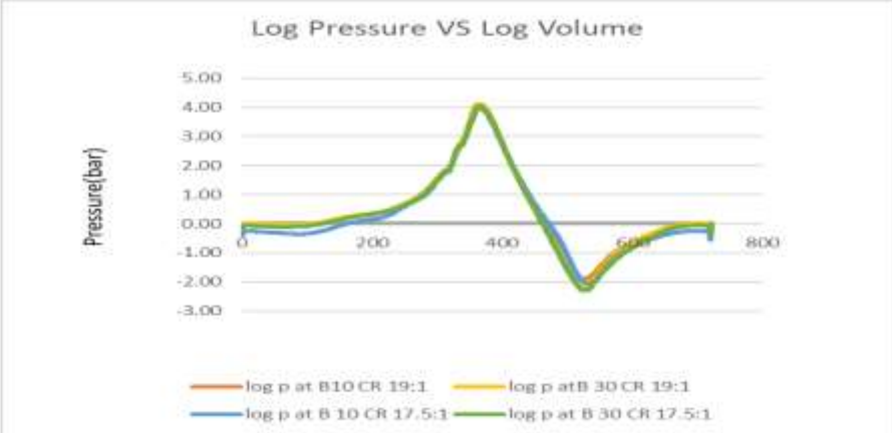

Figure 35:Log Pressure Vs Log Volume

4.5 Emission Analysis

The emissions obtained during the experimentation at different loads are obtained by using a Multi gas analyser. The experimentation is done for diesel, Juliflora bio diesel blends. The emission analysis for CO, $C0_2$, HC and O_2.

4.5.1 Emissions of CO_2

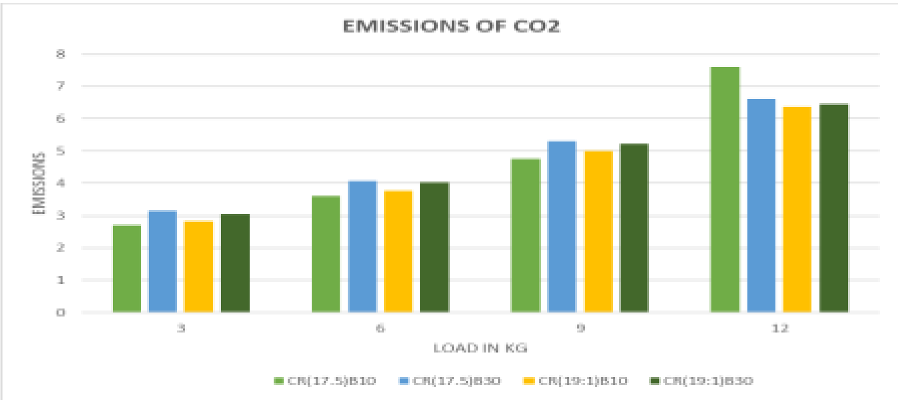

Figure 36: Load Vs CO_2 Comparison Graph

The variation of carbon dioxide emission for various blends at varying loads. The carbon dioxide emission for B30 at compression ratio 17.5:1 increases gradually at all loads and emissions for diesel and B10 at compression ratio 17.5:1 are almost equal. The emissions for B10 and B30 at compression ratio 19:1 are almost equal.

4.5.2 Emissions of CO

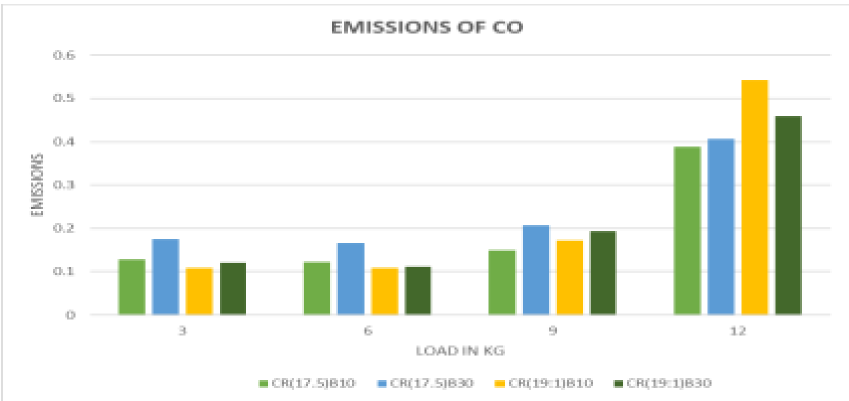

Figure 37: Load Vs CO Comparison Graph

The variation carbon mono oxide with load and compression ratio of the engine is shown in figure 37. It is observed that carbon monoxide emission decreases for diesel at both compression ratios. It

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means that proper combustion has not carried out for biodiesel. The carbon monoxide emission for B10 blend remains same for compression ratio 19:1 at all loads and it is gradually increases for B30 at compression ratio 19:1 at all loads.

4.5.3 Emissions of HC

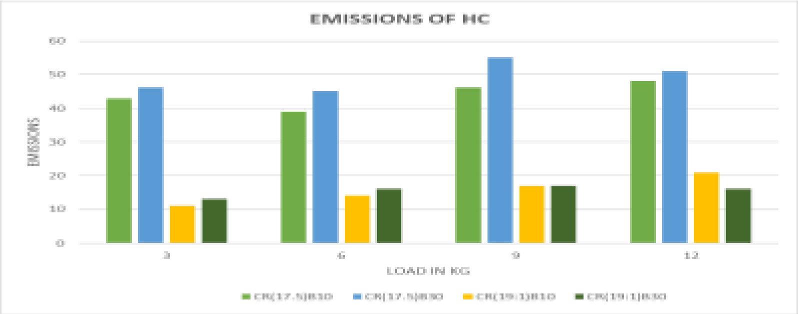

Figure 38: Load Vs HC Comparison Graph

The hydrocarbons variation with load for the Juliflora biodiesel and diesel are shown in the figure 38. The hydrocarbons are almost equal for B10 blends at the two compression ratios. The hydrocarbons for B30 and Diesel are equal at 19:1 compression ratio. The result depends on oxygen quantity and fuel viscosity and uniform vaporization during combustion.

4.5.4 Emission of O_2

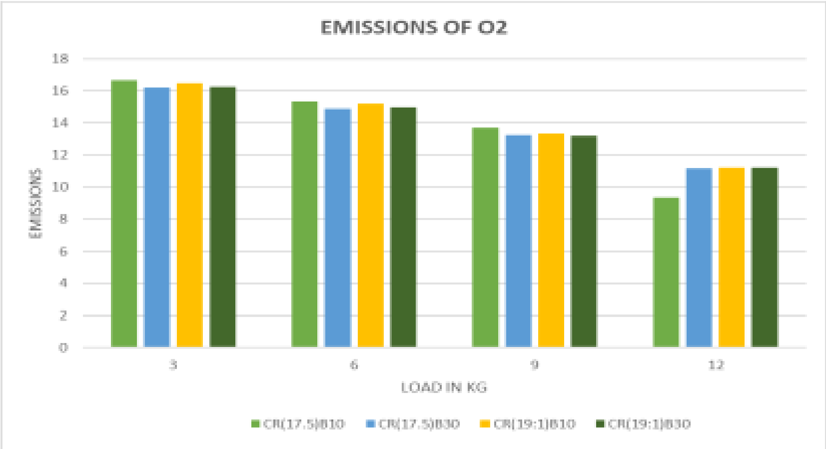

Figure 39: Load Vs O_2 comparison Graph

The variation of oxygen emission for various blends at varying loads. The oxygen emission for B30 at compression ratio 17.5:1 increases gradually at all loads and emissions for diesel and B10 at compression ratio 17.5:1 are almost equal. The emissions for B10 and B30 at compression ratio 19:1 are almost equal.

4.5.5 Emissions of NO_X

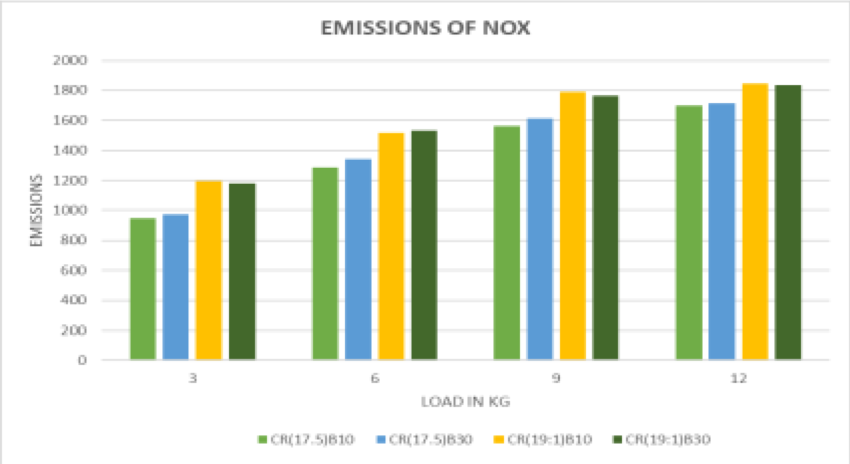

Figure 40: Load Vs Nitrogen Oxides Comparison Graph

The variation of nitrogen oxides emission for various blends at varying loads. The nitrogen oxides emission for B30 at compression ratio 17.5:1 increases gradually at all loads and emissions for diesel and B10 at compression ratio 17.5:1 are almost equal. The emissions for B10 and B30 at compression ratio 19:1 are almost equal.

4.6 Emission Characteristics

The emissions of optimized blend of biodiesel and diesel instead of the conventional diesel fuel significantly reduces the exhaust emissions particulate matter (PM), carbon monoxide (CO), sulphur oxides (SOx), and unburned hydrocarbons (HC). Moreover additives are an essential part of today's fuels. Together with carefully formulated base fuel composition, they contribute to efficiency reliability and long life of an engine. They can have surprisingly large effects even when used in parts per million (PPM) range. With use of fuel additives in the blend of biodiesel and diesel fuelled in CI Engine which furthers more improve performance, combustion, and diminish emission characteristics and also improved fuel properties which enhance the combustion characteristics.

The variation of carbon dioxide with load of the engine is shown in figure 32. It is observed that carbon dioxide emission decreases for diesel because it carries out proper combustion. The minimum carbon dioxide emission was observed for diesel at compression ratio 19:1 and increases gradually for B10 at compression ratio 17.5:1.

The variation of carbon monoxide with load of the engine is shown in the figure 33. It is observed that carbon monoxide emission decreases for diesel at both compression ratios. It means that proper combustion has not carried out for biodiesel. The carbon mono oxide emission for B10 blend remains same for compression ratio 19:1 at all loads and it is gradually increases for B30 at compression ratio 19:1 at all loads.

The hydrocarbons are almost equal for B10 blends at the two compression ratios. The results depends on oxygen quantity and fuel viscosity and uniform vaporization during combustion.

V. Conclusions

A single cylinder computerized variable compression ratio engine was operated successfully using Juliflora bio-diesel and its blends of Juliflora oil methyl ester in addition with cerium oxide nano-particle. The following considerations are made based on experimental results:

Engine works smoothly on Juliflora oil with performance comparable to neat diesel operation. ➢ Mechanical efficiency of the engine is more for the B10 blend of Juliflora oil with neat diesel at all loads. The brake thermal efficiency of the engine with Juliflora methyl ester-diesel blend was marginally better than that with neat diesel fuel.The brake thermal efficiency of the engine for neat diesel, B10 and B30 at 12kg load was found to be at a higher value.The Brake specific fuel consumption is low for B10 and B30 Juliflora methyl ester-diesel blends than diesel at all loads.

With the increase in load, the mechanical efficiency of B10 is increased in 17.5:1 compression ratio. With the increase in load, Brake thermal efficiency of B30 increases in 17.5:1 compression ratio. With the increase in load, Specific fuel consumption of B10 decreases in 17.5:1 compression ratio. With the increase in load, Mechanical efficiency of B30 increased in 19:1 compression ratio. With the increase in load, Brake thermal efficiency of B10 increases in 19:1 compression ratio. With the increase in load, Specific fuel consumption of diesel decreases in 19:1 compression ratio. For 17.5:1 compression ratio with B10, a better mechanical efficiency, brake thermal efficiency is observed when compared to diesel and other blends and brake specific fuel consumption for B10 was less. For 19:1 compression ratio with B30, better mechanical efficiency, brake thermal efficiency is observed when compared to diesel and other blends and brake specific fuel consumption for B30 was less. Hence it is concluded that the VCR Diesel engine works efficiently by giving lowest emission values of CO, CO_2 and HC for Juliflora biodiesel blend B10 with cerium oxide as nano-additive at both the compression ratios 17.5:1 and 19:1.

The experimentation can be extended in future to observe the combustion performance and emission variations on VCR Diesel engine by varying the fuel injection pressures with Juliflora bio fuel and Cerium oxide as nano-additive to draw final conclusions. The experimentation can be extended to observe the emissions of O_2 and NOx using a 5 gas analyzer. Also the knocking phenomenon and vibration analysis can be done to comment on the necessary modifications required on the engine parts. The experimentation can be extended to test other bio-fuels to suggest an alternate fuel for diesel in all aspects.

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