Performance and Emission Characteristics of a VCR CI Engine Fueled with Karanja Oil Blended with Diesel and Cerium Oxide Nano Additive

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The fast depletion of fossil fuel resources and increase in fuel prices in recent years has led to focus towards alternate fuels used in diesel engines. The vegetable oil has become in favour and cost effective and used under a wider range of conditions among various fuel alternatives. The random extraction and consumption of fossil fuels have lead to reduction in petroleum reserves. A single cylinder computerized variable compression ratio engine was operated successfully using Karanja Bio-diesel and its blends of Karanja oil methyl ester with cerium oxide as nano additive. Pure diesel with different esterified Karanja seed oil and its blends are tested for combustion, performance and emission characteristics and curves are drawn and compared with that of diesel. Exhaust emissions such as CO, CO_2 and HC were determined and compared with that of diesel. Burning of fossil fuels has caused serious detrimental environment consequences. The application of biodiesel has shown a positive impact in partitioning these problems. It is concluded that the VCR Diesel engine works efficiently by giving lowest emission values of CO, CO_2 and HC for Karanja 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, Karanja bio-diesel and Neat diesel, Nano-Additive.

I. INTRODUCTION

Fossil fuels have limited life and the ever increasing cost of these fuels has led to the search of alternate renewable fuels for ensuring energy security and environmental protection. Various sectors like transportation, agriculture and industries are consuming diesel fuel as a serious supply of power. As the stipulation of diesel fuel increases, the price of the fuel is also escalating. Biodiesel may be a cleaner burning replacement fuel for diesel drawn from natural sources such as virgin and used vegetable oil, algae and animal fats. India is not only a large importer of oil with the prospect of increased imports in the future, but also has significant potential for production of bio-fuels in the country. India actually has large areas of wasteland, which could be utilized for the production of bio-fuels. India and many countries in the world are on the verge of devising and implementing programs for production, conversion and use of bio-fuels. It is identified that more than 340 oil containing crops, among which only palm, jatropha, pongamia, cottonseed, soybean, rapeseed, sunflower, etc., are considered as potential substitute fuel for compression ignition engines. Rapeseed, soybean, sunflower, pongamia and jatropha are the most commonly used feedstock for biodiesel extraction.

Nano technology has already contributed to number of innovative products in various engineering disciplines because of their unique physical, chemical and mechanical properties. The present work studies the results of application of a Karanja 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 Karanja bio-diesel fuel. An experiment covering the performance, emissions is dealt with to evaluate the engine under various fuel blend implementations.

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II. LITERATURE REVIEW

Nwafor et al.2006 [1] studied the emission characteristics of a diesel engine operating on rapeseed methyl ester and found that rapeseed methyl ester and its blends with diesel fuel emitted high carbon dioxide as compared to diesel fuel. The emission of hydrocarbon was reduced when running on rapeseed methyl ester and are observed to extend with increased amount of diesel oil within the blend. Nobukazu Takagi and KoichiroItow 2009 [2] conducted experiments on a single cylinder I 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 vegetable oils and their blends generated the sutaible performance and engine exhaust emission levels for short-term operation. Shivakumar et al. 2010 [3] studied Performance and Emission characteristics of a 4 stroke CI engine operated on Honge methyl ester using artificial neural network. Performance research was carried out on a single cylinder four-stroke water-cooled compression ignition engine. Exhaust emissions Smoke, CO, HC were reduced for Diesel-biodiesel blends when compared with diesel values for all compression ratios and higher compression ratios have the advantage further reduction in those emissions.

H.Raheman and A.G. Phadatare et al., 2004 [4] observed the 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% more than the diesel. They concluded that B40 could replace diesel.

Sajith et.al 2013 [5] investigated the effect of cerium oxide nanoparticles on performance and emissions of diesel engine. Efficiency of the engine shows an increase up to 5% and a reduction of HC and NOx emissions by 45% and 30%, respectively. Arul mozhiselvan et al.2014 [6] conducted an experimental analysis to find out the performance and emission characteristics of a compression ignition engine while using cerium oxide nano-particles as additive in neat diesel and diesel-biodiesel-ethanol blends. The test proved to improve complete combustion of the fuel and the emissions singificantly by using diesel-biodiesel-ethanol blend.

Acharya et al.2014 [7] investigated the effect of preheated karanja and kusum oil on its emission characteristics. In this studied, the shell and tube type heat exchanger was used for preheating of karanja and kusum oil at before inlet of the engine and evaluated emission characteristics. This study was carried out at single cylinder, four stroke, water cooled engine with constant compression ratio (16.5:1) and 1500 rpm. It is reported that by using preheated karanja and kusum oil, the emission component such as carbon monoxide (CO), hydrocarbon (HC), carbon dioxide (CO_2) were increased with increase the engine load and oxide of nitrogen (NO_x).A.Pandey et.al 2018 [8] has shown experimental result that the engine performance with karnja oil bio diesel with fuel additive increased by 5% along with lower gaseous emission including 14%-25% lower NOx emission, and lower total particulate number concentration, as compared to diesel fuel . The performance of bio diesel fuel is found to be superior to that of diesel oil. Also, the lubricating oil life is found to be longer while operating the engine on bio diesel with fuel additive. Engine metals wear were found 26% lower for a KOME bio diesel with cerium oxide fuel additive operated engine. MeshackHawi, et.al 2019[9] concluded that the engine performance with waste cooking oil bio diesel with addition cerium oxide. The NOx emission, reduced to 24.6%-15.4% with addition of nano-additives as compared to diesel oil. Additionally, the fuel blend B30 with 10% FeCeO2 nano particles recorded better BSFC and BTE in low-to-medium loads compared to Diesel.

A.G.Dange, et.al [10] done experiments and evaluated that engine performance with karanja oil with blends of B10 and B15 and concluded that blends are efficient especially B10 is more useful.

III. EXPERIMENTATION

3.1 Experimental Set Up:

Direct Injection, VCR Diesel engine is utilized for the experimentation. Experimentation is done at various engine loads by using eddy current dynamometer. Engine performance data is important to study the performance and engine pollution parameters. The exhaust gas characteristics 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 karanja bio-diesel at different compression ratios. The engine setup is shown in figure 1.

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Figure 1, Computerized VCR Engine Test Rig

Table1, Specification of the Diesel Engine

Rated Horse power	6 kW
Rated Speed	1500rpm
No of Strokes	4
Mode of Injection	Direct Injection
Injection pressure	200 kg/cm^2
No of Cylinders	1
Stroke	116 mm
Bore	102 mm
Compression Ratio	17.5:1 and 19:1

This experiment was carried out on a Kirloskar made VCR engine. It was connected with the control panel unit with 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 software.

3.2 Dynamometer

Eddy current dynamometer

The eddy current dynamometer coupled with the engine output shaft (Fig. 2) for measuring the power and torque. The dynamometer connected with a load cell and different load applied on an engine (0-12 kg) by load cell. These load cells joined with the load sensors which signaled the load on the load indicator.

Figure 2, Dynamometer

3.3 Multi Gas Analyzer

A multi gas analyzer is a device that detects the presence of gases in an area, often as part of a safety system and is employed to notice the gas leaks or different emissions and integrate with a computing system so a process can be shut down automatically. It can also be used to detect combustible, flammable and toxic gases, and oxygen depletion. The gas analyzer measures the exhaust emissions such as Carbon Monoxide (CO), Carbon Dioxide (CO_2), Hydro Carbon (HC), and Oxygen (O_2) by means of Non-Dispersive infrared (NDIR) measurement as shown in figure3.

Figure3, Smart Caps Multi Exhaust Gas Analyzer

Table 2, Specifications of the multi exhaust gas analyzer

Make	Smart caps
Type	Probe
Range	CO - 0 to 15%
	CO_2 - 0 to 20%
	O_2 - 0 to 25%
	HC- 0 to 30000PPM
Resolution	CO, CO_2, O_2-0.01%
	HC - 1ppm

3.4 Ultra Probe Sonicator

The sonication is a method that uses sound energy for the aim of agitation particles during a sample for many functions like extraction compounds from plants, micro algae and seaweeds. Ultrasonic frequencies (>20 kHz) are used generally , resulting in the method being called as ultra-sonication. Sonication is usually utilized in engineering for equally dispersing nano-particles in liquids. Additionally, it is used to break up aggregates of micron-sized colloidal particles as shown in figure4.

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Figure 4, Ultra Probe Sonicator

3.5 Production of Karanja Oil Methylester

3.5.1 Transesterification

Required amount of catalyst KOH was dissolved in methanol and the rest amount of methanol along with the catalyst solution was added to the oil sample and placed in the water bath. The system was maintained airtight to stop the loss of alcohol. The reaction mix was maintained at temperature just above the boiling point of the alcohol i.e. around 60°C to speed up the reaction rate. Excess alcohol guarantees total conversion of the oil to its esters. After conforming of completion of methyl ester formation, the heating was stopped and the products were cooled and move to a separating funnel. The lower glycerol layer was separated. The oil was cleansed with water until it couldn't turned to pink beneath for further addition of acid-base indicator. To the bio diesel shaped anhydrous sulphate was added and left long for a night to remove moisture. The Bio diesel formed was then decanted.

1. Production of Karanja oil Methylester

Karanja oil is a bio-diesel produced by using raw Karanja seed oil. Due to high content of FFA of Karanja oil, the objective has been achieved in two steps namely

i)Acidesterification (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.5 and heated up to 60°C.

Figure 5, Acid Esterification

Figure 6, Alkaline Esterification

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 Karanja oil. Now required amount of methanol (4:1, 6:1, 8:1) were mixed with distinct percentage of KOH catalyst concentration (0.5, 1.0, 1.5). This homogeneous mixture of methanol and catalyst KOH was mixed with the Karanja 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 transesterification reaction, Karanja oil methyl ester was separated from glycerol by separating funnel Figure.6 and then the separated methyl ester was washed with hot distilled water. At last biodiesel was heated in the hot air oven to remove excess water content, and collected in jar as shown in the Figure 7.

Figure 7, Pure Karanja biodiesel

3.6 Blends Preparation

The series of exhaustive engine tests were carried out on a compression ignition diesel engine using diesel and karanja oil biodiesel blends. Several blends of varying concentration of karanja oil methyl ester (biodiesel) with diesel were prepared),Figure 9 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

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Figure 9, Karanja biodiesel BlendsB10 and B30 preparation

Table 3, Properties of karanja biodiesel and its blends

Properties	Diesel	Karanja oil	B10	B30
Specific gravity	0.831	0.936	0.823	0.857
Viscosity at 40 ^{0}c (centi poise)	4.3	5.3	3.1	3.8
Flash point ^{0}c	54	212	89	110
Fire point ^{0}c	65	224	119	118
Calorific value (kj/kg)	42,500	45,862	41,700	40,100

3.7 Cerium Oxide Nanoparticle 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 plays a role as an oxygen giving catalyst and provides oxygen for the oxidation of CO or absorbs oxygen for the lowering of NOx. The energy of activation of cerium oxide acts to burn off carbon deposits at intervals in the engine cylinder at the wall temperature and prevents the deposition of nonionic compounds on the cylinder wall leads to reduction in HC emissions.

Figure 10, Cerium Oxide Nano-particles

An experiment is done to determine the performance characteristics of a compression ignition engine using nano-particles as additive in pure diesel and diesel-biodiesel blends. In the first part of the experiment, stability of pure 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 mixing followed by ultrasonic bath stabilization improves the steadiness. In the second part, performance characteristics are investigated using the fuel blends in a single cylinder four stroke engine and cconnected with an electrical dynamometer and a data acquisition system.

The cerium oxide, figure 10 acts as an oxygen donating catalyst and provides oxygen for combustion. The tests revealed that cerium oxide nano-particles 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.

Table 4, Specifications of cerium oxide nano-particles

Molecular formula	CeO_2
Molecular weight	172.115 g/mol
Particle Size	30-50 nm

3.8. Experimental Procedure:

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

The series of exhaustive engine tests were carried out on a compression ignition diesel engine using diesel and Karanja oil bio-diesel blends. Blends of varying concentration of Karanja oil methyl ester (bio-diesel) with diesel were prepared as follows:

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

B30- This is the blend containing 30% bio-diesel and 70% neat diesel

Performance and emission tests were conducted under different loading condition on these various diesel-bio-diesel blends. The optimum blend was found out from the graphs based on maximum thermal efficiency, minimum brake specific energy consumption and safe emission at all load.

IV. RESULTS & DISCUSSIONS

A series of exhaustive engine tests were carried out on a compression ignition diesel engine using diesel and karanja oil biodiesel blends. Several blends of varying concentration of karanja oil methyl ester(biodiesel) with diesel were prepared as follows

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

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- 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 load.

4.1 Calorific Values for Diesel and Biodiesel Blends

Net Calorific value of diesel = 44,631 kJ/kg

Net Calorific value of B10 = 41,700 kJ/kg

Net Calorific value of B30 = 40,100 kJ/kg

4.2 Performance Characteristics:

Brake power, fuel consumption, brake specific fuel consumption (B.S.F.C), Brake thermal efficiency, Indicated thermal efficiency for both diesel and karanja biodiesel are calculated at different loads. The comparison graphs for diesel and biodiesel blends for Load Vs Mechanical efficiency, Load Vs brake thermal efficiency and Load Vs specific fuel consumption are shown below.

4.2.1 For Compression Ratio 17.5:1

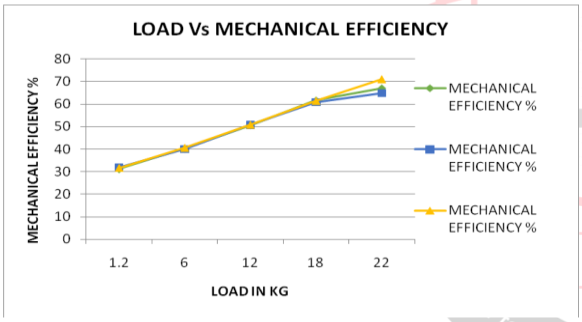

Figure 11, Load Vs Mechanical Efficiency

The maximum mechanical efficiency of the engine was observed as 70.8554% for diesel at 22kg load.

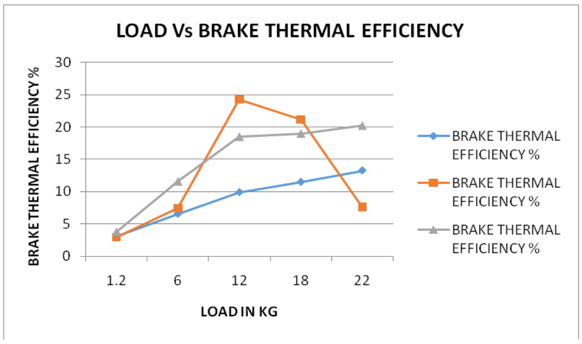

Figure 12, Load Vs Brake Thermal Efficiency

The brake thermal efficiency of the engine is 24.19 % for Karanja biodiesel B30 at12kg load.

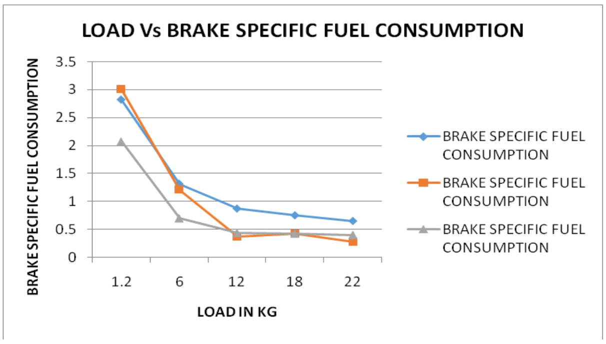

Figure 13, Load Vs Specific Fuel Consumption

The minimum brake specific fuel consumption of the engine was 0.2819 % for Karanja biodiesel B30 at 22kg load.

4.2.2 For Compression Ratio 19:1

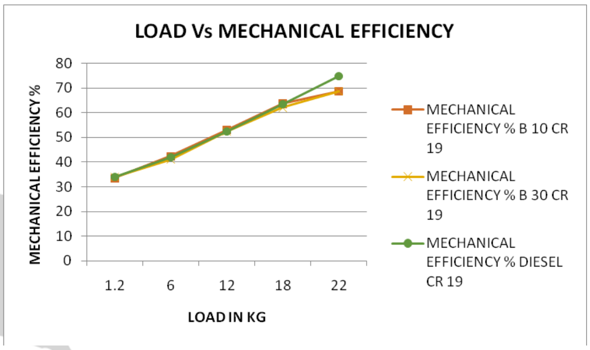

Figure 14, Load Vs Mechanical Efficiency

The maximum efficiency of the engine was 74.7085 % for Diesel at 22kg load

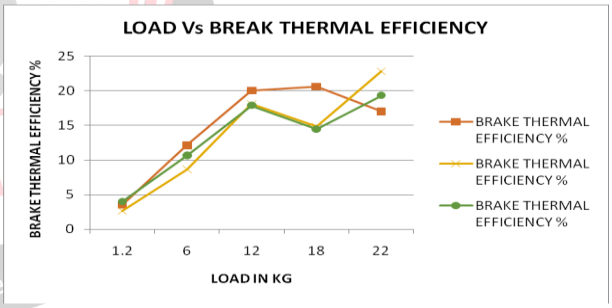

Figure 15, Load Vs Brake Thermal Efficiency

The maximum brake thermal efficiency of the engine was 22.8157 % for Karanja biodiesel B30 at 22kg load.

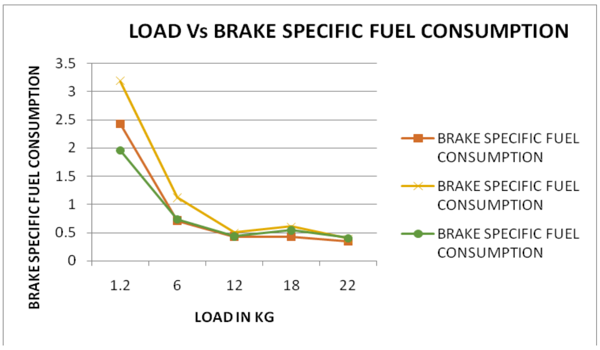

Figure 16, Load Vs Specific Fuel Consumption

The minimum brake specific fuel consumption of the engine was 0.3445 % for Karanja biodiesel B10 at 22kg load.

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4.2.3 Comparison Graphs For Mechanical Efficiency for Compression Ratios 17.5:1 & 19:1

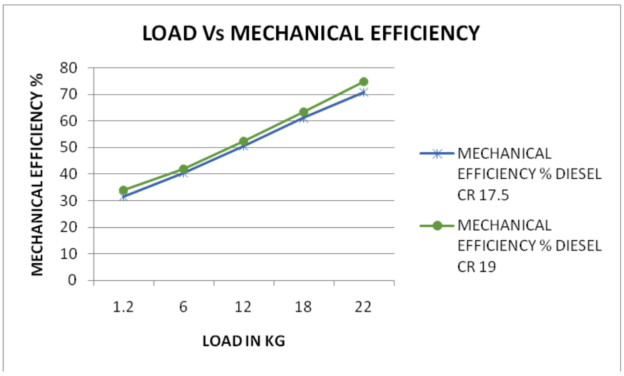

Figure 17, Comparison for Diesel

The maximum mechanical efficiency of the engine was increased with increase in the compression ratio and the mechanical efficiency for diesel was found to be 74.7085 at 22kg load.

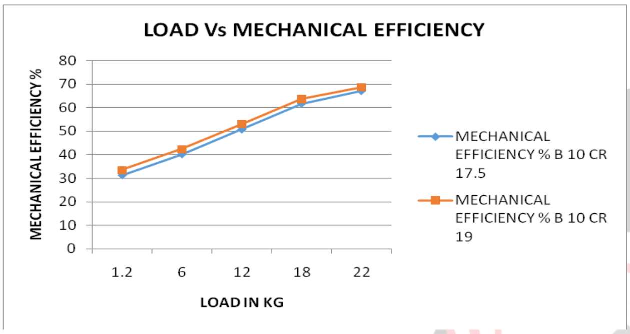

Figure 18, Comparison for Blends (B10)

The maximum mechanical efficiency of the engine was increased with increase in the compression ratio and the mechanical efficiency for B10 was found to be 68.5215 at 22kg load.

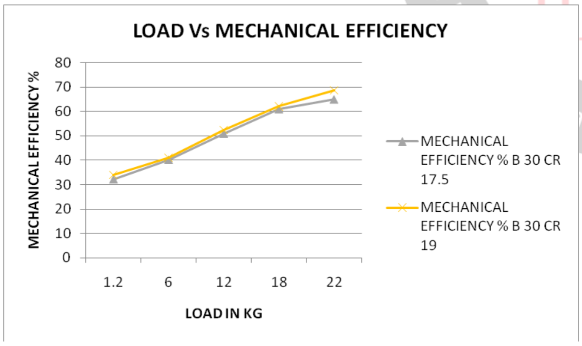

Figure 19, Comparison for Blends (B30)

The maximum mechanical efficiency of the engine was increased with increase in the compression ratio and the mechanical efficiency for B30 was found to be 68.6983 at 22kg load.

4.2.4 Comparison Graphs for Brake Thermal Efficiency for Compression Ratios 17.5:1 & 19:1

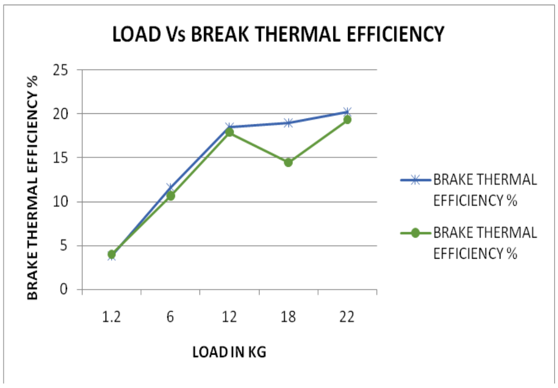

Figure 20, Comparison graph for Diesel

The maximum brake thermal efficiency of the engine was decreased with increase in the compression ratio and the brake thermal efficiency for diesel was found to be 19.2797 at 22kg load.

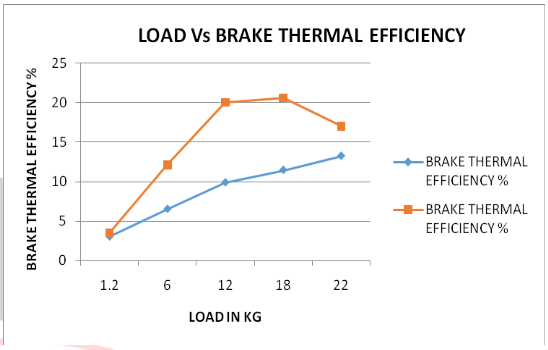

Figure 21, Comparison graph for Blends (B10)

The maximum brake thermal efficiency of the engine was increased with increase in the compression ratio and the brake thermal efficiency for B10 was found to be 20.6053 at 18kg load.

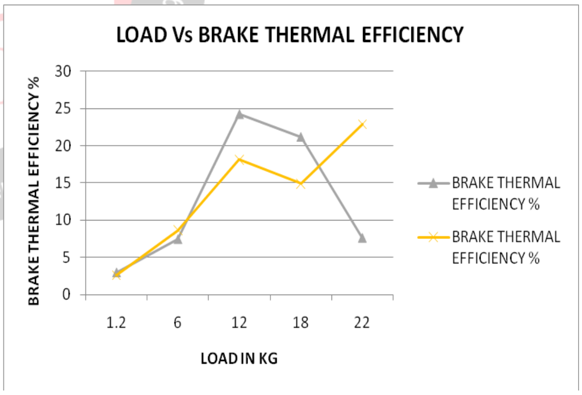

Figure 22, Comparison for Blends (B30)

The maximum brake thermal efficiency of the engine was increased with increase in the compression ratio and the brake thermal efficiency for B30 was found to be 24.19 at 12kg load.

4.2.5 Comparison Graphs for Brake Specific Fuel Consumption for Compression Ratios 17.5:1 & 19:1

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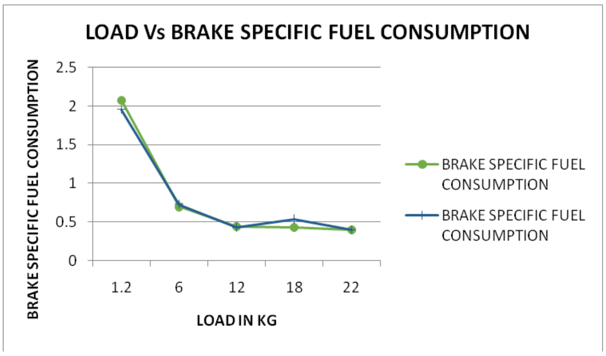

Figure 23, Comparison graph for Diesel

The minimum brake fuel consumption of the engine was decreased with increase in the compression ratio and the brake specific fuel consumption for diesel was found to be 0.3995 at 22kg load.

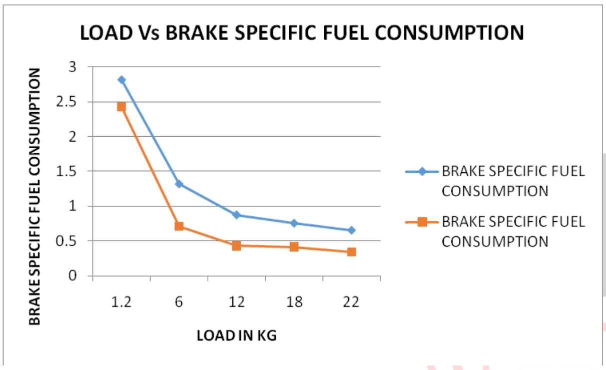

Figure24, Comparison graph for Blends (B10)

The minimum brake specific fuel consumption of the engine was decreased with increase in the compression ratio and the brake specific fuel consumption for B10 was found to be 0.3445 at 22kg load.

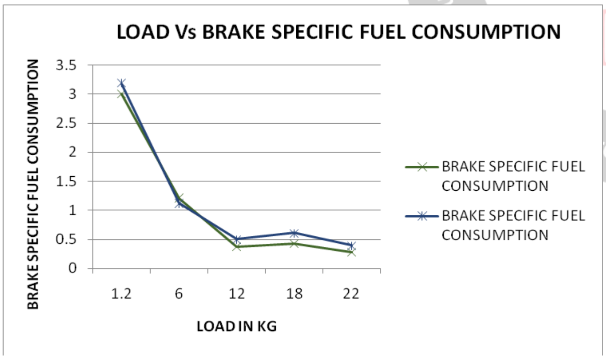

Figure 25, Comparison graph for Blends (B30)

The minimum brake specific fuel consumption of the engine was increased with increase in the compression ratio and the brake specific fuel consumption for B30 was found to be 0.2819 at 22kg load.

4.3 Effect of Compression Ratio for Diesel and Karanja Oil Blends B10 And B30 With Cerium Oxide as Nano Additive

In a CI engine, cylinder pressure depends on the burnt fuel fraction during the premixed burning phase, which is the beginig phase of combustion. Cylinder pressure characterizes the capacity of the fuel to mix properly with air and burn condition. The comparison of cylinder pressures with crank angle for the fuels tested are done at all compression ratios under the 75% of rated load. The results show that the peak cylinder pressure of the engine running with ester blends is marginally greater than the engine running with diesel at 75% of rated load and compression ratios.

There were some reasons for this behavior .Due to higher viscosity, low volatility, and higher cetane number of biodiesel blends, there is occurence of a short ignition delay and advanced injection timing for esters blend than diesel fuel. As a result, combustion starts later for diesel fuel and the peak cylinder pressure attains a lower value as it is further away from the TDC in the expansion stroke.

Due to the presence of oxygen molecule in biodiesel, the hydrocarbons achieve better combustion resulting in higher cylinder pressure.

These increased values of cylinder pressure with compression ratio were observed at 75% of rated load for all blends. This shows that increasing the compression ratio had more benefits with ester blends than with pure diesel. Due to their low volatility and higher viscosity and cetane number, biodiesel might be performing relatively better at higher compression ratios. Also the oxygen content of biodiesel may be a cause for this better performance.

4.4 Comparision Graphs Between Pressure And Crank Angle

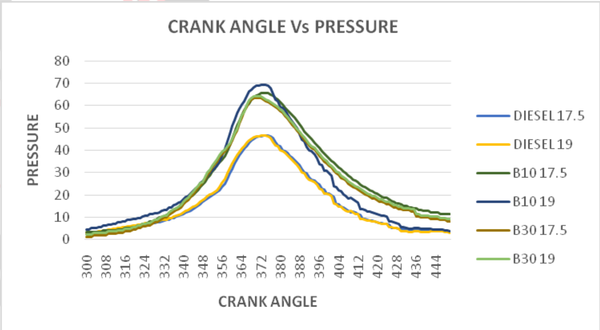

Figure 26, Crank angle Vs Pressure

From the above graph the peak pressure is obtained for karanja bio diesel blend B10 with cerium oxide as Nano additive when compared to other blends.

4.5 Emission Characteristics:

The emissions obtained during the experimentation at different loads are obtained by using a 5-Gas analyzer. The experimentation is done by diesel, karanja bio diesel blends. The emission characteristics for CO, CO_2, and HC are shown in figure 27 to 29 for diesel and bio diesel blends.

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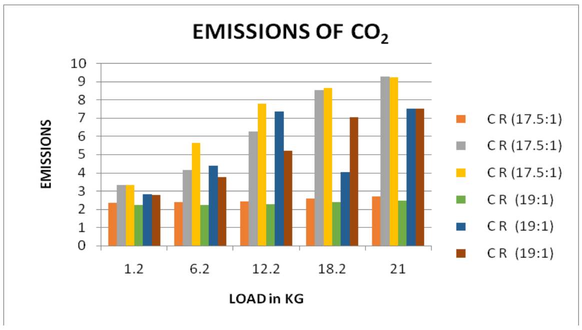

Figure 27, Load Vs CO_2 comparison graph

The emissions of carbon dioxide vary for various blends at varying loads. The carbon dioxide emission for the blends is higher than diesel for all loads and blends and decreases with increase in compression ratio. Carbon dioxide is formed on complete combustion of the fuel in oxygen. As the calorific value of the fuel is low, more fuel needs to be burnt to get equivalent power output. So combustion of more carbon compounds leads to higher carbon dioxide emissions.

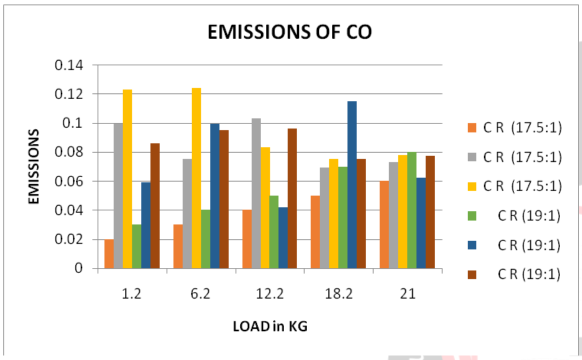

Figure 28, Load Vs CO comparison graph

The variation of carbon monoxide with load and compression ratio of the engine is shown in figure 28. It is observed that carbon monoxide emission decreases when comes to diesel. It means that proper combustion has not carried out for biodiesel. The minimum carbon monoxide emissions were obtained for diesel.

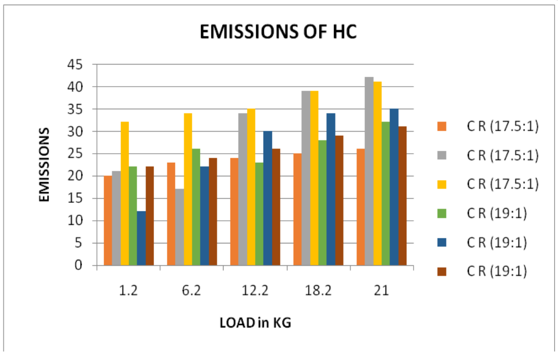

Figure 29, Load Vs HC Comparison Graph

The hydro carbons variation with load for the karanja biodiesel and diesel are shown in figure 29. The hydro carbons are higher for all the blends for the karanja biodiesel compared with diesel. The results depend on oxygen quantity and fuel viscosity and uniform vaporization during combustion.

The variation of carbon monoxide with load on the engine is shown in Figure 28. It is observed that carbon monoxide emission decreases when comes to diesel. It means that proper combustion has not carried out for biodiesel. The minimum carbon monoxide emissions were obtained for B10 blend. The variation of carbon dioxide with load on the engine is shown in Figure 27. It is observed that carbon dioxide emission increase with increase of load. The Minimum carbon dioxide emission was obtained for the diesel is 2.23% at 1.2 kg load. This is a result of low accessibility of gas throughout combustion.

The hydro carbons variation with load for the karanja biodiesel and diesel are shown Figure 29. It is observed that hydro carbon emissions increase with increase of load. The hydro carbons are greater for all the blends for the karanja biodiesel compared with diesel. The lowest value of HC was 12 at load 1.2 Kg and it was 42 at 22 kg for B10. This result 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 karanja biodiesel and its blends of karanja oil methyl ester in addition with cerium oxide nano-particles. The following conclusions are made based on experimental results.

Engine works smoothly on karanja oil with performance comparable to diesel operation. Mechanical efficiency of engine is increased by the blends of karanja oil with diesel. The brake thermal efficiency of the engine with karanja methyl ester-diesel blend was slightly better than with neat diesel fuel. Brake specific fuel consumption is lower for karanja methyl ester-diesel blends than diesel at all loading. With the increase in load, mechanical efficiency of B30 increased 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, brake thermal efficiency of B10 increases in 17.5:1 compression ratio. With the increase in load, mechanical efficiency of B30 increases in 19:1 compression ratio. With the increase in load, brake thermal efficiency of B30 increases in 19:1 compression ratio. With the increase in load, specific fuel consumption of B30 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 karanja biodiesel blend B10 with cerium oxide as nano- additive at both the compression ratios 17.5:1 and 19:1.

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