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## EXPERIMENTAL INVESTIGATIONS ON PERFORMANCE CHARACTERISTICS OF A VARIABLE COMPRESSION RATIO ENGINE OPERATED ON DUAL FUEL MODE USING DIESEL AND BIODIESEL (OBTAINED FROM COTTON SEED OIL AND RICE BRAN OIL)

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### ABSTRACT

Biodiesel is recognized replacement for fossil fuel in compressed ignition engines due to its significant environmental benefits. In this study, an experimental study has been evaluated on a variable compression ratio diesel engine to investigate the optimum compression ratio, optimum blend and engine performance. Experiments were conducted on single cylinder, four stroke, variable compression ratio and compression ignition engine was operated on a dual fuel mode with diesel and biodiesel obtained from cotton seed oil and rice bran oil and its blends of B5, B10, B15 and B20 at constant speed of 1500 rpm, different compression ratios of 15, 16, 17, 18 and varying the loads. When the various proportions of biodiesel are mixed with the diesel, the equal amounts of Methyl Ester Cotton Seed Oil and Methyl Ester Rice Bran Oil are mixed together and used along with pure diesel. Engine performance test results indicated that the biodiesel blend B20 produced brake thermal efficiency decreased by 4.1% and specific fuel consumption increased by 17.1% compared to pure diesel. It is observed that in the experiments, higher compression ratio CR18 results in higher brake thermal efficiency and thus lower specific fuel consumption. From the present study, by analyzing the various performance parameters with different blends, different compression ratios and the replacement of diesel it is concluded CR18 and blend B20 is optimum compression ratio and optimum blend respectively. This study gives a direction to utilize the renewable fuel to reduce the consumption of fossil fuel.

#### KEYWORDS

Compression Ratio, Compression Ignition, Methyl Ester Cotton Seed Oil, Methyl Ester Rice Bran Oil, Variable Compression Ratio.

### 1. INTRODUCTION

Energy is an essential and vital part of any country and particularly the developing countries like India. It is also the lifeline of modern societies. Building a strong base of energy resources is a prerequisite for sustainable economics and social development of a country. Environmental concern in recent times has become a very important issue. With increasing trend of motorization & industrialization, the world's energy demand is growing at a faster rate. World's energy consumption has increased continuously for decades except for a brief period like the oil crisis in 1970's in which the growth slowed down. Global primary energy consumption increased by 1% in 2016, following growth of 0.9% in 2015 and 1% in 2014. This compares with 10 year average of 1.8% a year [1]. Energy consumption is not expected to decrease in this century because the world population is increasing and the economics 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. Although the exact date is debatable, most researchers agree that production peak of oil and natural gas is near.

With the use of fuels like Cotton seed oil and Rice bran oil and its ester as an alternative to diesel, a country can become self-sufficient in its energy requirements and thereby the dependence on other countries for oil imports will get reduced. Moreover, the farmers of the nation would also be contributing towards a healthier environment. The biofuel used alone or in blended form with diesel has the advantage of contributing to cleaner exhaust and reduced dependency on fossil fuel resources of petroleum derivatives.

Of all the investigations conducted, Cotton seed oil and rice bran oil holds promise for further studies as this oil is not explored as an alternative bio-fuel for VCR diesel. However, the open literature appears to indicate very fewer details into the studies of thermal performance, emission characteristics and combustion analysis with Cotton seed oil and Rice bran oil on a VCR diesel engine particularly at different compression ratios. Cotton seed oil is an important source of vegetable oil which is yet to be exploited. India is the second largest country in the world in the production of cotton seed, Maharashtra especially Vidarbha is the region where the main yield for farmers is cotton on which their economy depends.

Rice bran oil is another important source of vegetable oil which is yet to be explored. India is the second largest rice producer in the world, next only to China. Rice is the main cultivation in subtropical southern Asia and it is a staple for a large part of the world's human population, especially in East, South and Southeast Asia, making it the most consumed cereal grain. Rice cultivation is well suited to countries and regions with low labor costs and high rainfall, as it is very labor intensive to cultivate and requires plenty of water for cultivation.

India produced 8.5 lakh tonnes of rice bran oil during 2010–11, which is 64% of the potential [2]. There is need to process all the rice bran produced in India for recovering the oil, which can make a significant contribution to the vegetable oils basket. This will change the economy entirely by 2050 [2]. Rice bran oil is commercialized as fuel and produced on a large scale basis then there is a possibility that its cost can be reduced and become a reliable and viable alternative to diesel.

## 2. LITERATURE REVIEW

Biodiesel has emerged as the best substitute for diesel because most of its combustion characteristics are quite similar to that of diesel. This section reviews the available literature on the engine performance and combustion characteristics. C.D. A group researchers conducted experimental investigation to evaluate and compare the performance of sunflower and cottonseed oil methyl esters (bio-diesels) of Greek origin as supplements in the diesel fuel at blend ratios of 10/90 and 20/80, in a fully instrumented, six-cylinder, turbocharged and after-cooled, direct injection (DI), Mercedes-Benz, mini-bus diesel engine installed at the authors' laboratory [3]. The engine performance with the bio-diesel blends of sunflower or cottonseed oil bio-diesels was similar to that of the neat diesel fuel, with nearly the same brake thermal efficiency and showing higher brake specific fuel consumption. Some researchers conducted experimental investigations on a single cylinder, four-stroke, VCR diesel engine at different engine speeds ranging from 1500 to 2400 rpm to study the performance and emission characteristics of dual biodiesel (Jatropha biodiesel and Waste cooking oil biodiesel) blends with diesel [4].

They concluded average torque reduction compared to DF for JB5, JB10 and J5W5 were found as 0.63%, 1.63% and 1.44% and average power reduction was found as 0.67%, 1.66% and 1.54% respectively. The average increase in bsfc compared to DF was observed as 0.54%, 1.0% JB10 and 1.14% for JB5, JB10 and J5W5 respectively. It can be concluded that JB5, JB10 and J5W5 can be used in diesel engines without any engine modifications; However J5W5 produced some better results when compared to JB10. Md. Other researchers conducted experimental investigations on a four cylinder, four-stroke, and VCR diesel engine at different engine speeds ranging from 1000 to 4000 rpm to study the performance and emission characteristics of dual biodiesel (Jatropha curcas and Moringaoleifera methyl ester) blends with diesel [5]. They concluded that JB10 and the MB10 fuels produced slightly lower brake powers and higher brake specific fuel consumption values compared to diesel fuel over the entire range of speeds. In other hand, a study conducted experimental investigations on a single cylinder, four-stroke, and VCR diesel engine to study the emission characteristics of dual biodiesel (Jatropha and Tyre pyrolysis oil) blends with diesel [6].

They concluded that brake thermal efficiency of JMETPO15 is almost the same as that of diesel at full load. The BSEC for JMETPO15 is 11.92MJ/kWh and for diesel 11.86MJ/kWh at full load. The EGT is higher for JMETPO15 compared to that of diesel at full load. M.I. Arbab and his friends conducted experimental investigations on a fourcylinders, four-stroke, and VCR diesel engine to study the emission characteristics of dual biodiesel (Jatropha, Palm and Coconut Biodiesel) blends with diesel [7]. They concluded that JPC20 (blend of 20% JPC biodiesel and 80% petroleum diesel) showed the highest engine torque at a BSFC lower than PC20 (blend of 20% PC biodiesel and 80% petroleum diesel). R. D. Eknath conducted experimental investigations on a single cylinder, four-stroke, and VCR diesel engine to study the performance and emission characteristics of dual biodiesel (Jatropha and Karanja oil) blends with diesel [8]. They concluded that decrease in compression ratio decreases the brake thermal efficiency of all the fuels significantly. R.Thirunavukarasuet conducted experimental investigations on a single cylinder, four-stroke, VCR diesel engine to study the performance and emission characteristics of dual biodiesel (Pongamiapinnata oil and Neem oil) blends with diesel [9].

They concluded that brake thermal efficiency of the blend was found higher than diesel. Exhaust gas temperature for dual biodiesel blends was lower than diesel. Deepesh Nagar conducted experimental investigations on a single cylinder, four-stroke, VCR diesel engine to study the performance and emission characteristics of dual biodiesel (Palm biodiesel and Jatropha biodiesel) blends with diesel [10]. They concluded that Brake thermal efficiency increase with an increase in load on the engine. Brake thermal efficiency of JPB20 was found to be 2.48%, 9.62% and 6.18% higher than that of D100 at 75% of rated load for a compression ratio of 12, 14 and 16 respectively. Brake specific fuel consumption of JPB20 were found to be 2.5% and 9.30% lower than that of D100 at 75% of rated load for compression ratio of 12 and 14 respectively but for compression ratio of 16 Brake specific fuel consumption of JPB20 were found to be 2.38% higher than that of D100 at 75% of rated load. The EGT was higher for JPB20 compared to that of D100 at full load.

There are various observations made by researchers in their respective studies. Some general observations which can be identified from the literature are, Brake thermal efficiency of a biodiesel fuelled engine is observed to be slightly lesser than that of a diesel fuelled engine. The harmful exhaust emissions are generally lesser for all biodiesels as compared to pure diesel. Biodiesels can be successfully used in existing

VCR diesel engines without any modifications. The different biodiesels which are considered by earlier researchers for studying the performance and emission characteristics are Rapeseed, Soybean, Palm, Jatropha, Sunflower, Cottonseed, Karanja, Putranjiva, Castor, Waste plastic oil, Ricebran, Mahua, Poon, Linseed, Sesame, and Rubberseed oil. Most of the studies are conducted by blending biodiesels with pure diesel. From the review of the literature, it can be seen that lots of work is done in the utilization of biofuels and to find the optimum blend ratio. However, most of the literature focused on single biodiesel and its blends. From previous studies, it is evident that single biodiesel offers acceptable engine performance and emissions for diesel engine operation. Very few experiments have been conducted with the combination of dual biodiesel and diesel as a fuel. Most of the literature suggested that cotton seed oil and rice bran oil are suitable substitutes for diesel and some research has also been carried out with cotton seed oil and rice bran oil separately [11-29]. So, in our research we have made an attempt to mix the two different biodiesels and operate the VCR engine with pure diesel and analyse the performance parameters.

### 2.1 Research Gaps

The facts cited in relevant published articles have been analyzed critically and the following salient features are found not being addressed properly.

1. A lot of research work has been reported on single biodiesel fuel mode of the engine using variety of vegetable oils and gaseous fuel. However, a limited work has been reported on dual fuel along with different combination of vegetable oil and diesel as a fuel.

2. Most of the research work has been done on performance and combustion analysis of single cylinder as well as multi-cylinder diesel engine in single mode and dual fuel mode operation. But in particular on single cylinder variable compression ratio diesel engine which has large potential for use in automotive sector and agriculture, no work has been published in dual fuel mode using cotton seed oil and rice bran oil blends with diesel.

3. Though much work has been reported on biodiesel application and its effect on the performance and combustion characteristics of diesel engine in dual fuel mode with variation of speed of the engine, load of the engine, injection pressure and timings of the engine. But the effect of variation of compression ratio on the emission characteristics of the engine at optimum biodiesel blends condition has not been reported.

### 2.2 Research Objective

Based on the review of literature, to address the research gap mentioned above, the following objectives were framed for the present work.

1. This experimental study examines the potential of using a combined blend of cotton seed oil and rice bran oil biodiesel as a partial replacement for diesel fuel in a single-cylinder, four-strokes, variable compression diesel engine. This study has particular relevance to India where the potential exists for both increased cotton seed oil and rice bran oil production and the establishment of economically viable application of biodiesels from these oils at a high percentage. Thus, this study examines the performance of using 5% to 20% combined biodiesel blends of cotton seed oil and rice bran oil-diesel in a single-cylinder, four- strokes, variable compression ratio diesel engine.

2. Preparation of MECO and MERBO biodiesel from the cotton seed oil and rice bran oil. Biodiesel property tests have to be conducted in order to understand the properties of newly formed biodiesel mixture and the changes in properties when mixed with diesel in different proportions.

3. Conduct the experiments using various blends of biodiesel obtained from MECO and MERBO as a partial replacement of diesel fuel in a single cylinder, four strokes and variable compression ratio diesel engine.

4. Determine the optimum blending ratio of the biodiesel and the optimum compression ratio using a variable compression ratio diesel engine. Study and analyze the engine performance and combustion characteristics of brake power, brake thermal efficiency, brake specific fuel consumption, brake mean effective pressure, exhaust gas temperature, peak pressure, ignition delay and heat release rate.

## 3. EXPERIMENTAL METHODOLOGY

### 3.1 Experimental Setup

The Figure 1 shows the layout of the experimental setup used for the present investigation and Table 1 shows the complete specifications of the experimental setup. An experimental test rig is developed to undertake the

performance and combustion characteristics evaluation of a variable compression ratio compression ignition engine fuelled with dual biodiesels (MECSO and MERBO) and its blends with diesel.



**Figure 1:** Experimental Setup

The setup consists of single cylinder, four stroke, and variable compression ratio diesel engine. The engine is connected to eddy current type dynamometer for loading. The compression ratio can be changed without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. Setup is provided with necessary instruments for combustion pressure and crank-angle measurements. These signals are interfaced to computer through engine indicator for P $\theta$ -PV diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement. The set up has a stand-alone panel box consisting of air box, two fuel tanks for dual fuel test, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. Rotameters are provided for cooling water and calorimeter water flow measurement.

The setup enables study of variable compression ratio 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 and heat balance. Lab view based Engine Performance Analysis Software package "Engine soft LV" is provided for online performance evolution. A computerized diesel injection pressure measurement is optionally provided.

**Table 1:** Technical Specifications of Experimental Setup

Description	Engine Specification
Make & Model	Kirloskar Oil Engine, TV1
Engine	Type - single-cylinder, four-stroke Diesel engine, water cooled, rated power 3.5 kW at 1500 rpm, stroke 110 mm, bore 87.5 mm. 661 cc, CR range 12 to 18
Dynamometer	Eddy current, water cooled, with the loading unit
Peak cylinder pressure	77.5 kg/cm <sup>2</sup>
Maximum speed	2000 rpm
Minimum idle speed	750 rpm
Minimum operating speed	1200 rpm
Fuel injection timing for standard engine	23 $^{\circ}$ BTDC
Dimensions	W 2000 x D 2500 x H 1500 mm

### 1.1 Procedure for Preparation of Cotton seed oil Biodiesel

The biodiesel fuel used in this study was produced from the transesterification of raw cotton seed oil [28]. The transesterification process of cotton seed oil was performed using 13 gm of potassium hydroxide and 250 mL of methanol per liter of raw cotton seed oil. First,

raw cotton seed oil was taken in a container and stirred with a mechanical stirrer and simultaneously heated with the help of a heating coil. The speed of the stirrer is maintained to be minimal till the temperature of the raw oil reached 55 $^{\circ}$ C. Then, KOH was mixed with methanol separately in a beaker and stirred until they were properly dissolved. The solution was then added to the preheated cotton seed oil in the reactor and the reactor was closed with an airtight lid. Now the solution was stirred at high speed of 650 rpm, care should be taken that the temperature does not exceed 60 $^{\circ}$ C as methanol evaporates at a temperature of 65 $^{\circ}$ C. Also, the KOH-alcohol solution was mixed with cotton seed oil only at 55 $^{\circ}$ C because heat generated when KOH alcohol was mixed together and the temperature of the raw oil should be more than this when the mixing was done if the reactions have to take place properly. After the mixture was stirred for 30 min at a fixed temperature of 60 $^{\circ}$ C, the solution was transferred to a glass container where the separation of glycerin takes place and allowed to settle down for 15 h.

Now the methyl ester of cotton seed oil gets collected in the upper portion of the glass container, whereas glycerin gets collected at the bottom portion and drain the bottom layer containing glycerin. Then the biodiesel was washed with water, again glycerin gets separated from the biodiesel and therefore removed. Again biodiesel was washed with water repeatedly for 4 to 5 times at a time interval of 1hr until no glycerin was left in the biodiesel. Now the biodiesel was heated at 103 $^{\circ}$ C to 105 $^{\circ}$ C in order to remove the water contained in it. Finally, the produced Methyl Ester of Cotton Seed Oil was left to cool down and was ready for use. A maximum of 800 mL methyl ester of cotton seed oil production was observed for 1 liter of raw cotton seed oil, 250 mL of methanol and 13 gm of potassium hydroxide at 60 $^{\circ}$ C.

### 1.2 Procedure for Preparation of Rice bran oil Biodiesel

Rice bran oil is converted into its methyl ester by the two-stage process [29]. In the first stage, rice bran oil is reacted with CH<sub>3</sub>OH in presence of an acid catalyst (H<sub>2</sub>SO<sub>4</sub>) to convert free fatty acid (FFA) into a fatty ester. A specified amount (1000 g) of rice bran oil is taken in a round bottom flask and heated up to 60-65 $^{\circ}$ C. In a separate flask, CH<sub>3</sub>OH (950 g) and H<sub>2</sub>SO<sub>4</sub> (22 g) were taken and properly mixed and then transferred to the round bottom flask containing rice bran oil. The mixture was stirred for 4 h and maintained at 60 $^{\circ}$ C. It was allowed to cool overnight without stirring. When the acid number of the mixture reached less than 1, the second stage was started. During this stage, the mixture (1000 g) obtained from the first stage was taken in a round bottom flask and heated up to 60 $^{\circ}$ C. Methanol (200 ml) and KOH (4.5 g) were properly mixed in other flask and then introduced into the round bottom flask containing the mixture from the first stage. The mixture was stirred vigorously for 2 h and then allowed to cool overnight. Glycerol and soap formed during the process settled down at the bottom. Top layer containing RBO methyl ester (91%) was removed with the help of a separating funnel and washed two times with water and dried. The produced Methyl Ester of rice bran oil was left to cool down and was ready for use. Table 2 and Table 3 shows the properties of MECSO and MERBO produced by the above procedures and its various blends with diesel.

**Table 2:** Fuel Properties of Diesel and Biodiesel

Properties	Diesel	MECSO	MERBO	ASTM (D6751)
Density (kg/m <sup>3</sup> ) @ 15 $^{\circ}$ C	815	875	890	860-900
Viscosity (mm <sup>2</sup> /s) @ 40 $^{\circ}$ C	2.57	5.4	5.8	1.9-6.0
Calorific Value (MJ/kg)	45.20	40.01	39.95	-
Cetane Number	51	54	54	47
Flash Point $^{\circ}$ C	53	162	168	130
Fire Point $^{\circ}$ C	59	173	174	-

**Table 3:** Fuel Properties of Biodiesel Blends

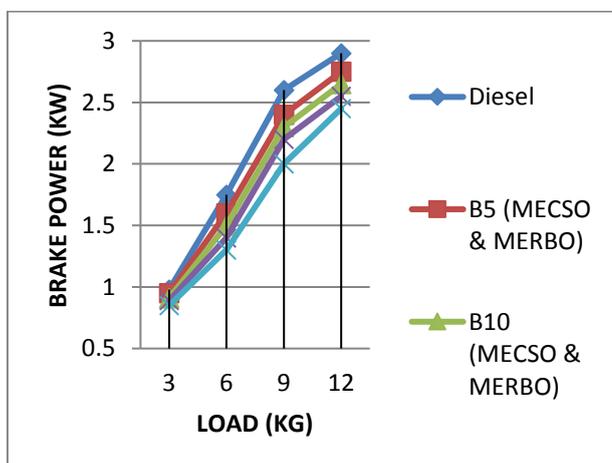
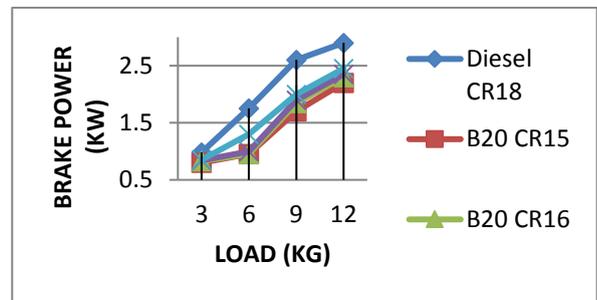
Properties	B5	B10	B15	B20
Density (kg/m <sup>3</sup> ) @ 15 <sup>o</sup> C	818.4	821.8	825.1	828.5
Viscosity (mm <sup>2</sup> /s) @ 40 <sup>o</sup> C	2.7	2.9	3.0	3.2
Calorific Value (MJ/kg)	44.93	44.67	44.41	44.15
Cetane Number	51.2	51.4	51.6	51.8
Flash Point <sup>o</sup> C	58.6	64.2	69.8	75.4
Fire Point <sup>o</sup> C	64.7	70.5	76.2	81.9

## 2. RESULT AND DISCUSSION

The results obtained from the experiments conducted for performance evaluation and combustion analysis are interpreted. Before carrying out the series of experiments, the engine's readiness for the test is validated by running the engine with diesel alone. The tests are conducted at different loads from 0kg to 12kg in steps of 3kg, at different preset compression ratios CR15, 16, 17 and 18. The blends selected for the experimental study are B5, B10, B15, and B20 with diesel. Following are the different performance characteristic curves obtained based on the experimental results. 0kg is not considered for a clear interpretation of various curves.

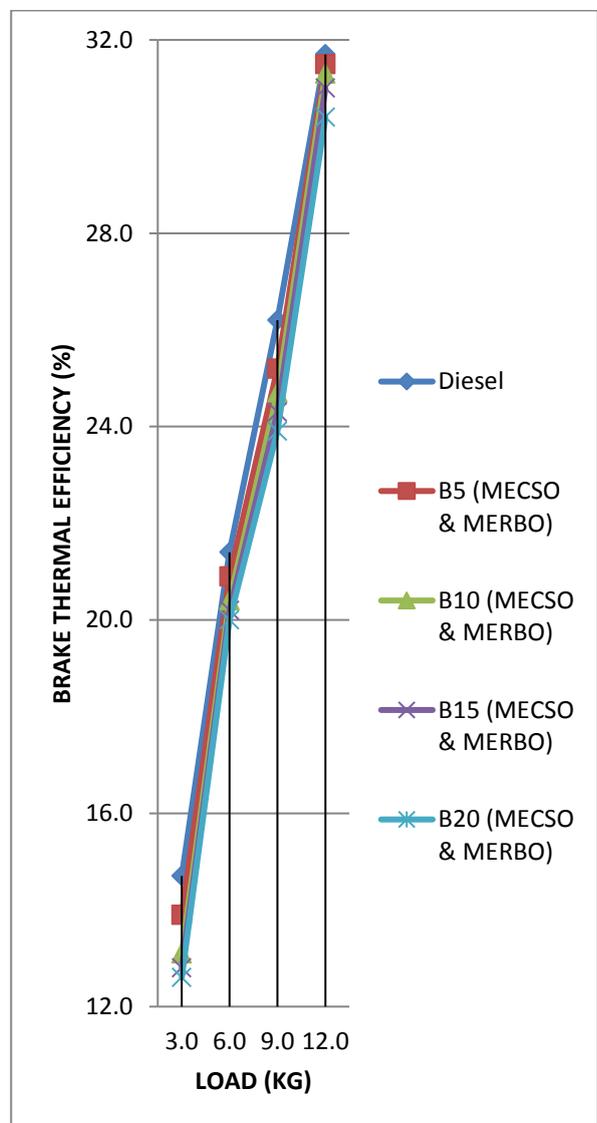
### 2.1 Brake Power

The variation of brake power with loads at CR18 for diesel and a different biodiesel blends shown in the Figure 2. It can be observed in Figure 2 that BP increases linearly with load for all the tested blends. As the load on the engine increases, the torque increases and thus there is an increase in brake power. It is also seen that BP is lower for biodiesel blends compared to diesel. However, the trend of variation of BP is same for all blends. The BP of biodiesel blend B20 is lower by 15.5% compared to diesel. The BP increases as the load on the engine increases. This could be a result of a reduction in the viscosity and the lubricity.

**Figure 2:** Variation of BP with Loads for Different Blends at CR18**Figure 3:** Variation of BP with Load for Different CRs with Diesel and B20 Blend

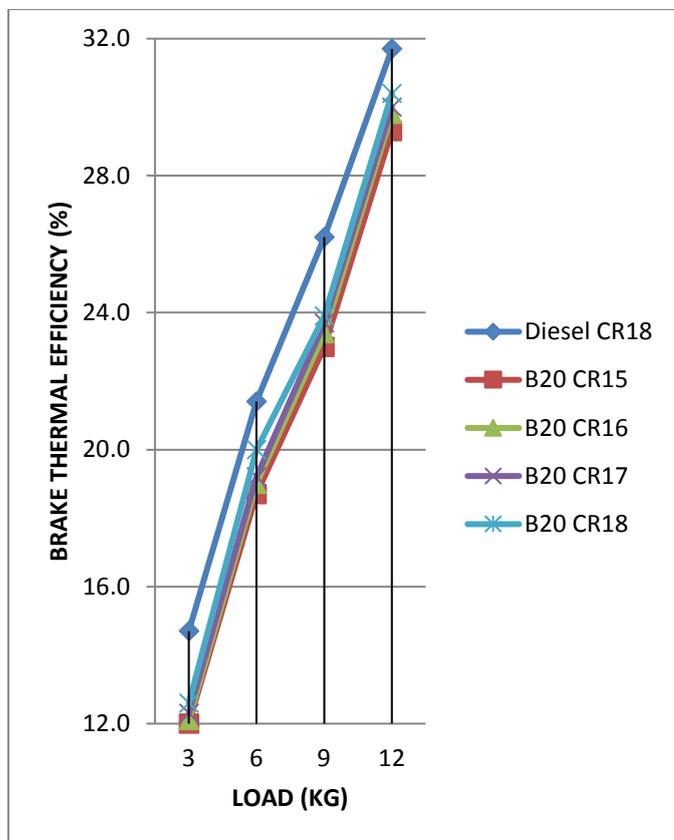
The variation of brake power with loads at different compression ratios for diesel and a blend of B20 is shown in the Figure 3. It can be observed in Figure 3 that at full load (12kg) with B20, it is evident that diesel has the higher brake power compared to biodiesel blends. The biodiesel blend B20 at CR18 has higher BP compared to CR 15, 16 and 17. Biodiesel blends produced lower brake power due to their lower calorific values and higher viscosities, which influences combustion. The uneven combustion characteristics of biodiesel blends reduced the engine brake power.

### 2.2 Brake Thermal Efficiency

**Figure 4:** Variation of BTHE with Loads for Different Blends at CR18

The variation of brake thermal efficiency with loads at CR18 for diesel and a different biodiesel blends shown in the Figure 4. In general, the brake thermal efficiency depends on the combustion process which is a complex phenomenon that is influenced by several factors like Cetane number, viscosity, and calorific value. It can be observed in Figure 4, at full load (12kg) and CR18, BTHE of biodiesel blend B20 is lower by 4.1% compared

to diesel. It is also observed that BTHE is decreased with increase in biodiesel blends. The decrease may be due to the higher viscosity of biodiesel which hinders the fuel evaporation due to poor atomization during the combustion process. Also the calorific value of the blends decreases with respect to pure diesel which is shown in the Table 2 and 3. This may be due to high density of the biodiesel compared to diesel and affects the mixture formation. This may lead to slow combustion and thus the lesser brake thermal efficiency with biodiesel.

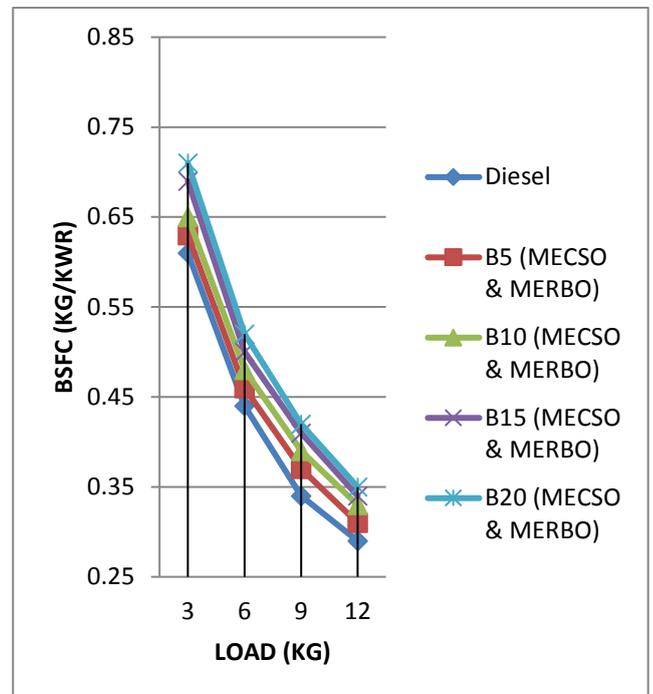


**Figure 5:** Variation of BTHE with Load for Different CRs with Diesel and B20 Blend

The variation of brake thermal efficiency with loads at different compression ratios for diesel and a blend of B20 is shown in the Figure 5. It can be observed in Figure 5 that at full load (12kg) with B20, the biodiesel blend B20 at CR18 has higher BTHE compared to CR 15, 16 and 17. It is evident that diesel fuel has the higher brake thermal efficiency compared to biodiesel blends. The diesel fuel has the highest brake thermal efficiency because of its higher calorific value and lower viscosity. With the higher calorific value the amount of heat produced in the combustion chamber is more, further, the combustion is complete and produces a higher temperature. It can be observed that BTHE increases continuously with increase in CR for all the biodiesel blends and diesel.

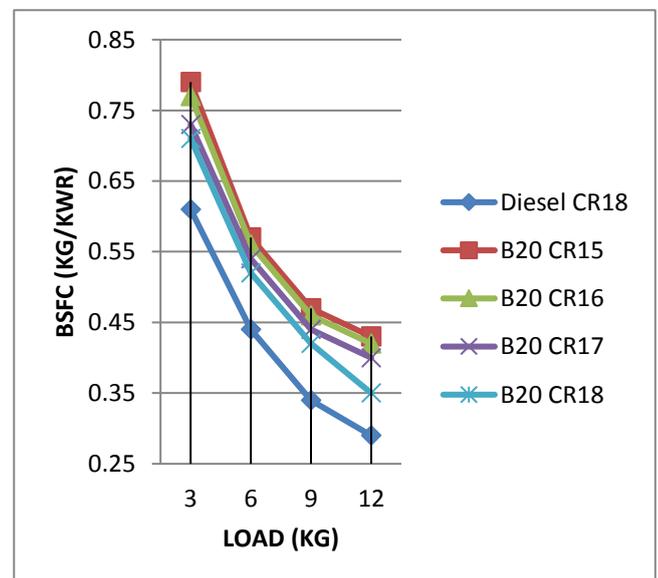
### 2.3 Brake Specific Fuel Consumption

The variation of brake specific fuel consumption with loads at CR18 for diesel and different biodiesel blends shown in the Figure 6. The BSFC is found to be the least at CR18 because at higher CRs complete combustion of fuel takes place due to high temperature of compressed air. The complete combustion produces higher brake power. Therefore, load demand is met with less fuel consumption. It is also seen that BSFC increases with the increase in the percentage of biodiesel blends. This may be due to the reason that fuel burning rate required is more with biodiesel because of its lower calorific values. It can be observed in Figure 6, at full load (12kg) and CR18, BSFC of biodiesel blend B20 is increasing by 17.1% compared to diesel. A higher proportion of biodiesel blends increase the viscosity which in turn increases the specific fuel consumption due to the poor atomization of the fuel. The oxygenated biodiesel may lead to the leaner combustion resulting in higher BSFC.



**Figure 6:** Variation of BSFC with Loads for Different Blends at CR18

The variation of brake specific fuel consumption with loads at different compression ratios for diesel and a blend of B20 is shown in the Figure 6. It can be observed in Figure 7 that at full load (12kg) with B20, the increase in the compression ratio leads BSFC closer to diesel due to their combustion feature, the biodiesel blend B20 at CR18 has lower BSFC compared to CR 15, 16 and 17. The BSFC is a parameter that reflects how good the engine performance is. The BSFC for the tested biodiesel blends is found slightly higher than diesel. The lower heating values and higher densities of those fuels require larger mass fuel flows for the same energy output from the engine, leading to the increase of the brake specific fuel consumption to compensate the reduced chemical energy in the fuel.



**Figure 7:** Variation of BSFC with Load for Different CRs with Diesel and B20 Blend

2.4 Brake Mean Effective Pressure

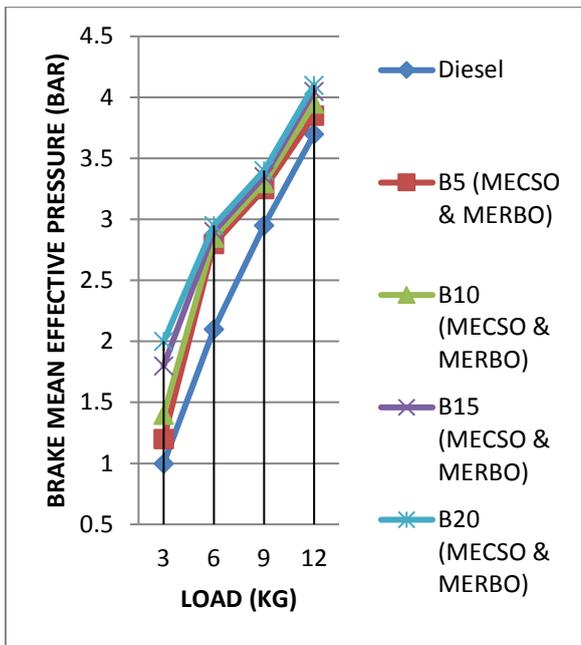


Figure 8: Variation of BMEP with Loads for Different Blends at CR18

The variation of brake mean effective pressure with loads at CR18 for diesel and a different biodiesel blends shown in the Figure 8. Brake Mean Effective Pressure is the external shaft work per unit volume displacement of the engine. It can be observed that BMEP increases linearly with load for all the blends tested. As the load on the engine increases, the rate of fuel consumption increases resulting in greater thermal energy release and hence effective pressure on the piston increases to develop the required brake power. It can be observed in Figure 8, at full load (12kg) and CR18, BMEP of biodiesel blend B20 is increasing by 9.8% compared to diesel. The higher BMEP for biodiesel blends may be due to a higher rate of fuel consumption and greater overall heat release with the complete burning of fuel due to the oxygenated nature of biodiesel.

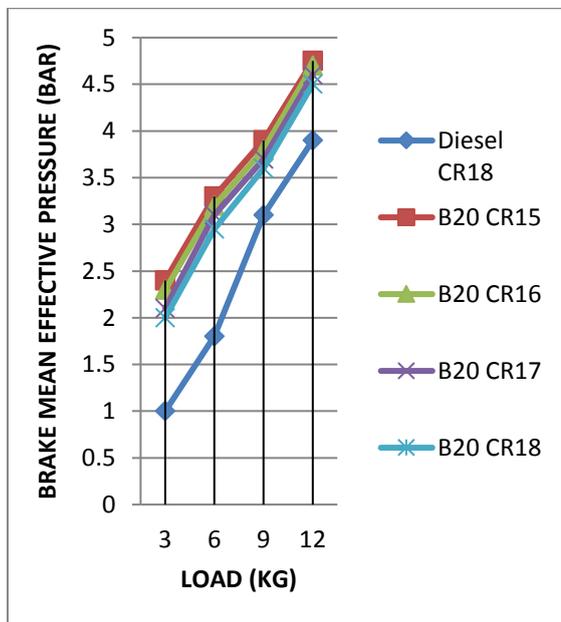


Figure 9: Variation of BMEP with Load for Different CRs with Diesel and B20 Blend

The variation of brake mean effective pressure with loads at different compression ratios for diesel and a blend of B20 is shown in the Figure 9. It can be observed in Figure 9 that at full load (12kg) with B20, The biodiesel blend B20 at CR18 has lower BMEP compared to CR 15, 16 and 17. At CR18 the BMEP of biodiesel blends are closer to diesel. The increase in the compression ratio leads BMEP closer to diesel. It can be observed that CR does not have a significant effect on BMEP.

2.5 Exhaust Gas Temperature

The variation of exhaust gas temperature with loads at CR18 for diesel and a different biodiesel blends shown in the Figure 10. It can be observed that EGT increases with the increase in load. The trend may be due to the higher temperature inside the engine cylinder as more fuel is burnt to meet the higher load demand. It is observed that EGT decreases with increase in biodiesel blends. It can be observed in Figure 10, at full load (12kg) and CR18, EGT of biodiesel blend B20 is lower by 4.6% compared to diesel. Heating value, cetane number, density and kinematic viscosity these four physicochemical properties have a potential impact on EGT. All biodiesel blends tested showed lower EGT than diesel fuel due to higher cetane number, higher viscosity and density and lower heating value of biodiesels. Lower EGT is an indication of the good burning of fuel inside the cylinder.

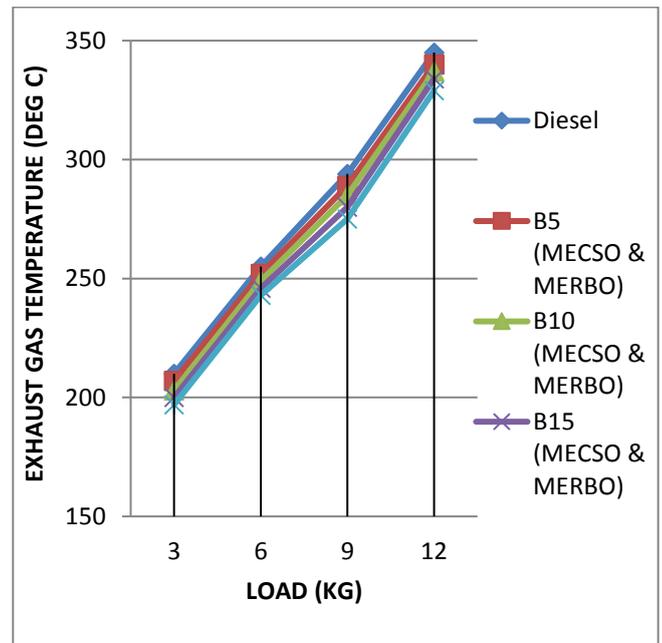


Figure 10: Variation of EGT with Loads for Different Blends at CR18

2.6 Peak Pressure

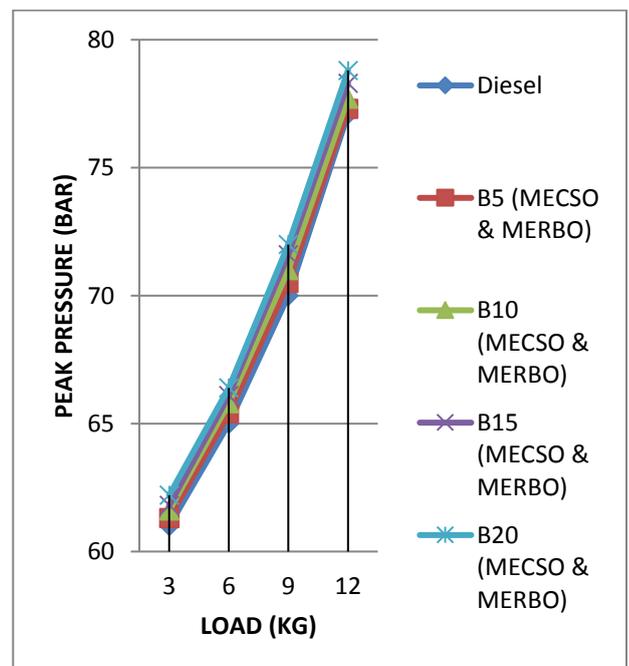


Figure 11: Variation of Peak Pressure with Loads for Different Blends at CR18

The variation of peak pressure with loads at CR18 for diesel and a different biodiesel blends shown in the Figure 11. Peak pressure increases with increase in load for MECSO and MERBO biodiesel blends. It can be

observed in Figure 11, at full load (12kg) and CR18, peak pressure of biodiesel blend B20 is higher by 2.2% compared to diesel. It can be observed that blend B20 has maximum peak pressure and it decreases with a decrease in biodiesel blends. The reason for this is the presence of oxygen in the biodiesel which results in complete combustion of fuel leading to increase in peak temperature and peak pressure.

## 2.7 Ignition Delay

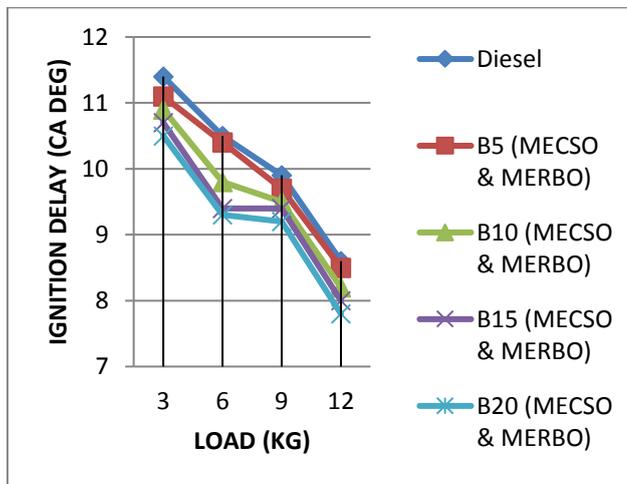


Figure 12: Variation of Ignition Delay with Loads for Different Blends at CR18

The variation of ignition delay with loads at CR18 for diesel and a different biodiesel blends shown in the Figure 12. The ignition delay is the most important parameter in the combustion analysis. Ignition delay is influenced by a group of parameters such as intake air temperature, pressure, air-fuel ratio, fuel type and quality fuel atomization. Ignition delay decreases with load and increases with biodiesel blends. The trend could be due to the higher autoignition temperature and higher latent heat of evaporation of biodiesel blends compared to diesel. It can be observed in Figure 12, at full load (12kg) and CR18, ignition delay of biodiesel blend B20 is lower by 9.3% compared to diesel.

## 2.8 Heat Release Rate

The variation of heat release rate with loads at CR18 for diesel and a different biodiesel blends shown in the Figure 13. Heat release rate for biodiesel blends are lesser than diesel due to its higher viscosity and better spray formation. At CR18 the heat release rate of biodiesel blend B20 is closer to diesel, which may be due to oxygenated nature of biodiesel blend resulting in complete combustion even though diesel has a higher calorific value of about 10% compared to biodiesel. It is evident that the heat release rate decrease at the start of combustion and increase further. This variation due to the air entrainment combined with lower air-fuel mixing rate and effect of viscosity of the biodiesel blends. It can be observed in Figure 13 that the value of heat release rate decreases with increase in biodiesel blends.

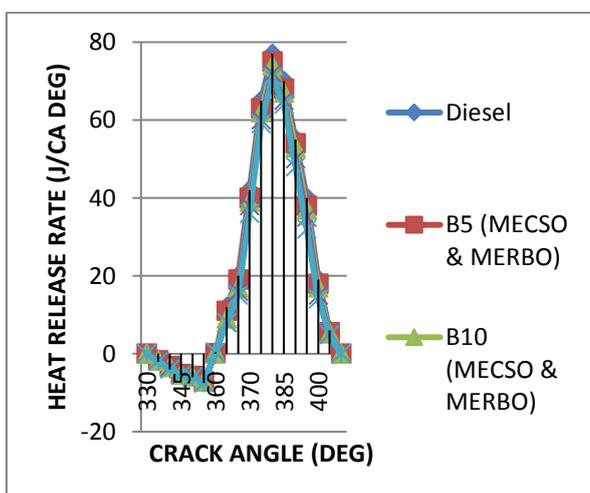


Figure 13: Variation of HRR with Loads for Different Blends at CR18

## 3. CONCLUSION

The effect of compression ratio and biodiesel blends on the VCR diesel engine performance and combustion characteristics is analyzed in this study. This study has been conducted in two phases. In the first phase, biodiesel was obtained. In the second phase, the blend properties, engine performance and combustion characteristics of MECO, MERBO and their combined blend with diesel were investigated. The results of this work can be summarized as follows:

The tests were conducted on single cylinder, four strokes and variable compression ratio diesel engine using different proportions of MECO and MERBO biodiesel with conventional diesel fuel. The blends B20 at CR18 showed 15.5% average decreases in brake power than those operated with conventional diesel. The result shows that higher viscosity and lower calorific values of fuel leads to lower brake power.

Brake thermal efficiency increase with increase in load on the engine. Brake thermal efficiency decreases with increase in percentage of biodiesel blends. It is found that the brake thermal efficiency of biodiesel blend B20 at CR18 is lower by 4.1% than pure diesel. Brake thermal efficiency generally increases moderately as the compression ratio increases.

Brake specific fuel consumption decrease with increase in load on the engine for all fuel blends. The increase in brake specific fuel consumption with increase in concentration of biodiesel blends in diesel fuel is attributed to lower heat values. It is found that the brake specific fuel consumption of biodiesel blend B20 at CR18 is higher by 17.1% than pure diesel. For biodiesel fuel and its blends it is observed that the loss of heating value is more than the increase of density which is the main cause of increase fuel consumption.

Higher density of biodiesel fuel and blends resulted in to a longer delay period. The biodiesel blend B20 has gives higher combustion pressure due longer ignition delay. There has been a notable decrease in exhaust gas temperature for biodiesel blends. Biodiesel blend B20 is the lowest exhaust gas temperature amongst all the blends. It has been confirmed that the heat release rate decrease at the start of combustion and increase further. While comparing the results obtained the heat release rate for B20 blends quite near to that of standard diesel. Biodiesel blends have less heat release rate than diesel.

It can be concluded that the VCR diesel engine operated with diesel with dual biodiesel MECO and MERBO and its blend B20 and CR18 is found to be suitable with respect to performance and diesel replacement. It is to be noted that the engine runs satisfactory and smoothly for all the blends of biodiesel without any modifications hence it may be concluded that the VCR diesel engine can be successfully operated with dual biodiesel blends of MECO and MERBO.

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