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EXPERIMENTAL INVESTİGATIONS ON EMISSIONS CHARACTERISTICS OF A VARIABLE COMPRESSİON 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

The global consumption of fossil fuels is increasing rapidly, and it affects the environment through greenhouse gases causing health hazards. Biodiesel has a great potential to reduce environmental pollution as an alternative fuel for diesel engines. The aim of the present study is to analyze and investigate the optimum compression ratio, optimum blend and engine emissions. Experiments were conducted on a 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 emission results indicated that the biodiesel blend B20 reduced the average emissions of carbon monoxide and hydrocarbon by 21.9% and 4.0% respectively. However, biodiesel blend B20 slightly increased emissions of carbon dioxide and oxides of nitrogen by 16.3% and 8.6% respectively compared to diesel. When compression ratio was increased from 15 to 18, the CO and HC emission decreased drastically, and CO2 and NOx emission increased considerably. From the present study, it is concluded that blend B20 and CR18 operates much inferior to diesel with respect to emissions. B20 blend may replace diesel fuel without modifying engines to produce cleaner exhaust emissions.

KEYWORDS

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

1. INTRODUCTION

The worldwide increase in energy consumption is drastically increasing day by day. A report published by "The International Energy Outlook in 2011"[1] shows that energy consumption of the world will rise by around 53% between 2008 and 2035. This is because of the strong economic growth of the two most important developing countries in the world, namely, China and India. The day is not far when both the countries will alone consume almost half of the projected rise of world energy use.

From the mid and near tail of 19th century, energy crisis had been a worldwide alarming concern. Exponentially increasing population, the rapid growth of industrialization and the global trend of urbanization have drastically increased the demand for energy resources. The rapid depletion of fossil fuel and environmental air pollution due to fossil fuel combustion are the two major consequences of energy demand compensation. These two consequences further affect the economy and development of any growing country like India.

Energy is the primary requirement in various sectors like power, transport, industrial, commercial and residential etc. The development of any country depends upon the availability of various natural resources, in particular, energy resources and their effective utilization. Energy conservation and efficient use of energy are essential to promote development. The per capita energy consumption determines the status of a country whether developed or underdeveloped. In the present day, energy and environment scenario, it is very crucial for any country, to promote the use of renewable energy sources for various applications.
Scientists and researchers are asked to focus their attention on finding new renewable and environment-friendly alternate sources of energy. Vegetable oils have become more attractive recently because of their environmental benefits and better exhaust emissions. They don't contribute any significant rise in the level of carbon dioxide in the atmosphere and most importantly they are renewable. Development of such vegetable-based biodiesel and their maximum utilization to meet the energy demand in various sectors across the globe is very much crucial to combat the twin alarming global concerns of "Global Warming" and "Environmental Degradation".

Total global energy consumption in the year 2012 has grown by 1.8% [2], in comparison with the consumption in the year 1965. India has witnessed extraordinary economic growth over past few decades. This economic growth is attracting more industries to come to India and this is placing an enormous demand on its energy resources. The imbalance in demand and supply of energy resources is forcing the Government of India to take serious steps to augment energy supplies. Even though the global economy is slowing down, energy demand in India has continued to rise rapidly.

The most desirable option for bridging the gap between supply and demand is improving energy efficiency. Indian economy suffers drastically due to the ever-growing crude oil import and the severe global threat posed by increasing fossil fuel combustion emissions. Hence scientists and researchers are forced to concentrate on finding renewable and environment-friendly alternative source of energy.

In the year 2012 – 2013, 30% to 40 % of the energy demand was met by crude oil import in India [2]. Increase in fossil fuel utility correspondingly increases the crude oil import, as India's crude oil resource is very low. The uncertainty in crude oil supply and frequent price hike give severe setback in the development of industrial and transport sectors. Hence, newer energy resource development with least possible cost attains importance to conquer self-reliance in energy and economic development. Global warming, ozone depletion, and acid precipitation are three major environmental degradations due to fossil fuel combustion. Acidification of lakes, streams, and groundwater, cause serious damage to aquatic life, forest and agricultural crops. The major contribution of air pollution is caused by fossil fuel combustion. Diesel engines are a major source of air pollution. The exhaust gases from diesel engines contain oxides of nitrogen, carbon monoxide, carbon dioxide, unburnt or partially burned hydrocarbon, and particulate matter. Hence efforts are being made to explore the alternative sources of energy.

The above-discussed twin problems of fossil fuel depletion and the environmental hazards emphasize the need for alternate renewable energy sources to have sustainability of energy resources, better sociability, and better environmental conditions. Finding an eco-friendly and energy efficient resource is the timely need for the world.

Biodiesel has gained greater attention because of the advantages such as being renewable and biodegradable; it has higher cetane number, lower emission of carbon monoxide, particulate matters and unburnt hydrocarbon, lower sulphur and aromatic content. However, still, it is not fully capable of replacing fossil fuel, because of various reasons such as higher NOx emission, higher viscosity, lower oxidative and storage stability.

2. LITERATURE REVIEW

Biodiesel has emerged as a 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 emission characteristics. Syarifah Yunus et al.,[3] conducted experimental investigations on a four cylinder, four-stroke, VCR diesel engine to study the emission characteristics of dual biodiesel (Jatropha biodiesel and Palm biodiesel) blends with diesel. They concluded that higher CO, CO_2 and NOx produced from all biodiesel blended as compared to diesel Fuel. This might be due to the higher oxygen content in the biodiesel structure and also higher exhaust temperature during combustion which promotes the formation of more hazardous gases.

A.Sanjid et al.,[4] conducted experimental investigations on a single cylinder, four-stroke, VCR diesel engine at different engine speeds ranging from 1400 to 2200 rpm to study the performance and emission characteristics of dual biodiesel Palm biodiesel and Jatropha biodiesel (PBJB) blends with diesel. They concluded that all the measured emission parameters and noise emission were significantly reduced, except for NO emission. CO emissions for PBJB5 and PBJB10 were 9.53% and 20.49% lower than for diesel fuel. HC emissions for PBJB5 and PBJB10 were 3.69% and 7.81% lower than for diesel fuel. The sound levels produced by PBJB5 and PBJB10 were also reduced by 2.5% and 5% compared with diesel fuel due to their lubricity and damping characteristics. M. Habibullah et al.,[5] conducted experimental investigations on a single cylinder, four-stroke, VCR diesel engine to study the performance and emission characteristics of dual biodiesel Palm biodiesel (PB) and Coconut oil biodiesel(CB) blends with diesel.

They concluded that all emissions, except for NOx, are significantly reduced. PB15CB15 reducing NOx emissions when compared with CB30. Meanwhile, compared with PB30, PB15CB15 reduces CO and HC emissions. The experimental analysis reveals that the combined blend of palm and coconut oil shows superior performance and emission over individual coconut and palm biodiesel blends.Venkateswara Rao P et al., [6] conducted experimental investigations on a single- cylinder, four-stroke, VCR diesel engine to study the performance and emission characteristics of dual biodiesel Pongamia pinnata biodiesel and Jatropha biodiesel blends with diesel. They concluded that D90PJBD10 and D80PJBD20 were very closer to diesel fuel values. Hence they can be used as fuels for stationary diesel engines for the purpose of agriculture. Ankur Nalgundwar et al.,[7] conducted experimental investigations on a single cylinder, four-stroke, VCR diesel engine to study the performance and emission characteristics of dual biodiesel Palm biodiesel (PB) and Jatropha biodiesel (JB) blends with diesel.

They concluded that a notable decrease in exhaust gas temperature for most of biodiesel blends was observed. There were 7.1%, 17.7% and 14.5% average reductions in CO emissions with samples D90JB5PB5, D80JB10PB10 and D70JB15PB15 (biodiesel blends containing 10%, 20% & 30% biodiesel) respectively, when compared to diesel. Lower blends of biodiesel samples D90JB5PB5 and D80JB10PB10 showed 5.3% and 9.2% average increase in NOx emissions respectively, than diesel. K.Srinivas et al.,[8] conducted experimental investigations on a single cylinder, four-stroke, VCR diesel engine to study the performance characteristics of dual biodiesel (Palm Kernel Oil and Eucalyptus Oil) blends with diesel. They concluded that 41.09% reduction in CO, 42.99% reduction in HC, 9.02% increase in NOx emissions and 37.05% reduction in smoke for B15 blend at 100% load conditions. K. Srithar et al.,[9] conducted experimental investigations on a four cylinders, four-stroke, VCR diesel engine speed of 3000 rpm to study the performance and emission characteristics of dual biodiesel (pongamia pinnata oil and mustard oil) blends with diesel. They concluded that the emissions of smoke, hydro carbon and nitrogen oxides of dual biodiesel blends were higher than that of diesel. But the exhaust gas temperature for dual biodiesel blends was lower than diesel.

Srinivasa VaraPrasad et al.,[10] conducted experimental investigations on a single cylinder, four-stroke, VCR diesel to study the performance and emission characteristics of dual biodiesel (Jatropha oil and Rice Bran oil) blends with diesel. They concluded that the emissions of CO, HC, CO_2, unused O_2 and Smoke of duel biodiesel are higher than diesel and Jatropha biodiesel. Husainsab M. Halemasuti et al., [11] conducted experimental investigations on a single cylinder, four-stroke, VCR diesel to study the performance and emission characteristics of dual biodiesel (Neem oil and Castor oil) blends with diesel. They concluded that the CO_2 (Carbon dioxide), HC(Hydrocarbon), CO (Carbon monoxide) and NOx (Nitrogen oxide) emissions for B20 are 0.28%, 1 ppm, 0% and 32 ppm respectively. Finally it is concluded that the blend of dual bio diesel B20 is the optimum blend for diesel engines for better performance and emissions.

There are various observations made by the researchers in their respective studies. Some general observations which can be identified from the literature include,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 diesel.

Biodiesels can be used as an alternative for diesel. Researchers from around the world tried for many years to find a suitable biodiesel which can substitute diesel. Many biodiesels have been produced from different sources and tested for their performances. Some of them try to find out a suitable blend of diesel and biodiesel to reduce the environmental impact and for better emission characteristics. The biodiesel selected to conduct this experimental investigation is a blend of cotton seed oil and rice bran oil. The selection of cotton seed oil and rice bran oil biodiesel is based on an extensive review of literature which indicated that this is relatively unexplored as fuel on a VCR diesel engine [12-30].

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 emission 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. Cotton seed oil and rice bran oil is an important source of vegetable oil which is yet to be fully exploited. India is the second largest cotton and rice producer in the world. India also produces huge quantity of rice bran oil

and cotton seed oil and the projected production is also very high in the coming years. They are currently used for cooking and for some non economical ways. If the bulk of the production is diverted for biodiesel it may result in huge saving in our oil import bills. Biodiesel production offers promising opportunities to create additional sources of income for India's rural population and to reduce India's energy dependency and bring down greenhouse gas emissions.

4. Though much work has been reported on biodiesel application and its effect on the emission 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. Preparation of MECSO 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.

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

3. Determine the the optimum blending ratio of the biodiesel and the optimum compression ratio using a variable compression ratio diesel engine. Study and analyze the engine emission characteristics of carbon monoxide, carbon dioxide, unburned hydro carbon and oxides of nitrogen.

3. EXPERIMENTAL METHODOLOGY

3.1 Experimental Setup

An experimental test rig is developed to undertake the emission characteristics evaluation of a variable compression ratio compression ignition engine, fuelled with dual biodiesel (MECSO and MERBO) and its blends with diesel. The experimental test rig is suitably developed to conduct various test runs under different working conditions to evaluate the emission constituents of a biodiesel run engine in comparison with that of a conventional diesel operated engine. Table 3.1.1 shows the complete specifications of the experimental setup. Table 3.1.2 and Tabele 3.1.3 shows the properties of MECSO and MERBO biodiesel and its various blends with diesel.

The VCR diesel engine exhaust is connected with AVL Diagas Analyser.The emission measurement system is used to measure the constituents of exhaust gas. The exhaust gas analyzer measures the exhaust gas constituents of Carbon monoxide, Carbon dioxide, Unburnt Hydrocarbons and Oxides of nitrogen.

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^2
Maximum speed	2000 rpm
Minimum idle speed	750 rpm
Minimum operating speed	1200 rpm
Fuel injection timing for standard engine	23^0 BTDC
Dimensions	W 2000 x D 2500 x H 1500 mm

Table 2: Fuel Properties of Diesel and Biodiesel

Properties	Diesel	MECSO	MERBO	ASTM (D6751)
Density (kg/m^3) @ 15° C	815	875	890	860-900
Viscosity (mm^2/s) @ 40º 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 Pointº C	53	162	168	130
Fire Point ºC	59	173	174	-

Table 3: Fuel Properties of Biodiesel Blends

Properties	B5	B10	B15	B20
Density (kg/m^3) @ 15º C	818.4	821.8	825.1	828.5
Viscosity (mm^2/s) @ 40ºC	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 ºC	58.6	64.2	69.8	75.4
Fire Point ºC	64.7	70.5	76.2	81.9

4. RESULT AND DISCUSSION

The results obtained from the experiments conducted for emission analysis are analyzed. Before carrying out the series of experiments, the engine's readiness for the test is validated by running the engine with diesel only. The tests are conducted at different loads from 0kg to 12kg, 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. The combustion product emissions from diesel engines are hydrocarbon emissions and form a significant part of the engine exhaust. Hydrocarbons in the exhaust may also condense to form white smoke during engine starting and warm up. Specific hydrocarbon compounds in exhaust gases are a source of diesel odour. Diesel engines are not a very significant source of carbon monoxide emission comparatively. The other exhaust emissions include NOx, oxides of nitrogen which are a major source of air pollution. Half of NOx, CO and HC pollutants in the air are primarily because of IC engines. NOx may react with solar radiation to form ozone. Hydrocarbons cause cellular mutations and are responsible for ground-level ozone formation. However, with the use of biodiesel, the harmful emissions like HC, CO, CO_2 can be significantly brought down. Following are the different emission characteristic curves obtained based on the experimental results. 0kg is not considered for clear interpretation of various curves.

4.1 Carbon Monoxide

The variation of carbon monoxide with loads at CR18 for diesel and a different biodiesel blends shown in the Figure 4.1.1. CO is an intermediate combustion product and is formed mainly due to incomplete combustion of fuel. If combustion is complete, CO is converted to CO_2. If the combustion is incomplete due to shortage of air or due to low gas temperature, CO will be formed. For biodiesel blend fuel mixtures CO emission is lower than that of diesel, because biodiesel blends contain additional oxygen in their molecule that resulted in complete combustion of the fuel and supplied the necessary oxygen to convert CO to CO_2. Biodiesel blends have higher cetane number, which results in the lower possibility of formation of rich fuel zone and thus reduces CO emissions as compared to diesel. A comparison is made for the variation in CO with load of biodiesel and its blends with diesel from a load of 0kg to 12kg is done. It can be observed in figure 4.1.1, at full load (12kg) and CR18, CO emissions of biodiesel blend B20 is lower by 21.9% compared to diesel. CO emissions are increased with increase in engine load and decrease with the increase in proportion of biodiesel blends.

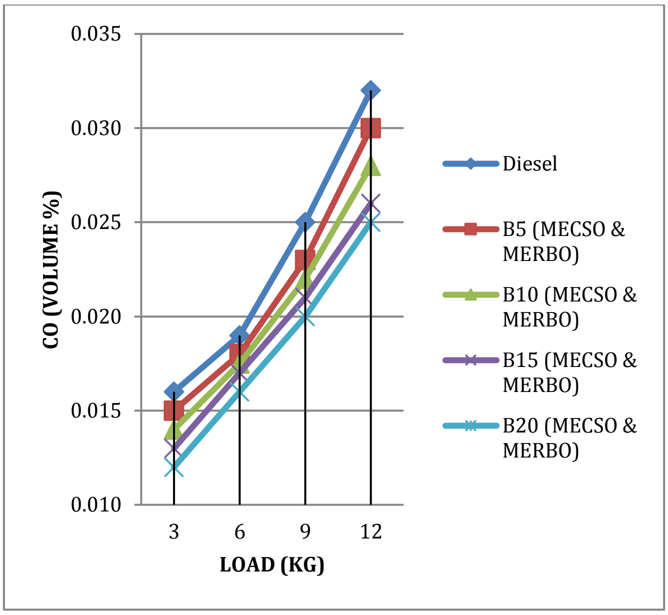

Figure 1: Variation of CO with Load for Different Blends at CR18

The variation of carbon monoxide with loads at different compression ratios for diesel and a blend of B20 is shown in the Figure 4.1.2. It can be observed in Figure 4.1.2 that at full load (12kg) with B20, the blend B20 with CR18 has lower CO emissions compared to CR 15, 16 and 17. CO emissions decrease with increasing the compression ratio for all biodiesel blends. While compression ratio increases temperature of combustion chamber also increases as result of this complete combustion takes place and hence lower formation of CO. CO percentage at low for biodiesel blends is due to decrease in the cylinder gas temperature and delayed combustion process. The lower temperature and delayed combustion would have suppressed the oxidation process even though enough oxygen was available for combustion. Reduction in CO emissions is noticed for blends at high load and that would be due to oxygen present in fuel and improved combustion process due to better mixing.

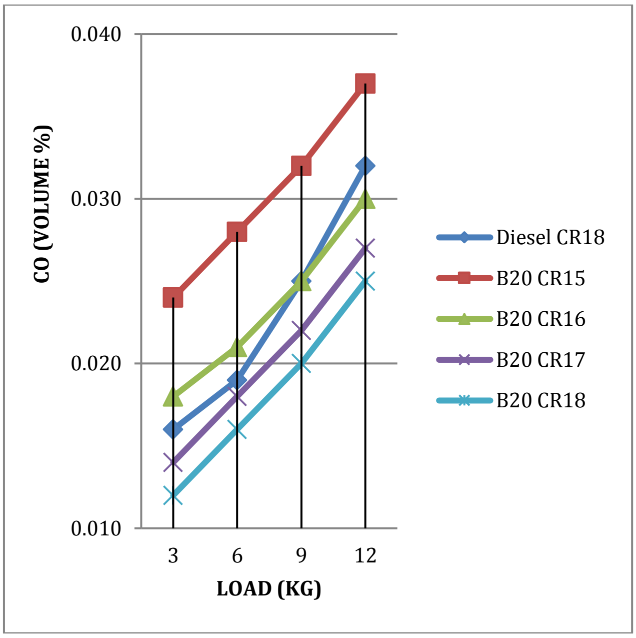

Figure 2: Variation of CO with Load for Different CRs with Diesel and B20 Blends

4.2 Carbon Dioxide

The variation of carbon dioxide with loads at CR18 for diesel and a different biodiesel blends shown in the Figure 4.2.1. The global warming and ozone depletion of environment due to periodically accumulation of CO_2 in the atmosphere. The CO_2 emissions from diesel engine can play a It can be observed in Figure 3, at full load (12kg) and CR18, CO_2 emissions of biodiesel blend B20 is higher by 16.3% compared to diesel. Due to the high oxygen content of biodiesel, combustion occurs more completely. During the combustion these oxygen reacts with unburned carbon and promotes more formation of CO_2. Thus, CO_2 emissions increases. If the amount of CO_2 is more in the exhaust emissions means complete combustion of fuel in engine cylinder. As a result of improved combustion role in serious public health problems and most important in formation of ozone layer. CO_2 emissions indicates complete combustion of fuel inside the engine cylinder, which occurs at high cylinder temperatures, hence the CO_2 emissions of all biodiesel blends increased with the increase in load. A comparison made for the variation in CO_2 with load of biodiesel and its blends with diesel from a load of 0kg to 12kg is done

due to presence of additional oxygen content in biodiesel, carbon dioxide (CO_2) emissions increased for biodiesel blends. It can be seen that higher blends of biodiesel combust more efficiently than lower biodiesel blends. The excess of CO_2 may be absorbed by growing plants which are the sources to the biodiesel preparation. The CO_2 emissions become insignificant in atmosphere as it will be taken up by plants, trees and crops.

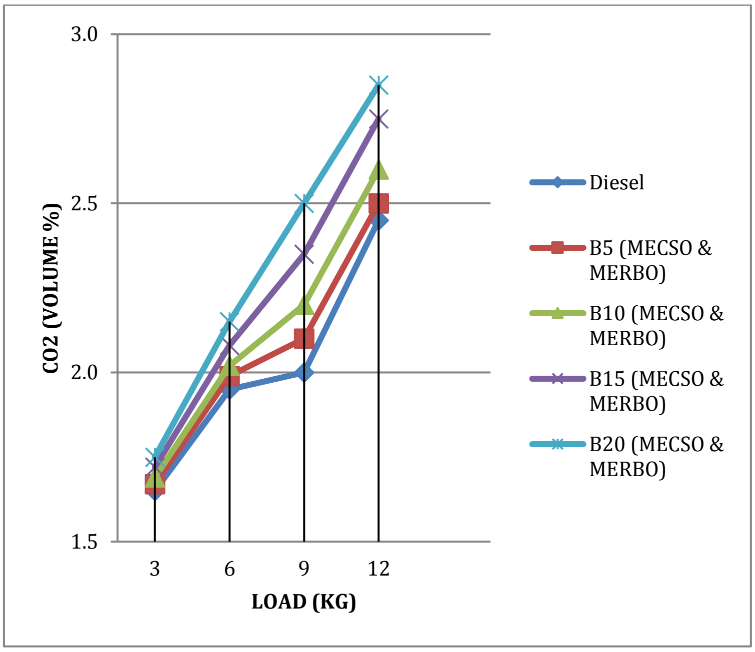

Figure 3: Variation of CO_2 with Load for Different Blends at CR18

The variation of carbon dioxide with loads at different compression ratios for diesel and a blend of B20 is shown in the Figure 4. It can be observed in Figure 3.2.2 that at full load (12kg) with B20, The blend B20 at CR18 has higher CO_2 emission compared to CR 15, 16 and 17. The complete combustion of fuel is indicated by the excess amount of CO_2 exhausted from tail pipe. As compression ratio increases, the CO_2 emission increases. As a result, temperature inside the combustion chamber also increases which leads to complete combustion of fuel hence it results to more formation of CO_2. The CO_2 emissions from the combustion of biodiesel blends may be absorbed by the plants and the carbon dioxide level may be kept constant in the atmosphere.

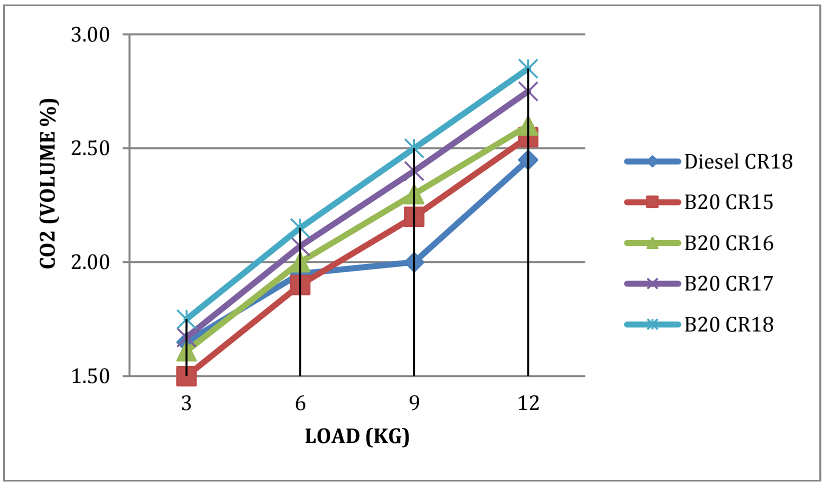

Figure 4: Variation of CO_2 with Load for Different CRs with Diesel and B20 Blends

4.3 Unburned Hydrocarbon

The variation of unburned hydrocarbon with loads at CR18 for diesel and a different biodiesel blends shown in the Figure 4.3.1. The oxygenated compounds available in the biodiesel blends improve the fuel oxidation hence it reduce the HC emissions. Oxygen content of biodiesel is the main reason for more complete combustion and HC emissions reduction. Higher cetane number of biodiesel blends reduces the combustion delay, and such a reduction may be the factor to decreases in HC emissions.

The HC emissions increase with increasing load and decrease with increase in amount of biodiesel blends. This is due to less oxygen being available for reaction when more fuel is injected into the engine cylinder at higher engine load. A comparison made for the variation in HC with load for biodiesel and its blends with diesel from a load of 0kg to 12kg is done. It can be observed in Figure 4.3.1, at full load (12kg) and CR18, HC emission of biodiesel blend B20 is lower by 4.0% compared to diesel.

Moreover,high oxygen content of biodiesel also aids complete combustion. It may be due to oxygen content in the biodiesel results in cleaner and complete combustion.

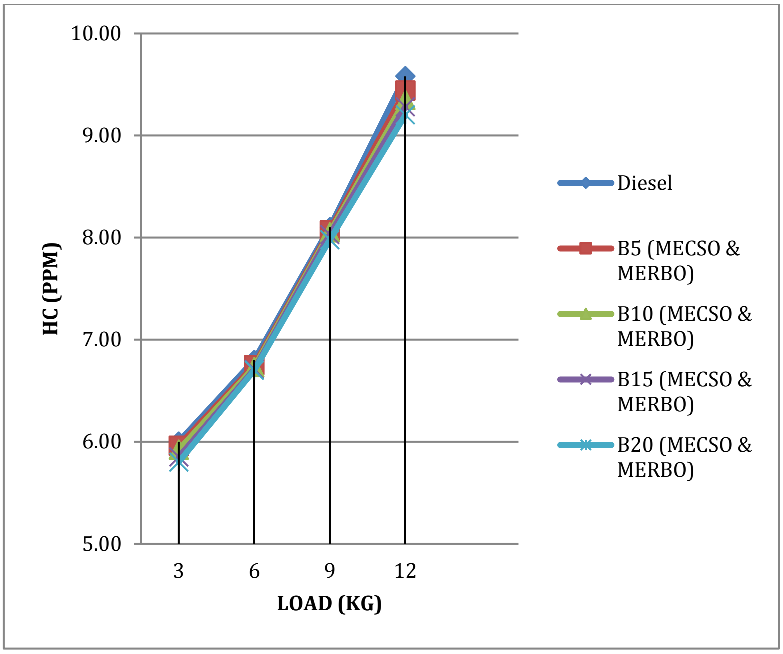

Figure 5: Variation of HC with Load for Different Blends at CR18

The variation of unburned hydrocarbon with loads at different compression ratios for diesel and a blend of B20 is shown in the Figure 4.3.2. It can be observed in Figure 4.3.2 that at full load (12kg) with B20, the biodiesel blend B20 at CR18 has lower HC emissions compared to CR 15, 16 and 17. There is reduction in HC emissions with increasing the load for all the biodiesel blends. With increasing the load, fuel consumption decreases due to this more fuel injected into combustion chamber. That cause results, increases the temperature and complete combustion take place. It is evident, that with increasing compression ratio from 15 to 18 hydrocarbon emission decreases. While a engine running at higher compression ratio the cylinder temperature increases which promotes more complete combustion and hence reduction of hydrocarbon emission. Lower heating value leads to the injection of higher quantities of fuel for the same load condition.

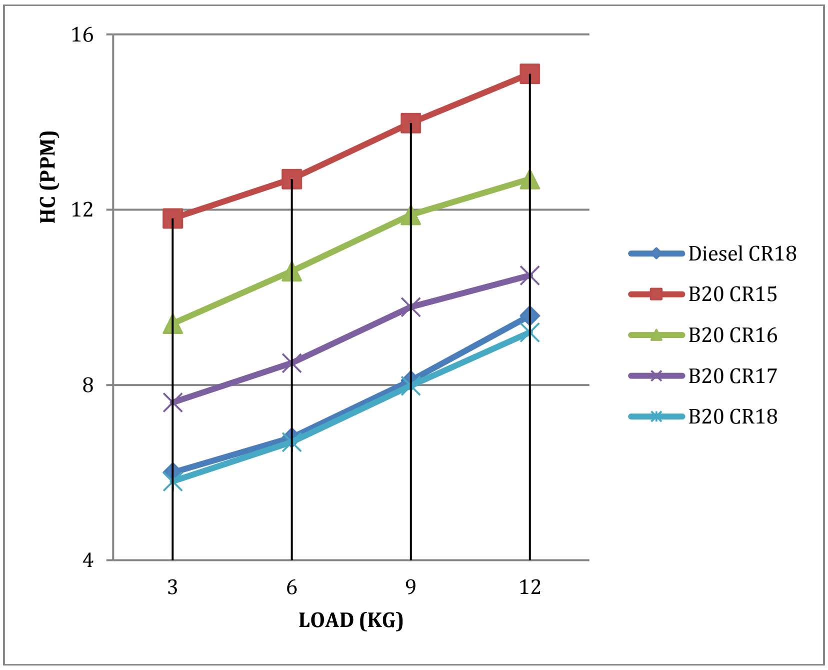

Figure 6: Variation of HC with Load for Different CRs with Diesel and B20 Blends

4.4 Oxides of Nitrogen

The variation of oxides of nitrogen with loads at CR18 for diesel and a different biodiesel blends shown in the Figure 4.4.1. The formation of NOx emissions are strongly dependent upon the equivalence ratio, oxygen concentration and burned gas temperature. The oxygen content of blend fuels was the main reason for higher NOx emissions. During the combustion process, the oxygen in the blend fuels can react easily with nitrogen. It is also agreed that in the production of NOx, the fuel borne oxygen is more effective than the external oxygen supplied with the air. It is determined that percentage of biodiesel addition resulted in higher NOx emissions. Vegetable based fuel contains a small amount of nitrogen. This contributes towards NOx production. It was also reported that an increase in fuel density results in higher NOx emissions. Though exhaust gas temperature decreases with the higher amount of biodiesel blends, the other factors which are mentioned above may contribute to higher NOx emissions. A comparison made for the variation in NOx with load for biodiesel and its blends with diesel from a load of 0kg to 12kg is done. It can be observed in Figure 4.4.1, at full load (12kg) and CR18, NOx emissions of biodiesel is higher by 8.6% compared to diesel. The NOx emissions with biodiesel blends are found little higher than the diesel. It is observed that, while the load increases it result in increase of NOx emission.

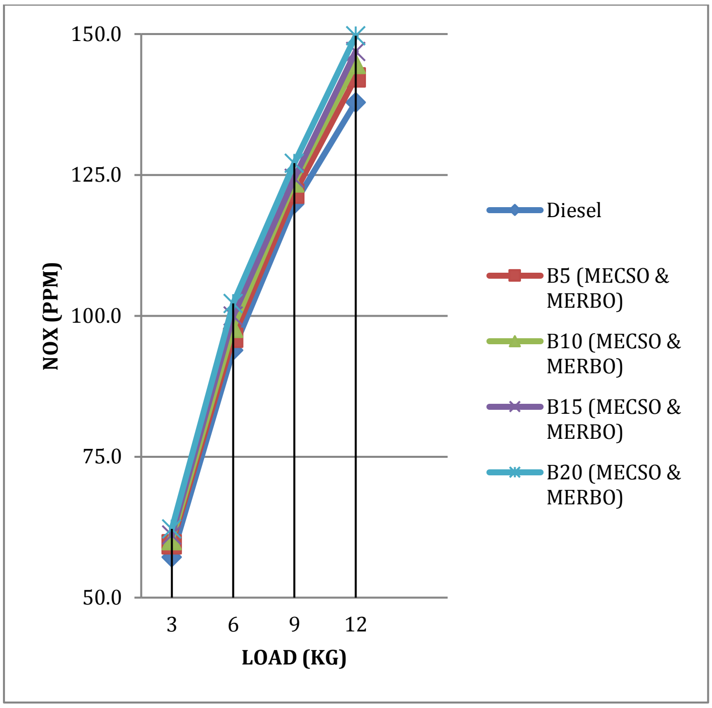

Figure 6: Variation of NO_X with Load for Different Blends at CR18

The variation of oxides of nitrogen with loads at different compression ratios for diesel and a blend of B20 is shown in the figure 4.4.2. Combination of nitric oxide (NO) and nitrogen dioxide (NO_2) is known as nitrogen oxides or NOx. NOx formation depends upon the following factors such as, temperature of the cylinder and time needed for the reaction to take place. It can be observed in Figure 4.4.2 that at full load (12kg) with B20, the blend B20 at CR18 has higher NOx emission compared to CR 15, 16 and 17. The reason for higher NOx emissions for biodiesel blends is due to higher peak temperature. As the compression ratio increase, the amount of NOx will increase. Fuel burns completely at high at CR that resulted in a higher peak temperature in engine cylinder and so the formation of NOx got increased.

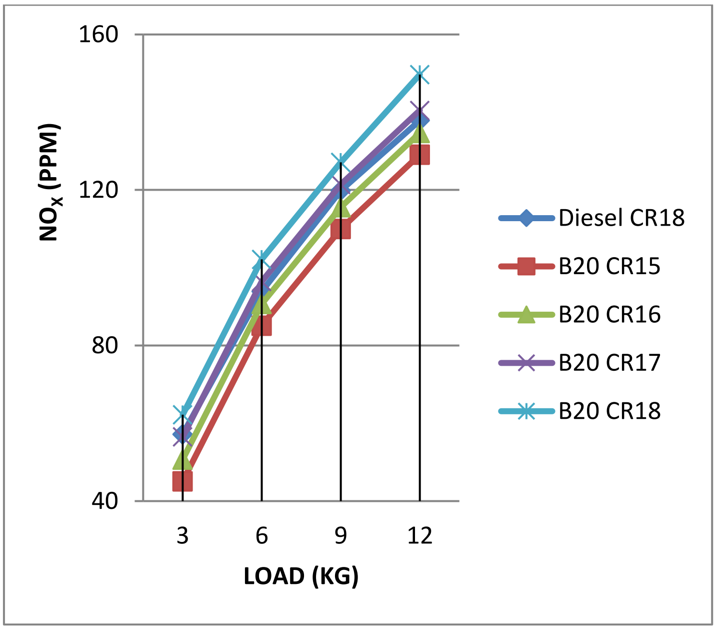

Figure 7: Variation of NO_X with Load for Different CRs with Diesel and B20 Blends

5. CONCLUSION

The purpose of this study is to find out the optimum blend, optimum compression ratio and emissions characteristics of single-cylinder, four-stroke variable compression ratio, compression ignition engine using dual biodiesel of MECSO and MERBO and its blends with diesel, different compression ratio and varying loads. From the experimental analysis results, following are the summary of findings. For CO emissions, reductions were estimated at 21.9% and 18.8 % for biodiesel blends B20 and B15 respectively at CR18 when compare to pure diesel. CO emissions decreases with increasing percentage of biodiesel in blends with diesel.
At higher load condition the hydrocarbon emission of various blends are lower. Biodiesel blend B20 at CR18 reduces the HC emissions by 4.0% than pure diesel. Due to complete combustion and adequate supply of oxygen at the measurement of CO_2 emission of biodiesel blends B20 at CR18 showed average 16.3% increase than pure diesel. Diesel has lowest CO_2 emission and among all fuel blends CO_2 emission increases with increasing percentage of biodiesel. It can be concluded that there was a gradual increase in NOx emission with increase in the blend concentration showed average 8.6% higher than that of diesel fuel. Among all the fuels it is observed that biodiesel blend B20 is observed to be environmental free as it has very low CO and HC emissions. However, regarding CO_2 and NOx emissions, biodiesel blends B20 can be considerable.

Based on the findings of this research it can be concluded that higher blends of dual biodiesel blend such as B20 and higher compression ratio CR18 is found to be the optimum combination of blend and compression ratio respectively. It can be concluded that the VCR diesel engine operated using dual biodiesel of MECSO and MERBO can be used as alternative fuels in diesel engine without any engine modification. Biodiesel blends having higher oxygen content enhances the combustion process, and increases the temperature, consequently influencing the NOx emissions. Increase in

NOx emissions will be a major deterrent for using the biodiesel in the diesel engine. The present work can also be extended by implementing Exhaust Gas Recirculation or mixing fuel additives to reduce NOx emissions are some of the solutions that can be adopted and investigated further without compromising other emissions characteristics.

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