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Effects of Compression Ratio on Performance combustion and emission of a Single Cylinder VCR Engine using Blends of Karanja Oil Methyl Ester with Diesel

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Abstract- ***Diesel engine plays an important role in the development of our country. Depletion of fossil fuel layer and pollution caused by the diesel engine is two major problem of the world today. In order to overcome the two problems bio fuels can be used as alternative fuel in diesel engine without any modification. In India million tones of non edible seeds like Karanja seeds are going in waste .Oil produced from these seeds can be used as alternative fuel in diesel engine. The performance, emission and combustion characteristics of a single cylinder, four stroke variable compression ratio engine fuelled with Karanja oil methyl ester(KOME) and its 20%,40% and 60% blends with diesel(on volume basis) are studied and compared with diesel. Experiments were done at a constant speed of 1500 rpm, 100% load and at three different compression ratios 16:1, 17:1, and 18:1. In the performance analysis Brake thermal efficiency of B40 is found to be maximum and brake specific fuel consumption is found to be minimum at compression ratio 18.In the combustion analysis ignition delay, maximum rate of pressure rise of biodiesel blends is found to be higher than diesel at compression ratio18. In the emission analysis reduction of CO emission, HC emission is found to be lower and NO_X emission is found to be higher for biodiesel as compared with diesel.***
Keywords: ***Karana oil methyl ester, variable compression ratio, performance, combustion, emission.***

I. INTRODUCTION

Energy is the major sources for the development of any country. India being a developing country requires much higher level of energy to sustain its rate of progress. According to the International Energy Agency (IFA), Hydrocarbon account for the majority of India's energy use. The importance of biodiesel as alternative fuel is more feasible towards reduction of harmful engine emissions. Karanaja oil methyl ester as a alternative fuel in a single cylinder, four stroke direct injection diesel engine experimentswas experimented. The BTE was found to be higher for B20 and B40 [1]. The performance and emission characteristics of a single cylinder agricultural diesel engine using preheated Karanja oil and its blends with diesel were studied. Marginal improvements in performance and emission as compared with diesel were found for lower blend percentage [2]. Using bio diesel obtained from Mahua oil and its blends with diesel in Recardo E6 engine experiments were conducted at different compression ratios, different injection timing and at different loads. In the performance analysis it was observed that brake specific fuel consumption, exhaust gas temperature increased and brake thermal efficiency decreased with the increased in blend percentage at all compression ratios(18:1-20:1) and injection timing(35-45^0 before TDC). It was concluded that biodiesel blended with high speed diesel can be used as alternative fuel [3]. Using biodiesel obtained from crude rice brain oil methyl ester (CRBME) in a small duty direct injection diesel engine combustion characteristics were studied. It was found that ignition delay maximum rate of pressure rise for biodiesel was increased as compared with diesel.[4].Using diesel and biodiesel-ethanol blends in a single cylinder four stroke direct injection diesel engine experiments were carried out at three different compression ratios (15:1,17:1,19:1).In the combustion analysis it was found that maximum rate of pressure of pressure rise , heat release rate increased with increased biodiesel percentage[5,6]. Using sea lemon oil-based fuels in a direct injection diesel engine, combustion and emission analysis were carried out.NO_X emission was found to be lower , CO and hydrocarbon emission found to be higher for Neat sea lemon oil as compared to that of diesel. Combustion characteristics of sea lemon oil and its methyl ester were found to be very close to that of diesel [7]. Peak cylinder for biodiesel and diesel are very close to each other at higher loads, but the peak rate of pressure rise and maximum rate of heat release rate were higher for diesel as compared to biodiesel. Brake specific fuel consumption increases with increase in biodiesel percentage. At full load marginal reduction of CO, HC, NO_X emission for biodiesel as compared to diesel [8]. Using mineral diesel and diesel biodiesel blends in a CI engine at injection pressure 200 bar performance and emission characteristics were studied .It was observed that CO emission increased,HC emission reduced 12.8% for B20 and 2.85% for B40 ,NO_X emission reduced 39% for B20and 28% for

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B40.BSEC value slightly higher for B20 and B40[10].Variation of performance parameters with variation of compression ratio and fuel injection pressure were studied using jatropa methyl ester as fuel.BTE found to be increased and BSFC found to be decreased with increased in compression ratio and injection pressure. Emission was reduced at higher compression ratio and injection pressure [11]. Performance and combustion parameters of Recardo E6 variable compression ratio engine was studied using raw algae and its methyl ester as fuel. It was concluded that engine output can be improved and noise can be reduced by controlling compression ratio and injection timing [12].

From the literature study some idea of performance, combustion and emission characteristics using biodiesel obtained from locally available non edible oil in an unmodified diesel engine at different compression is generated. Therefore the appropriate blends of biodiesel from neat Karanja oil that would give optimized performance, emission and combustion parameter is experimented in this paper.

II. METHODOLOGY

A. Actual engine setup

The principles and methodologies that have been used during the course of several experimental investigations in the VCR diesel engine test rig consisting of a single cylinder, 4-stroke, 3.5 kW at 1500 rpm. An eddy current Dynamometer Is fitted to a diesel engine. Performance, combustion parameters are observed by computerized mode at different compression ratio at different load condition from 0kg to 12kg using various blends of Karanja oil methyl ester and diesel. The detailed specification of the engine is shown in Table 1. Engine performance analysis software package "EnginesoftLV" has been employed for online performance analysis. Combustion pressure corresponding to a crank angle is measured by Piezo-sensor and crank angle sensor which are mounted into the engine head.

Applied load is measured by strain gauge type load cell fitted to the output shaft of the eddy current dynamometer. Type K-Chromel (Nickel-Chromium Alloy)/ Alumel (Nickel-Aluminium Alloy) thermocouples are used to measure gas temperature at the engine exhaust, calorimeter exhaust, water inlet of calorimeter and water outlet of calorimeter, engine cooling water outlet and ambient temperature. 50ml burette and stopwatch with level sensors are fitted to the setup to measure the fuel flow rate. Fig.1 shows the layout of the experimental set up.

Table:-1 Engine specifications

Make	Kirloskar
General details	VCR Engine test setup 1- cylinder, 4- stroke, Water cooled
Rated power	3.5Kw at 1500 rpm
Speed	1500 rpm(constant)
Number of cylinder	Single cylinder
Compression ratio	16:1 to 18:1(variable)
Bore	87.5 mm
Stroke	110 mm
Ignition	Compression ignition

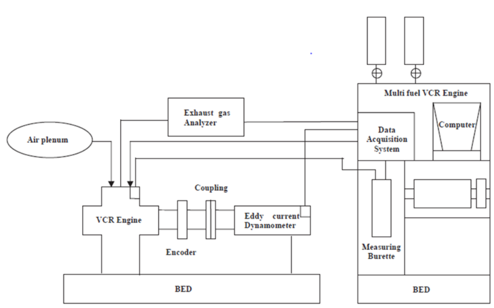

Fig.1 *Layout* of VCR engine

B. Experimental procedure

The variable compression ratio engine is started by using standard diesel. It is to run for 30 minutes. When the engine is warmed

up then readings are taken. The tests are conducted at the rated speed of 1500 rpm. Fuel consumption is measured by the help of the measuring burette attached to the data acquisition system. In every test, brake thermal efficiency, brake specific fuel consumption, exhaust gas temperature, mechanical efficiency. From the initial measurement, performance, combustion and emission parameters with respect to compression ratio 16:1, 17:1 and 18:1 at 100% load for different blends and different loads for different blends at compression ratio 18 are measured and recorded. At each operating conditions, the performance and combustion characteristics are also processed and stored in personal computer (PC) for further processing of results. The same procedure is repeated for different blends of Karanja oil methyl esters.
The specific gravity of biodiesel fuels is lower than that of straight vegetable oil. Therefore, the specific gravity of the blend increases with the increase of biodiesel concentration. Also, the specific gravity shows an inverse relationship with temperature. As the temperature is increased, specific gravity decreases. The viscosity of biodiesel is found lower than that of straight vegetable oil. The viscosity of the blend increases with the increasing biodiesel fraction for all. Similar to the effect of temperature on specific gravity, viscosity also shows linearly inverse trend i.e. increasing temperature reduces the viscosity. This property helps in better atomisation and hence fuel burning in application of biodiesels. It has been noticed that the specific gravity and the viscosity of the biodiesel blends increase with increase of the biodiesel fraction. It is also seen that the specific gravity and viscosity of each blend decreases with increase in the temperature.

III. RESULTS AND DISCUSSION

A. Fuel property testing at different blends and temperatures

1) Specific gravity of blends of bio diesel at different temperatures
The specific gravity of all fuel blends (neat Karanja oil, blended neat oil with diesel, 100% biodiesel and blended biodiesel with diesel) are measured as per standard ASTM D4052 at varying temperature using hydrometer. The specific gravity of Karanja biodiesel (B100) varies between 0.891 to 0.841 at same temperature range. Many studies show that biodiesel's specific gravity is not changed a lot, because the densities of methanol and oil is close to the specific gravity of the produced biodiesel. The specific gravity of biodiesel is found higher than that those of diesel fuel. As the specific gravity of biodiesel is high compared to diesel fuel so the energy content of it is lower. Specific gravity of biodiesel will vary with the fatty acid composition and their purity. Table -2 shows the variation of specific gravity with temperature and blends of Karanja oil methyl ester.

Table -2 Variation of specific gravity with temperature and blend (Karanja oil methyl ester)

Temperature / Blend	30^0C	40^oC	50^oC	60^oC	70^oC	80^oC	90^oC	100^oC
B-10	.826	.820	.813	.805	.798	.792	.785	.779
B-20	.837	.831	.823	.817	.810	.803	.796	.790
B-30	.8425	.836	.830	.823	.8155	.808	.802	.796
B-40	.849	.843	.835	.828	.822	.815	.809	.803
B-50	.854	.847	.840	.832	.826	.820	.812	.806
B-60	.860	.854	.846	.840	.833	.826	.820	.814
B-70	.867	.861	.854	.846	.837	.832	.826	.820
B-80	.871	.865	.859	.852	.845	.837	.831	.824
B-90	.884	.878	.872	.865	.858	.851	.843	.837
B-100	.891	.885	.877	.869	.862	.855	.848	.841

2) Viscosity of blend of bio diesel at different temperatures

Opposition to external force due to internal friction of a fluid is called viscosity. Atomization process is mostly affected by the fluid property viscosity. Mixing of air and fuel in combustion chamber is also affected if viscisity is too low and too high. Viscosity studies are conducted for different fuel blends (neat Karanja oil, blended neat oil with diesel, 100% biodiesel and blended biodiesel with diesel). Kinematic viscosity of liquid fuel samples are measured using the viscometer at different temperatures and blendings as per specification given in ASTM D445, using Cannon-Frensky viscometer tubes in viscometer oil bath. Viscosity of biodiesel blends (B10-B100) at 40°C varies from 2.18 cSt to 4.5249 cSt. Table 3 shows the variation of viscosity with temperature and blends of Karanja oil methyl ester.

Table- 3 Variation of viscosity with temperature and blend (Karanja oil methyl ester)

Temper-ature / Blend	30°C	40°C	50°C	60°C	70°C	80°C	90°C	100°C
B-10	2.696	2.183						
B-20		2.416	1.977					
B-30		2.714	2.173	1.875				
B-40	3.452	2.845	2.304	1.959				
B-50		3.125	2.603	2.173	1.893			
B-60		3.349	2.789	2.369	2.024			
B-70		3.722	3.078	2.631	2.295	1.959		
B-80		3.825	3.162	2.714	2.332	2.005		
B-90		4.263	3.470	2.882	2.453	2.108		
B-100		4.524	3.722	3.013	2.519	2.145		

B. Performance analysis of karanja oil methyl ester

1) Brake specific fuel consumption (BSFC)

With increase in compression ratio brake specific fuel consumption decreases. Brake specific fuel consumption for blend B40 is lower as compared to diesel and other blends is clearly observed from the "Fig.3.2.1".Brake specific fuel consumption for B40 is 0.32kg/kWh and for diesel is 0.34kg/kWh at compression ratio 18.

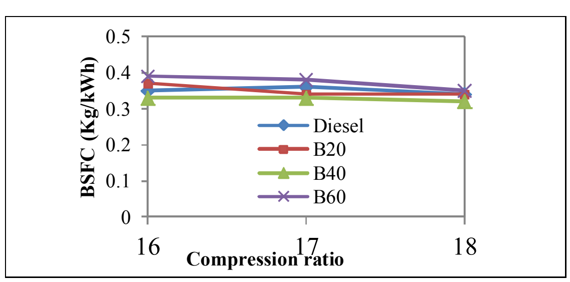

Fig.3.2.1.

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2) Brake thermal efficiency (BTE)

With increase in compression ratio brake thermal efficiency increases. It is observed from "Fig.3.2.2" that brake thermal efficiency of diesel, blend B20,B60 is lower as compared to B40.Brake thermal efficiency of blend B40 is 28.44% and it higher than that of diesel at compression ratio 18.Brake thermal efficiency of diesel is found to be 24.9% at compression ratio 18.

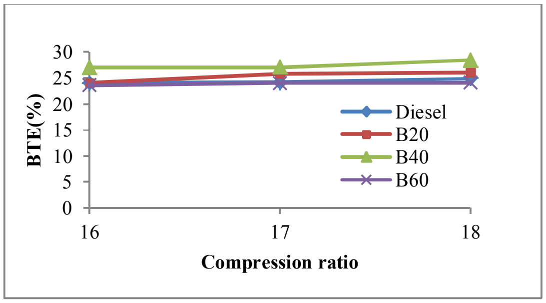

Fig.3.2.2

3) Mechanical efficiency

As the compression ratio increases mechanical efficiency increases for all blends this may be due to better atomization of fuel at higher compression ratio .It is observed from "Fig.3.2.3" mechanical efficiency is higher high compression ratio as compared with mechanical efficiency at low compression ratio. Mechanical efficiency of blends B20 and B40 at compression ratio 18 are 54.61% and 53.56% respectively.

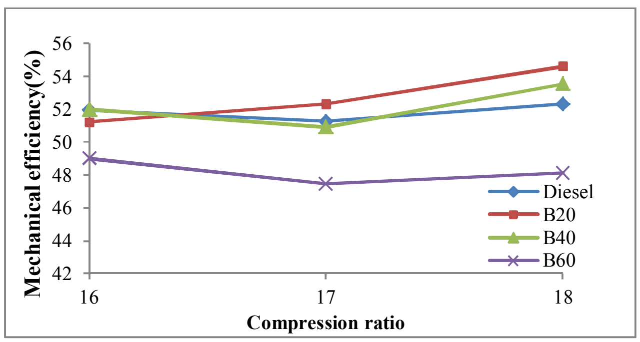

Fig.3.2.3

4) Exhaust gas temperature

With increase in compression ratio exhaust gas temperatures for the blends B20, B40, B60 found to be lower than that of diesel. Change of exhaust gas temperature with compression ratio is clearly observed from the "Fig.3.2.4".Exhaust gas temperature decreases with increase in compression ratio. Exhaust gas temperature for diesel and B40 is 324.53^{0}C and 301.63^{0}C respectively at compression ratio 18.

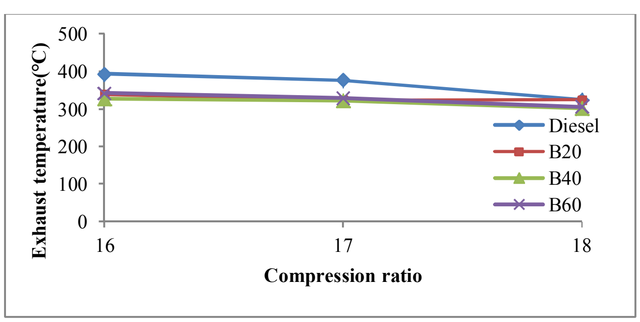

Fig.3.2.4

C. Combustion analysis of Karanja methyl ester

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1) Maximum combustion pressure

Peak pressure of diesel is nearly equal to the peak pressure of blend at full load at all three compression ratios. It is observed from the “Fig.3.3.1” peak pressure for diesel blend is slightly above than peak pressure for blends. Maximum combustion pressure for diesel and blends B20, B40 and B60 found to be 61.2 bar, 59.6 bar, 60.15 bar and 60.15 bar respectively.

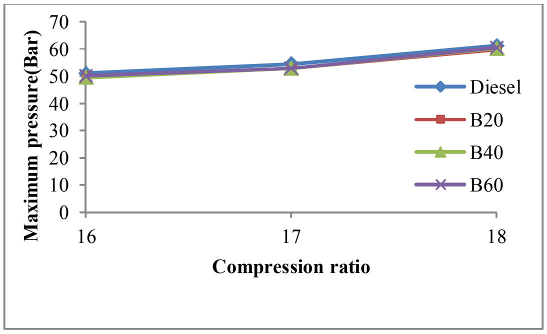

Fig.3.3.1

2) Net heat release rate

With increase in compression ratio net heat release per crank angle decrease. This may be due to the air entrainment and lower air fuel mixing rate and effect of viscosity.Net heat release rate per crank angle for diesel is found to be highest. It is observed from “Fig.3.3.2” heat release per crank angle decreases with increase in compression ratio. Maximum heat release rate of diesel, B20, B40, B60 is found to be 53.2, 48.8, 47.7 and 40.2 J/^{0} CA at compression ratio 18. Due to decrease in calorific value of the blends with increase in blend percentage maximum net heat release per crank angle for diesel found to highest as compared with the blends.

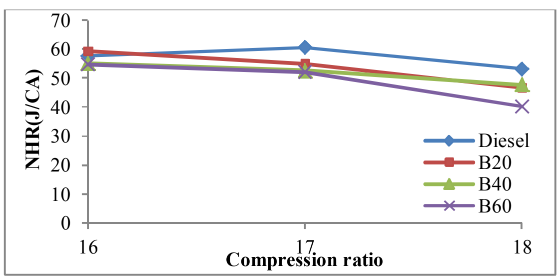

Fig.3.3.2

3) Ignition delay

With increase in compression ratio ignition delay decreases .This is due to better air fuel mixing and better atomization of fuel at higher compression ratio. “Fig.3.3.3” shows the variation of ignition delay for diesel, B20, B40, and B60 at three compression ratios. Ignition delay period of B20, B40 and B60 is 5.5, 6.2, 6.50 CA respectively at compression ratio 18 and all are higher than diesel. At compression 18 ignition delay of diesel is 5CA .This may be due to decrease of calorific value of the fuel with increase in blend percentage.

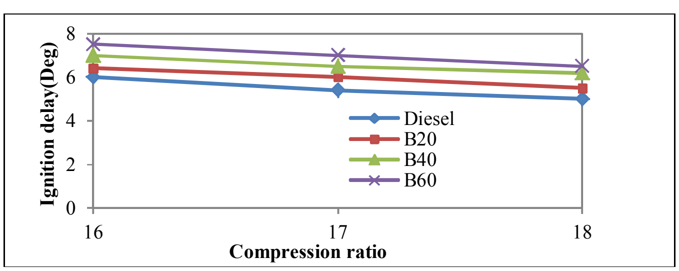

Fig.3.3.3

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4) Maximum combustion temperature

With increase in compression ratio combustion temperature increases .It is observed from "Fig.3.3.4" combustion temperature of B20 was maximum than other blends and diesel at compression ratio 16, 17 and 18. At higher compression ratio 18 maximum combustion temperatures of diesel, B20, B40, and B60 found to be 1429^0C, 14560^0C, 13980^0C, and 1390^0 C respectively.

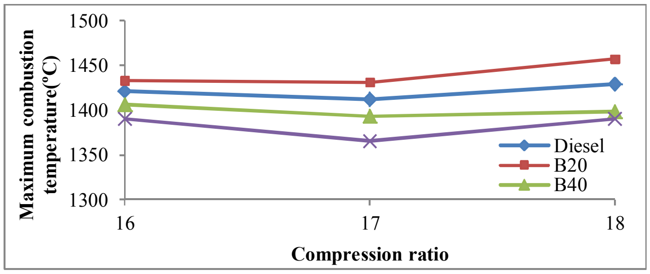

Fig.3.3.4

D. Emission analysis

1) Carbon monoxide emission (CO)

CO emission decreases at higher compression ratio as compared with CO emission at lower compression ratio. It is observed from "Fig.3.4.1" CO emission of diesel is lower than B40 at compression ratio 16. For blends B20 and B40 CO emission is lower than diesel at compression ratio 18.

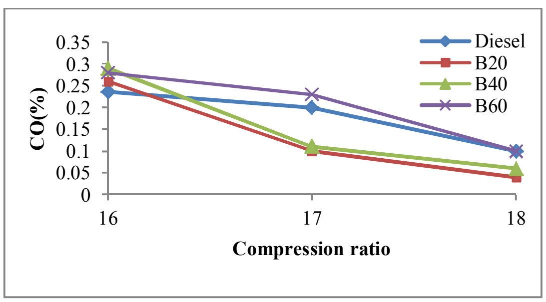

Fig.3.4.1

2) Carbon dioxide emission (CO_2)

It shows that the CO_2 emission of KOME blends is higher at all compression ratios. This may be due to the presence of oxygen content in the biodiesel blends which improves the oxidation process while increase in CR increases the peak cylinder temperature with improved atomization of the fuel leading complete combustion of the fuel. "Figure.3.4.2" shows in all compression ratios B20 shows highest CO_2 emission followed by B40, diesel and B60. Reduction of CO_2 at higher blends indicates poor combustion may be due to higher viscosity and decrease in calorific value with increase in percentage of KOME blends.

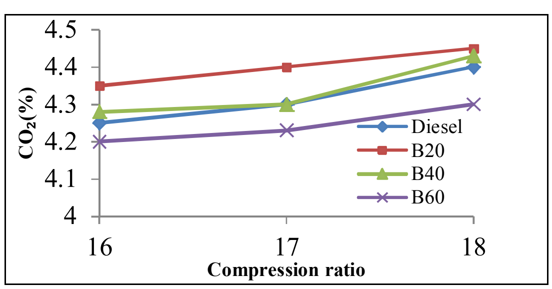

Fig.3.4.2

3) Hydrocarbon emission (HC)

Hydrocarbon emission decreases with increase in compression ratio for diesel, B20, B40 and B60.From “Fig.3.4.3” it is observed that B60 highest Hydrocarbon emission at all three compression ratios. Blends B20 and B40 produces less hydrocarbon as compared to diesel at compression ratio 18.

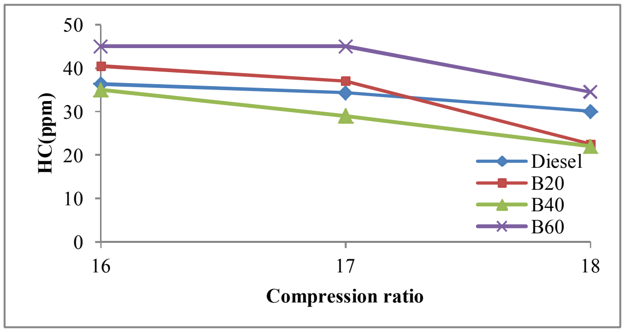

Fig.3.4.3

4) Nitrogen oxide emission (NO_X)

With increase in compression ratio NO_X emission increases. It is observed from the “Fig3.4.4” at compression ratio 18 NO_X emission of B20, B40 is more than diesel.B40 gives lowest NO_X emission at all three compression ratios.

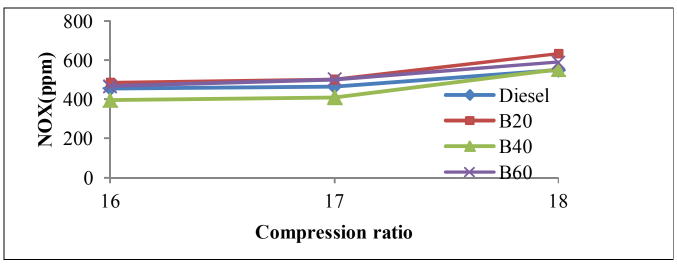

Fig.3.4.4

5) Smoke opacity

Smoke opacity decreases as the compression ratio changes from 16 to18.It is observed from “Fig.3.4.5” B40 and B60 give higher smoke opacity than diesel and B20.This may be due to higher ignition delay and higher viscosity of B40 and B60.B20 shows lowest smoke opacity at all compression ratios.

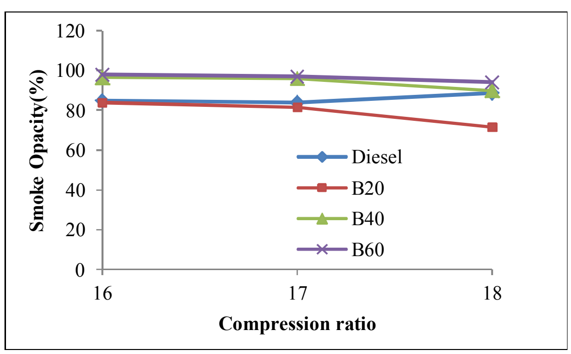

Fig.3.4.5

IV. CONCLUSION

The performance, emission and combustion characteristics of a variable compression ratio engine with Karanja oil bio-diesel and diesel blends have been investigated and compared with that of diesel. The experimental results confirm that the BTE, SFC,

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exhaust gas temperature, mechanical efficiency, combustion pressure, heat release and emission of variable compression ratio engine are the function of bio diesel blends, loads and compression ratios. Conclusions of the investigation are given below.

A. The brake thermal efficiency of diesel, B20, B60 are lower than B40 at compression ratio 18.Brake specific fuel consumption of the blend B40 is lower than that of diesel and blends B20, B60. The engine BTE at full load for diesel, B20, B40 and B60 fuels is 24.9%, 26.02%, 28.44% and 24.1% respectively. The brake specific fuel consumption of the blend B40 at the compression ratio of 18 is 0.32kg/kWh whereas for diesel it is 0.34kg/kWh. Mechanical efficiency obtained from blend B20 and B40 at full load are 54.61% and 53.56% respectively.

B. From the combustion analysis it is observed that pressure crank angle characteristics for KOME bends and diesel are same. . The peak pressure has been observed to be 61.2 bar, 59.6 bar, 60.15 bar and 60.55 bar for diesel and blends B20, B40, and B60 respectively at full load.

C. The combustion duration in general increases with load. At compression ratio 18, B60 gives better combustion duration as compared to diesel. With increase in compression ratio combustion duration increases.

D. The maximum heat release rate of diesel, B20, B40 and B60 has been observed to be 53.2, 48.8, 47.7 and 45.07 J/ ºCA. The heat release rate of KOME blends decreases compared to that of diesel at full load.

E. It has observed that the ignition delay decreases with biodiesel in the diesel blend with increase in load and increases in compression ratio. At compression ratio 18 and 100% load condition, the ignition delay period of B20, B40 and B60 is 5.5, 6.2, 6.5 ºCA higher than diesel.

F. B20 gives better combustion temperature than diesel. Increasing load combustion temperature increases for all cases. It has been observed that increasing compression ratio combustion temperature increases. B20 gives better combustion temperature than all other blends.

G. The CO emission of the blend B40 is close to diesel and it is found to be higher for compression ratio 16. The other blends B20, B60 have slightly lesser CO emission for compression ratio 16. It observed that by increasing compression ratio CO emission decreases.

H. CO_2 emission of the blend B40 is slightly higher than diesel. The blend emits higher percentage of CO_2 than diesel at lower compression ratios and vice versa.

I. It shoes that the hydrocarbon emission of various blends is lower at higher compression ratios. The blends B20 and B40 produce lesser hydrocarbon emissions at higher compression ratio than diesel except B60.

J. The NO_x emission for biodiesel and its blends is higher than that of diesel except B60. The NO_x emission for diesel and other blends increase with increase of compression ratio.

K. Smoke opacity increases with increase in load. B40 and B60 give higher smoke opacity than diesel. Smoke opacity decreases with increase in compression ratio. B40 and B60 give higher smoke opacity than that of B20 and diesel.

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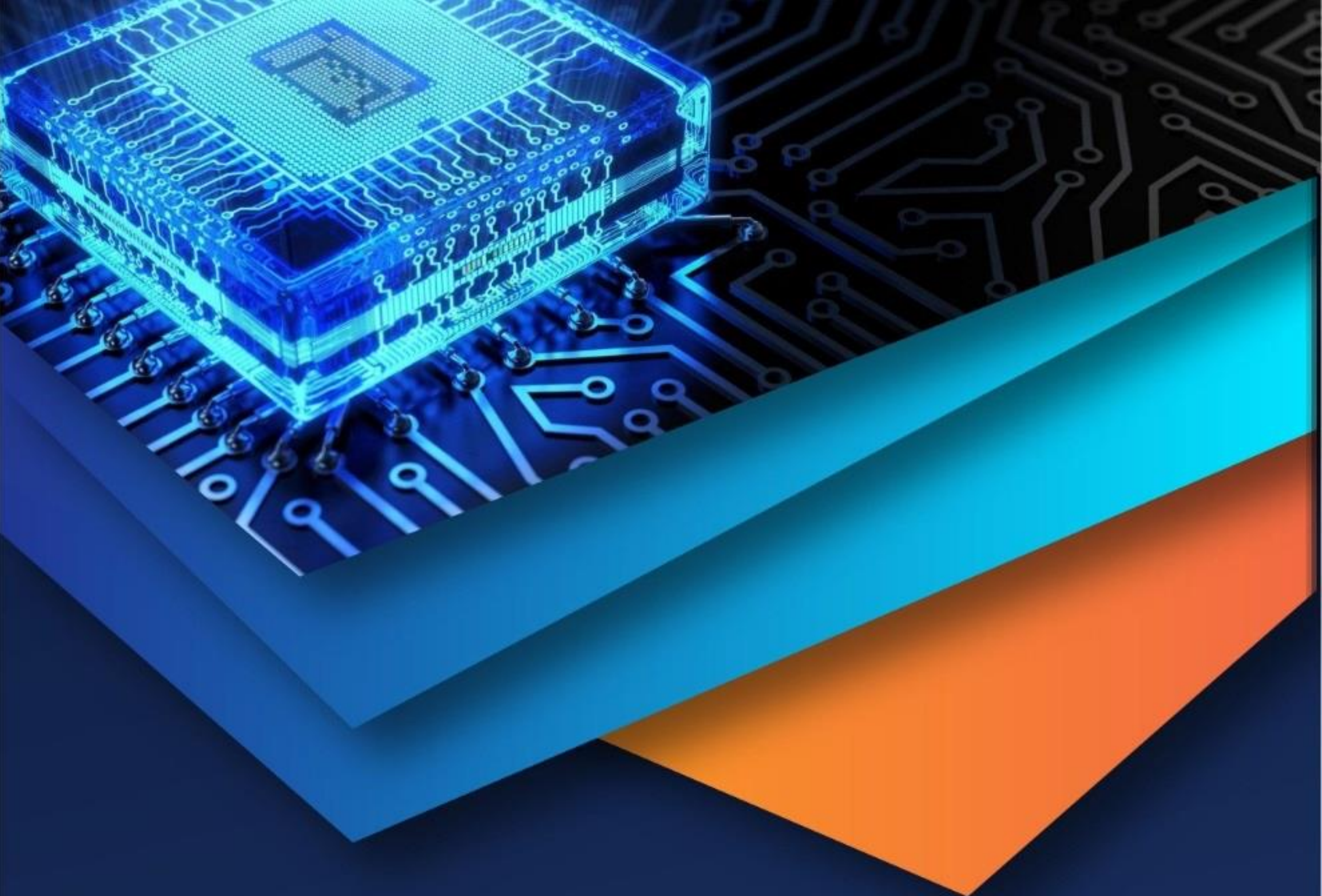

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