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Effects of Compression Ratio on Performance combustion and emission of a Single Cylinder 4-Stroke Compression Ignition Engine using Blends of Neat Karanja Oil with Diesel

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Abstract- Compression ignition engines play the major role for the development of any country. Fossil fuel layer depletion and emissions of compression ignition engine are two challenges for the world now days. To overcome the challenges it is necessary to replace conventional fuel by alternative fuels. Now a day's bio fuels become popular as an alternative fuel for compression ignition engines. It can be used in compression ignition engine with many difficulties. In India million tonnes non edible seeds like Karanja seeds are going in waste. . This study is performed to find the effect of compression ratio on performance parameters such as brake specific fuel consumption, brake thermal efficiency, mechanical efficiency in a single cylinder four stroke VCR engine fuelled with diesel and its blends with neat Karanja oil on volume basis (10%, 20%) and compared the results with diesel. Experiments have been conducted at compression ratios of 16:1, 17:1, 18:1. At higher compression ratio minimum value of brake specific fuel consumption (BSFC) was recorded as being 0.33Kg/kWh for 10% blend of Karana oil (K10). Maximum value of brake thermal efficiency was found to be 26.63% for K10. At higher compression ratio mechanical efficiency of diesel was higher than10% blend of Karanja oil.
Keywords- VCR engine, Karanja oil, 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 experiments was 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 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 Diesel engine connected to eddy current dynamometer in computerized mode to study the performance, emission and combustion of engine by varying its 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. Piezo-sensor and crank angle sensor which measure the combustion pressure and the corresponding crank angle respectively are mounted into the engine head. The output shaft of the eddy current dynamometer is fixed to a strain gauge type load cell for measuring applied load to the engine. 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. The fuel flow is measured by using 50ml burette and stopwatch with level sensors.

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

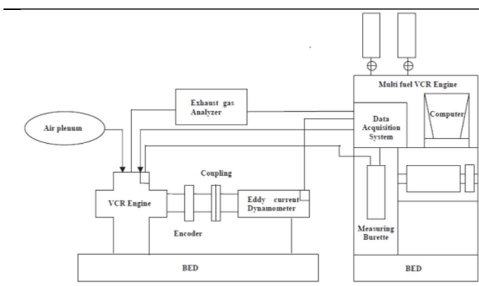

Fig.1 Layout of VCR engine

B. Experimental procedure

Taking diesel as fuel the engine was started and run for 30 minutes. The engine was run for 30 minutes then readings were taken at the rated speed of 1500 rpm. Measuring burette fixed to the data acquisition system measures the fuel consumption. In every test, brake thermal efficiency, brake specific fuel consumption, exhaust gas temperature, mechanical efficiency. From the initial measurement, performance, combustion and emission parameters data's at compression ratio 16:1, 17:1 and 18:1 at 100% load for different blends are collected. At each operating conditions, the performance and combustion characteristics were saved in personal computer (PC) for analysis. The same method is repeated for different blends of Karanja oil. The exhaust emissions are measured by online AVL- 444 model, multi-gas analyzer which is capable of measuring CO, HC, CO_2, and NO_x concentrations in the exhaust. Smoke opacity is measured with AVL-437 model smoke meter (measuring range 0 to 100% with resolution 0.1%).

C. Fuel property testing at different blends and temperatures

1) *Specific gravity blend of Karanja oil at different temperature:* The specific gravity of all fuel blends (blended neat Karanja oil with diesel) are measured as per standard ASTM D4052 at varying temperature using hydrometer. Referring to table-2, it can be seen that specific gravity go on decreasing for all the blend with increase in temperature. It is found that the specific gravity of neat Karanja oil (K100) varies from 0.925 to 0.878 at a temperature range of 30-100°C.

Table-2 Variation of specific gravity with temperature and blend (neat Karanja)

Temperature / Blend	30 ^{0}C	40 ^{0}C	50 ^{0}C	60 ^{0}C	70 ^{0}C	80 ^{0}C	90 ^{0}C	100 ^{0}C
K-10	0.827	0.8215	0.814	0.807	0.800	0.793	0.785	0.780
K-20	0.8375	0.832	0.825	0.820	0.812	0.8055	0.797	0.791
K-30	0.850	0.843	0.836	0.830	0.823	0.816	0.810	0.803
K-40	0.860	0.854	0.847	0.840	0.834	0.827	0.821	0.816
K-50	0.871	0.866	0.860	0.853	0.845	0.838	0.833	0.8265
K-60	0.883	0.877	0.870	0.866	0.859	0.852	0.846	0.840
K-70	0.892	0.886	0.880	0.873	0.866	0.860	0.853	0.846
K-80	0.905	0.898	0.891	0.884	0.877	0.871	0.866	0.858
K-90	0.916	0.913	0.904	0.895	0.887	0.881	0.874	0.870
K-100	0.925	0.919	0.914	0.907	0.901	0.891	0.885	0.878

2) *Viscosity of blends of Karanja oil at different temperatures:* Viscosity is a measure of resistance to deformation of a fluid. The viscosity of the fuel has direct influence on physical delay. Physical delay gets affected gets affected if viscosity is too low or too high. Viscosity studies are conducted for different fuel blends. Kinematic viscosity of liquid fuel samples are measured using the viscometer at different temperatures and blends as per specification given in ASTM D445, using Cannon-Frensky viscometer tubes in viscometer oil bath. Referring to the table-3, it is observed that viscosity for all blends go on decreasing with increase in temperature. It is found that the viscosity of neat Karanja oil blends (K10) varies from 4.116 cSt to 2.2912 cSt at a temperature range of 30 to 100°C.

Table- 3 variation of viscosity with temperature and blend (neat Karanja)

Temperature / Blend	30 ^{0}C	40 ^{0}C	50 ^{0}C	60 ^{0}C	70 ^{0}C	80 ^{0}C	90 ^{0}C	100 ^{0}C
K-10	4.116	3.238	2.351	2.043	1.763	1.2572	2.0572	2.2912
K-20	4.976	4.354	3.421	2.724	2.332	2.052	1.842	1.7
K-30	8.061	6.563	4.5	3.695	2.852	2.612	2.316	2.005
K-40	10.344	8.382	6.420	5.25	4.189	3.586	2.789	2.556
K-50	14.821	11.948	8.917	6.920	4.683	3.933	3.494	3.147
K-60	18.678	14.789	10.898	9.024	7.384	5.305	4.372	4.189
K-70	27.167	20.686	16.562	11.185	9.667	7.633	6.563	4.226
K-80	34.513	24.602	17.645	12.475	9.956	8.989	8.097	7.491
K-90	36.478	30.665	23.436	16.753	12.785	10.636	9.631	8.561
K-100	58.1324	42.785	32.173	22.228	13.256	11.649	7.589	9.346

III. RESULT AND DISCUSSION

A. *Performance Analysis of Neat Karanja Oil*

1) *Brake specific fuel consumption (BSFC):* From "Fig 3.1.1." it was found that the brake specific fuel consumption decreases with the increase in compression ratio. K10 shows less BSFC as compared to K20 and diesel at all compression ratio. Increase in blend percentage of Karanja oil BSFC increasing this may be due to low calorific value of fuel at higher blend. BSFC for K10 was found to be lower may be due to better burning quality due to presence of extra oxygen. At higher blend BSFC was increased because viscosity plays the dominant role. The BSFC varies with diesel, K10 and K20 at compression ratio 18 is found to be 0.34 kg/kWh, 0.33kg/kWh, 0.35kg/kWh respectively.

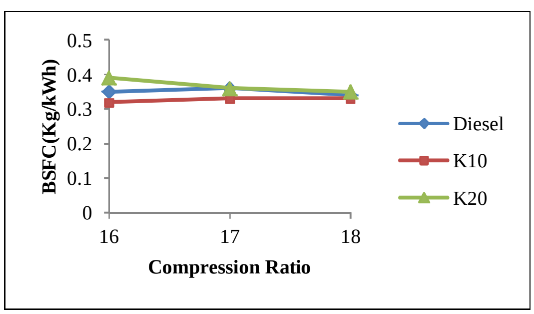

Fig 3.1.1

2) *Brake thermal efficiency:* From the "Fig 3.1.2. "It was observed that the BTE of the blend K10 is higher than that of K20 and diesel at compression ratios 16, 17, 18. BTE is directly proportional to the compression ratio. The engine BTE at compression ratio 18 for diesel, K10, and K20 fuels is 24.9%, 26.63%, and 24.1% respectively. It is also observed that the BTE of the blend K20 is slightly lower than that of the diesel and K10 is higher than diesel. This may be due to higher viscosity of the blend K20 which affects the physical delay period.

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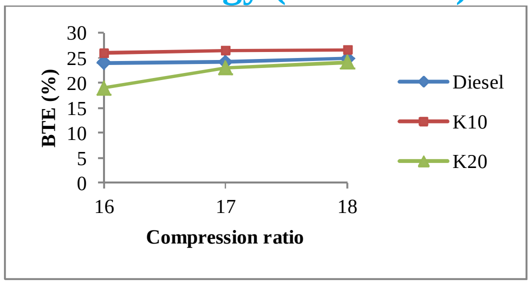

Fig 3.1.2

3) *Mechanical efficiency:* From the "Fig 3.1.3." we observed that the mechanical efficiency increases with increase in compression ratio. Mechanical efficiency of diesel is higher than K10 and K20 at all compression ratios. The efficiency of the fuel blends is in general very closer to that of diesel. The mechanical efficiency at full load for diesel, K10, and K20 fuels are 52.32%, 35.41%, and 32.56% respectively.

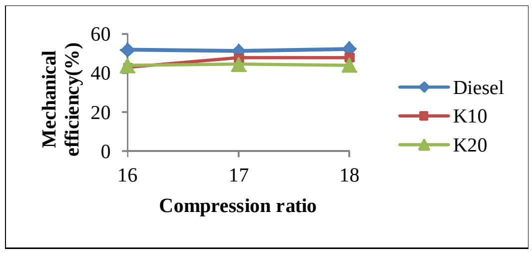

Fig 3.1.3

4) *Exhaust gas temperature:* From the "Fig 3.1.4". It was observed that exhaust gas temperature decreases with increase in compression ratio. As compression ratio increases brake thermal efficiency increases means more energy converted to work and enthalpy Exhaust gas decreases and thus exhaust gas temperature decreases. Exhaust gas temperature of the blends was found to be lower than that of diesel. At compression ratio 18, highest temperature obtained is 324.53ºC for diesel whereas the temperature is only 317.93ºC and 310.39ºC for the blend K10 and K20. It may be due to energy content in diesel is higher as compared to K10 and K20.

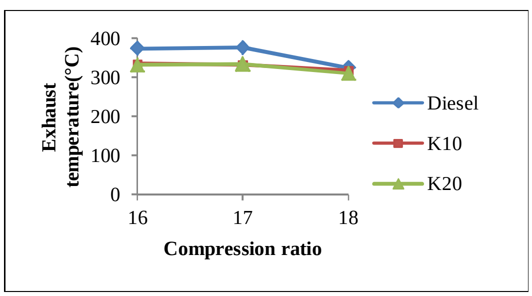

Fig 3.1.4

B. Combustion analysis of neat Karanja

1) *Combustion pressure :* From the "Fig 3.2.1." It shows that increasing compression ratio, combustion pressure increases. It shows that diesel gives maximum pressure as compared toK10 and K20. It is seen that the maximum pressure for diesel as well as Karanja oil blends are very close to each other at compression ratio 18, the maximum pressure value for diesel and blends K10 and K20 being 61.2 bar, 58.93 bar, and 59.19 bar respectively. The peak pressure depends on the amount of fuel taking part in the uncontrolled phase of combustion, which is governed by the delay period and spray envelop of the injected fuel.

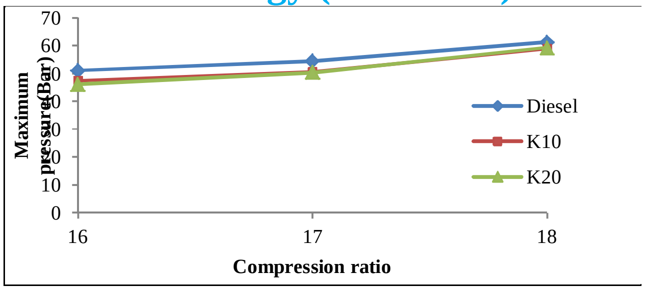

Fig 3.2.1

2) *Combustion duration:* From “Fig 3.2.2” it was observed that with increase in compression ratio combustion duration was increased. Combustion duration for K20 was to be higher than others. At compression ratio18, the combustion duration for the fuel blends K10, K20 and diesel are 47, 77 and 19 ºCA respectively. Calorific value of the Karanja oil blend is lower than diesel, more quantity of fuel is consumed to produced in order to produce same amount of energy for that reason combustion was increased with increased in blend percentage.

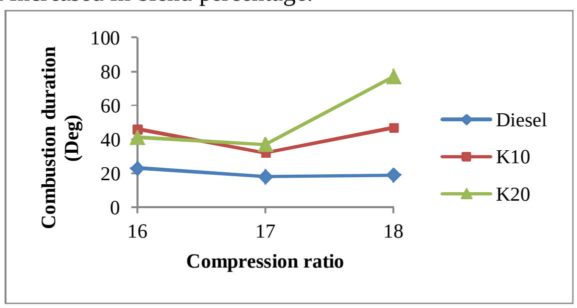

Fig 3.2.2

3) *Net Heat release rate:* From “Fig 3.2.3” it was found that heat release rate slightly decreased at compression ratio 18. This may be due to the air entrainment and lower air/fuel mixing rate and effect of viscosity blends. The heat release rate of diesel is higher than the blends. Maximum heat release rate per crank angle was highest for diesel because for unit crank angle same amount of fuel is consumed and among the three type of fuels used diesel has the highest calorific value. The maximum heat release rate of diesel, K10, and K20 at compression ratio 18 has been observed to be 53.2, 47.2 and 41.5J/ ºCA.

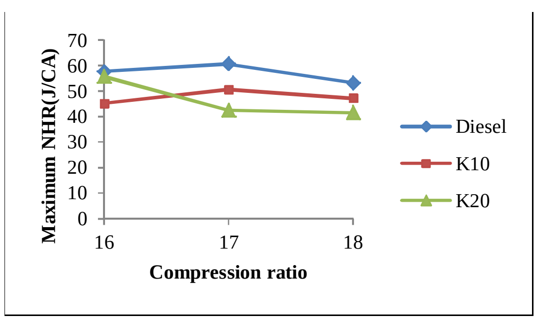

Fig 3.2.3

4) *Maximum combustion temperature:* “Fig 3.2.4” it was found that increasing compression ratio Maximum combustion temperature increases. Diesel gives better combustion temperature than all other blends. Due to more fuel accumulated in the combustion chamber. Increasing compression ratio combustion temperature increases for all cases. The maximum combustion temperature of diesel, K10, and K20 at compression ratio 18 has been observed to be 1429.04, 1425.74 and 1400.01ºC respectively.

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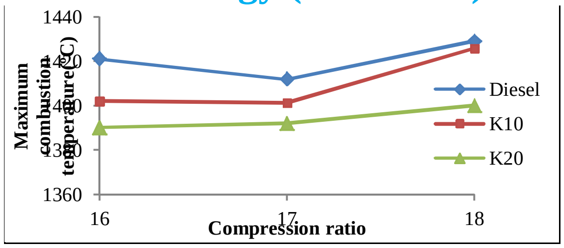

Fig 3.2.4

C. Emission analysis of Karanja oil

1) *Carbon monoxide emission (CO):* "Fig.3.3.1" it was found that CO emission decreases with increase in compression ratio. The CO emission of diesel is minimum compared to K10 and K20. At higher compression ratio air fuel mixing is better. The CO emission of the blend K10 and K20 is more compared to diesel; it may be due to higher viscosity and improper spray pattern resulting in incomplete combustion.

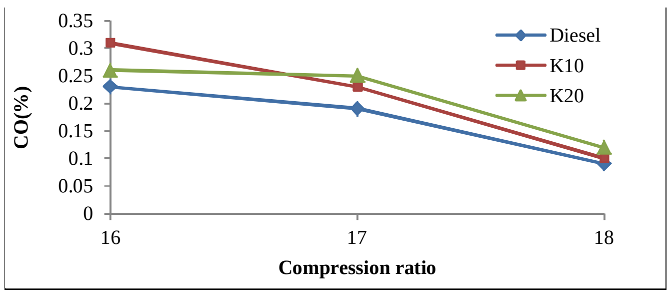

Fig.3.3.1

2) *Carbon dioxide emission (CO_2):* From the "Fig.3.3.2" it was found that with increased in compression ratio CO_2 emission was increased this may be due to better fuel spray formation at higher compression ratio which leads to better combustion. The blend emits higher percentage of CO_2 than diesel at lower compression ratios and vice versa.

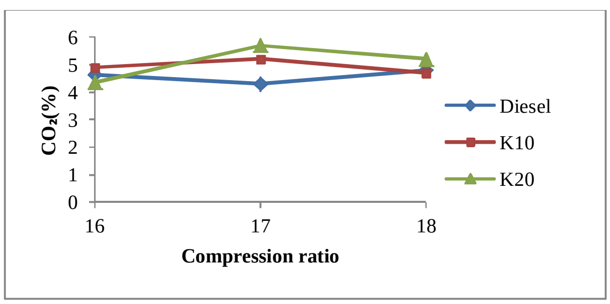

Fig 3.3.2

3) *Hydrocarbon emission (HC):* From the "Fig 3.3.3". it was found that blend K20 gives higher HC emission at lower compression ratio but at higher compression ratio K10 gives higher. Increased HC emissions were clear indication of improper combustion. This may be due to poor atomization of the blended fuel because of higher viscosity.

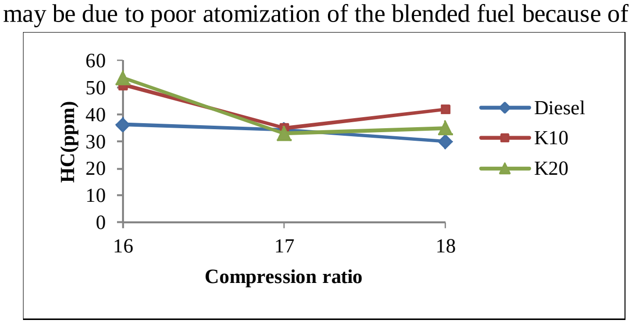

Fig 3.3.3

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4) *Nitrogen oxides emission (NO_x):* The variations of nitrogen oxides (NO_x) emission with respect to different compression ratio for different blends are shown in "Fig 3.3.4". The NO_x emission for diesel and other blends increase with increase of compression ratio. Diesel gives higher NO_x emission than other blends. The other blends closely follow diesel. It is also observed that with increasing the percentage of Karanja oil blend there is a trend of decreasing NO_x emission. NO_x emission for diesel, K10, and K20 are 550ppm, 493ppm, and 524ppm at compression ratio 18.

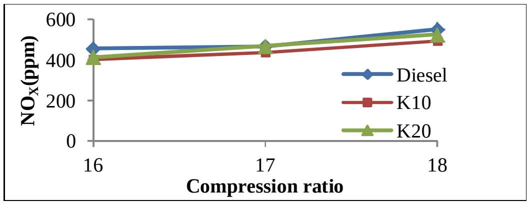

Fig 3.3.4

5) *Smoke opacity:* From the Fig "3.3.5" it was found that smoke opacity increase with increase in compression ratio. K20 give higher smoke opacity than that of K10 and diesel. K10 and K20 give higher smoke opacity than diesel. Hence it can be conclude that K20 would be better blend from other. The smoke opacity for diesel, K10, and K20 at compression ratio 18 is 88.7%, 96%, and 97.8% respectively.

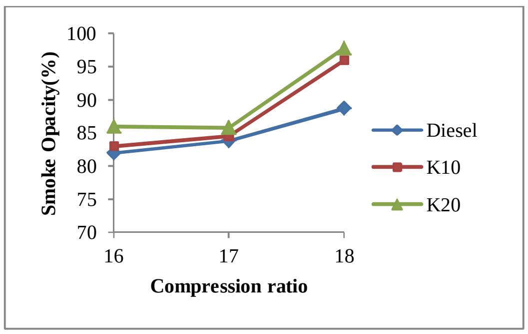

Fig 3.3.5

IV. CONCLUSION

The performance characteristics of a dual fuel variable compression ratio engine with Karanja oil and diesel blends have been investigated and compared with that of diesel. The experimental results confirm that the BTE, BSFC, exhaust gas temperature, mechanical efficiency of variable compression ratio engine, is a function of neat Karanja oil blend, load and compression ratio. However by increasing the compression ratio the engine performance varied and it becomes comparable with that of diesel. The following conclusions are drawn from this investigation:

A. The performance characteristics of a dual fuel variable compression ratio engine with Karanja oil and diesel blends have been investigated and compared with that of diesel.

B. The following conclusions is drawn from this investigation was found out. K10 gives less BSFC compared to K20 and diesel. The engine BTE at compression ratio 18 for diesel, K10, and K20 fuels is 24.9%, 26.63%, and 24.1% respectively. It is also observed that the BTE of the blend K20 is slightly lower than that of the diesel and K10 is higher than diesel.

C. The highest temperature obtained is 324.53ºC for diesel for compression ratio 18, whereas the temperature is only 317.93ºC and 310.39ºC for the blend K10 and K20. It may be due to energy content in diesel is higher as compared to K10 and K20.

D. CO, HC emission of K10 and K20 is lower than diesel and NO_x emission was higher than diesel.

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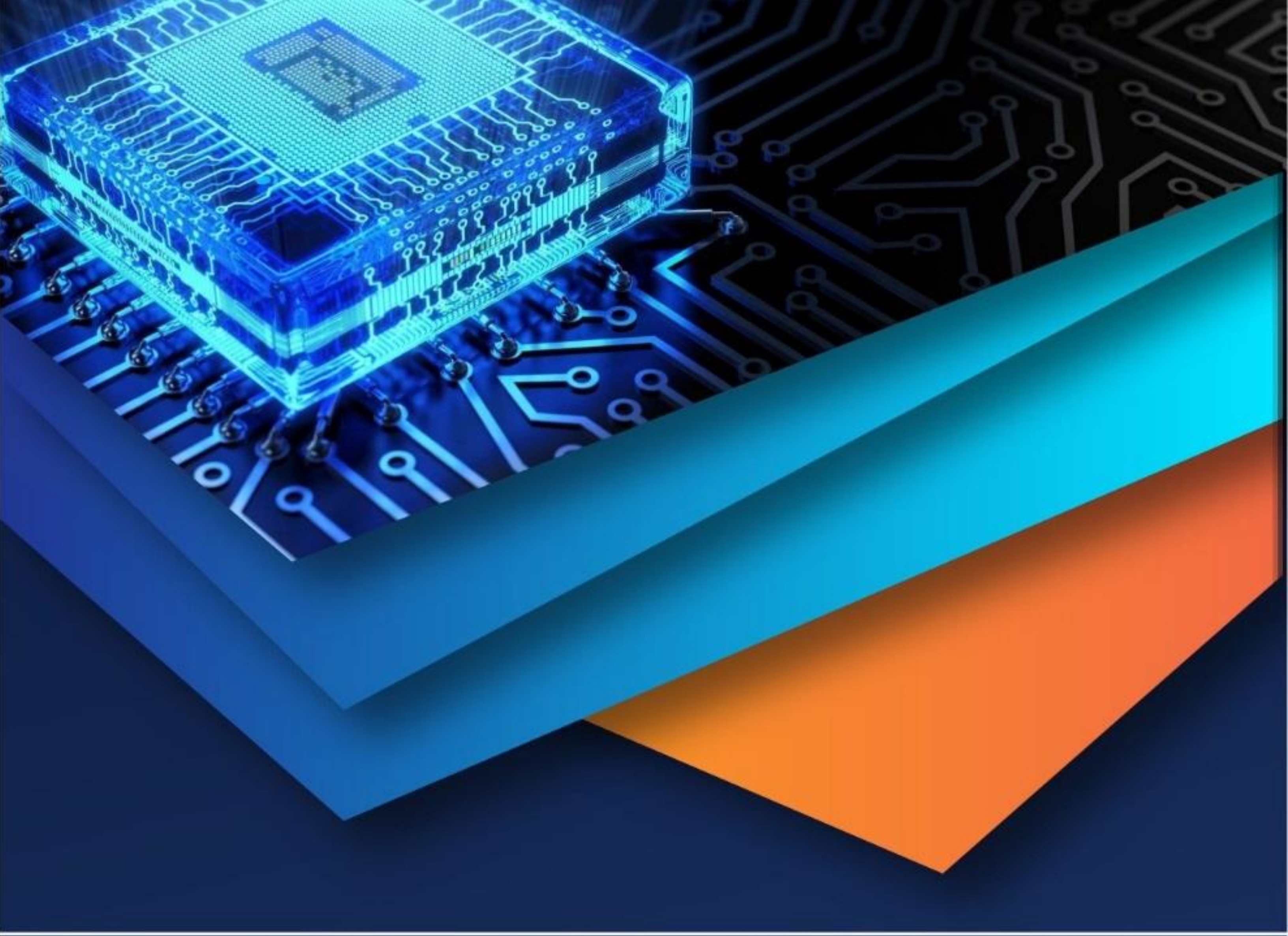

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