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Investigate the Effect of Compression Ratio over the Performance and Emission Characteristics of Variable Compression Ratio Engine Fueled with Preheated Palm Oil - Diesel Blends

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Abstract

The performance and emission characteristics of a direct injection variable compression ratio engine when fueled with pre-heated palm oil and its 5%, 10%, 15%, 20% blends with diesel (on a volume basis) are investigated and compared with standard diesel. The suitability of raw palm oil using pre-heated in the temperature range of 90° C as a fuel has been presented in this study. Experiments were conducted at constant speed of 1500 rpm, full load and at compression ratios of 16:1, 17:1, 18:1, 19:1 and 20:1. The effects of compression ratio on brake power, mechanical efficiency, indicated mean effective pressure and emission characteristics has been investigated and presented. The blend O20 is found to give maximum mechanical efficiency at higher compression ratio and it is 14.6% higher than diesel. Also the brake power of blend O20 is found to be 6% higher than standard diesel at higher compression ratio and indicated mean effective pressure of blend O20 is found to be lower than diesel at higher compression ratio. Exhaust gas temperature is low for all the blends compared to diesel. The emission of CO, HC dropped with an increase in blending ratio and compression ratio of maximum load. Also CO₂ emission found to be higher than diesel. The engine performance was found to be optimum when using O20 as fuel at compression ratio 20:1 during full load condition.

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Keywords: Performance, Compression ratio, Variable compression ratio engine, Preheated palm oil, Emissions

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1. Introduction

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From previous studies, Straight vegetable oils used in engine lead to various problems like fuel filter clogging, poor atomization and incomplete combustion because it is highly viscous, high density and poor non volatility. In order to reduce the viscosity of the straight vegetable oil the following four techniques are adopted; namely heating/pyrolysis, dilution/blending, micro-emulsion and transesterification. Among all these techniques the transesterification is an extensive, convenient and most promising method for reduction of viscosity and density of the straight vegetable oils. However, this adds extra cost of processing because of the transesterification reaction involving chemical and process heat inputs¹⁻⁵.

Most of the researchers have reported the preheating of inlet fuel reduces viscosity and can be implemented as indicated by the many results.

Deepak Agarwal et al.⁶ Preheating of Jatropha oil reduces the viscosity and also found to optimum fuel injection pressure. Bari et al.⁷ Preheating of crude palm oil up to 90 °C leads to reduce the viscosity, smooth flow and avoid the fuel filter clogging. Preheating oil with diesel substitute is used for short-term engine operation and also performance and emissions results are clearly indicating⁸⁻⁹. Ingle et al.¹⁰ compared the performance of neat and preheated transesterified cottonseed oil with diesel at various temperatures such as 50, 70 and 90oC and the properties such as viscosity, flash point, pour point were experimentally measured. The results revealed that preheating cotton seed oil methyl ester up to 90oC at higher load lead to increase in brake thermal efficiency compared to diesel and brake specific fuel consumption increases at higher load as compared to diesel. Senthil Kumar et al.¹¹ studied the combustion characteristics of animal fat are close to diesel and emissions are lower than diesel. Venkatraman et al.¹² investigated that increase in compression ratio; injection timing and injection pressure increases the performances with lower emissions for pungam methyl ester compared to diesel and evaluated the optimum output parameters. Improve the performance of the engine with higher compression ratio, injection timing and injection pressure, with lower emissions which are still lower than that with diesel fuel of different loads and biodiesels¹³⁻¹⁴.

	Nomenclature	HC	Hydrocarbon
DI	Direct Injection	CI	Compression ignition
O5	5% Preheated palm oil 95% diesel	EGT	Exhaust gas temperature
O10	10% Preheated palm oil 90% diesel	CR	Compression ratio
O15	15% Preheated palm oil 85% diesel	ASTM	American society of testing and materials
O20	20% Preheated palm oil 80% diesel	CO ₂	Carbon dioxide
D100	Standard diesel	IMEP	Indicated mean effective pressure
CO	Carbon monoxide		

From the literature review it can be inferred that a lot of research work has been carried out on evaluating the performance and emission characteristics of different grades of vegetable oils and biodiesels at a standard compression ratio but very little work has been done in evaluating the performance of preheated palm oil. The effect of compression ratio has not been analyzed for the preheated palm oil - diesel blends. This oil has the potential to become an alternate for conventional diesel oil. Hence, the study of the characteristics of preheated palm oil on diesel engine for variable compression ratio is very essential. In the present work, effect of compression ratio of preheated palm oil – diesel blended fuels on the performance and emission characteristic of fuel has been studied. The different blends of pre-heated palm oil and standard diesel fuel are prepared and the following investigations are carried out

- The performance of a variable compression ratio engine using different blends at different compression ratios like 16:1, 17:1, 18:1, 19:1 and 20:1 for full load and it is compared with the result of standard diesel fuel.
- The emission parameters such as CO, CO₂, HC and EGT are discussed with different compression ratios of different blends at full load conditions.

It was found that the pre-heated palm oil blends with diesel are obtaining better performance and emission characteristics results in a diesel engine without any modification.

2. Experimental setup and procedures

The experimental setup is shown in Fig.1. It consists of single cylinder, four stroke diesel engine

with data acquisition system. It has eddy current dynamometer for loading. The setup is provided with necessary instruments for combustion pressure and crank-angle measurements. These signals are interfaced to a computer through engine indicator for pressure - volume diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement. The setup has a stand-alone panel box consisting of two fuel tanks for multi fuel test, manometer reading, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. Rotameters are provided for measurement of engine cooling water and calorimeter water. The setup enables study of diesel engine performance and combustion parameters. Lab view based engine performance analysis software package "Engine test expresses V5.75" provides for online performance evaluation. A computerized cylinder in line pressure measurement is optionally provided¹⁵. The variable compression ratio engine is started by using diesel and when the engine reaches the stable operating conditions applied with part and full load. To cool the engine socket, cooling water is used when the flow rate is maintained 60ml/sec and the cooling water temperature is stabilized at 40°C. The tests are conducted at the rate of constant speed of 1500rpm. In every test, all the performance and combustion parameters are measured.

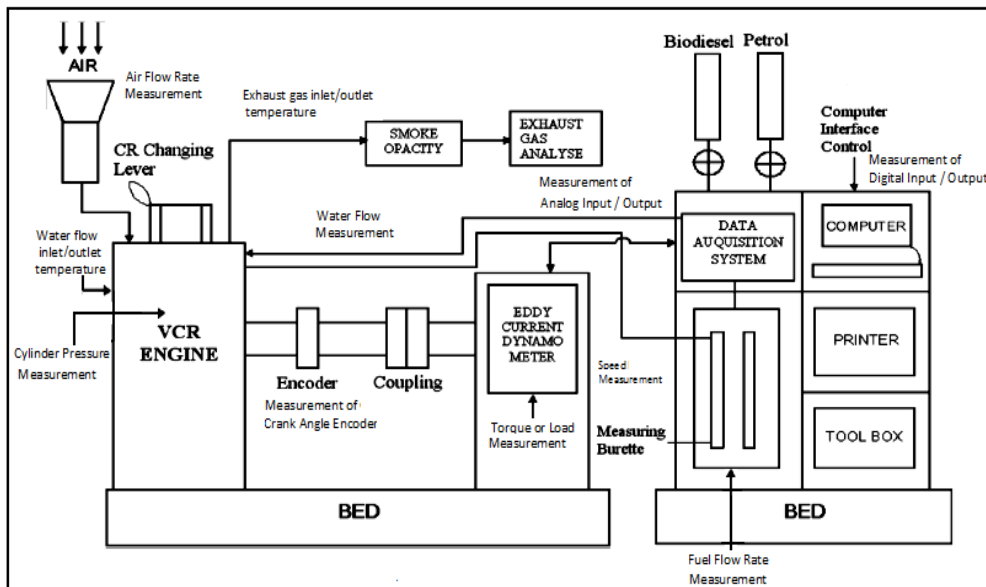


Fig. 1 Schematic diagram of the experimental setup

Table 1. Engine Specification

Type	: Kirloskar, single cylinder, inline, vertical, water cooling
No. of strokes	: Four
Rated power	: 3.7 KW
Bore/ stroke	: 80 mm/110 mm
Rated RPM	: 1500
Compression ratio	: 7:1 to 20:1
Injection timing	: 23° before top dead center
Type of ignition	: Compression ignition
Method of loading	: Eddy current dynamometer
Method of starting	: Manual crank start
Injection opening pressure	: 200 bar

From the initial measurement, brake power and mechanical efficiency with respect to compression ratio 16:1, 17:1, 18:1, 19:1 and 20:1 for different blends are calculated and recorded. The combustion and emission levels are also processed and stored in computers for further processing of the results. The same procedure is repeated for different blends of preheated palm oil. Table 1 shows the specifications of the VCR test rig.

3. Measurements of fuel properties

Palm oil is derived from the fruits of palm trees and it is extracted from the pulp of the palm fruit. Palm oil is naturally reddish in color because it contains a high amount of beta-carotene. This oil can be used in diesel engines as two methods (i) trans esterification (ii) preheating and blended with diesel. Among this method preheating is low cost and convenient. The palm oil was preheated up to 90° C and the following properties of the preheated oil were measured. The smallest amount of preheated palm oil is blended with diesel on volume basis. Table 2 shows the properties of diesel and preheated palm oil.

Table 2. Fuel properties of PBDF and preheated palm oil

Property	Test method	PBDF	Preheated palm oil at 90°C
Density kg/m ³	ASTM D1298	835	856.1
Viscosity at 40°C mPas	ASTM D445	3.66	8.087
Flash point ° C	ASTM D93	65	195
Cetane number	ASTM D 976	52	49
High calorific value kJ/kg	ASTM D2382	44000	39500
Carbon residue %wt	ASTM-D5291	0.13	0.09
Sulfur content %wt	ASTM-D5453	0.10	0.04
Acid value Mg KOH/g	ASTM- D664	0.18	0.6
Pour point ° C	ASTM D 97	15	16

4. Results and discussion

4.1. Performance and emissions characteristics

4.1.1. Brake power and mechanical efficiency

The Fig.2 shows the brake power with compression ratio for different blends. From this graph blend O20 attain higher brake power than other blends and standard diesel. Also the brake power increases from lower compression ratio to higher ratio at full load condition. The maximum brake power obtained for O20 and diesel is 3.9927 KW and 3.9339 KW for compression ratio 20:1 at full load. The other blends also attain higher brake power than diesel for all compression ratios at full load.

This may be due to better improvement of fuel spray characteristics, proper mixing of fuel–air ratio and complete combustion occurred by preheating and another reason is the density of the blend O20 is higher than that of diesel fuel. So that, a larger mass flow rate for the same fuel volume is pumped to the engine, resulting in the increase in brake power¹⁸.

The variations of mechanical efficiency with compression ratio for different blends are shown in Fig. 3. It has been observed that the mechanical efficiency of the blends is lesser at lower compression ratio and it is higher at higher compression ratio for blends O20, O5 and O15. The other blends like O10 and D100 is obtained higher mechanical efficiency at lower compression ratio and lower efficiency at higher compression ratio. The mechanical efficiency of the blend O20 increases with the increase in compression ratio when compared to that of standard diesel and other blends. The maximum mechanical efficiency obtained from blend O20 for compression ratio 20 is 97.66% and it is 14.6% higher than diesel. This is due to better lubricity properties of blended fuels compared to diesel.

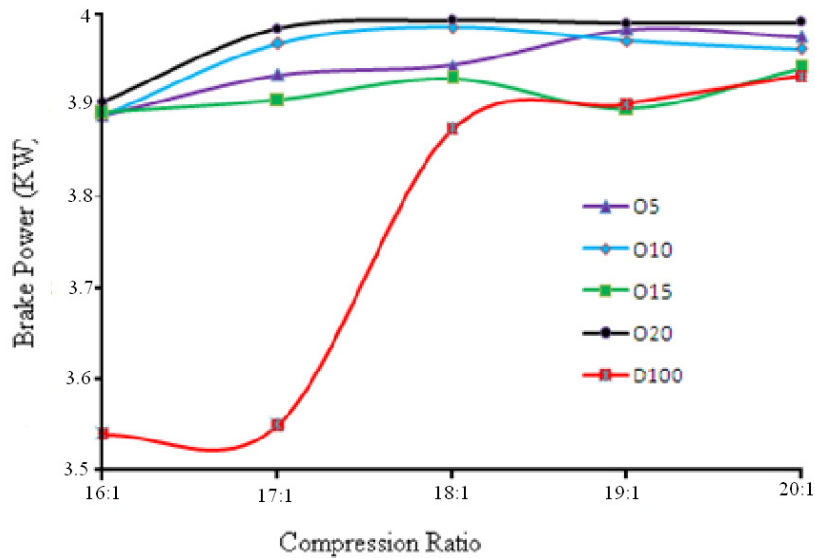


Fig. 2. Variation of break power with compression ratio for different blends

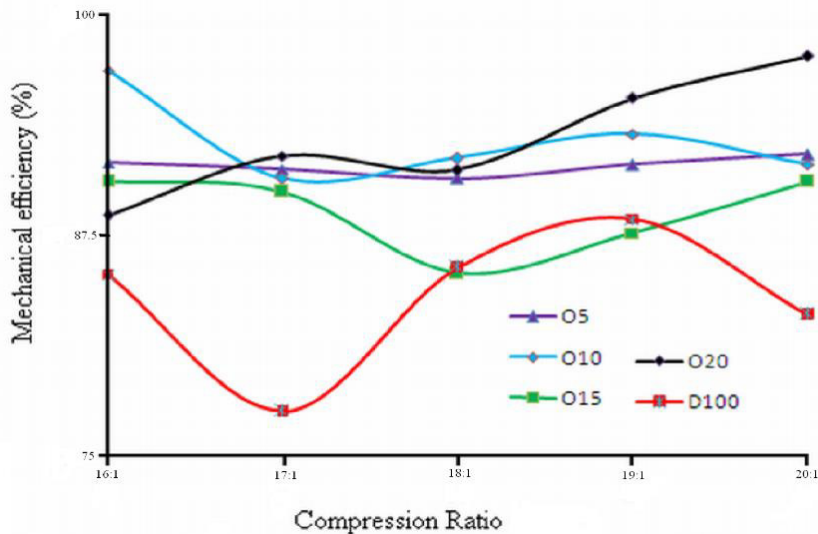


Fig. 3. Variation of mechanical efficiency with compression ratio for different blends

4.1.2. Indicated mean effective pressure and exhaust gas temperature

Fig. 4 shows the variation of indicated mean effective pressure with compression ratio for different blends. The indicated mean effective pressure for D100 is higher for lower compression ratio and blends O20 is lower at higher compression ratio than other tested fuels. The indicated mean effective pressure of D100 and O15 is 6.87 bar and O20 is 6.22 bar at compression ratio 20:1 and full load condition. As a whole it was found that among all the test fuels O20 obtain lower indicated mean effective pressure than all other tested fuels at compression ratio 19:1 and full load.

The Fig.5 shows the variation of Exhaust gas temperature with compression ratio for different blends. The result indicated that the exhaust gas temperature decreases for all the blends when compared to that of diesel from lower compression ratio 16:1 to higher compression ratio 20:1, except blend O5 it is 16.8° C higher than D100 at compression ratio 16:1 to 17:1. Also the blend O10 has the lowest exhaust gas temperature of the fuel when compared to all other tested fuels and it is about 110 ° C lower than that of the D100 at maximum compression ratio of 20:1 and at full load. As the compression ratio increases, the exhaust gas temperature of the various blends is decreasing than diesel. The reason for this is preheated

oil blends have a low calorific value than diesel. So that it leads to lower temperature at the end of compression¹⁵.

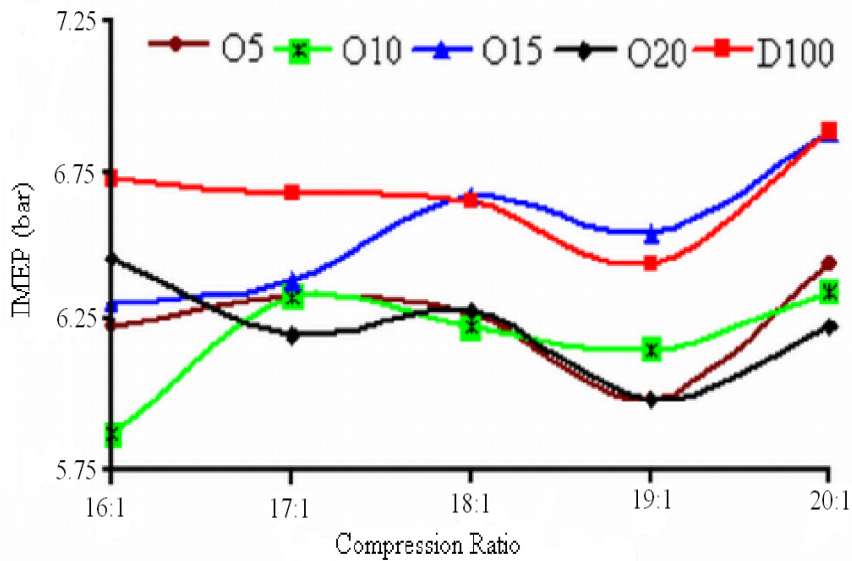


Fig. 4. Variation of indicated mean effective pressure with compression ratio for different blends

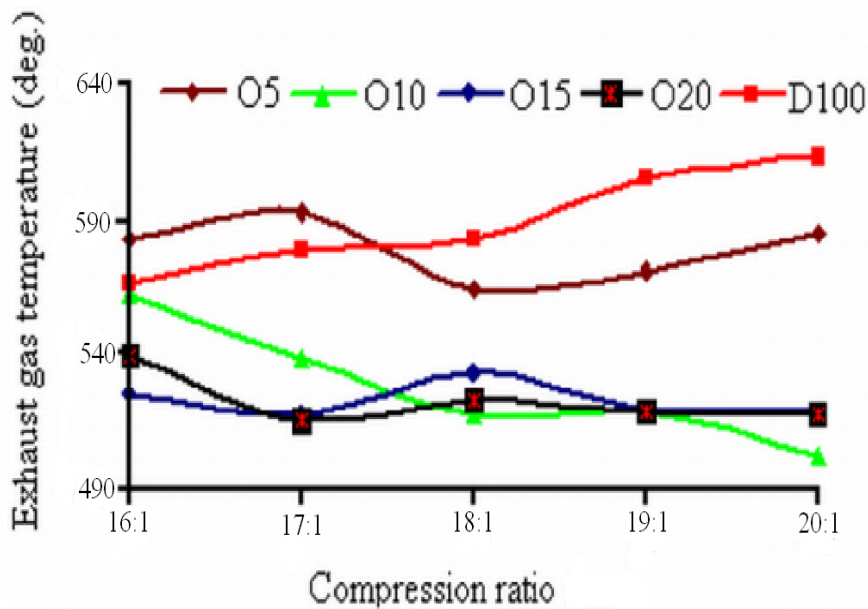


Fig. 5. Variation of exhaust gas temperature with compression ratio for different blends

4.1.3. Exhaust gas emissions for CO, CO₂ and HC

The figure 6 shows the variation of carbon monoxide emission with different compression ratios of the different blends and diesel. Here the blends O20 is lower than all other blends and diesel for higher compression ratio. The other blends like O5, O10 and O15 also a lower amount of emission produced than diesel at compression ratio 20:1. When compared to diesel, O20 produced 45.45% lesser emission. The CO emission was decreased for all the blends than diesel due to preheating of fuel leads to the improvement in spray characteristics and better air-fuel mixing¹⁷⁻¹⁸.

The variation of carbon dioxide emission with different compression ratios are shown in Fig. 7. The tested fuels emit higher amount of CO₂ than diesel at higher compression ratio 20:1. The other blends O5, O10 and O15 were also higher than diesel. The more amount of CO₂ is an indication for complete combustion of fuel in the combustion chamber. More CO₂ is not much harmful to humans but it leads to higher ozone depletion potential and global warming¹⁵.

Figure 8 shows the variation of hydrocarbon emission with different compression ratio of the different blends and diesel. The hydrocarbon emission of different blends is higher at higher compression ratio. For increasing compression ratio of the engine also increase HC emission for D100 and O5. For the other blend O10 it is 21.21%, O15 it is 27.27% and O20 is 24.24% lower hydrocarbon emissions than that of diesel. This is due to longer ignition delay, more fuels accumulate in combustion chamber may lead higher hydrocarbon emission^{16,19-20}.

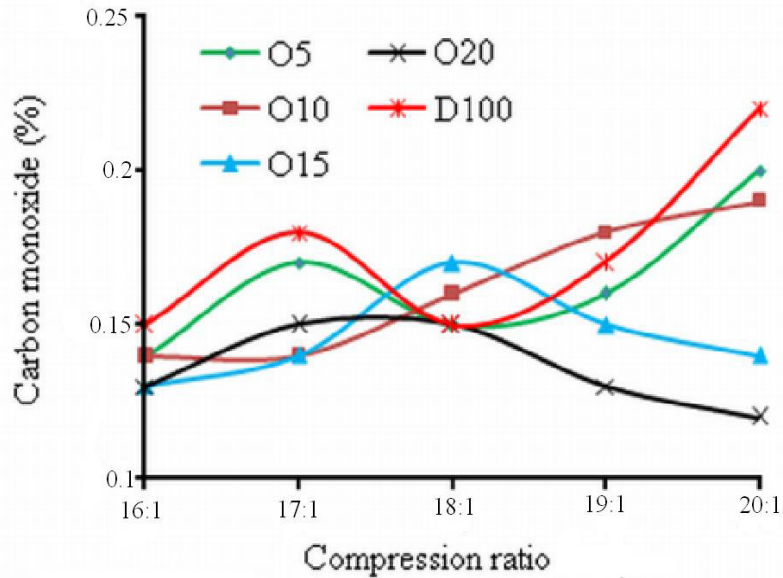


Fig.6. Variation of carbon monoxide emission with compression ratio for different blends

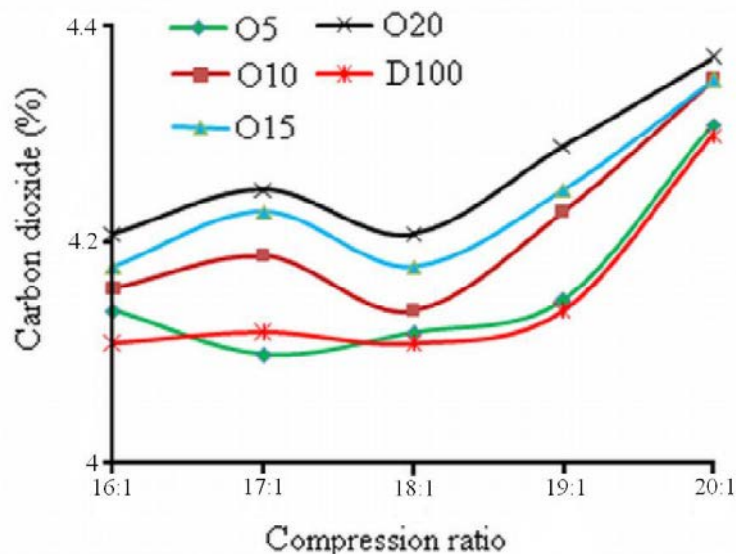


Fig.7. Variation of carbon dioxide emission with compression ratio for different blends

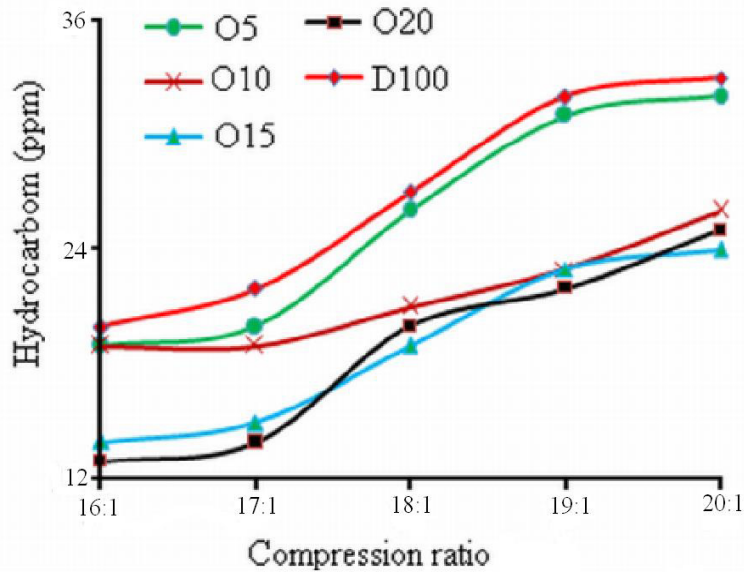


Fig.8. Variation of hydrocarbon emission with compression ratio for different blends

5. Conclusions

Moreover by increasing compression ratio, the engine performances are varied and it is compared with standard diesel. The following results are presented in variable compression ratio engine with functions of fuel blends, load, and compression ratio.

- The brake power of O20 is higher than that of standard diesel and other tested fuels at higher compression ratio and full load condition.
- From the observation of this study while increasing the compression ratio of the engine the mechanical efficiency was increased at full load condition. This may lead to better thermal efficiency of the engine.
- The indicated mean effective pressure for diesel is higher than other tested fuels from lower compression ratio to higher compression ratio but the blend O20 has lower for compression ratio 17:1 to compression ratio 20:1.
- The exhaust gas temperature of the tested fuels was found O10 is 110 ° C, O15 and O20 are 93 - 94 ° C, O5 is 28 ° C lower than that of diesel at higher compression ratio and full load.
- There is a significant reduction in CO and unburned hydrocarbon for all blends of preheated palm oil at higher compression ratio and full load.
- Also the CO₂ level was higher than that of diesel for all other tested fuels from lower compression ratio to higher compression ratio. These clearly indicate the better performances and emissions result.

From the above observation, it has been found that the blend O20 shows better performance and emission characteristics than other blends and diesel at compression ratio 20:1 and full load condition. The experimental result also proves that lower percentages of preheated palm oil can be substituted as diesel fuel.

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