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Performance and Operating Characteristics of Variable Compression Ratio Engine Using PPME - Diesel Blends

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Abstract - **The performance characteristics of a four-stroke, single-cylinder, variable compression ratio engine were investigated fueled with esterified pongamia pinnta oil. Transesterification process is used for preparation of methyl ester from pongamia pinnta oil [PPME]. Experiments has been conducted at various loads like 0, 3, 6, 9 and 12 kg with engine speed of 1500 rpm for varying compression ratios from 14:1 to 18:1 and at common injection pressure of 200 bar. The affect of compression ratio is investigated on fuel consumption, performance parameters and exhaust gas emissions. The compression ratio is varied with changing the clearance volume by movement another piston in opposite direction with the help of screw rod and hand wheel mechanism. The performance characteristics like BSFC, brake power, MEP, brake thermal efficiency and exhaust gas temperature are analyzed for PPME-Diesel blends in the variable compression ratio engine. The emission characteristics like carbon dioxide hydrocarbon, nitrogen oxides, carbon monoxide, and smoke level are also measured for PPME-diesel blends in the same engine. The motivation behind this analysis is to fix the effective compression ratio of the engine for this blend fuel.**

Keywords: **Performance, PPME, Compression ratio, Exhaust emissions, VCR Engine, Pongamia pinnta biodiesel.**

I. Introduction

Both edible and non-edible oils have proven to be potential alternatives and renewable fuels to diesel. Vegetable oils have several advantages compared to fossil diesel fuel. They are mainly renewable and carbon neutral. The energy content and cetane number are comparable to that of diesel fuel. The major limitations of vegetable oils are high viscosity and poor ignition characteristics which impose a negative impact on the engine performance, emissions and durability of the engine. Hemmerlein *et al.,* [1] and many investigators have reported operational and durability problems such as injector nozzle choking, lubricating oil thickening and abnormal engine wear. Agarwal [2] conducted experiments on diesel engine and observed significant improvement in performance and emission characteristics for the biodiesel used engine compared to diesel. Thermal efficiency of the engine improved, *bsfc* reduced and a considerable reduction in the exhaust smoke opacity was observed. Goering *et al.,* [3] studied eleven vegetable oils characteristic properties to determine which oil would be the best suitable for an alternative fuel source. Of the eleven oils tested corn, cottonseed, rapeseed, sesame, and soyabean oils had the most favorable fuel properties. Altin *et al.,* [4] evaluated the performance and exhaust emissions of a diesel engine using 100% refined vegetable oil and with their biodiesels finally concluded that biodiesels have better performance than diesel.

Pramanik *et al*., [5] reported the engine performance using Jatropha blends as fuel and found that significant improvement in engine performance was observed compared to vegetable oil alone. The specific fuel consumption and the exhaust gas temperature were reduced due to decrease in viscosity of the vegetable oil and emission characteristics closer to the diesel fuel. Barabas *et al*., [6] studied the performance and emissions of the diesel–biodiesel–ethanol blends and comparing them with those of diesel fuel and reported that performances decrease, especially at low engine loads. CO emissions decrease significantly due to an increase of CO_2 emissions as a result of a prolonged oxidation process. Raheman *et al.,* [7] studied the fuel properties of karanja methyl esters blended with diesel from 20% to 80% by volume. It was found that B20 could be used as appropriate alternative fuel because it had less CO, NO_X emissions and smoke density. Lin *et al.,* [8] confirmed that emission of polycyclic aromatic hydrocarbons (PAH) decreased when the ratio of palm biodiesel increased in a blend with petroleum diesel. In general, biodiesel demonstrate improved emissions by reducing CO, CO_2, HC and PM emissions though, in some cases, NO_X increased. Duraisamy *et al.,* [9] concluded that the blend fuel of 20% methyl ester of thevetia peruviana seed oil and 80% pure diesel reveled that a significant improvement in performance and reduction in emissions when compared with pure diesel operation and increasing the compression ratio.

Muralidharan *et al.* [10] estimated the performance, emission and combustion characteristics of a single-cylinder, four-stroke, VCR, multi-fuel engine fuelled with waste cooking oil methyl ester and its blends with diesel. The results show that considerable improvement in the performance parameters as well as exhaust emissions was observed especially at full load. Gandure and Ketlogetswe [11] carried out their work to compare the performance of variable compression ratio engine fuelled with native marula seed oil and petrodiesel fuels. The results indicated that engine performance when powered with marula oil as fuel was very close to that when powered with petrodiesel at 80% load and the compression ratio of 16:1 yields optimum performance in terms of engine torque and brake power for both petrodiesel and marula oil fuels. The objective of the present study is to compare the performance and emission characteristics of a Variable Compression Ratio, four strokes, water cooled, constant speed diesel engine using Pongamia piñata methyl ester (PPME) and diesel blends as fuel for compression ratio varying from 14:1 to 18:1 and 0 to 12Kg.

II. Experimental Set Up

The experimental setup shown in Fig. 1 consists of single cylinder, four stroke, Variable Compression Ratio (VCR)) diesel engine connected to eddy current type dynamometer for loading. The compression ratio can be changed without stopping by moving counter piston against the original with the help of a screw rod and hand wheel mechanism. Necessary instruments for combustion pressure measurement are provided. The setup has panel box consisting of air box, fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements and engine indicator.

Fig. 1 Experimental Setup

III. Experimental Procedure

The performance analysis was carried out using esterified pongamia oil in the variable compression ratio (VCR) engine at a rated speed of 1500 rpm. In every test specific fuel consumption, exhaust gas temperature and emissions such as carbon monoxide (CO), hydrocarbon (HC), nitrogen oxides (NOx), carbon dioxide (CO_2) are measured. From the initial measurement, brake thermal efficiency and specific fuel consumption with respect to compression ratios 14:1 to 18:1 are calculated from the measured data. The result indicates that the variation in exhaust gas temperature is very minimal when the compression ratio is varied from 14 to 18. The calculated and obtained data are shown in the form of graphs for comparison with diesel readings.

IV. Results and Discussion

A. Brake Thermal Efficiency

Brake thermal efficiency (B_{the}) is continuously increases with increase in compression ratio (CR) for all the blend fuels except B20 blend and diesel. The trend is due to higher temperature achieved at higher CR, results in better combustion. The observation is that B_{the} decreased with increase in biodiesel quantity in blend fuel at the same CR, this may due to higher viscosity of biodiesel tends to poor atomization in the combustion process with increase in CR from 14 to 18 the B_{the} increased up to 6% for all fuels. The observation from Fig. 2 is that with increase in CR the performance with biodiesel and its blends approaches to that of diesel. At CR18 biodiesel B_{the} of the engine is 9.7% less than that of diesel.

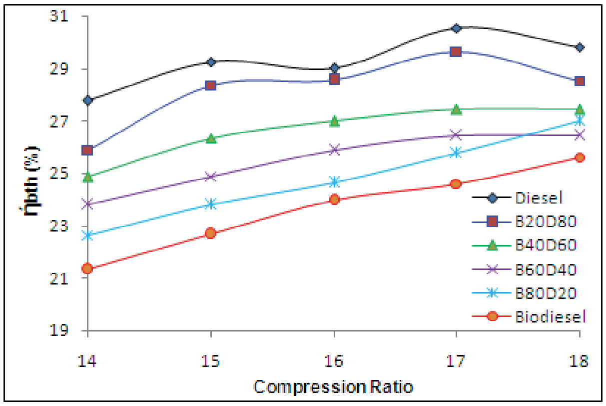

Fig. 2 Variation of B_{the} with Compression Ratio

B. Brake Specific Fuel Consumption: The observation from Fig. 3 is that brake specific fuel consumption (BSFC) increases with increase in percentage of biodiesel in the blend. This may be due to the fuel burning rate is more with PPME because of its lower calorific values. With increase in CR the BSFC decreases by about 5 to 13% as the biodiesel quantity increases in the blend fuel. The consumption of pure biodiesel is 25% more at CR of 14, while that at CR of 18 is about 10% more and the performance of biodiesel at CR18 is very close to that of diesel.

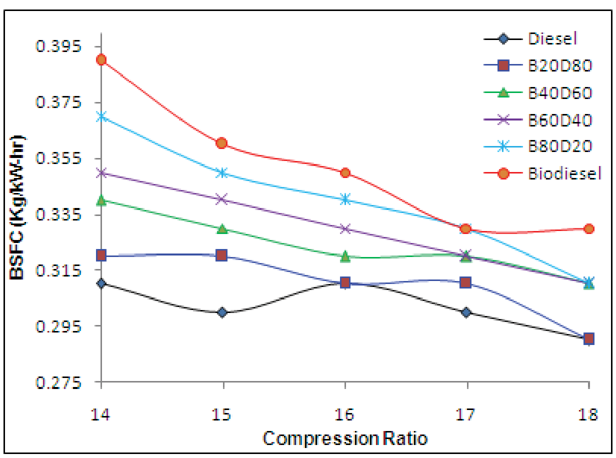

Fig. 3 Variation of BSFC with Compression Ratio

C. Exhaust Gas Temperature: Exhaust Gas Temperature (EGT) indicates the effectiveness of fuel combustion and conversion of energy into thermal. For any engine lower temperature is always preferable. The observation from Fig. 4 is that EGT decreases with increase in CR for all blend fuels. This reduction is due to complete combustion of fuel at higher temperatures attained at higher CR. The EGT reduces up to 18% for all blend fuels as CR increases.

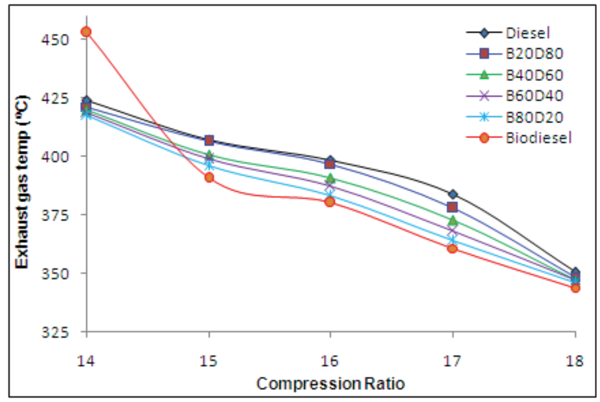

Fig. 4 Variation of EGT with Compression Ratio

D. Carbon Monoxide: It is observed that Carbon Monoxide (CO) emission decreases with increase in CR, this may be due to better combustion of fuel with higher temperature at higher CR. Further it is also observed from Fig. 5 that at low CR emissions of CO are higher and at higher CR emissions decreases for blend fuels as compared to diesel. Lower CO emissions for blend fuel at higher CR may be due to the oxygenated nature of biodiesel converting more CO into CO_2, similarly for less CO at low CR may be poor combustion due higher viscosity. From the graph it is noted that CO emissions are 66% less for pure biodiesel compared to diesel at CR 18.

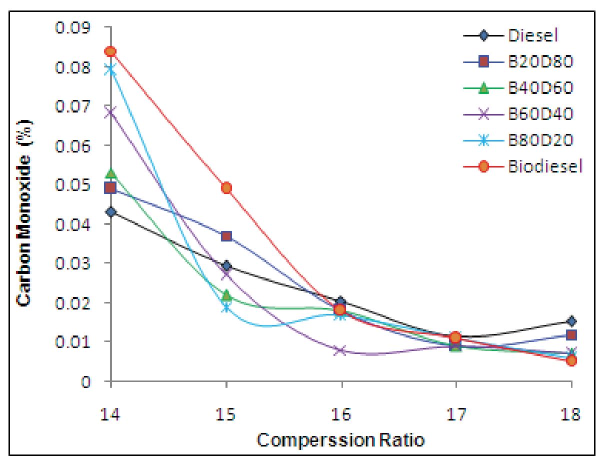

Fig. 5 Variation of CO with Compression Ratio

E. Carbon dioxide: The amount of CO_2 in exhaust shows the degree of chemical energy conversion into thermal energy. The Fig. 6 shows that CO_2 emission initially decrease and reach lowest subsequently increase with increase in CR for all the blend fuels. It is also observed that higher CO_2 emission for biodiesel compared to diesel at all CRs, may be due to complete combustion of biodiesel. The percentage of decrease in CO_2 emissions is between biodiesel and diesel, over the range of CR is 22%.

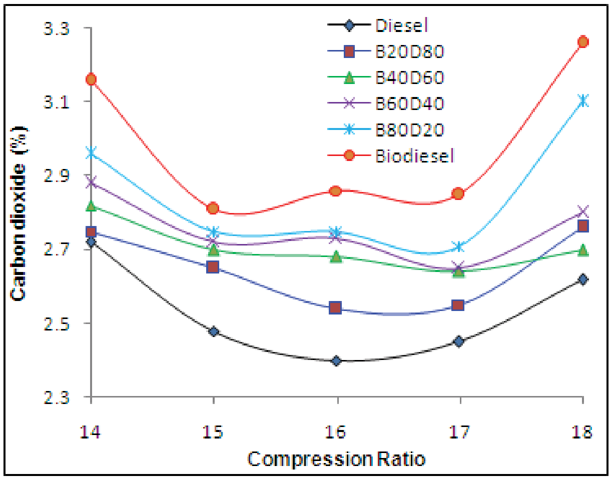

Fig. 6 Variation of CO2 with Compression Ratio

F. Hydrocarbons: From Fig. 7 the observation is made that Hydrocarbon (HC) emissions decrease with increase in CR for all fuel combinations. It is also observed that HC decreases with increase in blend proportion, this may be due to the oxygenated nature of biodiesel. The mean percentage decrease in HC with biodiesel as compared to diesel is of the order of 60% except at 14 CR where it is around 32%. The HC emission for pure biodiesel is 24% higher than diesel at CR of 18.

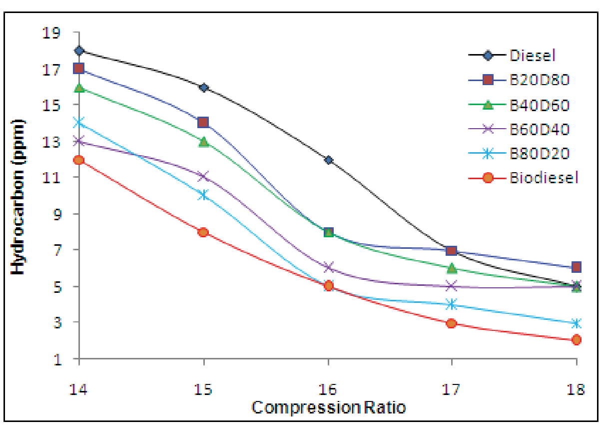

Fig. 7 Variation of HC with Compression Ratio

G. NOx emissions: The observation from Fig. 8 is that NOx emissions increase for blends increasing biodiesel and in CR. This is because at lower CR less oxygen is available to form NOx due low temperature of compressed air, but at higher CR higher temperature of air by compression which indicates early combustion ensuring complete heat release of fuel. At CR of 14 the NOx emissions for diesel are higher by 70% and at CR 18 are lower by 24% as compared to biodiesel.

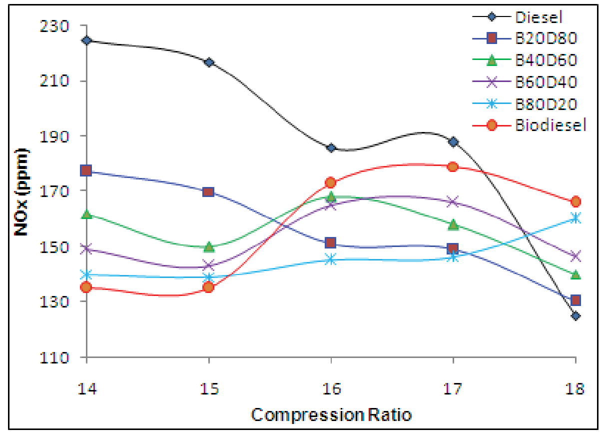

Fig. 8 Variation of NOx with Compression Ratio

H. Smoke Density: The smoke density (HSU) is higher for biodiesel and its blends because they have more viscosity than pure diesel and this have a negative effect in the combustion process. The Fig. 9 shows that HSU decreases by 44% for diesel and 40% for pongamia biodiesel as CR increases from 14 to 18.

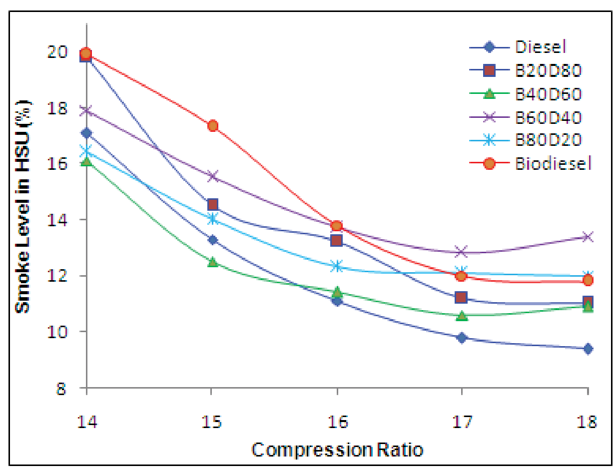

Fig. 9 Variation of HSU with Compression Ratio

V. Conclusions

The aim of the investigation was successfully carried out on VCR engine and the following conclusions were drawn: The B_{the} is decreased with increase in biodiesel quantity in blend fuel at same CR, due to higher viscosity of biodiesel tends to poor atomization. With increase in CR from 14 to 18 the B_{the} increased up to 6% for all fuels. Biodiesel and its blends performance approaches to that of diesel with increase in CR. Brake thermal efficiency of the engine with biodiesel is 9.7% less than that of diesel at CR18. The consumption of pure biodiesel is 25% more at CR of 14, while at CR of 18 is about 10% more. The consumption of biodiesel is very close to that of diesel at CR18. EGT is reduced due to complete combustion of fuel at higher temperatures attained at higher CR. The EGT reduces up to 18% for all blend fuels as the CR increases

The CO emissions lower for blend fuel at higher CR, may be due to the oxygenated nature of biodiesel converting more CO into CO_2. Poor combustion due higher viscosity causes less CO at low CR. The CO emissions attained at CR 18 are 66% less for pure biodiesel compared to diesel. For the blend fuels percentage decrease in CO_2 emissions is between biodiesel and diesel over the range of CR is 22%.

The mean percentage decrease in HC with biodiesel as compared to diesel is 60% except at CR 14 where it is around 32%. The HC emission for pure biodiesel is 24% higher than diesel at CR of 18. At CR of 14 the NOx emissions for diesel are higher by 70% and at CR 18 are lower by 24% as compared to biodiesel. The smoke density as CR increases from 14 to 18 decreases by 44% for diesel and 40% for pongamia biodiesel.

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