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Original Research Article

Effects of varying the compression ratio on the performance of a biodiesel fuelled diesel engine

S.Jaichandar[1*], K.Annamalai[2], V.Elango[1], P.Arikaran[1] and V. Antony Aroul Raj[1]

[1]Easwari Engineering College, Chennai, Tamilnadu, India
[2] Madras Institute of Technology, Anna University, Chennai, Tamilnadu, India

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ABSTRACT

Improved thermal efficiency, reductions in fuel consumption and pollutant emissions from biodiesel fuelled diesel engines are important issues in engine research. To achieve these, rapid and better air-fuel mixing is the most important requirement. The mixing quality of biodiesel with air can be generally improved by selecting the best engine design parameters. Experiments were performed using a single cylinder Direct Injection (DI) diesel engine at different compression ratios. The effects of varying the compression ratio on the combustion, performance and exhaust emissions using a blend of 20% Pongamia Oil Methyl Ester (POME20) by volume in diesel were evaluated. The test results showed that improvement in terms of brake thermal efficiency and specific fuel consumption for engine having higher compression ratio, particularly with compression ratio of 18.5. Substantial improvements in reduction of emission levels were observed for higher compression ratio in terms of carbon monoxide, hydrocarbon and smoke. However improved air motion inside the cylinder and high pressure injection increases the oxides of nitrogen (NOx). The change of compression ratio from 17.5 to 18.5 resulted in reduction in delay period and improvement in heat release rate.

Keywords: Biodiesel, diesel engine, compression ratio, combustion, performance, emissions.

Nomenclature

POME	Pongamia Oil Methyl Ester	DI	Direct Injection
CR	Compression ratio	BTE	Brake Thermal Efficiency
BSFC	Brake Specific Fuel Consumption	UBHC	Unburned Hydrocarbons
CO	Carbon Monoxide	NOx	Oxides of Nitrogen

* Corresponding Author
E-mail: jcdhanesh@gmail.com

1. Introduction

India's economic growth is placing enormous demand on its energy resources. India imports about 80% of its oil. There is a threat of these increasing further, creating serious problems for India's future energy security. In the recent national policy on biofuels released by Ministry of New and Renewable Energy, Government of India, it has been mentioned that, India's energy security would remain vulnerable until alternative fuels to supplement petroleum - based fuels are developed, based on indigenously produced renewable feedstock. In the policy it has been proposed that, an indicative target of 20% blending of biofuels with diesel by 2017 [1].

Research on use of biodiesel in diesel engine is not new. A large number of experimental investigations on the performance, emission and combustion characteristics of biodiesel fuel in diesel engines have been carried out without any modification to the diesel engine [2-4]. These studies have reported that the use of biodiesel blends and neat biodiesel in diesel engine decreases the performance of diesel engine [5-8].

Therefore, it is of interest to investigate the use of biodiesel in diesel engine, aiming to reduce fuel consumption, increase efficiency of operations and to reduce the emission of pollutants. The performance and emission characteristics of diesel engines mainly depend upon the combustion process [9]. combustion of the fuel inside the cylinder, in turn depends on various factors like engine design such as compression ratio, injection timing, injection pressure, shape of combustion chamber and position of injector, fuel properties, fuel spray pattern, air swirl, fuel quantity injected etc. [10].

The compression ratio has significant influence on the performance and emission characteristics of diesel engine. Theoretically, increasing the compression ratio (CR) of an engine can improve the overall efficiency of the engine by producing more power output. Operating the engine at optimum compression ratio can improve fuel economy and reduce tail pipe emissions [11-15]. Hence an experimental analysis to study the effect of varying the compression ratio on the performance of biodiesel fueled diesel engine is very essential. In the present work, the effect of varying the compression ratio on engine performance and emission behaviour of DI diesel engine fueled with biodiesel obtained from pongamia was studied and optimum compression ratio was determined.

2. Materıals and Methods

2.1. Production of POME and its properties

POME was prepared by the transesterification process from raw Pongamia oil. Transesterification is the chemical splitting up of the heavy, branched, triglyceride molecules of vegetable oils into smaller, straight chain molecules, almost similar to diesel fuel. The process takes place by the reaction of raw pongamia oil with methyl alcohol in the presence of alkaline catalyst. The properties of the raw pongamia oil and POME were experimentally estimated. The properties of raw pongamia oil, POME and its 20% blend with diesel are compared with the standard diesel in Table. 1. Most of the properties of POME, such as calorific value, viscosity, density, flash point, cloud point and pour point are comparable with those of diesel. However, certain properties of biodiesel such as viscosity, calorific value, density and volatility slightly differ from diesel.

2.2. Experimental setup

The test engine used was a four-stroke, single cylinder, water cooled diesel engine developing 5.2 kW at 1500 rpm. The detailed technical specifications of the standard engine are given in Table.2. This engine was coupled to an eddy current dynamometer with a control system. The cylinder pressure was measured by a piezoelectric pressure transducer fitted on the cylinder head and a crank angle encoder fitted on the flywheel. Both the pressure transducer and encoder signal were connected to the charge amplifier to condition the signals for combustion analysis using SeS combustion analyzer. UBHC and CO were measured using a CRYPTON 5 gas analyzer. NO_X emissions were measured using a chemiluminescent type SIGNAL heated vacuum NO_x analyzer. The smoke intensity was measured with the help of the AVL 437C Smoke meter. Figure 1 shows the photographic view of the experimental set up.

Table 1. Properties of diesel, biodiesel from pongamia and its blend

OIL PROPERTIES	DIESEL	Raw Pongamia Oil	POME	POME20
Kinematic Viscosity (cSt)	2.9	37.84	5.46	3.49
Density (Kg/m^3)	850	912	898	862
Calorific Value (MJ/kg)	44.12	34	39.15	43.126
Flash Pt °C	76	242	196	91
Cloud Pt °C	6.5	14.6	10.2	7.1
Pour Pt °C	3.1	-	4.2	3.6

Table 2. Standard engine specifications

Make	Kirloskar TV1
Type	Vertical diesel engine, 4stroke, water cooled, single cylinder
Displacement	661 cc
Bore & Stroke	87.5 mm & 110 mm
Compression ratio	17.5:1
Fuel	Diesel
Rated brake power	5.2 kW @ 1500 rpm
Ignition system	Compression ignition
Injection timing	21^o bTDC
Injection pressure	200 bar

Fig. 1. Photographic view of the experimental set up

2.3. Test method

In the present investigation, to investigate the effects of varying the compression ratio on combustion, performance and emission characteristics of biodiesel fueled direct injection diesel engine, the compression ratio of the engine was varied by changing the number of shims in between crank case and cylinder block. By changing the number of shims, the compression ratio of the engine was varied to have 16.5, 18.5 and 19.5 from the standard 17.5.

For the experimentation standard diesel and a blend of 20% POME by volume in the diesel were used as fuel. The test was conducted by starting the standard engine with diesel fuel only. After the engine was warmed up, it was then switched to POME20 blend. Then the engine tests were carried out using POME20 blend by varying the compression ratio of the engine. The engine tests were carried out at 0%, 25%, 50%, 75% and 100% load and their results were compared and analysed with standard engine having a compression ratio of 17.5. In order to have meaningful comparison of emissions and engine performance, investigation was carried out at same operating conditions i.e. engine speed, torque, air-fuel ratio and peak conditions were maintained. In the experimental investigations different equipment and instruments were used for measurement of different parameters. These instruments and equipment are made by different manufacturers using different technologies. The accuracy of measurement and their performance may vary depending on the operating conditions and experimental environment. Hence the uncertainty occurs due to fixed or random errors. The uncertainties in the measured parameters were estimated based on analytical methods.

3. Results and Dıscussıon

The performance and emission characteristics of the engine with different compression ratios were determined, compared and analysed in terms of brake thermal efficiency, brake specific fuel consumption, unburnt hydrocarbon, carbon monoxide, oxides of nitrogen, smoke emissions and combustion parameters such as ignition delay and heat release rate.

3.1. Performance analysis

The variations of Brake Thermal Efficiency (BTE) in relation with brake power for diesel and POME20 at CR's of 16.5, 17.5, 18.5 and 19.5 are shown in figure 2. It shows that the BTE increased with the increase in brake power for all fuel. However, BTE of POME20 was lower (26.99%) compared to that of diesel (28.8%). On the other hand BTE for CR-18.5 (29.8% at full load) was higher compared to other compression ratio operations at all loads when operated with POME20. This was due to increased pressure, temperature and better air motion inside the combustion chamber. Increased pressure and air motion inside the combustion chamber, results in better atomization which in turn results in better mixture formation of POME and air. This leads to better combustion of the biodiesel and thus increased the BTE.

The Brake Specific Fuel Consumption (BSFC) variations of the engine with diesel and POME20 at different compression ratios are shown in figure 3. The specific fuel consumption for CR-18.5 (0.26 kg/ kW-hr) was lower than the baseline engine having a CR-17.5 (0.30 kg/ kW-hr) with biodiesel operation. This can be attributed to better combustion of POME20 due to better air fuel mixing. The BSFC for CR-18.5 further decreased. This behaviour can be attributed to much improved mixing due to better atomization and vaporization of the fuel that leads to better combustion. However it was noticed that the BSFC increased, when the compression ratio was increased beyond CR-18.5. This outcome could be attributed to poor combustion due to oxygen starvation as a result of lower penetration and poor dispersion of the fuel.

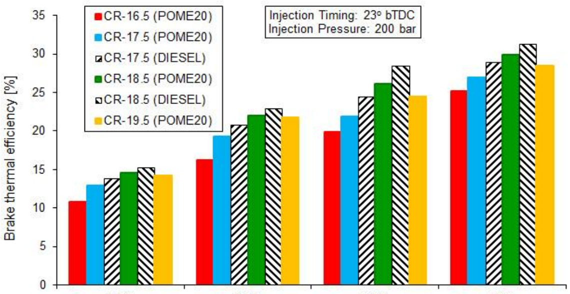

Fig. 2. Comparisons of BTE

3.2. Emission analysis

The comparisons of Unburnt Hydrocarbon (UBHC) emissions for both diesel and POME20 at different compression ratios are shown in figure 4. UBHC emissions were reduced over the entire range of loads fuelled with POME20 when compared to diesel operation. It was also noticed that engine operation with CR-18.5 emitted less level of UBHC compared to other compression ratio operations.

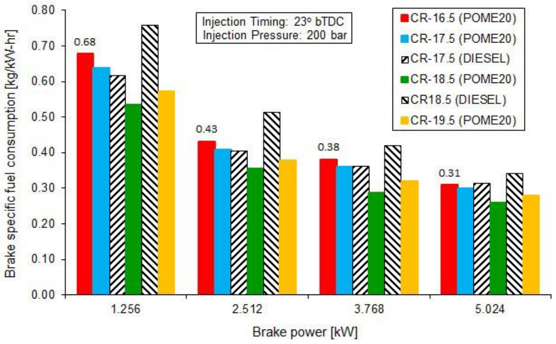

Fig. 3. Variations of BSFC

This was due to better combustion of POME as a result of improved atomisation, air motion and presence of oxygen in POME. There was a reduction of 3.7% HC emissions for the engine operation with CR-18.5 compared to baseline engine having CR-17.5 when tests are carried out with POME20 and 21.2% reduction with standard diesel oil at full load operation. Further the increased compression ratio decreased the formation of UBHC due to better combustion and reduction in quench layer due to increased cylinder wall temperature.

Figure 5 shows the comparison of CO emissions with brake power at different compression ratios. CO emissions for all compression ratios fueled with biodiesel blend decreased significantly when compared with those of standard diesel at all loads. This shows that CO emissions are greatly reduced with the addition of POME to diesel. It decreased with, engine operation with CR-18.5 than the other compression ratio operations. Improved atomization and air movement in combustion chamber and presence of oxygen in POME, led to better combustion of fuel, resulting in the decrease of CO emissions. Secondly increase in the proportion of oxygen in POME promoted further oxidation of CO during the engine exhaust process. Reduction in CO emissions was observed with increased compression ratio operation mainly due to better atomization, evaporation and complete combustion. There was a reduction of 5.7% CO emissions for the CR-18.5 operation compared to standard engine when tests are carried out with POME20.

Figure 6 shows the variations of oxides of nitrogen emissions for both diesel and POME20 at different compression ratios. Oxides of Nitrogen (NO_x) are formed by chain reactions involving Nitrogen and Oxygen in the air. These reactions are highly temperature dependent. Since diesel engines always operate with excess air NO_x emissions are mainly functions of gas temperature and residence time. The NO_X emissions were higher for the engine operated with CR-18.5 than the base engine having CR of 17.5. The reason for the increase in NO_X may be attributed to higher combustion temperatures arising from increased in-cylinder temperature due to increased compression ratio, improved combustion due to better mixture formation and availability of oxygen in POME. Another reason for increased NO_X emissions may be attributed to that, a larger part of the combustion was completed before top dead centre for POME blend compared to diesel due to their lower ignition delay [16]. So it is highly possible that higher peak cycle temperatures are reached for POME compared to diesel.

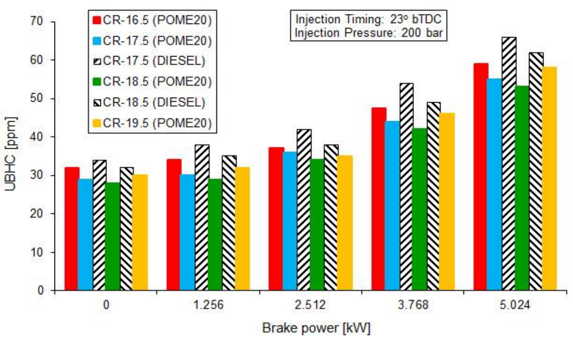

Fig. 4. Variations of UBHC Emissions

The smoke intensity comparison for different compression ratios with diesel and POME20 is shown in figure 7. Smoke is due to incomplete combustion. Smoke formation strongly depends on the air entrainment into the cylinder, the Oxygen amount in the fuel and the composition and structure of hydrocarbon in the fuel.

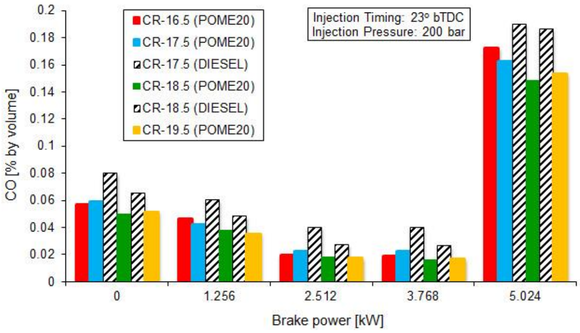

Fig. 5. Variations of CO emissions

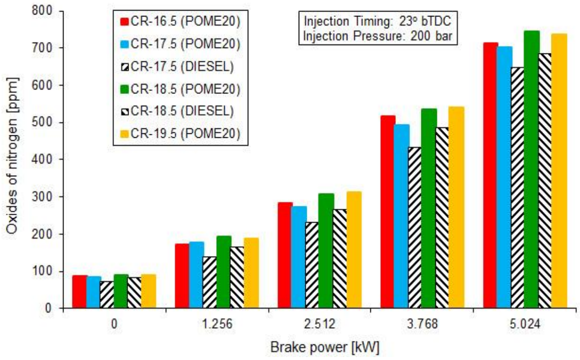

Fig. 6. Comparisons of NO_X emissions

At all loads and for all compression ratio operations, smoke emissions for the blend decreased significantly when compared with that of standard diesel. The reduction in smoke emission was due to the presence of oxygen in biodiesel blend. It was observed that, smoke emissions for CR-18.5 were lower when compared with other compression ratio operations. This was due to more complete combustion as a result of better air fuel mixing and presence of oxygen in the POME. It was also observed that the lower compression ratio operation resulted in higher smoke emissions than higher compression ratio. At lower compression ratio operation the atomization and air-fuel mixing process was very poor. This resulted in poor combustion. Hence, at lower compression ratio higher smoke emissions were formed due to bigger droplet. However at a higher compression ratio of 18.5, it was observed that lower smoke emissions were formed due to small size fuel droplets, better air-fuel mixing and complete combustion. Engine operation with CR-18.5 gave a 22% reduction of smoke opacity when compared with standard engine fueled with diesel.

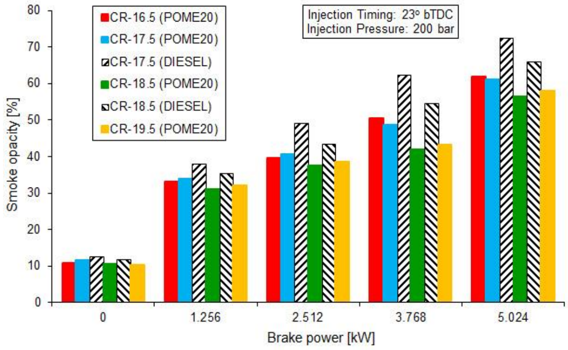

Fig. 7. Comparisons of smoke emissions

3.3. Combustion analysis

The cylinder pressure variation with crank angle for different compression ratios are shown in figure 8. The pressure variations of the engine operated at compression ratio of 18.5 and with POME20 followed the similar pattern of the pressure rise as that of the baseline engine operated at compression ratio of 17.5. However, the values of pressure data were higher at all operating conditions. This may be attributed to better combustion due to enhanced air fuel mixing in the modified engine. The results also indicated that cylinder pressure variations increased while increasing the compression ratio initially from standard compression ratio, i.e. increasing the compression ratio from 17.5 to 18.5 and then decreased with a further increase in compression ratio to 19.5. It was also observed that the best results were associated with the compression ratio of 18.5 with POME20. This performance can be reasoned to better combustion due to better atomization, vaporization of the fuel and air-fuel mixing. It was also noticed that peak cylinder pressure decreased with lowering the compression ratio from 17.5 to 16.5. This may be reasoned to poor combustion of POME20 due to poor atomization, vaporization and air fuel mixing.

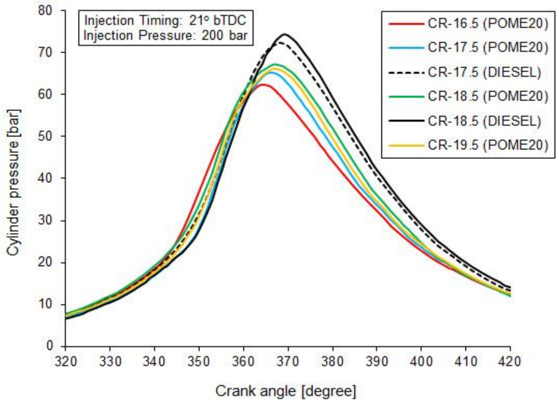

Fig. 8. Comparisons of cylinder pressure at full load

The comparison of the heat release rate curves for different compression ratios with diesel and POME20 is shown in figure 9. It can be seen from the figure 9 that the maximum heat release rate of POME20 blend was lower than that of diesel in the baseline engine. This was attributed to shorter ignition delay for POME20 compared with that of standard diesel. In addition the poor spray atomization characteristics of biodiesel due to higher viscosity and surface tension may be responsible for the lower heat release rate. Further it was noticed that heat release rate during diffusion combustion phase of POME20 was slightly higher than that of diesel. However the heat release rate curve for engine operation with higher compression ratios, particularly with CR of 18.5, POME20 demonstrated similar but better than baseline engine fuelled with diesel. This may be attributed to improved air fuel mixing, evaporation and better combustion.

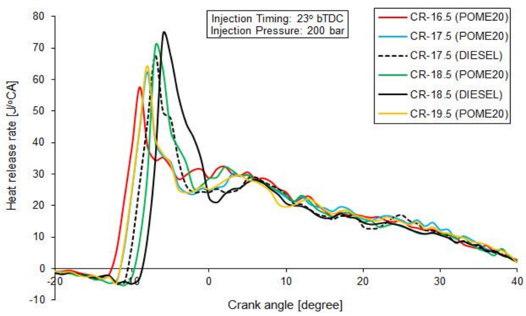

Fig. 9. Comparisons of heat release rate at full load

4. Conclusion

The effects of varying the compression ratio on the performance, emissions and combustion characteristics of a 5.2 kW DI compression ignition engine fuelled with a 20% blend of POME have been analyzed, and compared to the baseline diesel fuel. Increasing the compression ratio from 17.5 to 18.5 resulted in a significant improvement in the performance, combustion and emissions of POME20 due to increased pressure, temperature, better air motion inside the combustion chamber, better atomization and better mixture formation. The results of present work are summarized as follows:

Increasing the compression ratio of the biodiesel fuelled engine

1. Increases BTE.
2. Decreases BSFC.
3. Decreases CO, HC, and Smoke emissions.
4. Increases NOx.
5. Increases maximum peak pressure and maximum heat release rate compared to baseline engine operated with diesel.

The present investigation reveals that biodiesel from pongamia oil is quite suitable as an alternative to diesel and increasing the compression ratio improves the performance, combustion and emission characteristics of the biodiesel fuelled engine, due to better air-fuel mixing and improved combustion.

5. References

1. National Policy on Biofuels, Ministry of New and Renewable Energy, Government of India, http://mnre.gov.in/file-manager/UserFiles/biofuel_policy.pdf
2. Laforgia, D., Ardito, V., Biodiesel fueled IDI engines performances, emissions and heat release investigation, Bioresource Technology, 51, 1, 53–59, 1995.
3. Canakci, M., Erdil, A., Arcaklioglu, E., Performance and exhaust emissions

of a biodiesel engine, Applied Energy, 83, 6, pp.594–605, 2006.

4. Nabi, N., Akhter, S., Shahadat, Z., Improvement of engine emissions with conventional diesel fuel and diesel–biodiesel blends, Bioresource Technology, 97, 3, 372–378, 2006.
5. Agarwal, A. K., Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines, Progress in Energy and Combustion Science, 33, 3, 233–271, 2007.
6. Schumacher, L. G., Borgelt, S. C., Fosseen, D., Goetz, W., Hires, W. G., Heavy-duty engine exhaust emission tests using methyl ester soybean oil/diesel fuel blends, Bioresource Technology, 57, 1, pp.31–36, 1996.
7. Sharp, C. A., Howell, S. A., Jobe, J., The effect of biodiesel fuels on transient emissions from modern diesel engines. Part I: regulated emissions and performance, SAE paper 2000-01-1967, 2000.
8. Akasaka, Y., Suzuki, T., Sakurai, Y., Exhaust emissions of a DI diesel engine fueled with blends biodiesel and low sulfur diesel fuel, SAE paper 972998, 1997.
9. Challen, B., Barnescu, R., Diesel engine reference book, Society of Automotive Engineers, Bath Press, England, 1999.
10. Kouremenos,D. A., Hountalas, D. T., Kouremenos, A. D., Experimental investigation of the effect of fuel composition on the formation of pollutants in direct injection diesel engines, SAE paper 1999-01-0189,1999.
11. Jindal, S., Effect of injection timing on combustion and performance of a direct injection diesel engine running on jatropha methyl ester, International Journal of Energy and Environment, 2, 1, 113-122, 2011.
12. Anand, R., Kannan, G. R., Rajasekhar Reddy, K., Velmathi, S., The performance and emissions of a variable compression ratio diesel engine fuelled with bio-diesel from cotton seed oil, ARPN Journal of Engineering and Applied Sciences, 4, 9, 72-87, 2009.
13. Nitesh Mohite., Sujit Kumbhar., Vinay Kale., Tausif Mulla., Study of performance characteristics of variable compression ratio diesel engine using ethanol blends with diesel, International Journal of Engineering Science and Technology, 4, 6, 2784-2795, 2012.
14. Deore, E.R., Jahagirdar, R.S., Patil, M.S., Desale. P.S, Performance of single cylinder DI diesel engine-varied compression ratio fueled with blends of ethanol, Proceedings of the World Congress on Engineering, London, U.K., Vol. III, 2011.
15. Venkatraman, M., Devaradjane, G., “Effect of compression ratio, injection timing and injection pressure on a DI diesel engine for better performance and emission fueled with diesel, diesel- biodiesel blends, International Journal of Applied Engineering, 1, 3, 288-298, 2010