ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

EFFECT OF COMPRESSION RATIO ON CI ENGINE FUELED WITH METHYL ESTER OF THEVETIA PERUVIANA SEED OIL

M. K. Duraisamy, T. Balusamy and T. Senthilkumar
Department of Mechanical Engineering, AC College of Engineering and Technology, Karaikudi, India
E-Mail: duraisamy_mk@rediffmail.com

ABSTRACT

The high energy demand in the industrial world as well as in the domestic sector and pollution problems caused due to the widespread use of fossil fuels make it increasingly necessary to develop the renewable energy sources with lesser environmental impact than the conventional one. This has inspired curiosity in alternative sources for petroleum-based fuels. One possible alternative to fossil fuel is the use of oils of plant origin like vegetable oils/tree borne oils. A wide variety of tree borne oils and their suitability as alternate fuel had been investigated. In this paper, an attempt has been made to investigate the effect of compression ratio on performance and emission characteristics of 20% methyl ester of Thevetia Peruviana Seed Oil (TPSO) blended with 80% diesel (B20) when used as fuel in a diesel engine. Experiments were conducted in a Variable Compression Ratio (VCR) diesel engine with different compression ratios and base line experiment was also conducted with neat diesel operation at higher compression ratio for comparison. The various performance and emission parameters like, brake thermal efficiency, specific fuel consumption, the exhaust gas temperatures CO, CO_2, HC, NO_x, and smoke intensity were measured and analyzed. It was found that performance of the engine increased appreciably with less bsfc by increasing the compression ratio for biofuel blend. Also, it was observed that increase in compression ratio significantly reduced the CO, HC, NO_x and smoke emissions but with a slight increase in CO_2.

Keywords: thevetia peruviana seed oil, compression ratio, performance, emission characteristics, diesel engine.

INTRODUCTION

Agricultural and transport sectors are almost diesel dependent. The various alternative fuel options tried in place of hydrocarbon oils are mainly biogas, producer gas, ethanol, methanol and vegetable oils. Out of all these, vegetable oil [1-6] offers an advantage because of their comparable fuel properties with that of diesel. Investigation to control the NO_x emissions [1] in biodiesel-fueled diesel engine have reported that Exhaust Gas Recirculation (EGR) with biodiesel blends resulted in reduction in NO_x emissions without any significant penalty in particulate matter and brake specific energy consumption. An experiment to find the effect of compression ratio [2] on the performance and emissions of an insulated piston head diesel engine using linseed oil reported that bsfc, exhaust gas temperature, CO and smoke intensity are decreased but brake thermal efficiency and NO_x are decreased at different blends and compression ratio. Vegetable oils are more viscous than diesel. Hence, although short term tests using neat vegetable oils showed promising results, long term tests showed problems [3-5] like injector clogging with trumpet formation, more carbon deposits and piston oil ring sticking, as well as thickening and gelling of engine lubricating oil. High viscosity of neat vegetable oils [6-9] can be overcome by blending in small blend ratios with normal diesel fuel, micro-emulsification with methanol or ethanol, cracking and their conversion into bio-diesel fuels. Comparing to diesel, seed-based oils have several advantages and disadvantages [10-11]. The various edible vegetable oils like sunflower, soybean, peanut, cotton seed etc have been tested successfully in the diesel engine [12]. Research in this direction with edible oils yielded encouraging results.

But as India still imports huge quantity of edible oils, edible oil based biodiesel become debatable and the use of methyl ester of thevetia peruviana seed oil non-edible oil assumes greater importance.

Authors [13-14] have already established that engine performance and combustion characteristics with methyl ester of thevetia peruviana seed oil are comparable to that of diesel and CO, HC emissions are less but NO_x and smoke are slightly higher than that of diesel. In this paper, an attempt has been made to study the effect of compression ratio in a variable compression ratio engine over a range of 14.5 to 20.6 fueled with 20% of methyl ester of TPSO blended with pure diesel.

MATERIALS AND METHODS

Yellow oleander (*Thevetia peruviana* (Pers.) Merrill), called *Manjarali* in Tamil Nadu, is a small evergreen tree (3-4 m high) cultivated as an ornamental plant in tropical and subtropical regions of the world, including India. Fruit contains 2-4 flat gray seeds, which yield about more than ½ litre of oil from one kg of dry kernel. This oil (Table-1) is taken up to test the fuel properties as per ASTM codes [15]. This plant can be cultivated in wastelands. It requires minimum water when it is in growing stage. It starts flowering after one and a half year. After that, it blooms thrice every year. In a hectare, 3000 saplings can be planted and out of which 52.5 tons of seeds (3500 kg of kernel) can be collected. Hence, about 1750 liters of oil can be obtained from a hectare of wasteland.

Transesterification

Sodium hydroxide (4g) is added to methanol (130 ml) and stirred until properly dissolved. The solution is added to TPSO (850 ml) and stirred at a constant rate at 60°C for 1 h. After the reaction is over, solution is allowed to settle for 4-5 h in a separating flask. Coarse biodiesel, separated from glycerin, is heated above 100°C and maintained for 10-15 min for removing untreated methanol. Certain impurities like NaOH were cleaned two or three times by washing with 50 ml of petroleum ether and 100 ml of water for 1000 ml of coarse biodiesel. This cleaned biodiesel was taken up for this investigation.

Table-1. Properties of fuels used.

Property	Diesel	TPSO	B100	B20	ASTM code
Calorific value (KJ/Kg)	43200	40148	40462	42652	D4809
Specific gravity	0.804	0.92	0.839	0.828	D445
Kinematic viscosity (at 40^0C) CST	3.9	4.8	4.2	4	D2217
Cetane number	49	42	47	48	D4737
Color	Light brown	Yellow	Light yellow	Light brown	D1500-2
Flash point ^{o}C	56	128	110	72	D92
Fire point ^{o}C	64	135	120	79	D92
Cloud point ^{o}C	-8	-4	-6	-7	D97
Pour point ^{o}C	-20	-7	-8	-12	D97
Ash content %	0.001	0.003	0.003	0.002	D976

Experimental setup and measurements

A Kirloskar make variable compression, single cylinder, four strokes, water cooled engine (2.27 KW) having a bore, 85 mm and stroke, 82 mm was used for this study and the experimental setup is as shown in Figure-1. The normal speed range was 1500 rpm to 2500 rpm but the experiments were conducted at a constant speed of 1500 rpm. The engine was coupled with an eddy current dynamometer. The standard instrumentation was used to measure the fuel consumption, exhaust gas temperature, coolant temperature and air consumption. The injection pressure was set at 210 bar and injection timing of 37.5° bTDC for diesel and all fuel blends as per instruction manual. The emission parameters are measured using AVL-444 Gas Analyzer and AVL-437 Smoke meter.

For the stabilization of measuring parameters, the engine was allowed to run 10 min at each load setting and then readings were taken. The overall period of test was spread over for more than 45 min. 20% (by vol.) of methyl ester of TPSO with diesel was tested in the engine for various compression ratio of 20.6:1, 19.2:1, 18.1:1, 17.0:1, 16:1, 15.3:1 and 14.5:1. In the process of testing with methyl ester of TPSO-diesel fuel blend, no change was made in the engine. The various performance and emission parameters [16] like., brake thermal efficiency, specific fuel consumption, the exhaust gas temperatures CO, CO_2, HC, NOx and smoke intensity were measured and analyzed.

Figure-1. Photographic view of the experimental setup.

RESULTS AND DISCUSSIONS

Brake thermal efficiency

The effect of compression ratio on brake thermal efficiency at different loads is shown in Figure-2. It is observed that brake thermal efficiency increased when increasing compression ratio for all fuels at all loads. For biodiesel blend, brake thermal efficiency was always less compared to that of diesel at all compression with a compression ratio of 20.6:1. This is due to increase in temperature of the compressed air, which results in better

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

atomization of TPSO, which may cause better combustion leading to increase in brake thermal efficiency of the engine.

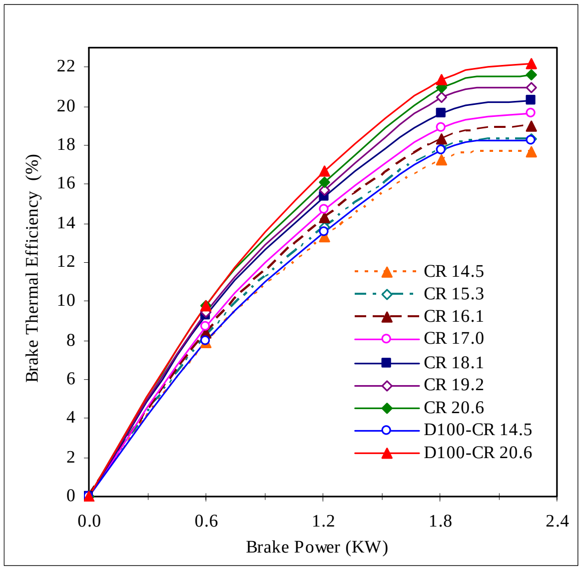


Figure-2. Variation of brake thermal efficiency with BP.

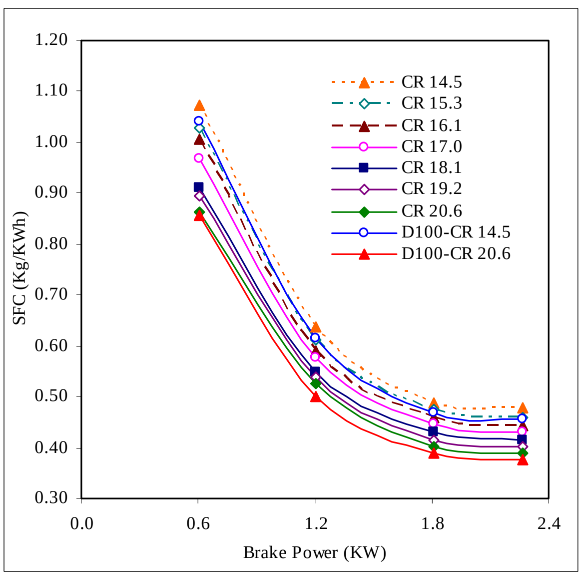


Figure-3. Variation of bsfc with BP.

Brake specific fuel consumption

The variation of bsfc with brake power for various compression ratios is shown in Figure-3. It is observed that bsfc decreased with increasing of brake power and compression ratio. For biodiesel blend, bsfc was 2.6 % higher compared to that diesel at 20.6:1 for maximum load. At the maximum load operation, the bsfc was 18.75% less with increasing the compression ratio from 14.5:1 to 20.6:1 for the biofuel blend.

Volumetric efficiency

The effect of compression ratio on volumetric efficiency for different loading conditions is shown in Figure-4. The volumetric efficiency decreased with increasing compression ratio and load. For biodiesel blends, volumetric efficiency was less by 1.1% compared to that of diesel at a compression ratio of 20.6:1 at maximum load. At the maximum load, the volumetric efficiency was 3.4% decreased with increasing the compression ratio from 14.5:1 to 20.6:1 for the biofuel blend. This is due to higher pressure and temperature of the residual gas in the clearance volume and also high combustion chamber temperature.

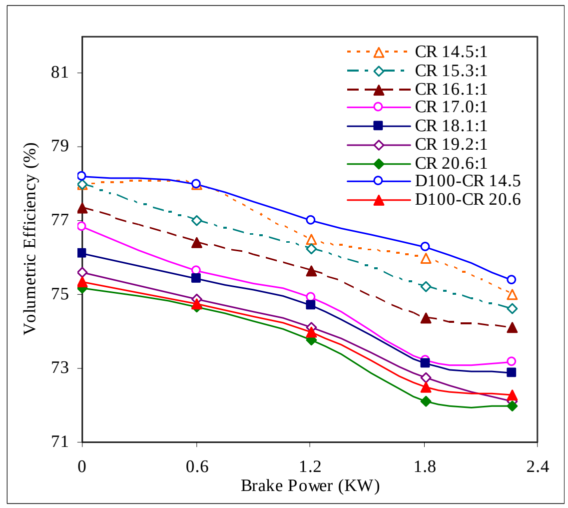


Figure-4. Variation of volumetric efficiency with BP.

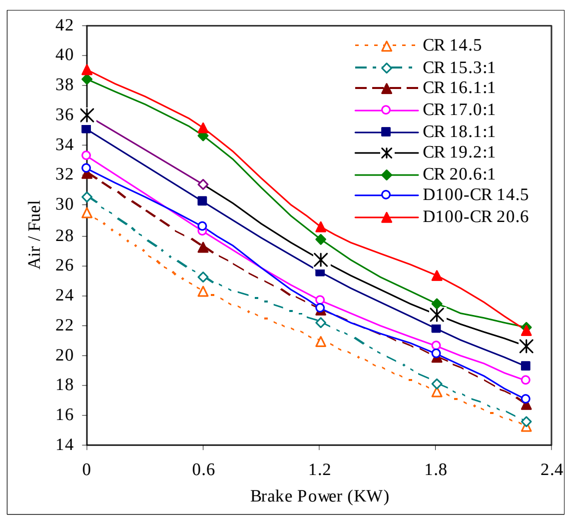


Figure-5. Variation of air-fuel ratio with BP.

Air-fuel ratio (A/F)

The effect of compression ratio on air-fuel ratio for different loading conditions is shown in Figure-5. The air-fuel ratio increased with increasing compression ratio.

VOL. 7, NO. 2, FEBRUARY 2012 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

For biodiesel blend, A/F was almost same as compared to that of diesel at 20.6:1 for maximum load for biofuel blend. At the maximum load, the air-fuel ratio 43.66% was increased with increasing the compression ratio for the biofuel blend. This due to counteract to develop the same power output when increasing the compression ratio.

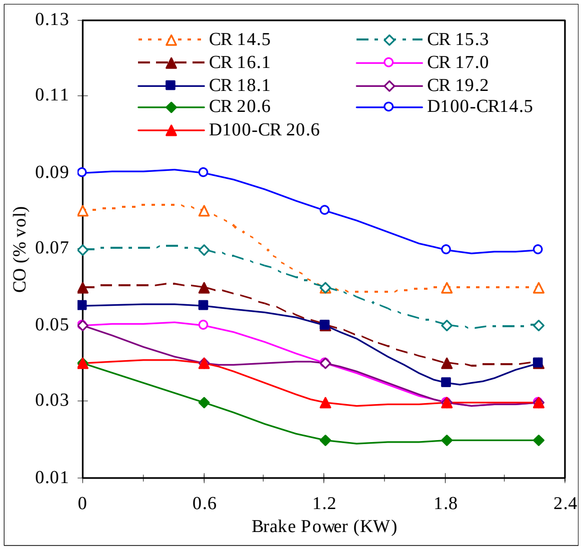


Figure-6. Variation of CO with brake power.

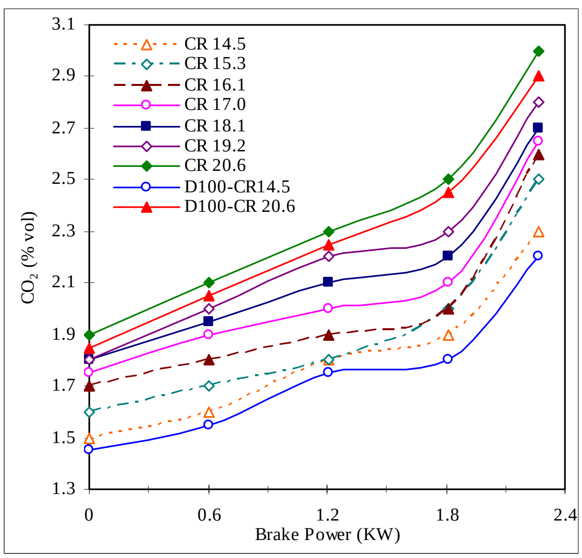


Figure-7. Variation of CO_2 with brake power.

Carbon monoxide (CO)

The effect of compression ratio on carbon monoxide emission for various brake power is shown in Figure-6. It is observed that the CO emission decreased with increasing both compression ratio and brake power. CO emission of biofuel blend was 33.3% less compared to that of diesel at 20.6:1 for maximum load. CO emission 66.6% was decreased by increasing the compression ratio at the full load for biofuel blend. CO emission is formed due to the incomplete combustion of organic material where the oxidation process does not have enough time to occur completely. The fuel droplets in combustion volume are too less, adequate turbulence or swirl is created in the combustion chamber at the higher compression ratio which leads to complete combustion and hence the CO emission is less. Also, it is reconfirmed for the reduction of CO emission that at the higher compression ratio, the A/F is high which leads to complete combustion.

Carbon dioxide (CO_2)

The effect of compression ratio on carbon dioxide emission for various loads is shown in Figure-7. It is observed that the CO_2 emission increased with increasing the compression ratio for all the loads. It is also observed that CO_2 emission increased with increase in brake power. CO_2 emission of biofuel blend was 3.4 % higher compared to that of diesel at 20.6:1 for maximum load. By increasing the compression ratio, the CO_2 emissions are 30.4% higher at the maximum load for biofuel blend. This is due to improved combustion of fuel while increasing the compression ratio. CO_2 is not toxic; however, it is linked to the 'greenhouse effect' and global warming. This can be balanced by the plants through "photosynthesis".

Unburnt hydro carbon (HC)

The effect of compression ratio for unburnt hydrocarbon emission for various brake power is shown in Figure-8. It is observed that the HC emission decreased with increasing the compression ratio for all the loads. HC emission of biofuel blend was 27.2% less compared to that of diesel at 20.6:1 for maximum load. For the biofuel blend, at the maximum load operation, the unburned hydrocarbon emission was 55.5% decreased while increasing the compression ratio. It is due to the presence of oxygen molecules in the biofuel blend has led to the improved combustion of the fuel.

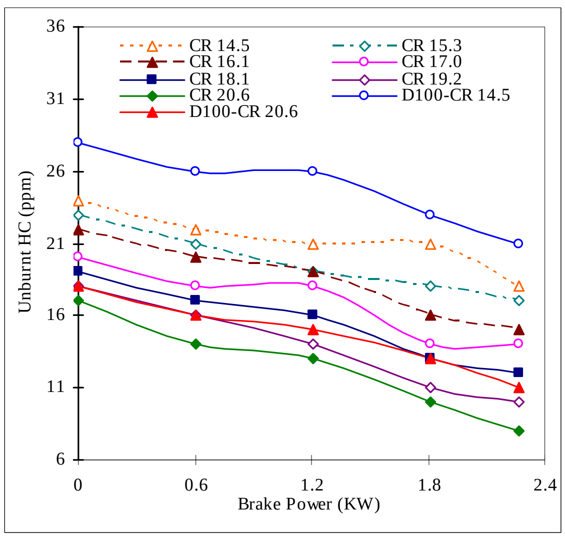


Figure-8. Variation of unburnt HC with BP.

VOL. 7, NO. 2, FEBRUARY 2012 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

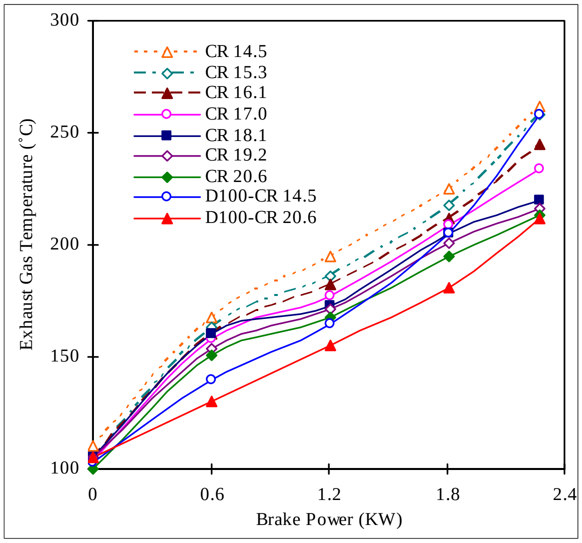


Figure-9. Variation of EGT with BP

Exhaust gas temperature

Figure-9 shows the effect of compression ratio on exhaust gas temperature (EGT) with brake power. It is observed that the exhaust gas temperature decreases while increasing compression ratio. EGT of biofuel blend is almost same compared to that of diesel at 20.6:1 for maximum load. In the no load operation, no appreciable change was observed in the EGT. But at the part load and maximum load, the value of EGT was less by 13.3% and 19.08% with increase in compression ratio from 14.5:1 to 20.6:1. At higher compression ratios, the combustion process shifts slightly to the earlier stroke of the cycle and hence more of the fuel energy is utilized effectively for developing brake power resulting lower exhaust gas temperature.

Nitrous Oxide (NO_x)

The effect of compression ratio on NO_x emission for various brake power is shown in Figure-10. It is observed that the NO_x emission increased with increasing the compression ratio for all the brake power. NO_x emission of biofuel blend was 10.3% less compared to that of diesel operation at 20.6:1 for maximum load. At the maximum load, the NOx emission 68.7% increased with increasing in compression ratio for the biofuel blend. The amount of NOx produced is a function of the maximum temperature in the cylinder, oxygen concentrations, and residence time. Also, it is observed that the oxygen content of exhaust gas at the higher compression ratio is less, NO_x formation is lowered.

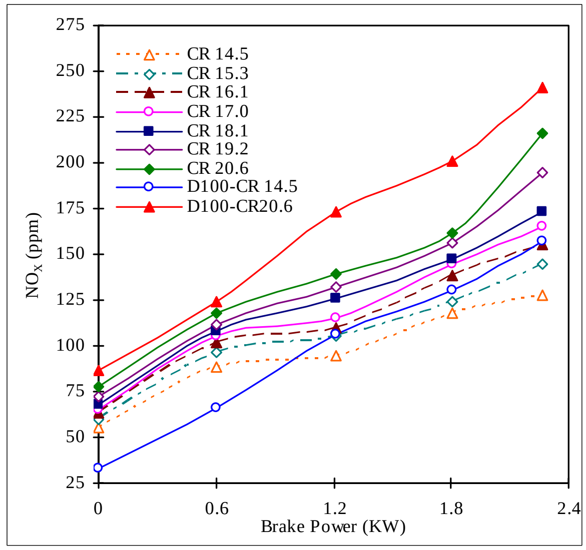
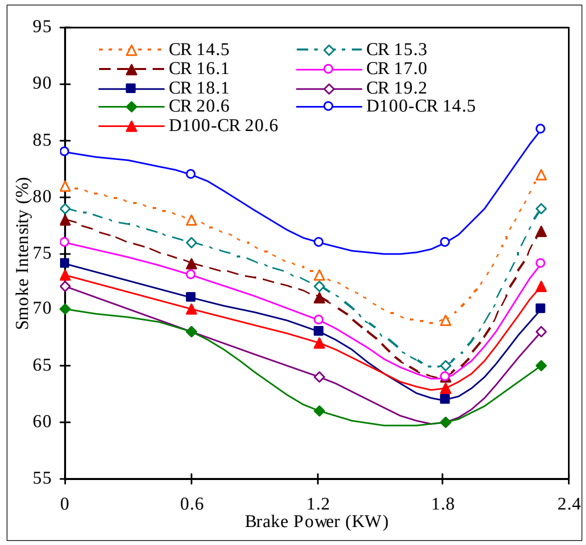


Figure-10. Variation of nitrous oxides with BP.



Figuire-11. Variation of Smoke intensity with BP.

Smoke intensity

The effect of compression ratio on smoke intensity for various brake power is shown in Figure-11. It is observed that the smoke intensity decreased with increasing the compression ratio up to a brake power of 1.8 KW and increase thereafter. Smoke emission of biofuel blend was 9.72% less compared to that of diesel at 20.6:1 for maximum load. At the maximum load, smoke emission of biodiesel blend is 20.7% lower for the biofuel blend by increasing the compression ratio from 14.5:1 to 20.6:1. This is due to better oxidation environment and existence of higher temperature and pressure at higher compression ratio. Also it is reconfirmed from the trend of CO and HC emission cures.

CONCLUSIONS

Based on this experimental work on a direct injection diesel engine fueled with 20% methyl ester of TPSO and pure diesel, the following conclusions were drawn:

- For the biofuel blend, brake thermal efficiency, volumetric efficiency, CO, HC, NO_x and smoke were 2.5%, 1.1%, 33.3%, 27.2%, 10.3% and 9.72% less compared to that of diesel, respectively at the higher compression ratio (20.6:1). On the other hand, bsfc and CO_2 were 2.6% and 3.4% higher.
- While increasing compression ratio from 14.5:1 to 20.6:2, brake thermal efficiency, A/F, CO_2 and NO_x were increased to 4%, 43.66%, 30.4% and 68.7% at the maximum load operation, respectively. At the same time, bsfc, volumetric efficiency, CO, HC and smoke were decreased to 18.75%, 3.4%, 66.6%, 55.5% and 20.7%, respectively.

On the whole, an engine fueled with 20% methyl ester of thevetia peruviana seed oil blended with 80% pure diesel reveled that a significant improvement in performance and reduction in emission with that of pure diesel operation when increasing the compression ratio.

REFERENCES

[1] Deepak Agarwal, Shailendra Sinha and Avinash Kumar Agarwal. 2006. Experimental investigation of control of NO_x emissions in biodiesel-fueled compression ignition engine. Renew Ener. 31: 2356-2369.

[2] Beg R. A., Bose P. K. and Gose B. B. 2000. Effect of compression ratio on the performance and exhaust emission of an insulated piston head diesel engine using vegetable oil. National Conference on IC Engine and Combustion. pp. 82-88.

[3] Ramadhas A S, Jayaraj S and Muralidharan C. 2004. Use of vegetable oils as IC engine fuels- a review, Renew Ener. 29: 727-742.

[4] Leenus Jesu, Martin M, Prithiviraj D and Veleppan K C. 2005. Performance and emission characteristics of a CI engine fueled with esterified cottonseed oil. SAE. pp. 26-355.

[5] Suryawanshi J. G. and Deshpande N. V. 2004. Experimental investigation on pongamia oil methyl ester fuelled diesel engine. SAE. 28-0018.

[6] Barnwal B K and Sharma M P. 2005. Prospects of biodiesel production from vegetable oils in India. Renew Sustain Ener Rev. 9: 363-378.

[7] Ramesh A and Narayana Reddy J. 2006. Parametric studies for improving the performance of jatropha oil-fuelled compression ignition engine. Renew Ener. 31: 1994-2016.

[8] Kumar N. and Dhuwe A. 2004. Fuelling agriculture engine with derivative of palm oil. SAE. 28-0039.

[9] Naik S N, Meher L. C. and Vidya Sagar D. 2006. Technical aspects of biodiesel production by transesterification- a review. Renew Sustain Ener Rev. 10: 248-268.

[10] Rakopoulos C. D. and Antonopoulos K. A. 2006. Comparative performance and emission study of a direct injection diesel engine using blends of biodiesel fuel with vegetable oils or bio-diesels of various origins. Ener Conver Manage. 47: 3272-3287.

[11] Seatore A., Cardone M., Rocco V. and Prati M. V. 2001. A comparative analysis of combustion process in DI diesel engine fueled with biodiesel and diesel fuel. SAE. 01-0691.

[12] Muralidharan M., Mathew P., Thariyan Sumit Roy, Subramanyam J. P. and Subbrao P. M. V. 2004. Use of pongamia biodiesel in CI engine for rural application. SAE. 28-0030.

[13] Balusamy T. and Marappan R. 2007. Performance evaluation of direct injection diesel engine with blends of thevetia peruviana seed oil and diesel. Journal of Scientific and Industrial Research. 66: 1035-1040.

[14] Balusamy T. and Marappan R. 2008. Focus on combustion characteristics of thevetia peruviana seed oil fueled in a direct injection diesel engine. Int. Jour. of Ener. Sour. - Part (A) - Article in Press.

[15] 1994. Annual Book of ASTM Standards. American Society for Testing and Materials, Philadelphia.

[16] John B. Heywood. 1988. Internal Combustion Engine Fundamentals, Automotive Technology Series. McGraw-Hill International Editions, Singapore.