Experimental and Theoretical Performance Analysis of Emission and Combustion Characteristics of Diesel Engine using Bio Diesel as an Alternate Fuel

Saurabh Dayal, Devendra Singh, Ajay Kumar Sharma

Abstract**:** ***In this study the biodiesel derived from different vegetable oil esters (VOE) including Jatropha and Karanja is compared with diesel. The efficiency, emission and combustion properties of different VOE in single cylinder compression ignition engine were compared with Diesel. The main objective of our study is the theoretical and experimental comparison of the efficiency, emission and combustion properties of biodiesel using Jatropha and Karanja esters with diesel. Vegetable oil from Jatropha and Mahua was transesterified and used in a turbocharged engine water-cooled single-cylinder Diesel Engine attached to an ac induction motor with a current of 0 to 5kw. Brake thermal efficiency is decreased by around 1.4 percent for Jatropha, 2.0 percent for Karanja compared to Diesel. Brake specific fuel consumption improved by 0.2 percent for Jatropha and 3.4 percent for Karanja compared to Diesel.***

Keywords: Emission and Performance, Injection pressure, I.C. Engine.

I. INTRODUCTION

Transportation is essential for daily activities and economic growth. Transportation of various modes, power generation, agriculture, mine locomotives, all are depended on fossil fuels. The crude oil consumption over the past six decades had increased sixteen times. The need and usage of petroleum derived fuel is increasing day by day but there is scarcity. The huge amount spend by our country for crude oil import had lowered our country's economy. The present fuel demand can be met out by biodiesel in the place of fossil fuels. The biodiesel can be derived from both conventional and non conventional sources with certain modifications to meet the performance of diesel. Hideki Fukuda et al. [1] studied regarding transesterification using methonal and concluded that it is the best method to produce biodiesel. Ayhan Demirbas [2] have analysed the property of biodiesel manufacture using catalytic and non catalytic super critical transesterification methods.

Revised Manuscript Received on November 26, 2020.

***** Correspondence Author

Saurabh Dayal*, Department - Mechanical Engineering, Sachdeva Institute of Technology, Mathura-281122, Uttar Pradesh, India.
Email: sarswati.17@gmail.com

Devendra Singh, Department - Mechanical Engineering, Sachdeva Institute of Technology, Mathura-281122, Uttar Pradesh, India.
Email: devendrasinghsit@gmail.com

Ajay Kumar Sharma, Department - Mechanical Engineering, Institute of Engineering & Technology, Lucknow-226021, Uttar Pradesh, India.
Email: ajaysharma@ietlucknow.ac.in

Xiaoling Miao et al. [3] studied regarding biodiesel production using trifluro acetic acid and found that it is the one of the quickest. Patil Prafulla [4] had produced biodiesel from jatropha, pongamia, kacanola, and corn by tranesterification using potassium hydroxide as a catalyst and the yield was higher for jatropha. Dennis Y.C. Leung et al. [5] had done a study on biodiesel production using transesterification. Transesterification is a catalytic reaction that involves acid or base catalyst with methonal producing glycerene and a mixture of fatty acid esters. Ashwani Kumar et al.[6] have studied sustainable feedstock for the production of biodiesel among non-edible oil seeds. They concluded that three non-edible oil crops do not contend with food crops in small producing countries. It is therefore important to look for sustainable non-edible feed stock and its suitability as biodiesel. Geyer et al. [7], found that by transesterification density and calorific values were improved. Specific gravity was equal to diesel. The cross heating value of transesterified VOME (Vegetable oil Methyl Esters) was lower than that of diesel. Marugu Mohan Kumar et al. [8], have shown that increased oxygen content in biodiesel promotes complete combustion thereby less emission. The engine performance with biodiesel was also similar to diesel. Agarwal et al[9], researched jatropha as biodiesel and noticed that engine output comparable to diesel emissions of hydrocarbons and carbon monoxide was reduced by around 20% compared to diesel. Panneer selvam et al. [10] reviewed the impact of injection timing and biodiesel in diesel engines. Advancing the timing of injection improves the thermal performance of the brake and Nox, reduces hydrocarbon, carbon monoxide and smoke. Vice versa occurs with the timing of the delayed injection. Research on biodiesel started as earlies 1960s, realsing the non renewability of fossil fuels. Studies on edible oils, non edible oils and biomass have been done. Properties of biodiesel, significance, advantages and comparsion between them have been analysed to a greater extent. Most of the researchers have concentrated on blends of biodiesel with diesel. Hence in this study vegetable oil methyl esters are two non edible oil seeds- Jatropha and karanja had been used as a biodiesel and their efficiency compared with diesel both experimentally and theoretically.

II. EXPERIMENTAL SETUP AND PROCEDURE

Experimentation to research the effect of VOME on the working of a diesel engine were carried out on a computerized kirloskar making four strokes of a single cylinder-natural suction and water cooling.

Two different fuel tanks were used, one for diesel and one for biodiesel. The engine and dynamometer were the gateway to the system preferences connected to the machine. It is being used to track test factors include temperature, load, fuel flow rate and air flow rate for the measurement of engine output characters. This is demonstrated in Figure 1.

Fig. 1: Laboratory Experimental Setup

The engine and dynamometer are linked to the command prompt tied to the processor. This computerised test apparatus has been used to track input variables like fuel flow rate, air flow rate, temperature and load to measure engine output i.e. cylinder pressure, brake strength, basic fuel consumption of the brakes, thermal efficiency of the brakes and emissions such as HC, CO, NOx and smoke.

The experimental work been conducted on a single cylinder water cooled engine. In the cylinder, the gas pressure background was calculated using a cylinder pressure transducer flush mounted within the cylinder head. The electrical charge from the transducer has been translated into a voltage by a pulse generator. The engine was also configured with a shaft microcontroller, which produced pulses of one degree of crank angle precision. This transmitter produced clock and activate indications for high-speed measurements. Compilation of these data was carried out using a window-based data acquisition system. This data capture method is aimed of collecting and averaging up to 1,000 data cycles. The exhaust gas being permitted to flow via the crypton computed exhaust gas scanner technique for the measurement of HC, CO, NOx and then progressed via the Bosch type smoke metre probing for the measurement of co emissions. The thermocouple was connected to the exhaust manifold to determine the exhaust gas temperature.

III. SELECTION OF BIODIESEL AND METHODS

Jatropha and karanja have been commonly studied because of their availability and non edible nature. Jatropha, karanja trees are available in all parts of India and can be grown with mineral water. Hence seeds from these two trees have been chosen for biodiesel preparation. Their properties have been studied. The performance characteristics, emission and combustion attributes of the biodiesel have been assessed. These are described in the following sections.

A. Seperation of oil

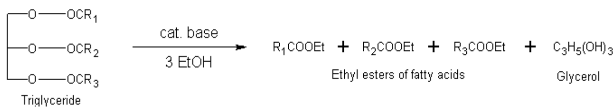
The following methods are involved in extraction of VOMEoil.

1. VOME Plants
2. Seeds collection
3. Extracting the coat from the seeds
4. Eliminating the moisture content of the seeds
5. Extraction of oil by crushing the seeds
6. By filtration, eliminating the solid impurities

Fig. 2: Shows the methods involved in extraction of VOME oil.

B. Transesterification

The transesterification response framework seems to be as shown in:



R1, R2, and R3 in this illustration portray long chain that get too long to be included in the illustration.

Fig. 3: Expeller machine for the extraction

IV. RESULTS AND DISCUSSION

A. Comparison of experimental functionality of methylester vegetable oil with diesel

Brake thermal efficiency tells as about conversion of heat into work whose efficiency depends on engine design and fuel used. This is the fraction of the Brake power obtained to the fuel energy provided. BTE generally increases with increasing load on all fuels. The variation is shown in the figure 4(a) and 4(b). Maximum efficiency is obtained at Brake power of 4kW. The Efficiency obtained for Diesel, Jatropha, and Karanja Esters were 32.9%, 32.1% and 32.1% respectively. The reduction in brake thermal efficiency for VOE when compared to diesel was 1% to 4%. The good calorific value of these ester oil is responsible for their efficiency to be closer that of diesel. The relatively high viscosity and density of VOE contribute to lower efficiency. Figure 4(b) describes the specific fuel consumption of the fuel with respect to the brake power. SFC generally increases with increasing load. The minimum consumption was observed at a brake power of 4kW.

B. Comparison of experimental emission characteristics of vegetable oil methyl esters with diesel

The figure 5(a) reveals the emission of carbon monoxide for all the fuels at various loads. The emission increase with brake power. The emission of CO at brake power 4kW for Diesel, Jatropha and Karanja Methyl esters were 0.49, 0.38 and 0.41. The decrease in emission of CO for the above said two VOME when compared to diesel were 22.44% and 16.32% respectively. Figure 5(b) demonstrates the emission of Hydrocarbons across all fuels as compared to brake power. The emission increases with the power of the brake. The HC emissions for diesel, Jatropha and Karanja methyl esters were 87PPM, 71PPM and 73PPM respectively. Decreased hydrocarbon emissions for jatropha, Karanja were 18.39 per cent and 16.09 per cent respectively compared to diesel.The figure 5(c) demonstrates the emission of nitric oxide for all the three fuels as compared to brake power. The emission increases with brake power. The emission of Nox for diesel, Jatropha and Karanja methyl esters were 825PPM, 819PPM and 810PPM respectively. The decrease in NOx emission for jatropha, Karanja where 0.72% and 1.8% than diesel respectively. The figure 5(d) shows the release of smoke from engine using three fuels with respect to BP. The smoke emission increase with increase in load. The formation of smoke depends on efficiency of combustion of fuel. Incomplete combustion of diesel releases more smoke when compared with VOME. The emission of smoke for diesel, Jatropha and Karanja methyl esters were 6.9 BSU, 6.1 BSU and 6.2 BSU respectively. The decrease in Smoke emission for jatropha, Karanja where 16.39%, 16.12% than diesel respectively.

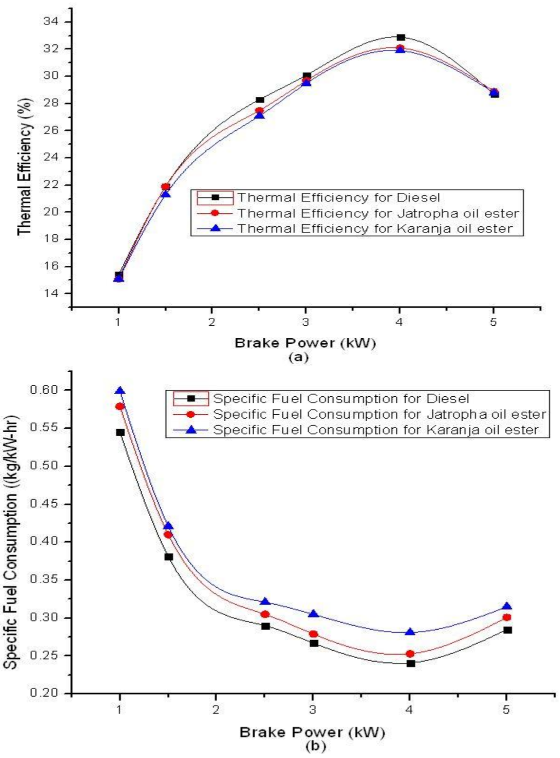


Fig. 4: Comparsion to brake power for two VOE and diesel by experimental with respect (a) brake thermal efficiency (b) specific fuel consumption

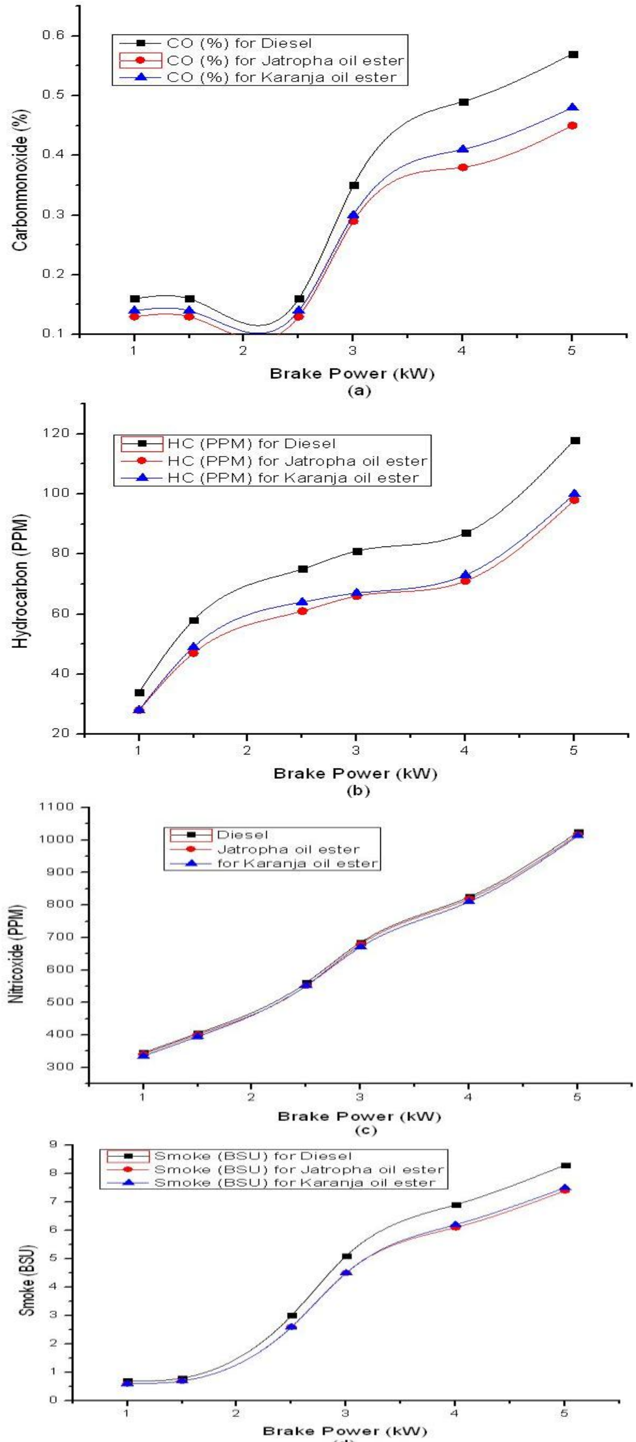


Fig. 5: Experimental emission of using three fuels at various brake power in diesel engine (a) carbonmonoxide (b) hydrocarbon (c) nitric oxide (d) smoke

C. Comparison of experimental combustion characteristics of vegetable oil methyl esters with diesel

Figure 6(a) indicates the crank angle pressure for 3 distinct fuels. The maximum pressure obtained for diesel, Jatropha and Karanja methyl esters was 72.83 bar, 70.66 bar and 69.48 bar respectively. Figure 6(b) indicates the rate of pressure increase for the three fuels with regard to the angle of the crank. The maximum rate of pressure rise of 4.72 bar/θ, 4.6 bar/θ and 4.4 bar/θ respectively.

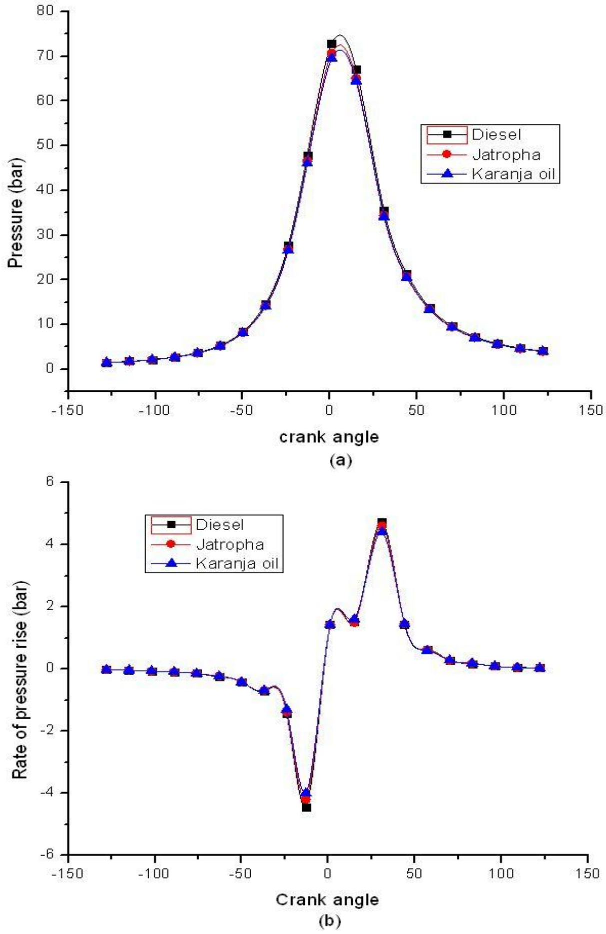


Fig. 6: Change with respect to crank angle in diesel engine using VOME and diesel in rate of (a) pressure (b) rate of pressure rise

D. Comparison of theoretical prediction performance characteristics of vegetable oil methyl esters with diesel

The Comparison between these three have been shown in the figure 7(a) below shows the brake thermal efficiency was highest at 4 kW for all the three. Maximum was obtained for Diesel (33.9%) followed by Jatropha (32.6%), Karanja (32.4%) respectively. It is the ratio of rate of fuel consumption to brake power. The specific fuel consumption for all the two vegetable oil methyl esters and diesel at various loads was predicted, which is shown in the figure 7(b) below The specific fuel consumption was lowest at 4kW, Diesel (0.251kg/kW-hr), Jatropha (0.263 kg/kW-hr), Karanja (0.284kg/kW-hr).

E. Comparison of theoretical prediction emission characteristics of vegetable oil methyl esters with diesel

Figure 8(a) shows the predicted increase in carbon monoxide emission with increase in break power. The emission of CO for diesel, Jatropha and Karanja Methyl esters were 0.48%, 0.39% and 0.47% respectively. The decrease in emission for jatropha, karanja where 18.75%, 2.08% than diesel respectively. Figure 8(b) shows the predicted emission of HC from diesel, Jatropha and karanja methyl esters were 88PPM, 72PPM and 74PPM. The decrease in hydrocarbon emission for jatropha, Karanja where 18.18%, 15.90% than diesel respectively. The figure 8(c) shows the emission of nitric oxide for all the three fuels with respect to brake power based on theoretical considerations. The emission increases with brake power. The emission of Nox for diesel, Jatropha and Karanja methyl esters were 826PPM, 820PPM and 813PPMrespectively. The decrease in NOx emission for jatropha, Karanja where 0.72%, 1.57%, than diesel respectively. The figure 8(d) shows the release of smoke from engine using three fuels with respect to BP based on theoretical considerations. The emission of smoke for diesel, Jatropha and Karanja methyl esters were 6.8 BSU, 6.2 BSU and 6.2 BSU respectively. The decrease in Smoke emission for jatropha, Karanja,Mahua, Neem where 8.8%, 8.8% than diesel respectively.

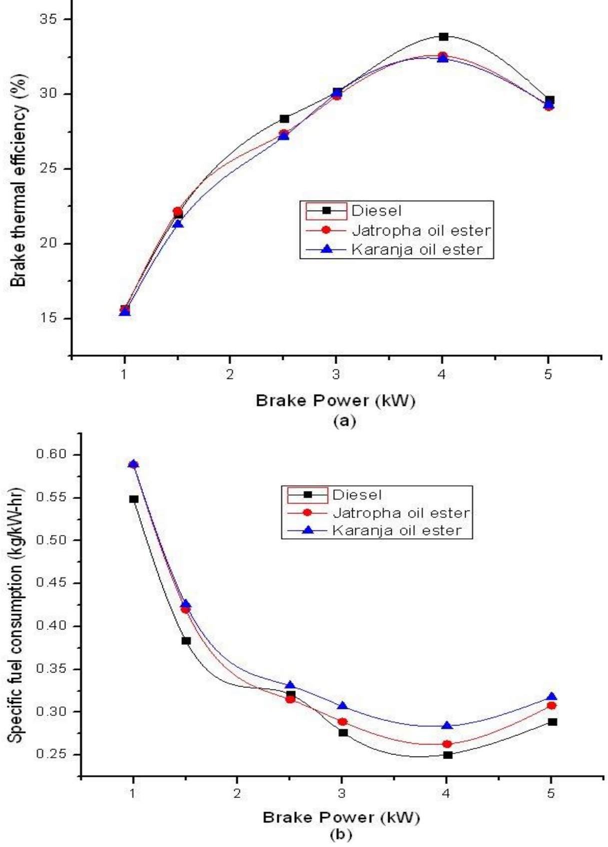


Fig. 7: Comparsion to brake power for two VOE and diesel by theoretical with respect (a) brake thermal efficiency (b) specific fuel consumption

F. Comparison of theoretical prediction combustion characteristics of vegetable oil methyl esters with diesel

Figure 9(a) indicates the crank angle pressure for three different fuels. The maximum pressure obtained for diesel, Jatropha and Karanja methyl esters was 72.70 bar, 70.54 bar and 69.36 bar respectively. Figure 9(b) measures the trend of pressure increase for the three fuels with regard to the angle of the crank. The maximum rate of pressure rise of 4.73 bar/θ, 4.61 bar/θ, 4.41 bar/θ, respectively. The decrease in rate of pressure rise for jatropha and karanja methyl esters were 2.53% to 6.76%.

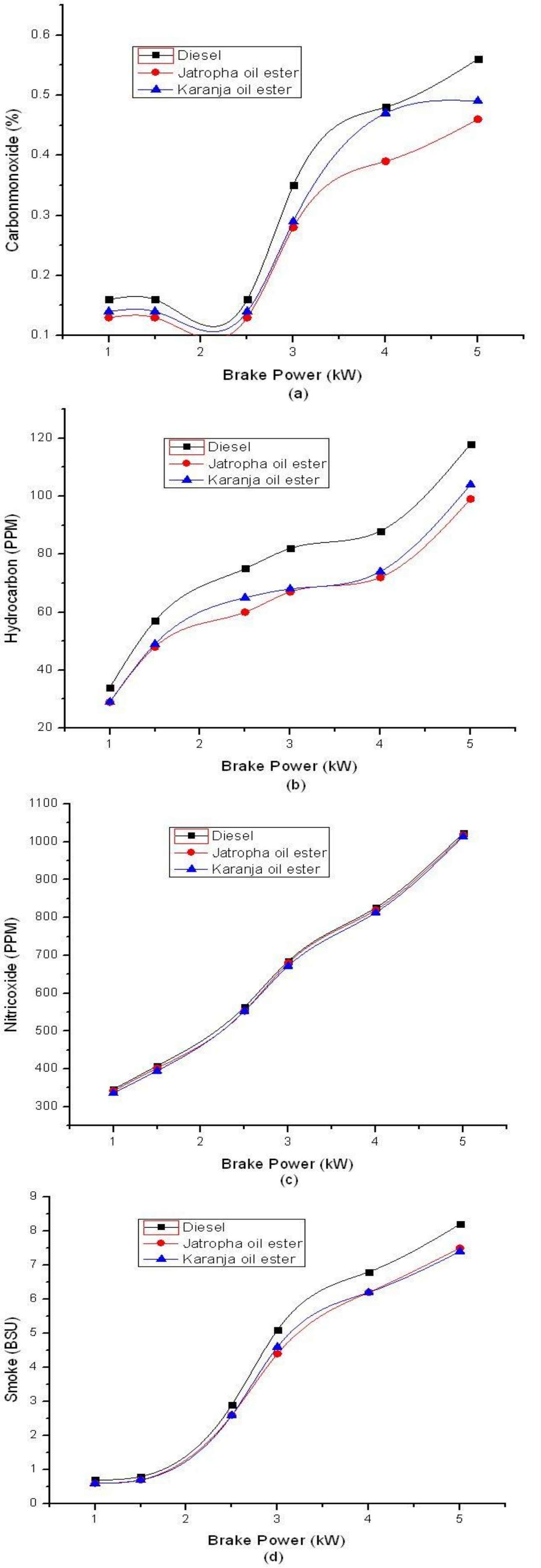


Fig. 8: Theoretical emission of using three fuels at various brake power in diesel engine (a) carbonmonoxide (b) hydrocarbon (c) nitric oxide (d) smoke

G. Comparison of experimental and theoretical prediction performance characteristics of vegetable oil methyl esters with diesel

Figure 10(a) shows the Comparison of Experimental and Projected Brake Thermal Efficiency of Distinct VOE and Diesel in relation to Brake Capacity. Brake thermal efficiency improves with load as efficient combustion takes place at higher loads. The predicted and experimental value of the thermal brake efficiency was in good agreement. Brake Thermal Efficiency is reduced by around 1.4 per cent for Jatropha and 2.0 per cent for Karanja compared to Diesel. Figure 10(b) shows that the theoretical and experimental values of the Brake Specific Fuel usage were identical. Brake specific fuel consumption increased by 0.2 per cent for Jatropha, 3.4 per cent for Karanja compared to Diesel.

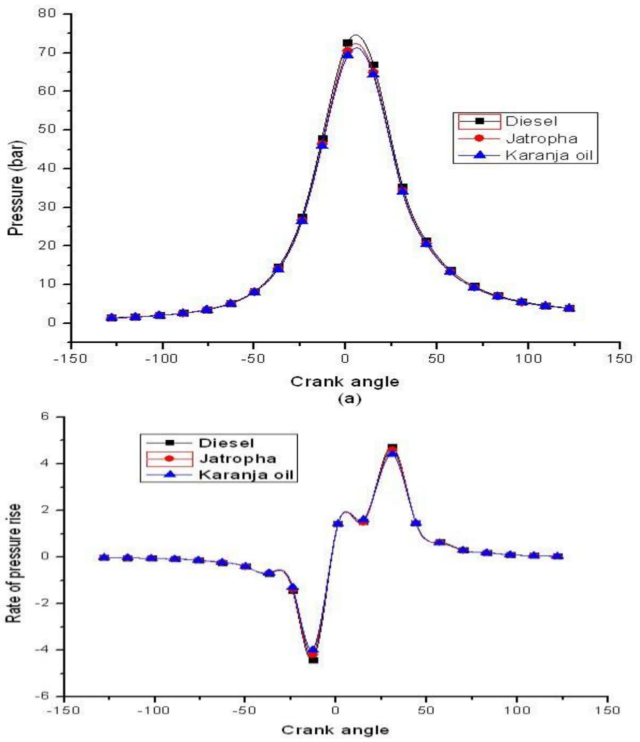
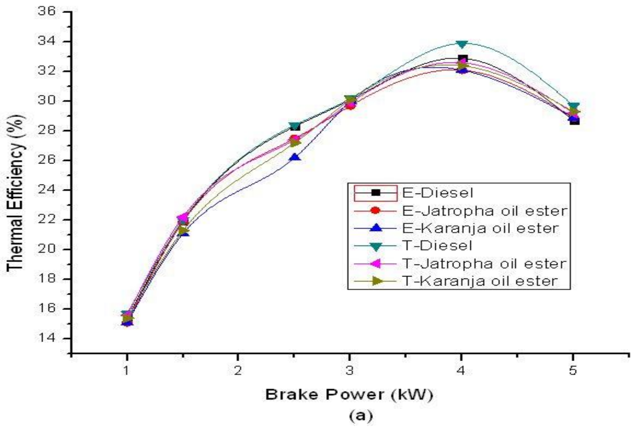


Fig. 9: Theoretical change with regard to crank angle in diesel engine using VOME and diesel in rate of (a) pressure (b) rate of pressure rise



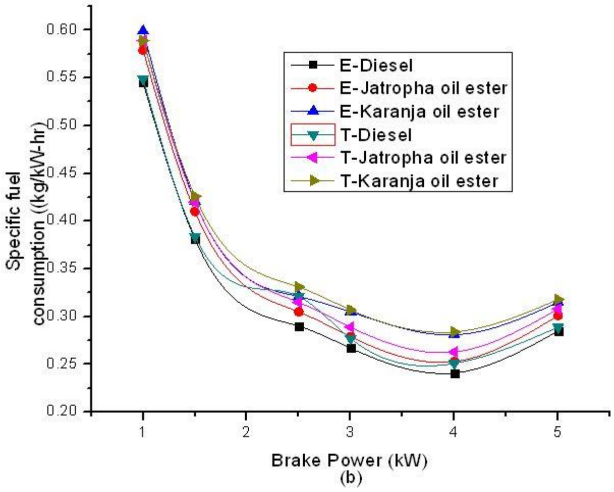
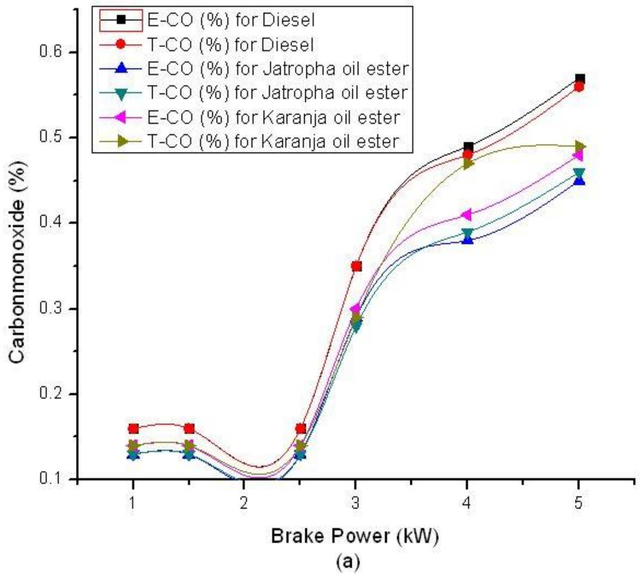
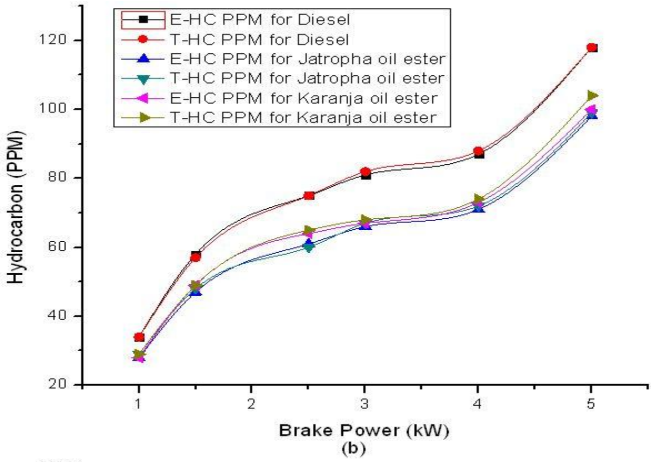


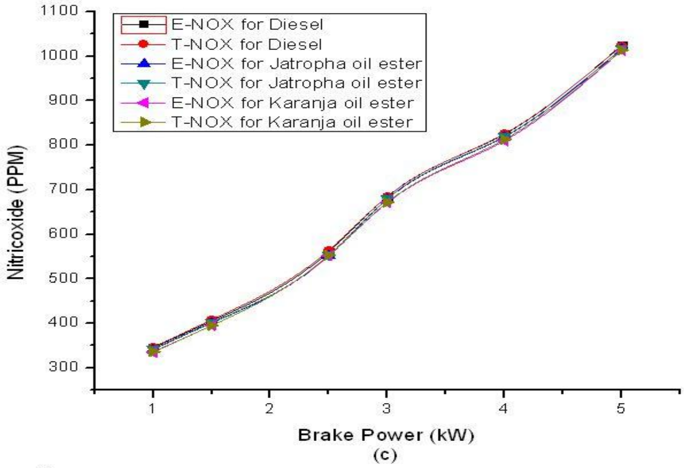
Fig. 10: Comparison of experimental and theoretical (a) brake thermal efficiency (b) specific fuel consumption, at various brake power using VOME and diesel.

H. Comparison of experimental and theoretical prediction emission characteristics of vegetable oil methyl esters with diesel

Figure 11(a) the emission of carbon monoxide decreased by 3.69 per cent, 14.23 per cent for Jatropha, Karanja, respectively, compared to diesel. The reduction in CO emissions is due to the full burning of fuel. Figure 11(b) Hydrocarbon emissions decreased by 0.20 per cent, 0.18 per cent for Jatropha and Karanja comparable with diesel emissions. The oxygen content of biodiesel molecules increases the full combustion, resulting in a decrease in the emission of hydrocarbons. Figure 11(c) shows the Contrast of Experimental and Theoretic Nitric Oxide Emission of Different Vegetable Oil Ester and Diesel with respect to Brake Power and the values are in good agreement. Nitric oxide emissions decreased by 0.01 per cent respectively 0.24 per cent for Jatropha and Karanja compared to diesel. Figure 11(d) the emission of smoke decreased by 2.76 per cent, 1.31 per cent for Jatropha, Karanja, respectively, compared to diesel. Decreased emissions of smoke are due to the full combustion of fuels.







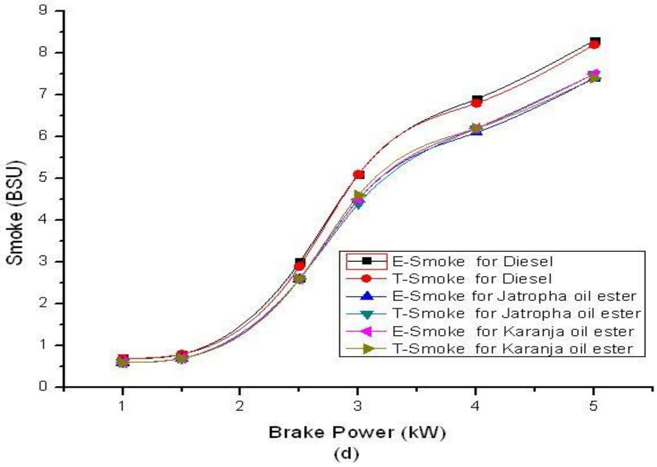


Fig. 11: Comparison of experimental and theoretical (a) carbon monoxide (b) hydrocarbon (c) nitric oxide (d) smoke, emission at various brake power using VOME and diesel

V. CONCLUSION

- Brake thermal efficiency is decreased by around 1.4% for Jatropha, 2.0%Karanja, in comparison to diesel.
- Brake specific fuel consumption was enhanced by 0.2% for Jatropha, 3.4% for Karanja, in comparison to diesel.
- The emission of Carbon monoxide is reduced by 3.69%, 14.23% for Jatropha, Karanja, in comparison to diesel.
- The emission of Hydrocarbon is reduced by 0.20%, 0.18% for Jatropha, Karanja respectively in comparison to diesel.
- The emission of Nitric oxide is reduced by 0.01%, 0.24% for Jatropha, Karanja respectively in comparison to diesel.

● The emission of Smoke is decreased by 2.76%, 1.31% for Jatropha, Karanja respectively when compared with diesel.

REFERENCES

1. Hidekl Fukuda, Akihiko Kondo, And Hide Noda, Biodiesel Fuel Production by Transesterification of Oils', journal of bioscience and bioengineefxng vol. 92, No. 5,405-416.2001.
2. Ayhan Demirbas, 'Current Advances in Alternative Motor Fuels', Energy exploration & Exploitation · Volume 21 · Numbers 5 & 6·2003.
3. Penglin Li, Xiaoling Miao, Rongxiu Li and Jianjiang Zhong, 'In Situ Biodiesel Production from Fast-Growing and High Oil Content Chlorella pyrenoidosa in Rice Straw Hydrolysate', Hindawi Publishing Corporation Journal of Biomedicine and Biotechnology Volume 2011, Article ID 141207, 8 pages doi:10.1155/2011/141207.
4. Patil Prafulla, 'Transesterification of Camelina Sativa Oil Using Heterogeneous Metal Oxide Catalysts', Energy Fuels 2009, 23, 4619–4624.
5. Dennis Y.C. Leung, Xuan Wu, M.K.H. Leung, 'A review on biodiesel production using catalyzed transesterification', Applied Energy 87 (2010) 1083–1095.
6. Ashwani Kumar, Satyawati Sharma, 'An evaluation of multipurpose oil seed crop for industrial uses (Jatropha curcas L.): A review', ndustrial crops and products xxx (2008) xxx–xxx.
7. MS Geyer, MJ Jacobus, & SS Lestz 1, 'Comparison of diesel engine performance and emissions from neat and transesterified vegetable oils', Trans. ASAE, vol. 27, no. 2, (1984) pp. 375-381.
8. Mohan Kumar Marugu & JK Sorangan, 'Critical review on biodiesel as substitute fuel for diesel engines', (1990) SAE 900354.
9. AK Agarwal & LM Das, 'Biodiesel development and characterization for use as a fuel in compression ignition engines', Trans. ASME, vol. 123, no. 2, (2001) pp. 440-447.
10. Sirivella Vijaya Bhaskar & Satish Babu, 'Effect of biodiesel and their diesel blends on performance and emission characteristics of CIDI engine: A review', IJRASET, vol. 3, no. 12, (2015), pp. 210-220.

AUTHORS PROFILE

Saurabh Dayal as a student in mechanical department in SIT, Mathura. I am pursuing M.Tech. from Dr.APJ Abdul Kalam Technical University (Formerly U. P. T. U) Lucknow. I am publishing 1st research paper in Journal and conferences of international.

Devendra Singh is an assistant Professor in Mechanical Engineering department in Sachdeva Institue of Technology, Farah, Mathura, Uttar Pradesh, India. He has thirteen years of Academic and Professional experience. He received M.Tech degree in Mechanical Engineering from Uttar Pradesh Technical University, Lucknow and pursuing Ph.D. from Dr.APJ Abdul Kalam Technical University (AKTU) Lucknow. He has guided several students at master and undergraduate level. His area of current research includes distillation, design, CFD and thermal engineering. He has also been a principal investigator in the DST department. He has organized many seminars in the college. He has published more than 14 research papers in Journals and Conferences of International

Dr. Ajay Kumar Sharma as an Assistant Professor in Mechanical Department in Institute of Engineering & Technology (IET), Lucknow and He has 20 years of Academic and Professional experience. He received Ph.D. from Indian Institute of Technology (IIT) Delhi. He has guided several students at master and undergraduate level. His area of current research includes Renewable Energy and Thermal Engineering. He has published more than 21 research papers in SCI Journals, Scopus and Conferences on International. He has also received the award for the best teacher. He is also a supervisor to Ph.D. of four students. He ahs also held a conference in his college.