International Journal of Ambient Energy

ISSN: 0143-0750 (Print) 2162-8246 (Online) Journal homepage: https://www.tandfonline.com/loi/taen20

Bio diesel production by using Jatropha: the fuel for future

I. Vinoth Kanna, A. Devaraj & K. Subramani

To cite this article: I. Vinoth Kanna, A. Devaraj & K. Subramani (2020) Bio diesel production by using Jatropha: the fuel for future, International Journal of Ambient Energy, 41:3, 289-295, DOI: 10.1080/01430750.2018.1456962

To link to this article: https://doi.org/10.1080/01430750.2018.1456962

INTERNATIONAL JOURNAL OF AMBIENT ENERGY
2020, VOL. 41, NO. 3, 289–295
https://doi.org/10.1080/01430750.2018.1456962

Bio diesel production by using Jatropha: the fuel for future

I. Vinoth Kanna, A. Devaraj and K. Subramani

Department of Mechanical Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, Tamil Nadu, 600 062, India

ABSTRACT

Presently biodiesel is widely used globally due to high scarcity of petroleum products and being a renewable fuel which can be used with the current fuelling infrastructure in an unmodified diesel engine. It is a harmless, recyclable, and ecofriendly fuel (reduces air pollutions such as dust, particulates, carbon monoxide, hydrocarbons, and oxides of sulphur and air toxics). In India, the favourable conditions for the growth of Jatropha exist. Its use a biofuel is going to prove very beneficial for the Indian as well as the world market with the increase in fossil fuel's demand and its reducing availability. The only drawback in using jatropha oil as a fuel is that the NO_x emission is more than that of petroleum diesel. This paper deals with the implementation of exhaust gas recirculation to reduce the emission of NO_x and to study its characteristics with respect to the performance of the engine.

Abbreviations: HSD: high-speed diesel; BD: biodiesel; EGR: exhaust gas recirculation; NO_x: nitrous oxide; CO: carbon mono oxide; NaOH: sodium hydroxide; RCAC: Rural Action Community Action Center

ARTICLE HISTORY
Received 28 November 2017
Accepted 15 March 2018

KEYWORDS
Biodiesel; *Jatropha curcas*; exhaust gas recirculation (EGR); performance test

1. Introduction

The potential for biodiesel availability is limited to roughly 2% of the current diesel fuel consumption. Presently the cost of biodiesel is 3–4 times higher than diesel (Balakrishnan and Mailsamy 2014). Higher taxes on diesel fuel or tax incentives for biodiesel to eliminate this price differential do not seem feasible presently. Hence, biodiesel must find uses in markets where its positive attributes may support its higher cost and preferably in the form of lower level blends in diesel in order to minimise the increase in cost (Jain and Sharma 2009).

For any new fuel to get market acceptance, it must be approved by the engine/vehicle manufacturers. If biodiesel needs to be used as a blend with diesel fuel, it should also be accepted by the petroleum industry (Kameoka et al. 2005). In order to obtain these endorsements, it is absolutely essential to have solid data to support its environmental benefits and other positive attributes.

Besides the monetary incentives, the government policy and regulations can also help a fuel to find markets. If the federal and provincial governments in India impose stringent emission regulations in underground mines, marinas, and other environmentally sensitive areas, it would certainly help biodiesel to enter these markets even at its current higher cost and efforts should be made to include biodiesel as an alternative fuel under the Indian Alternative Fuels Act (Kaul et al. 2003; Ganesan 2013).

2. Problem identification by using raw Jatropha oil in diesel engines

The major problem in using the raw Jatropha oil will be choking of the filter and other parts of the engine. Furthermore, due to its high viscosity, raw Jatropha oil can cause a lot of problems during cold seasons. So it can become an issue of concern especially in northern parts of India and the hill stations where temperatures reach as low as 0°C. Also the following major problems can occur.

1. Due to higher density of Jatropha oil, the atomisation in combustion will become difficult.
2. Poor volatility accounts for improper vaporization and ignition incapability. This also causes thermal cracking resulting in heavy smoke emissions and carbon deposits in the engine. Also, the durability of the engine will be affected (Hashimoto et al. 2008).
3. The presence of wax contents in the oil causes the formation of gum in the combustion chamber.
4. Increase in the emission of NO_x with use of Jatropha oil.

The above-mentioned difficulties cause fluctuations of load after some period of operation and ultimately lead to the breakdown of the engine. Hence, it is difficult to use Jatropha oil without further processing as a fuel in a direct injection engine. It either requires the oil to be processed further or some modifications should be made in the engine. We have opted for the former part (Hashimoto et al. 2008; Ganesan 2013).

2.1. Emission considerations

With biodiesel, the emission results were satisfactory for CO, CO_2, and SO. Except for the NO_x emissions which increased slightly, even though all other pollutants were present in a lesser amount.

CONTACT I. Vinoth Kanna vinothkanna.research@gmail.com

NO_x is one of the main contributors to smog and acid rain. The burning of fossil fuels also produces NO_x which can result in the formation of smog. Smog highly affects humans by causing breathing difficulty in asthmatics, coughs in children and general illness of the respiratory system. Acid rain can harm vegetation, and when enters lakes and rivers it can change the chemistry of the water and making it potentially uninhabitable of all acid tolerant bacteria (Kannan, Nabi, and Hustad 2009).

The EGR was implemented in the diesel engine to reduce NO_x since it causes these kinds of problems.

2.2. Problem rectification

- The transesterification process.
- A program was developed using Visual Basic for the performance and volumetric test.
- Engine modification for EGR was made.
- The performance tests and the heat balance tests have been carried out to compare the various blends and their performance with each other was carried out for the following (a) without any engine modification and (b) with the implementation of EGR (Sharma and Agarwal 2007).
- A comparison study between the performance of the various blends and the emission with EGR and without EGR is also presented.

Comparative performance of the diesel engine was conducted using:

- Diesel oil (HSD)
- Blends of HSD and biodiesel from *Jatropha curcas* (25% BD, 50% BD,75%BD)
- Hundred per cent biodiesel

3. Objectives

The study was carried out in four major steps which include the transesterification of the Jatropha oil, formulation of a program using Visual Basic for the performance test, modification of the engine with EGR and conducting various tests using various blends of biodiesel (Figure 1).

3.1. Purchasing of Jatropha oil

The raw oil was purchased from Rural Action Community Action Center (RCAC), Muthur. The main plantation was located at Kanisolai, Maatukadai, Kudumudi road and Muthur.

Ten litres of raw Jatropha oil was bought from this plant. RCAC has an official agreement with Indian railways, thus the oil was sold to us at a cost of Rs.80/litre.

3.2. Transesterification process

The transetherification process was carried out in order to reduce the viscosity of the oil by removing the fatty acid present in it.

Initially, 5.3 g of NaOH was weighed and mixed with 300 ml of methanol in a closed container so as to prevent the evaporation of methanol.

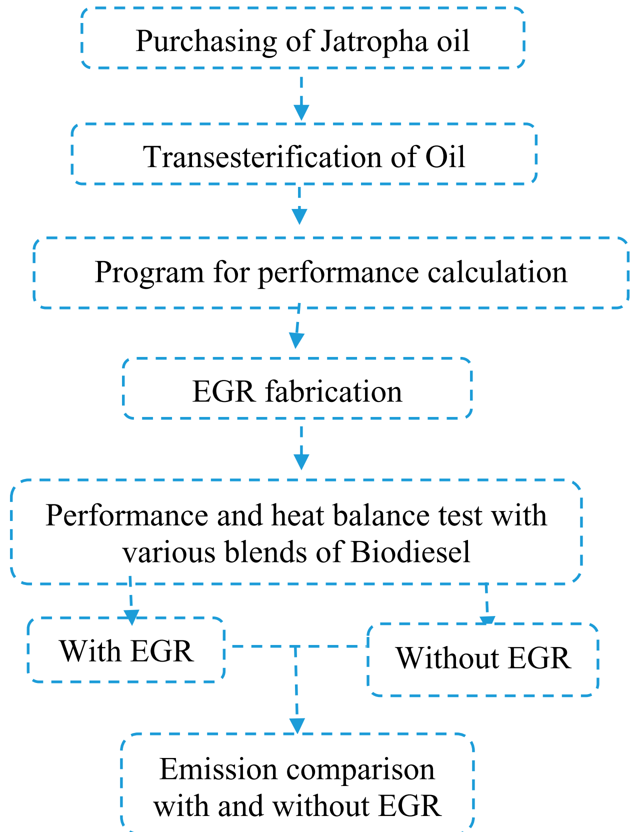

Figure 1. Process flow diagram.

After mixing, 1.5 litre of raw Jatropha oil was taken in a container and heated to a temperature of 40°C with constant stirring, without any swirl formation so as to enhance uniform stirring.

One hundred millilitres of a mixture of NaOH and methanol was taken in a burette and added to the raw Jatropha oil with a constant interval of 30 min. During the addition of the mixture, the temperature should be maintained between 50°C and 60°C. If the temperature exceeds beyond this limit, the oil could catch fire since methanol ignites at a very low temperature (Figure 2).

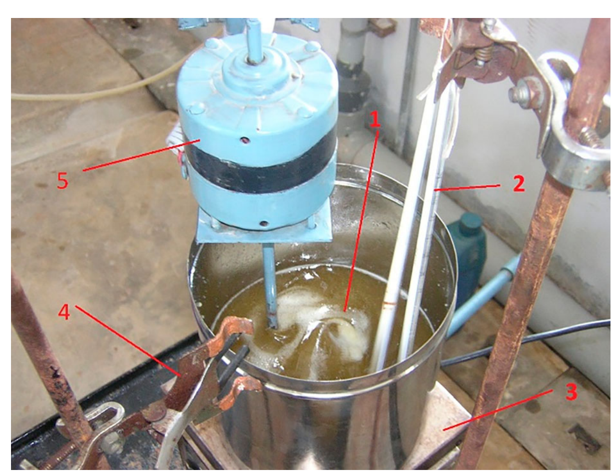

Figure 2. Transesterification process.

Figure 3. Soap from Jatropha oil.

Figure 4. Electrical centrifuge for separating oil and glycerol.

1. Mixture of raw Jatropha oil, methanol and NaOH.
2. Thermometer.
3. Heating instrument.
4. Container.
5. Stirrer.

All the mixture of methanol and NAOH was added to the raw Jatropha oil and was allowed to settle in the container for 10 h. After this there will be a clear separation of glycerol and the ester which is the required oil, i.e. the biodiesel required.

Initially, the transesterification process was carried out with ethanol and methanol. During the process of transesterification with ethanol, the NAOH pilots were added into the raw Jatropha oil without mixing with ethanol. This did not show any satisfactory chemical process. Then the same quantity of NaOH was added again, which changed all the 3 litres of oil into soap (Figure 3).

This resulted in a loss of Rs. 240 which is the cost of 3 litres of Jatropha oil. Because of this ethanol was replaced with methanol in the transesterification process. The ester was separated using an electrical centrifuge, which is shown in Figure 4.

Golden colour formation and the absence of alcohol smell is the final test which proves that the oil has undergone a good transesterification process. Figure 5 shows the difference between raw Jatropha oil and transesterified oil.

3.3. *Program for calculation*

This study included a lot of calculation since the performance of the engine was to be studied with various blends of biodiesel and with EGR. To make it fast and to evaluate the results obtained with the engine, a program using Visual Basic was developed.

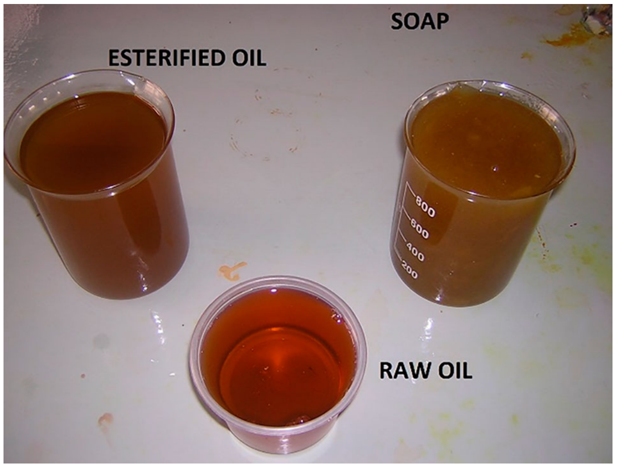

Figure 5. Transesterified oil.

The program involves four forms which include the following:

1. Welcome screen.
2. Input data window.
3. Frictional power window.
4. Results window.

3.4. *Fabrication of EGR*

External EGR, using piping to route the exhaust gas to the intake system where it is inducted into the succeeding cycles, has emerged as the preferred current approach. This methodology was followed in our project.

The engine exhaust and intake manifold were modified so as to enhance the EGR set. The constraints involved in the fabrication of EGR are as follows:

- Effective cooling has to be enforced for good performance of EGR since gas at 500–600°C cannot be allowed into the engine.
- Effective throttling has to be maintained so as to allow the required gas inside the cylinder.
- The exhaust has to be modified and the following condition has to be reached, so as to use the AVL 4370C Smoke meter.
- The temperature at the position of measurement should be maintained between 200°C and 250°C.
- The pressure at the position of measurement should be maintained between 60 and 75 mm of the manometer.
- Exhaust gas should be taken at an angle of 135° so as to have accurate readings.

The prototype of the model was developed in AUTO CAD before being fabricated in the engine. The prototype and actual set-up are given in Figure 6.

3.4.1. *Final test*

The main processes carried out in the Mechanical Department were the performance tests, the exhaust emissions test and the heat balance test. The performance tests are indicators of the various parameters such as the specific fuel consumption and

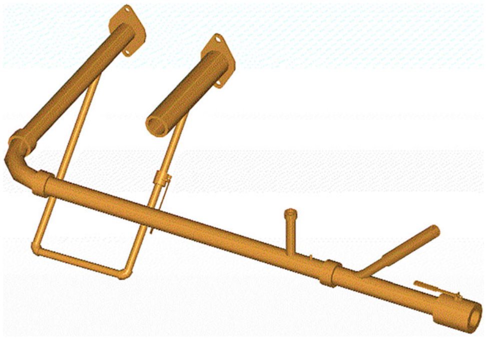

Figure 6. Prototype of EGR and exhaust pipe modifications.

thermal efficiency, which will enable the fuel to be compared with the petroleum diesel. The exhaust emissions indicated the percentages of the various gases present in the exhaust and thus helped in comparing the pollution levels of the biodiesel with the petroleum diesel. The engine used for conducting the mechanical tests was a Kirloskar Electrical Loading Engine. Its specifications are given below.

An electrical loading engine was chosen so as to have an effective and accurate loading. The original set-up of the engine was changed with respect to the work.

It was decided to test the characteristics with various blends as well as with 100% biodiesel. We opted for the following blends of biodiesel along with petroleum diesel.

3.5. Various blends used for testing

B0	100% HSD	0% BD
B25	75% HSD	25% BD
B50	50% HSD	50% BD
B100	0% HSD	100% BD

For measuring the mass flow rate of water, a 5 litre can was used. A stop watch was used to calculate the time taken to fill the 5 litre container.

The fuel tank, the burette-stand and the stand to carry the fuel tank were also fabricated by us.

3.5.1. Test procedure

1. The room temperature was noted down first.
2. Required quantities of blends were prepared according to their ratios by volume.
3. The fuel in the fuel tank, the supply of cooling water, level of lubricant in the sump as indicated by the dipstick and no load on the engine were checked before starting the engine.
4. The engine was started and allowed to run at no load for about 10 min to warm up and attain a steady state. The speed of the engine was measured using a tachometer and it was adjusted to the rated speed of 1500 rpm by adjusting the governor connected to the fuel pump.
5. The fuel was then supplied from the burette by opening the metering valve. By noting the change in the level of fuel in the burette, the time taken for 10 cc of fuel consumption was noted using a stop watch.

Table 1. Engines performance for various blends @ brake power = 2 kW.

Blends	BP kW	η_{BT} %	η_{Mech} %	50% EGR	100% EGR
B0	2	29.89	50.223	55.66	56.225
B25	2	29.44	51.263	52.33	54.444
B50	2	28.25	54.156	55.455	59.556
B75	2	27.644	48.996	50.112	51.112
B100	2	34.52	62.45	64.445	74.56

6. The desired cooling water flow rate was obtained by adjusting the valve and was kept constant throughout the experiment.
7. The inlet and outlet temperatures of the cooling water are noted. The temperature of the exhaust gas was noted.
8. The full load of the engine was distributed equally so as to run at least five trials during the test from zero load (0 amps) to full load (12 amps). The set-up readings were taken and tabulated.
9. The emissions are measured using the Flue gas analyser, AVL 437C Smoke meter for all the combinations of biodiesel with HSD.
10. The manometer readings are also noted.
11. All the above readings were taken for various loads with applying and without applying EGR.

Electrical loading arrangement was used for loading the engine. All parameters related to the engine performance were observed from the reading and it is tabulated in Table 1. Parameters such as

1. Brake power.
2. Fuel consumption rate, specific fuel consumption.
3. Fuel power.
4. Brake thermal efficiency, indicated thermal efficiency.
5. Brake and indicated mean effective pressure.

The observed and calculated values of the engine are given in the table. After the experimental part of the project was completed, the calculations were carried out and various graphs were drawn so as to discuss and arrive at the specified result. From the analysis of graphs, the conclusion was made.

3.6. Comparison graphs – without EGR

From the results, the following can be interpreted (Figure 7):

- Mechanical efficiency increases with increasing percentage of biodiesel in the blend. One hundred per cent of biodiesel had the best performance in terms of mechanical efficiency.
- The brake thermal efficiency was the best for the 50% blend and very similar to the brake thermal efficiency of the HSD.
- No considerable change in the value of the torque was noticed. The torque remained almost the same for all the blends.
- No considerable change in the values of the brake mean effective pressure though the values of the 50% blend and the 25% blend were closer when compared to other blends which

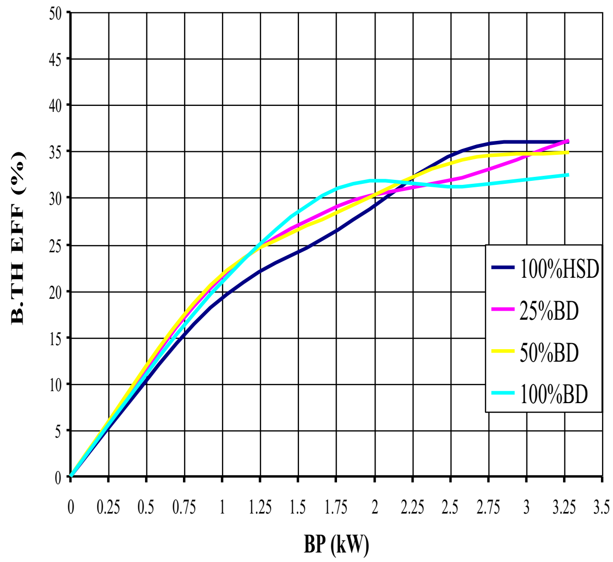

Figure 7. Brake power vs brake thermal efficiency.

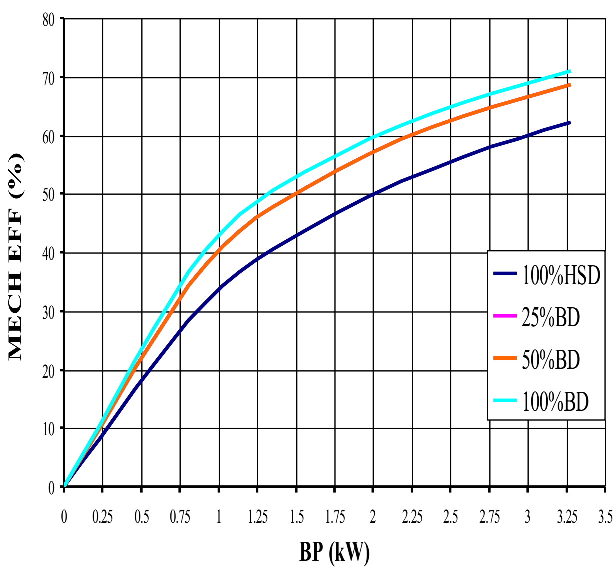

Figure 8. Brake power vs mechanical efficiency.

had slightly lower values. The SFC of all the blends was lower when compared to the SFC of the HSD. But the 50% blend had the closest SFC value to that of the HSD (Figure 8).

3.7. Comparison graphs – with EGR

From the results, the following can be interpreted:

- Mechanical efficiency was better with biodiesel with the increase in EGR and also with the increase in the percentage of biodiesel.
- The specific fuel consumption of biodiesel and the petroleum diesel reduced with the EGR both in 50% and as well as in 100% EGR (Figure 9).
- The brake thermal efficiency was best for the 50% EGR and very similar to the brake thermal efficiency of the HSD (Figure 10).

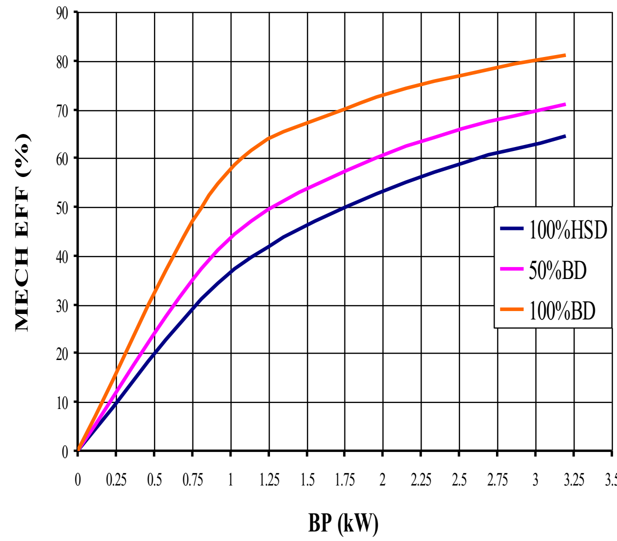

Figure 9. Brake power vs mechanical efficiency for 100% EGR.

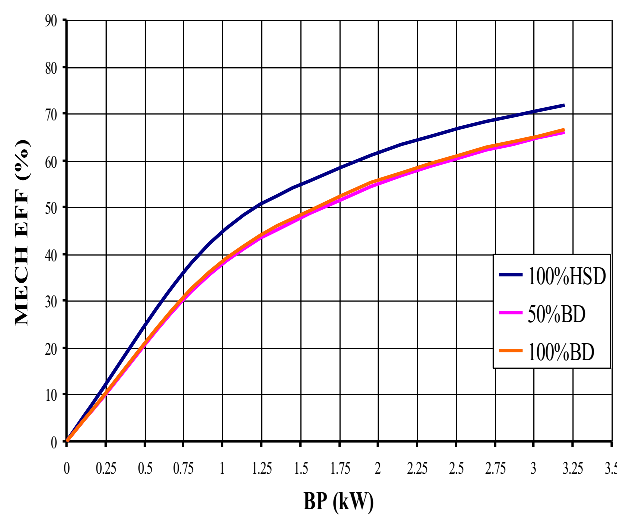

Figure 10. Brake power vs mechanical efficiency for 50% EGR.

3.8. Comparison graphs for emission

The emission of NO_x got reduced drastically with the implementation of EGR. The above graphs clearly show the reduction of NO_x (Figure 11).

The emission of CO got reduced drastically with biodiesel. With the implementation of EGR, there was no considerable change in its emission. Biodiesel almost completely eliminates lifecycle carbon dioxide emissions. When compared to petroleum diesel it reduces the emission of particulate matter by 40%, unburned hydrocarbons by 68%, and carbon monoxide by 44% (Figure 12).

With the implementation of EGR, the emissions of biodiesel almost remained the same and but the NO_x emission got reduced drastically which was the only disadvantage in the implementation of biodiesel. The emission of NO_x is reduced to 0.05% (Figure 13).

During full throttle of EGR and with full load, the engine struggled to run using petroleum diesel and which stopped the

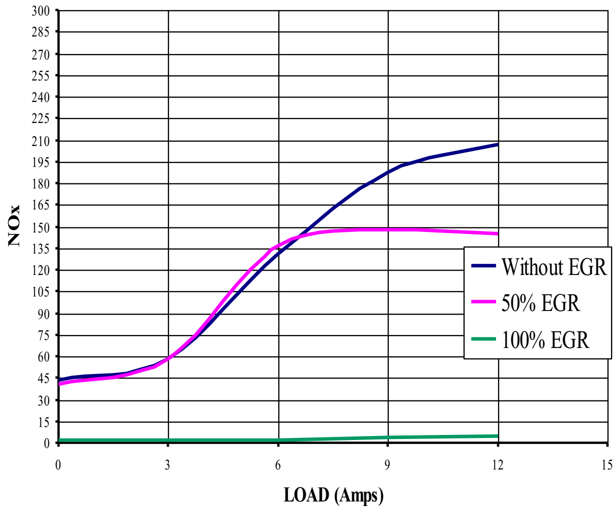

Figure 11. NO_x emission graph for 50% HSD 50% BD.

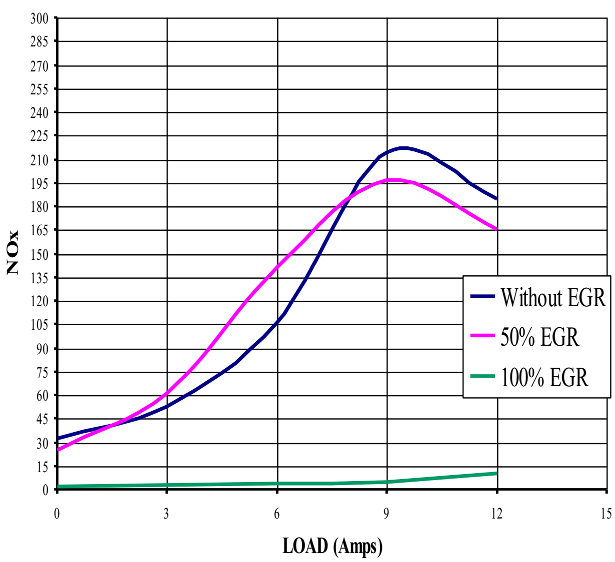

Figure 12. NO_x emission graph for 100%BD.

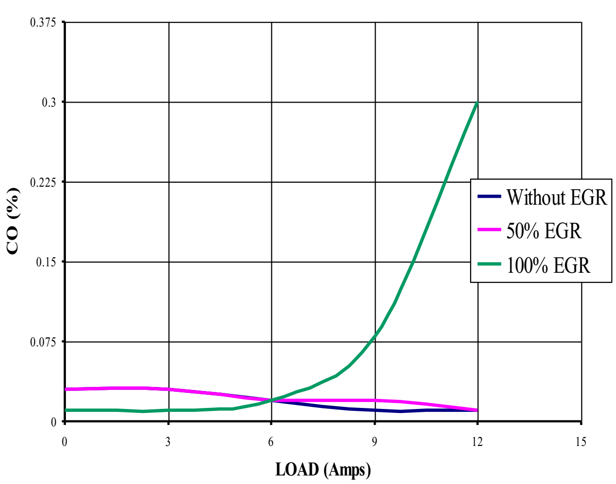

Figure 13. CO emission graph for 50%HSD 50%BD.

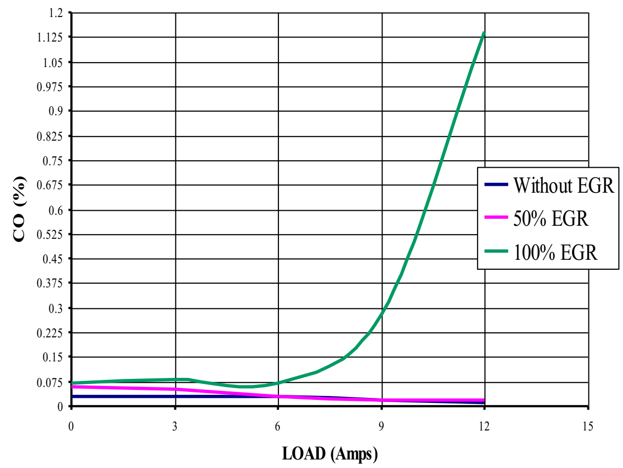

Figure 14. CO emission graph for 100%BD.

engine. But with 100% biodiesel, the engine ran without any trouble (Figure 14).

4. Conclusion

From the above results, the following can be interpreted:

- The mechanical efficiency of the engine while using biodiesel is more than the conventional petroleum diesel. When the percentage of biodiesel increases, the mechanical efficiency also increases simultaneously. With EGR, the mechanical efficiency is a maximum.
- No considerable change in the value of the torque was noticed. The torque remained almost the same for all the blends irrespective of EGR.
- There was no considerable change in the value of the brake mean effective pressure though the value of the 50% blend was closer when compared to other blends.
- There was a slight decrease in indicated thermal efficiency while using EGR and with various blends of biodiesel.
- Other performance characteristics of the diesel engine running with biodiesel almost remained the same with the implementation of EGR.

The emission of NO_x came down drastically. The emission was reduced to 0.5% of the original emission using biodiesel and with petroleum diesel.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

I. Vinoth kanna has completed his B.E (Mechanical Engineering) and M.E (Thermal Engineering) in Anna University, Chennai and is currently working as an Assistant Professor at Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, Tamil Nadu, India.

A. Devaraj has completed his B.E (Mechanical Engineering) and M.E (IC Engines) in Anna University, Chennai and is currently working as an Assistant Professor at Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, Tamil Nadu, India.

K. Subramani has completed his B.E (Mechanical Engineering) and M.E (CAD) in Anna University Chennai, and is currently working as an Assistant Professor at Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, Tamil Nadu, India.

ORCID

I. Vinoth Kanna http://orcid.org/0000-0001-8194-8781

References

Balakrishnan, N., and K. Mailsamy. 2014. "Effect of Compression Ratio on Compression Ignition Engine Performance with Biodiesel and Producer gas in Mixed Fuel Mode." *Renewable and Sustainable Energy* 6: 23–103.

Ganesan, V. 2013. *Internal Combustion Engines, Volume 4*. New Delhi: Tata McGraw Hill.

Guru, Metin,Atilla Koca, Ozer Can, Can Cinar, and Fatih Sahin. 2010. "Biodiesel Production from Waste Chicken Fat Based Sources and Evaluation with Mg Based Additive in a Diesel Engine." *Renewable Energy* 35 (3): 637–643.

Hashimoto, Nozomu, Yasushi Ozawa, Noriyuki Mori, Isao Yuri, and Tohru Hisamatsu. 2008. "Fundamental Combustion Characteristics of Palm Methyl Ester (PME) as Alternative Fuel for Gas Turbines." *Fuel* 87: 3373–3378.

Jain, S., and M. P. Sharma. 2009. "Prospects of Biodiesel from Jatropha in India: A Review." *Renewable and Sustainable Energy Reviews*. doi:10.1016/j.rser.2009.10.005.

Kameoka, A., K. Nagai, G. Sugiyama, and T. Seko. 2005. "Effect of Alcohol Fuels on Fuel-Line Materials of Gasoline Vehicles." SAE Technical Paper 2005-01-3708. doi:10.4271/2005-01-3708.

Kannan, D., M. Nabi, and J. Hustad. 2009. "Influence of Ethanol Blend Addition on Compression Ignition Engine Performance and Emissions Operated with Diesel and Jatropha Methyl Ester." SAE Technical Paper 2009-01-1808. doi:10.4271/2009-01-1808.

Kaul, S., A. Kumar, A. K. Bhatnagar, H. B. Goyal, and A. K. Gupta. 2003. "Biodiesel a Clean and Sustainable Fuel for Future. Scientific Strategies for Production of Non-edible Vegetable oils for Use as Biofuels." All India seminar on National Policy on non-edible oils as biofuels, SUTRA IISc Bangalore.

Sharma, M. P., and R. Agarwal. 2007. "Non-edible Oils as Potential Resources of Biodiesel." Proceedings of 23rd National Convention of Chemical Engineers on recent trends in chemical engineering, IIT Roorkee, India, 202–211.