Volume : 4 | Issue : 7 | July 2015 ISSN - 2250-1991

Research Paper Engineering

Performance and Emission Characteristics of CI Engine Fuelled With Various Ester of Jatropha – An Overview

Jeyaraj R	Associate Professor, Dept. of Mechanical Engineering, Bethlahem Institute of Engineering, Karungal, Kanyakumari
P. Seenikannan	Dean & Head, Dept. of Mechanical Engineering, Sethu Institute of Technology, Kariapatti, Chennai

ABSTRACT

The use of biodiesel is increasing around the globe, making it imperative to understand the impacts of biodiesel on the diesel engine performance and reduce the emissions. Presently, the focus on renewable energy and alternative fuels has increased significantly due to increasing oil prices, environment pollution, and also concern on preserving the nature. Biodiesel has been known as an alternative fuel although biodiesel produced from edible oil is very expensive than conventional diesel. Therefore, the uses of biodiesel produced from non-edible oils are available better option. Currently Jatropha biodiesel (JBD) is receiving attention as an alternative fuel for diesel engine. This paper briefly explains the (i) advantages and limitations of jatropha as biodiesel (ii) performance studies carried out by various investigators (iii) future directions.

KEYWORDS

INTRODUCTION

It is very well known that energy is very important for life quality and social development as well as economic growth. Fossil fuels have been an important conventional energy source for years. Energy demand around the world is increasing at a faster rate as a result of ongoing trends in industrialization and modernization. Consequently, these countries have to spend their export income to buy petroleum products [Hanbey Hazar, 2010]. The climate changes occurring due to increased Carbon Dioxide (CO2) emissions and global warming, increasing air pollution and depletion of fossil fuels are the major problems in the present century. The trend of the present investigators is on the biofuels as environment friendly energy source to reduce dependence on fossil fuels and to reduce air pollution. The biofuels can play an important role towards the transition to a lower carbon economy and also combine the benefits of low green house emissions with the reduction of oil import. The role biofuels can play within these economies becomes clearer when their relatively developed agricultural sector is taken into account [Radinko et al., 2009]. Bioethanol, biodiesel and to a lesser extent pure vegetable oils are recently considered as most promising biofuels. Since 19th century, ethanol was used as a fuel for diesel engines. Ethanol is a low cost oxygenated compound with high oxygen content (34.8%). Ethanol is an alcohol most often chosen because of the ease of production, can be obtained from various kinds of biomass such as maize, sugarcane, sugar beet, corn, cassava, red seaweed etc., relatively low-cost and low toxicity [Lapuerta et al., 2007]. Fig. 1 shows CO2 emission from different energy sources [Niraj Kumar, 2010].

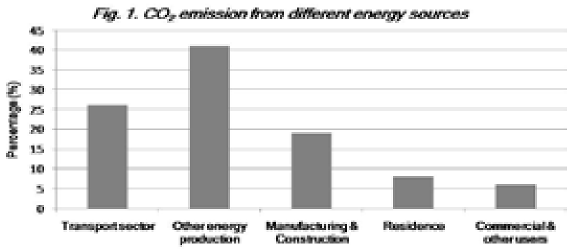

Fig. 1 CO2 emission from different sources [Niraj Kumar et al., 2010]

Diesel-ethanol blends are a more viable alternative and require little or no change in diesel engines. The use of diesel-ethanol blends can significantly reduce the emission of toxic gases and particulate matters when compared to pure diesel

Biodiesel is produced through the reaction of a vegetable oil or animal fat with methanol in the presence of a catalyst to yield glycerine and methyl esters [Le et al., 2004]. The process of production of biodiesels is known as transesterification [Sahoo et al., 2007; Sahoo et al., 2009]. There are several of species from which biodiesels can be made available. Biodiesel can be harvested and sourced from non-edible oils like Jatropha, Pongamia, Neem (Azadirachta indica), Mahua, castor, linseed, Kusum (Schlechera trijuga), etc and edible oils like coconut, palm, sunflower ,mustered, soybean etc [Anjana Srivastava and Ram Prasad, 2000].

It is known that Biodiesel has some important advantages when compared to diesel fuel. Biodiesel contains almost no sulphur; is biodegradable, nontoxic and a natural lubricant. Biodiesel has a high flashpoint, about 130ºC (266ºF), so it not explode spontaneously or ignite under normal circumstance. This feature makes biodiesel much safer to transport and store. Although biodiesel contains 10% less energy per gallon than convectional diesel fuel, it exhibits almost the same performance compared to diesel fuel, because, beyond reduces engine friction between engine parts, biodiesel useable energy is partially offset by approximately 7% increase in the combustion efficiency. It is also known that Biodiesel has others advantages, compared to conventional diesel fuel, such as: ready availability, renewability, biodegradability, higher centane number, flash point, cloud point and cold filter plugging point. Since biodiesel comes from a renewable energy source, its production and use as a replacement for fossil fuel provides three main benefits: reduces economic dependence on petroleum oil; decreases gas emissions that cause the greenhouse effect; and diminishes the proliferation of deceases caused by the pollution of the environment. The use of biodiesel in diesel engines generally require no hardware modification because vegetable oils have cetane umbers close to that of diesel fuel High viscosity of the vegetable oil leads to poor fuel atomization, which in turn may lead to poor combustion, ring sticking, injector cocking, injector deposits, injector pump failure and lubricating oil dilution by crank-case polymerization [Rakopoulos et al., 2006; Engelman et al., 1978]. Table 1 presents fatty acid methyl ester composition of different biodiesel

 ISSN - 2250-1991

fuels [Gopinath et al., 2009; 2013].

Table 1. Fatty acid methyl ester composition of different biodiesel fuels.

Biodiesel	Fatty acid methyl ester composition (wt %)							
	Lauric	Myristic	Palmitic	Stearic	Oleic	Linoleic	Linolenic	Others
Coconut	45.6	22.1	10.2	3.6	8.2	2.7	0	7.6
Cottonseed	0.1	1	20.1	2.6	19.2	55.2	0.6	1.2
Jatropha	0	0.1	15.6	10.5	42.1	30.9	0.2	0.6
Karanja	0	0.1	9.9	7.8	53.2	19.1	0	9.9
Mahua	0	0.2	20.8	25.2	36.4	15.8	0.3	1.3
Neem	0.8	0.5	18.2	20.1	41.3	16.4	0.3	2.4
Palm	0.2	0.8	39.5	5.1	43.1	10.4	0.1	0.8
Rapeseed	0	1	3.5	0.9	64.1	22.5	8	0
Rubber seed	0	0.2	12.5	8.3	27.8	37.7	13.4	0.1
Soybean	0.1	0.1	10.2	3.7	22.8	53.7	8.6	0.8
Sunflower	0.2	0.8	38.6	4.6	44	10.7	0.1	1

Note: The table values adapted from Gopinath et al. (2009)

2.0 About Jantropha [Gomma et al., 2010]

It is mentioned that productivity of non-edible oils tend to be higher, for Jatropha as example its productivity 1590 kg of oil per hectare [Hossain and Davies, 2010]. Therefore, big biodiesel development countries like Malaysia focus on producing biodiesel from Jatropha [Biopact team, 2007]. Although Jatropha biodiesel has many advantages, but it still have several disadvantages one of them is higher NOX emission. The higher NOX emission is a common disadvantage for most of biodiesel. Previous researches achieved reduction in NOX by using exhaust gas recirculation (EGR) technique with different types of biodiesel.

Jatropha is a non-edible plant, grow in waste lands and consume less water. Also, biodiesel from Jatropha have advantages compared to conventional diesel fuel such as [Jookaplee, 2007; Gomaa et al., 2010]:

- The Jatropha Biodiesel molecules are simple hydrocarbon chains, containing no sulfur, or aromatic substances associated with fossil fuels. They contain higher amount oxygen (up to 10%) that ensures more complete combustion of hydrocarbons.
- Biodiesel almost completely eliminates lifecycle carbon dioxide emissions.
- Jatropha Biodiesel has a high flash point, or ignition temperature, of about 300 F compared to petroleum diesel fuel which has a flash point of 125 F. This means it is safer to transport. Auto ignition, fuel consumption, power output, and engine torque are relatively unaffected by Jatropha Biodiesel.
- Jatropha Biodiesel has a high cetane number. Cetane number is a measure of a fuel's ignition quality. The high cetane numbers of biodiesel contribute to easy cold starting and low idle noise.
- It can extend the life of diesel engines because of it high lubricating properties.
- Jatropha Biodiesel replaces the exhaust odor of petroleum diesel with a more pleasant smell of popcorn or French fries.

3. REVIEW ON PERFORMANCE AND EMISSION STUDIES BY USING ESTER OF JATROPHA

In general, experiments are to be carried out on diesel engine using diesel, methyl ester of jatropha oil (MEJO) and MEJO with ignition improver and Ethanol. The ignition improver generally used in the studies is Tetra Nitro Methane (TNM). The ignition improver, TNM is to be added to the methyl ester of jatropha oil at different proportions such as 1 to 3%, Ethanol is to be added to the methyl ester of jatropha oil at different proportions such as 5 to 25%. The performance parameters such as brake thermal efficiency, brake specific fuel consumption are to be studied with respect to load. The exhaust emissions such as carbon monoxide, carbon dioxide, hydrocarbons, oxides of nitrogen and unused oxygen and smoke opacity can also be studied with respect to load. The experimental set up consists of a diesel engine, engine test bed, fuel and air consumption metering equipments, gas analyzer, and smoke meter (Nasarullah and Raja Gopal, 2014).

Ozer Can et al; [2004] investigated the effects of ethanol addition to Diesel No. 2 on the performance and emissions of a four stroke cycle, four cylinder, turbocharged indirect injection diesel engine with different fuel injection pressures at full load. They showed that the ethanol addition reduces Carbon monoxide (CO), soot and Sulphur Dioxide (SO2) emissions, but increases Oxides of nitrogen (NOx) emissions. It was also found that increased injection pressure, reduced the CO and smoke emissions with some reduction in power. Andrzej Kowalewicz [5] showed that the injection of ethanol into the inlet port reduced CO2, NOx and CO emissions and smoke at higher loads with both diesel fuel and rape oil methyl ester. Jincheng Huang et al [6] studied the performance and emissions of a diesel engine using ethanol-diesel blends. They showed that the thermal efficiencies of the engine fuelled by the blends were comparable with that fuelled by diesel, with some increase of fuel consumption. They also found reduced smoke emissions, CO emissions above half loads, and increased HC emissions with the blends comparing with the diesel fuel.

Nasarullah and Raja Gopal (2014) investigated the performance and emission characteristics of a direct injection (DI) diesel engine when fuelled with methyl ester of jatropha oil (MEJO). The ignition improver tetra nitro methane (TNM) and ethanol are added to methyl ester of jatropha oil to examine the performance and emissions of the diesel engine. The experimental results showed that the maximum brake thermal efficiency was obtained with 20%Etanol-2%TNM blended with MEJO when compared with pure MEJO and methyl ester of jatropha oil blends. Among the TNM-Ethanol blends, the minimum brake specific fuel consumption was observed with 20% Ethanol-2%TNM. The lowest carbon monoxide (CO) and unburned hydrocarbons (HC) with 20%Ethanol-2%TNM blend. The smoke density of 20%Ethanol-2%TNM with MEJO was reduced by 20.69% when compared with diesel. Hence, the 20%Ethanol-2%TNM blended with MEJO could improve the performance and reduce the emissions of the diesel engine. Pramanik et al.[2003] evaluated the engine performance using the prepared Jatropha blends as fuel. Author reported that significant improvement in engine performance was observed compared to vegetable oil alone. The specific fuel consumption and the exhaust gas temperature were reduced due to decrease in viscosity of the vegetable oil and emission characteristics closer to the diesel fuel.

Rao et al. [2009] performed studies on Jatropha biodiesel and its blends. The effects of Jatropha on the performance and emissions of a single cylinder, water cooled diesel engine investigated. Experimental results showed that the engine works smoothly on B100 with performance comparable to diesel fuel operation. B100 results in a slightly increased thermal efficiency as compared to that of conventional diesel fuel. The exhaust gas temperature was decreased with B100 as compared to diesel fuel. CO2 emission was low with B100 compared to diesel fuel. CO emission was low at higher loads for B100 when compared with diesel. NOX emission was slightly increased with B100 compared to diesel fuel. There was significant difference in smoke emissions when B100 was used. Smoke was increased with increased in brake power. Smoke emission was lesser for blended Jatropha biodiesel compared to diesel fuel. When percentage of blend biodiesel increased, smoke density decreased, but smoke density increased for B50 and B75 due to insufficient combustion. Rao et al. [2008], used single cylinder, water cooled, DI diesel engine used to investigate the performance and emission characteristics of Jatropha and other two types of non-edible oils on diesel engine. They observed slight drop in thermal efficiency with methyl esters when compared with diesel. Biodiesel gave less smoke density compared to petroleum diesel. When percentage of blend biodiesel increases, smoke density decreases, but smoke density increased for B80 and B100 due to insufficient combustion. Smoke, HC, and CO emissions at different loads were found to be higher for diesel, compared to B10, B20 and B40. In conclusion, good mixture formation and lower smoke emission were the key factors for good CI engine performance. These factors are highly influenced by viscosity, density, and volatility of the fuel. For biodiesels, these factors are mainly decided by the effectiveness of the transesterification process. Banapurmath et al. [2008], carried out experiments by using a single cylinder, direct injection, air cooled diesel engine fuelled with JB100. The experiments result presented that was JB100 had a thermal efficiency lower than diesel fuel. Also observed, JB100 had slightly higher smoke emissions than diesel fuel.

On the basis of experimental data of Gomaa et al. (2010), it was found that blended biodiesel and EGR both can be used in compression ignition engine to simultaneously reduce NOX and soot emissions. The JB5 blended Jatropha biodiesel together with 15%EGR was found to be useful in improving both of brake thermal efficiency, brake specific energy consumption and reduces exhaust emissions. Silambarasan et al. (2015) carried out experiments to study the performance and emissions of the engine fuelled with Ethanol-Biodiesel blends and compared with those fuelled by diesel. From the above all experimental the following conclusions were made by authors.

- Brake Thermal Efficiency is higher for JE50 than all other blends and diesel fuel.
- NOx emission in JE55 lower compared to all other blends and also with diesel.
- Smoke emission is lower in all JE blends compared with diesel fuel.
- JE50 seems to be the best blend ratio.

From the experimental investigations on physicochemical properties, performance and emissions of jatropha methyl ester and its blends with petroleum diesel, the following conclusions were drawn by authors [Jerekias Gandure et al., 2013]

a) Physicochemical properties of jatropha methyl ester and its blends with petroleum diesel depict comparable fuel properties to those of petroleum diesel. Viscosity values for all fuels (petroleum diesel, B100 and blends) fall within specifications of ASTM standards, with a maximum difference of 21% observed between B0 and B100. Cold flow properties of cloud and pour points indicate that biofuels investigated can power the diesel engine without much difficulty in cold weather. The flash points of jatropha methyl ester and its blends were however

found to be lower than the ASTM specification of a minimum of 130oC, implying that the fuels are highly flammable and may need extreme handling precaution during transportation.

b) Biofuels depicted better engine performance when compared to petroleum diesel in terms of brake power, SFC and BTE. This is largely attributed to higher combustion efficiency due to extra inbound oxygen.

c) Higher combustion efficiency of biofuels culminated in reduced production of HC, CO and CO2 emissions when compared with petroleum diesel. Petroleum diesel was also observed to produce the highest amount of soot during combustion in the magnitude of approximately 3% per 3ml of fuel.

Palash et al. (2013) investigated the Jatropha biodiesel blends on engine performance and emissions of multi cylinder diesel engine. The blends of Jatropha biodiesel with diesel produce less HC (up to 48%) and CO (up to 52.6%), but higher NO emission (up to 11.82%). From the results presented above, it can be concluded that Jatropha biodiesel blends up to 20% can be applicable in diesel engine without any engine modification.

Fig. 2 shows the typical comparisons of thermal efficiencies and air fuel ratios for different fuels at 70 % full load for 10 hours engine run when heated up to 60°C.

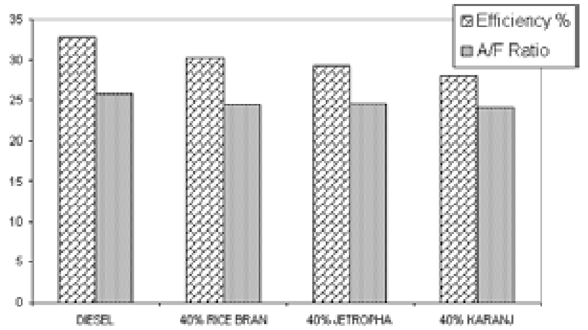

Fig. 2 Comparisons of thermal efficiencies [Nafis and Bokhary, 2010]

4.0 SUMMARY AND CONCLUDING REMARKS

To solve both energy concern and environmental concern, the renewable energies with lower environmental pollution impact should be necessary. Nowadays, there are many sources of renewable energy. Biofuels are just one source, but a very important one. From the literature, it is observed that

- the performance parameters such as brake thermal efficiency, brake specific fuel consumption increased with the increasing percentage of ethanol to biodiesel-ignition improver blend.
- the emission parameters such as CO, unused oxygen and smoke intensity reduced with ethanol addition.
- the CO2, NOx increased with increasing percentage of ethanol in biodiesel-ignition improver blend.

Further, it is noted that although biodiesel has many advantages, but it still has several properties need to improve, such as lower calorific value, lower effective engine power, higher emission of nitrogen oxides (NOX) and greater sensitivity to low temperature. Exhaust gas recirculation (EGR) is effective technique to reduce NOX emission from diesel engines because it enables lower flame temperature and oxygen concentration in the combustion chamber. Some studies succeeded to reduce the NOX emission from biodiesel by EGR but they observed increasing soot emission.

Extensive studies are required to confirm the above results.

REFERENCES

1. Nasarullah. M and Raja Gopal. K, (2014), "Effect of Ethanol and Tetra Nitro Methane on Performance and Emission Characteristics of CI Engine Fuelled With Methyl Ester of Jatropha", International Journal of Emerging Engineering Research and Technology, Volume 2, Issue 3, June 2014, PP 31-39 | 2. Hanbey Hazar, "Cotton methyl ester usage in a diesel engine equipped with insulated combustion chamber", Applied Energy, 87, 2010, pp. 134–140. | 3. Radinko GLIGORIJEVIC, Jeremija JEVTIC, Djuro BORAK, and Velimir PETROVIC, "Potentials and limitations of alternative fuels for diesel engine", Thermal science, Vol. 13, No. 3, 2009, pp. 175-183. | 4. Lapuerta M, Armas O, Garcı´a-Gontreras R, "Stability of diesel–bioethanol blends for use in diesel engines", Fuel, 86, 2007, pp.1351–1357. | 5. Ozer Can, Ismet Celikten, and Nazim Usta, "Effects of ethanol addition on performance and emission characteristics of a turbocharged indirect injection diesel engine running at different injection pressures", Energy Conversion and Management, 45, 2004, pp.2429-2440. || 6. Lee S. W., Herage T. and Young. B., Emissionreduction potential from the combustion of soy methyl ester fuel blended with petroleum distillate fuel. Fuel. 83, 2004, 1607-1613. | 7. Sahoo P.K. and Das L.M., Combustion analysis of Jatropha, Karanja and Polanga based biodiesel as fuel in a diesel engine, Fuel, 88, 2009, 994-999. | 8. Sahoo P.K., Das. L.M, Babu. M.K.G and Naik. S.N., Biodiesel development from high acid value polanga seed oil and performance evaluation in a CI engine, Fuel, 86, 2007, 448-454. | 9. Anjana Srivastava, Ram Prasad., Triglycerides–based diesel fuels. Renewable Sust Energ Rev 4, 2000, 111–33. || 10. Rakopoulos CD, Antonopoulos KA, Rakopoulos DC, Hountalas DT and Giakoumis EG., Comparative performance and emissions study of a direct injection diesel engine using blends of diesel fuel with vegetable oils or bio-diesels of various origins. Energy Conversion Management, 47, 2006, 3272-3287. | 11. Engelman HW, Guenther DA and Silvis TW. 1942. Vegetable oil as a diesel fuel. Diesel and Gas Engine Power Division of ASME paper no. 78-DGP-19. New York: ASME; 1978. || 12. M. Gomaa, A.J. Alimin and K.A. Kamarudin Trade-off between NOX, Soot and EGR rates for an IDI diesel engine fuelled with JB5, World Academy of Science, Engineering and Technology 38 2010, 522-527. | 13. Hossain, A.K. & Davies, P.A., "Plant oils as fuels for compression ignition engines: A technical review and life-cycle analysis". Renewable Energy, vol. 35, 2010, pp.1–13. | 14. BIOPACT TEAM. (2007). Malaysia to trial Jatropha in Sabah. http://news.mongabay.com/bioenergy/2007/09/malaysia-to-trialjatropha-in-sabah.html. | 15. Jookaplee. (2007). what is Jatropha Biodiesel? http://jatropha-blog.blogspot.com/2007/01/what-is-jatrophabiodiesel.html. | 16. Rao, Y.V.H., Voleti, R.S., Raju, A.V.S. & Reddy, P.N., "Experimental investigations on Jatropha biodiesel and additive in diesel engine". Indian Journal of Science and Technology, vol. 2, 2009, pp.25-31. | 17. Rao, T.V., Rao, G.P., Principal & Reddy, K.H.C.,"EXPERIMENTAL INVESTIGATION OF METHYL ESTERS OF NON-EDIBLE OILS AS BIODIESEL ON C.I ENGINE".International Journal of Meterials Sciences, vol. 3, 2008. | 18. Banapurmath, N.R., Tewari, P.G. & Hosmath, R.S., "Performance and emission characteristics of a DI compression ignition engine operated on Honge, Jatropha and sesame oil methyl esters".Renewable Energy, vol. 33, 2008, p.1982–1988. | 19. R.Silambarasan, R. Senthil, G. Pranesh, P. Mebin Samuel, M. Manimaran, PERFORMANCE AND EMISSION CHARACTERISTICS OF JATROPHA-ETHANOL BLEND FUELLED WITH COMPRESSION IGNITION ENGINE , Journal of Chemical and Pharmaceutical Sciences, Issue 9: April 2015, 6-8. | 20. Jerekias Gandure, Clever Ketlogetswe and Abraham Temu, FUEL PROPERTIES OF JATROPHA METHYL ESTER AND ITS BLENDS WITH PETROLEUM DIESEL | ARPN Journal of Engineering and Applied Sciences, VOL. 8, NO. 11, NOVEMBER 2013, 900-908 | 21. Nafis Ahmad, A Y F Bokhary, "A Comparative Study of Performance and Emissions Characteristics under Pure Diesel and Blends of Alternative Fuels of a C I Engine", International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS Vol: 10 No: 06, 2010, 9-21. | 22. Niraj Kumar, Varun and Anoop Kumar (2010), "Biodiesel as an alternative fuel for CI engines: environmental effect", Indian Journal of Science and Technology, Vol. 3 No. 5 (May 2010), 602-606. | 23. S.M. Palash, M.A. Kalam, H.H. Masjuki, B.M. Masum, A. Sanjid, (2013), "Impacts of Jatropha biodiesel blends on engine performance and emission of a multi cylinder diesel engine", Proc. of the Intl. Conf. on Future Trends in Structural, Civil, Environmental and Mechanical Engineering -- FTSCEM 2013, ISBN: 978-981-07-7021-1 doi:10.3850/ 978-981-07-7021-1_58 | 24. Gopinath A, Sukumar Puhan, Nagarajan G (2009) Relating cetane number of biodiesel fuels to their fatty acid composition: a critical study. Proc Inst Mech Eng. Part D 223: 565-583. || 25. Gopinath Anantharaman, Sairam Krishnamurthy, Velraj Ramalingam, (2013), "A review on combustion, performance, and emission characteristics of fuels derived from oil seed crops (biodiesels)", Australian Journal of Crop Science, 7(9):1350-1354 (2013) |