Performance characteristics of Jatropha ethyl ester as diesel engine fuel at different compression ratios

Rajneesh Kumar, Anoop Kumar Dixit*, Shashi Kumar Singh, Gursahib Singh, Rohinish Khurana

(*Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology Punjab Agricultural University, Ludhiana, Punjab, India*)

Abstract: The results of the performance and emission of a variable compression ratio ignition engine (vertical single cylinder) by using Jatropha ethyl ester blends with diesel fuel at two levels of compression ratio (16.5:1 and 18.5:1) have been presented in this paper. The fuel samples were prepared by blending Jatropha ethyl ester with diesel in the composition of 0:100, 10:90, 20:80, 30:70 and 40:60 (%). Results indicated that Brake thermal efficiency for all biodiesel blends was more as compared to diesel. Brake thermal efficiency increased with the increase in load and also increased with the increase in compression ratio. Brake specific fuel consumption in case of blends was more as compared to diesel. Brake specific fuel consumption decreased with the increase in load as well as with the increase in compression ratio. Exhaust gas temperature increased with the increase in load and also increased with the increase in compression ratio for all fuel blends.

Keywords: Jatropha ethyl ester, diesel engine, compression ratio, brake thermal efficiency, brake specific fuel consumption

Citation: Rajneesh Kumar, Anoop Kumar Dixit, Shashi Kumar Singh, Gursahib Singh, and Rohinish Khurana. 2013. Performance characteristics of Jatropha ethyl ester as diesel engine fuel at different compression ratios. Agric Eng Int: CIGR Journal, 15(3): 95−100.

1 Introduction

The world energy demand has, for the last two decades, witnessed uncertainties in two dimensions. Firstly, the price of conventional fossil fuel is too high and the ever increasing number of automobiles has led to an increase in demand of fossil fuels (petroleum) thus, added burden on the economy of the importing nations. Secondly, combustion of fossil fuels is the main culprit in increasing the global carbon dioxide (CO_2) level, a consequence of global warming. On the other hand, the agriculture sector of the country is mainly dependent on diesel for its tractive power. Diesel usually is used to power the irrigation pumps and other use. So, the scarcity and depletion of fossil fuels sources are cases of concern and have prompted research world-wide into alternative fuels sources for internal combustion engines.

Among the alternate fuels for the petroleum fuel, biodiesel is a new, alternate and green fuel which has the potential to replace petroleum diesel in the near future. Biodiesel is non-toxic and renewable in nature. Further advantages over petro-diesel include higher cetane number, no sulphur emission, low aromatics, low volatility and the presence of oxygen atoms in the fuel molecule (Bhatt, 1987). Vegetable oil esters (biodiesel) have gained good promise and suitability for their use in compression ignition engine (Srivastava and Prasad, 2000; Verma and Gupta, 2000; Mcdonell et al., 2000). Because biodiesel can help to reduce our dependence on conventional/non-renewable fossil fuels as well as improve environment quality by reducing automotive/ vehicular emissions (Antolin et al., 2002; Barnwal and Sharma, 2005; Good rum and Geller, 2005; Ishii and

Received date: 2011-11-04 **Accepted date:** 2013-04-29

* **Corresponding author: Anoop Kumar Dixit,** Research Engineer, Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana, 141004 India. Email: anoopdixit@pau.edu.

Takeuchi, 1987; Peterson et al., 1987). But vegetable oil esters from edible oils may not be the right option for their substitution in diesel engine due to the lack of self-sufficiency of edible oil production in India. Hence attention has been diverted to test the suitability of non-edible oils for diesel engine

Non-edible oil holds good promises as an eco-friendly fuel. In India, there are several non-edible oil plants such as Jatropha, Pongamia, Neem, Mahua, Simarouba, etc. Out of these plants, Jatropha and Pongamia have shown good promise for biodiesel production (Lapuerta et al., 2008). Forson et al. (2004) used Jatropha oil and diesel blends in CI engines and found its performance and emissions characteristics similar to that of mineral diesel at low concentration of Jatropha oil in blends.

Agarwal et al. (2008) conducted experiments with esters of linseed, Mahua, rice bran and Lome. They observed that the performance and the emission parameters were very close to diesel. They even observed that a diesel engine can perform satisfactorily by esterified biodiesel blends without any modifications. Baiju et al. (2009) used methyl and ethyl ester of Karanja oil to run CI engine. They observed good engine performance with reduced emissions of HC and Smoke. Several studies have shown that diesel-biodiesel blends reduce smoke emission, particulates, unburned hydrocarbons, carbon dioxide and carbon monoxide emissions with a slight increase in oxides of nitrogen emissions (Kumar et al. 2003; Cheng et al. 2006; Sinha and Agarwal, 2006; Lapuerta et al., 2008).

Studies on performance of diesel engine using methyl ester as an alternative fuel have been carried out in India and abroad. However, very limited studies have been carried out in this field using ethyl ester instead of methyl ester. Considering the advantages of esters as an alternative fuel, this study was planned to evaluate the performance of a 3.73 kW diesel engine using different blends of Jatropha ethyl ester oil with diesel as fuel.

2 Materials and methods

2.1 Preparation of fuel blends

Non edible Jatropha oil was obtained from market. Jatropha ethyl ester was produced by trans-esterification process. Different blends of diesel and Jatropha ethyl ester were premixed on a volume basis and stored in auxiliary tanks separately. Pure diesel and four Jatropha ethyl ester blends were used: 100% diesel (B0), 90% diesel with 10% Jatropha ethyl ester (B10), 80% diesel with 20% Jatropha ethyl ester (B20), 70% diesel with 30% Jatropha ethyl ester (B30) and 60% diesel with 40% Jatropha ethyl ester (B40). The substitution ratio of Jatropha ethyl ester with diesel beyond 40% was not done because it was observed that during trial run the engine performance was not smooth and engine sound was abnormal when the blending ratio was 50 % of Jatropha ethyl ester. The fuel properties of diesel, Jatropha ethyl ester and Jatropha ethyl ester blends used in the study are given in Table 1. Indexes determined in the experiments included viscosity, density, calorific value, cloud point, pour Point and flash point.

Table 1 Fuel characteristics of different blends/fuel

S.No	Fuel properties	Diesel (B0)	Crude Jatropha oil	Jatropha Ethyl Ester	Jatropha Ethyl Ester Blends			
					B10	B20	B30	B40
1.	Viscosity at 37°C, cS	4.38	38.33	7.33	5.16	5.66	5.83	6.00
2.	Density at 37°C, g cm^{-3}	0.83	0.93	0.87	0.84	0.85	0.85	0.86
3.	Calorific value, MJ kg^{-1}	42.9	32.62	35.77	41.47	40.39	39.52	39.08
4.	Cloud Point, °C	0.5	8.0	1.7	0.7	0.8	1.3	1.5
5.	Pour Point, °C	-7.8	4.0	-2.8	-7.2	-6.8	-6.3	-5.3
6.	Flash Point, °C	58.3	287.7	111.7	61.7	68.7	76.3	83.7

2.2 Experimental set-up

Tests were conducted at the Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana in India. A single cylinder, water cooled and 3.73 kW power, variable compression ratio engine was used for the test as is shown in (Figure 1).

This test bed has a provision to change its compression ratio by raising or lowering bore head of the engine. Various sensors are mounted on the engine to measure different parameters. The test bed is also equipped with all the control electrical, electronic computer and data acquisition system. For running the engine, the compression ratio of the engine was changed to the desired ratio. Engine was started manually. Loading and unloading was done through computer. All the measurements and calculations were done by the software loaded in the computer and the data was exported as CSV files, which could be opened using MS Excel for further analysis. Technical specifications of the engine are given in Table 2. A constant level of engine cooling water flow was maintained at more than 60 mL sec^{-1}. The standard fuel injection timing for the test engine was 23^o BTDC. Engine performance test was done using software 'Engine Test Express' (Figure 2). This software is highly integrated C language based software.

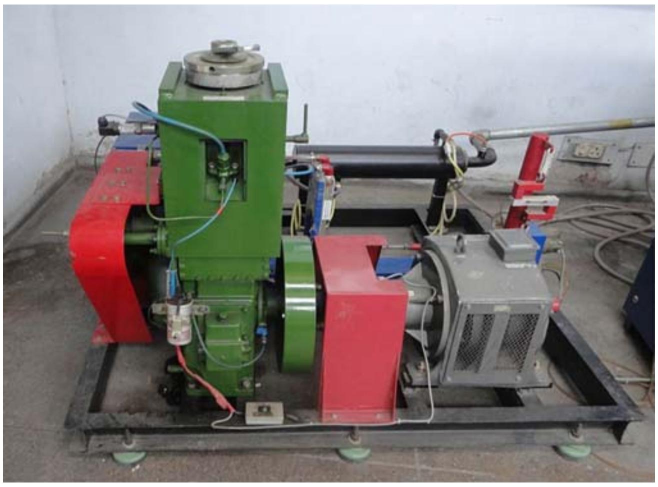

Figure 1   Variable Compression Ratio (VCR) engine

Table 2   Brief specification of Variable Compression Ratio (VCR) engine

S.No.	Parameter	Specification
1	Engine power	5 HP
2	Engine speed	1,350 to 1,600 rpm variable governed speed
3	Number of cylinders	One
4	Compression ratio	5:1 to 20:1
5	Bore, mm	80
6	Stroke, mm	110
7	Type of ignition	Spark ignition or Compression ignition
8	Method of loading	Eddy Current Dynamometer
9	Method of starting	Manual crank start

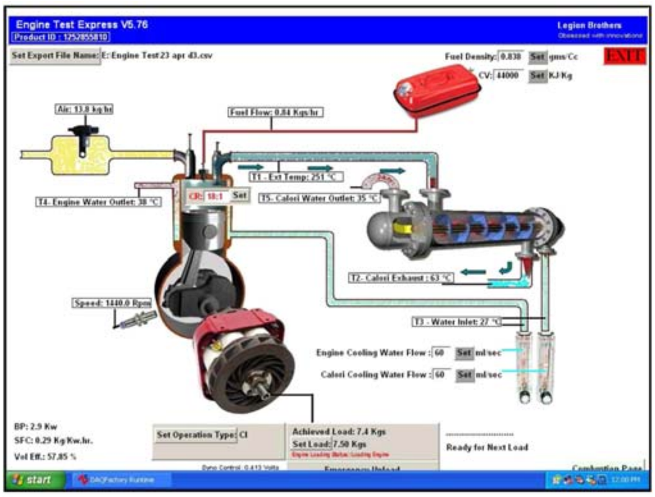

Figure 2   A screen view of software 'Engine Test Express'

2.3   Evaluation procedure

The engine was evaluated using different fuel blends of Jatropha ethyl ester and diesel fuel at loads of 0 (no load), 25, 50 and 75% of rated load at compression ratio of 16.5:1 and 18.5:1. Compression ratio of 16.5:1 is standard ratio for evaluating the performance of diesel engine and compression ratio of 18.5:1 was taken due to higher flash point of Jatropha ethyl ester blends. Higher compression ratio contributes better combustion of fuel at initial. The brake thermal efficiency, brake specific fuel consumption and exhaust gas temperature were measured and recorded.

3   Results and discussion

The performance results of the diesel engine for different blends of Jatropha ethyl ester and diesel fuel (B10, B20, B30 and B40) at two different compression ratios (16.5:1 and 18.5:1) are given below.

3.1   Brake thermal efficiency (B.Th.E)

The relationship between brake thermal efficiency of the engine on diesel and ethyl ester blends at different loads for two compression ratios is shown in Figure 3. For the compression ratio of 16.5:1, the brake thermal efficiency values at 75% of rated load were 30.65, 31.27, 31.46, 32.08 and 33.81 for diesel, B10, B20, B30 and B40 blends which shows that B40 blend has highest value for the biodiesel operation and is 3.15% more than that of neat diesel. Whereas for the compression ratio of 18.5:1, the brake thermal efficiency values at 75% of rated load were 31.02 and 32.39, 32.25, 33.17, 34.03 for diesel and

B10, B20, B30, B40 blends respectively. Increased efficiency with the increase percentage of Jatropha ethyl ester in the fuel might be due to increased fuel temperature as blends contain more oxygen. So, higher fuel temperature reduced its viscosity and might have reduced the ignition lag also, resulting in better combustion and hence increased efficiency. Increasing the compression ratio will increase the operating temperature and hence a increase in the brake thermal efficiency at higher compression ratios.

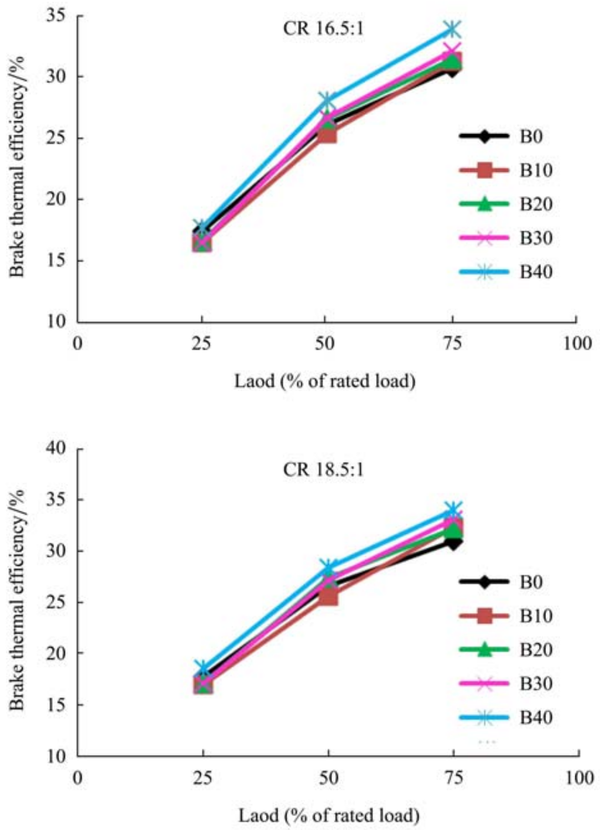

Figure 3 Brake thermal efficiency as a function of engine load at various compression ratios

3.2 Brake specific fuel consumption (BSFC)

The relationship between brake specific fuel consumption of the engine on diesel and ethyl ester blends at different loads for two compression ratios is shown in Figure 4. It can be observed that brake specific fuel consumption for the compression ratio 18.5:1 will be lesser than the 16.5:1. The energy required per kW is lesser when the compression ratio is higher in the test. At the compression ratio of 16.5:1, the brake specific fuel consumption of 0.267 kg kWh^{-1} was obtained for the diesel fuel at 75% of rated load. Due to lesser calorific values of blends (B10, B20, B30 and B40) fuels shows a brake specific fuel consumption of 0.271, 0.278, 0.274 and 0.281 kg kWh^{-1} respectively, at 75% of rated load. At a higher compression ratio of 18.5:1, the brake specific fuel consumption at 75% of rated loaded engine for diesel fuel is 0.263 kg kWh^{-1}, whereas that of B10, B20, B30 and B40 shows a brake specific fuel consumption of 0.266, 0.271, 0.273 and 0.277 kg kWh^{-1}, respectively. From above results, it was observed that at both the compression ratio i.e. 16.5:1 and 18.5:1, the brake specific fuel consumption in case of blends were slightly more than that of diesel fuel. It was due to the fact that in blends there was presence of biodiesel which has lower calorific value than diesel, which resulted in increase of brake specific fuel consumption.

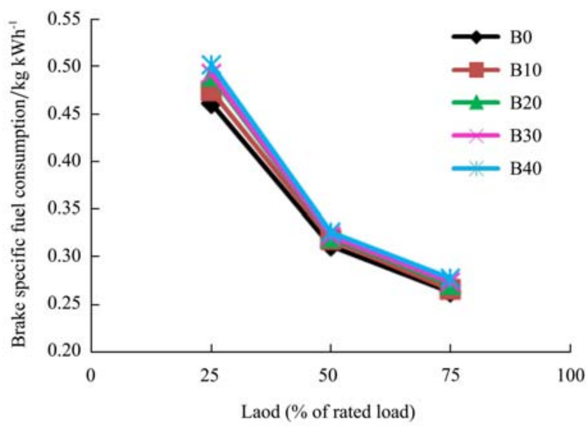

Figure 4 Brake specific fuel consumption as a function of engine load at various compression ratios

3.3 Exhaust gas temperature

The relationship between Exhaust gas temperature of the engine on diesel and ethyl ester blends at different load for two compression ratios (16.5:1 and 18.5:1) is shown in Figure 5. As shown in the figure 5 exhaust gas temperature increased with the increase in load Rise in exhaust temperature with increase in load could be attributed to increase in quantity of fuel injected. The increased quantity of fuel generated greater heat in combustion chamber. For all blends operations, the exhaust gas temperature is higher than the diesel. In blends operation the combustion is delayed due to longer physical delay period. As the combustion is delayed, injected blends fuel particles may not get enough time to burn completely before top dead centre. Hence, some fuel mixtures tend to burn during the early part of expansion and caused to increase in the exhaust temperature. At compression ratio of 16.5:1, the exhaust gas temperature value were 244.18, 262.86, 268.18, 271.03 and 290.10℃ for diesel, B10, B20, B30 and B40 blends, respectively. Whereas at compression ratio of 18.5:1, the exhaust gas temperature value were 286.65, 293.60, 311.92, 317.85 and 323.25℃ for diesel, B10, B20, B30 and B40 blends, respectively. It was due to fact that with the increase of load on the engine, the fuel intake increased which after combustion resulted in rise of the temperature of exhaust gas. For higher compression ratios, exhaust gas temperature also increased which may due to the higher operating temperature at higher compression ratios.

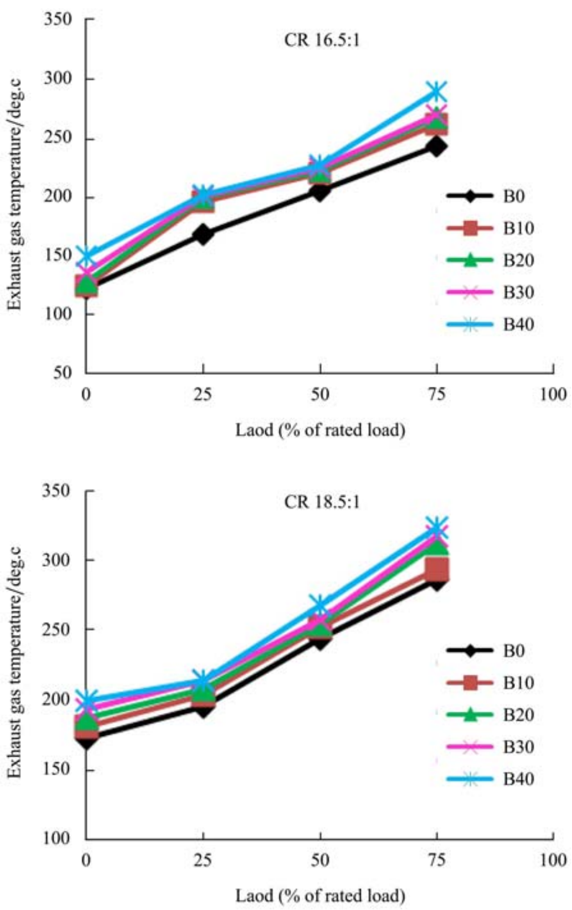

Figure 5 Exhaust gas temperature as a function of engine load at various compression ratios

4 Conclusions

The experimental conclusions of this investigation can be summarized as follows:

1) Brake specific fuel consumption was found to have minimum for pure diesel compared to ester blends at all loads as well as at two compression ratios. At 16.5: 1 compression ratio, the brake specific fuel consumption is increased for all the blends as compared to diesel whereas at 18.5:1 compression ratio. The blend suggests slightly better fuel economy.

2) The brake thermal efficiency was found to increase with the load as well as with the increase in compression ratio. B40 blend provided the maximum efficiency for blends operation for all compression ratios.

3) Exhaust gas temperature increased with the increase in load as well as with the increase in compression ratio for diesel and all blends.

Acknowledgements

The authors are thankful to the Head, Department of Farm Machinery and Power Engineering, for providing the necessary facilities.

Nomenclature

B10: 10% Jatropha ethyl ester + 90% Diesel
B20: 20% Jatropha ethyl ester + 80% Diesel
B30: 30% Jatropha ethyl ester + 70% Diesel
B40: 40% Jatropha ethyl ester + 60% Diesel
CO: Carbon monoxide
NOx: Nitric oxide
BSFC: Brake specific fuel consumption
B.Th.E: Brake thermal efficiency

References

[1] Agarwal, D., L. Kumar, and A. K. Agarwal. 2008. Performance evaluation of a vegetable oil fuelled compression ignition engine. *Renewable Energy*, 33(6): 1147-1156.

[2] Antolin, G., I. V. Tinaut, Y. Briceno, V. Castano, C. Perez, and A. I. Ramirez. 2002. Optimization of biodiesel

production by sunflower oil transesterification. *Bioresource Technology*, 83(2): 111-114.

[3] Baiju, B., M. K Naik, and L. M. Das. 2009. A comparative evaluation of compression ignition characteristics using methyl and ethyl esters of karanja oil. *Renewable Energy* 34(6): 1616-1621.

[4] Barnwal, B. K., and M. P. Sharma. 2005. Prospects of biodiesel production from vegetable oils in India. *Renewable and Sustainable Energy Reviews*, 9(4): 363-378.

[5] Bhatt, Y. C. 1987. Use of some non-edible vegetable oils as a source of energy for CI engines. Unpublished Ph.D. diss., IIT, Kharagpur, Nov 1987.

[6] Cheng, A. S., A. Upatnieks, and C. J. Mueller. 2006. Investigation of the impact of biodiesel fuelling on NOx emissions using an optical direct injection diesel engine. *International Journal of Engine Research*, 7(4): 297-318.

[7] Forson, F. K., E. K. Oduro, and E. H. Donkoh. 2004. Performance of jatropha oil blends in a diesel engine. *Renewable Energy*, 29(7): 1135-1145.

[8] Goodrum, J. W., and D. P. Geller. 2005. Influence of fatty acid methyl esters from hydroxylated vegetable oils on diesel fuel lubricity. *Bioresource Technology*, 96(7): 851-855.

[9] Ishii, Y., and R. Takeuchi. 1987. Transesterified curcas oil blends for farm diesel engines. *Transactions of the ASAE*, 30(3): 605-609.

[10] Kumar, S. M., A. Ranesh, and B. Naglingam. 2003. An experiment comparison of methods to use methanol and jatropha oil in a compression ignition engine. *Biomass and Bioenergy*., 25(3): 309-318

[11] Lapuerta, M., O. Armas, and J. R. Fernandez. 2008. Effect of bio-diesel fuels on diesel engine emissions. *Progress in Energy and Combustion Science*, 34(2): 198-223.

[12] Mcdonell, K. P., S. M. Ward., P. B. Menulty, and R. H. Hildige. 2000. Results of engine and vehicle testing of semi refined rapeseed oil. *Transactions of the ASAE*, 43 (6): 1309-1316.

[13] Peterson, C. L., R. A. Korus., P. G. Mora, and J. P. Madsen. 1987. Fumigation with propane and transesterification effects on injector coking with vegetable oil fuels. *Transactions of the ASAE*, 30(1): 28-35.

[14] Sinha, S., and A. K. Agarwal. 2006. Experimental investigation of the combustion characteristics of a biodiesel (rice–bran oil methyl ester)-fuelled direct-injection transportation diesel engine. *Proc. Instn. of Mech. Engrs.* Part D, *J. Automobile Engineering*, 221: 1575-1583.

[15] Srivastava, A., and R. Prasad. 2000. Triglycerides-based diesel fuel. *Renewable and sustainable energy Reviews*, 4(2): 111-133.

[16] Verma, S. R., and P. K. Gupta. 2000. Biodiesel as substitute for petroleum oil. *Agricultural Engineering Today*, 24 (3): 40-62.