Effect in Performance and Emission of Jatropha Biodiesel Added with DEE Fuelled in Electric Generator

Indraj Singh

***Abstract*— India consumed five times more diesel as compare to gasoline. India import 80% of crude oils. Mineral diesel is major source of environmental pollution because of SOx and NOx. Present research work deals with the production and characterization of diesel substitute as biodiesel from jatropha oil using trans-esterification process. Physio-chemical properties influence the performance and exhaust emission of compression ignition engine. Calorific value, density and other physio-chemical properties were tested. The performance of jatropha biodiesel (JBD) as a fuel was improved by adding DEE as additive and compare with mineral diesel fuel. Performance of compression ignition engine coupled with electric generator set was observed by adding 4% and 8% DEE as additive in JBD and compare with pure JBD and mineral diesel fuel at 1.5 kW, 3kW and 5kW load condition. Exhaust emission of compression ignition engine coupled with electric generator set was also recorded for JBD added with 4% and 8% DEE as additive and compare with mineral diesel fuel at 1.5kW, 3kW and 5kW load. A decreasing trend in CO and CO_2 emission of electric generator set were recorded when 4%and 8% DEE added as additive in JBD as compare to pure JBD under different load condition. NO_x Emission of electric generator set increases by adding 4% and 8% DEE as additive in JBD at different load condition. It is concluded that physio-chemical properties of pure JBD improves by adding 4% and 8% DEE as additive and become comparable to mineral diesel fuel. Overall performance of electric generator set fuelled with JBD adding DEE as additive improves as load increases and fuel consumption decreases at same load conditions. Thus, Jatropha biodiesel with 8% DEE as additive is recommended as a substitute of mineral diesel for compression ignition engine coupled with electric generator set.**

Index Terms*— Jatropha, biodiesel, di ethyl ether, overall efficiency, bsfc.

I. INTRODUCTION

Supply of petroleum oil is always under threat due to extensive depletion of petroleum reserve in present days and expected to face severe problems of various kinds in coming years. This has attracted the attention of major importing petroleum oil countries; India is one of them. The oil consumption is increasing exponentially day by day [1,2]. Presently, India imports nearly 80% of its total oil needs [1]. This accounts for about one third of its total imports. The total diesel sold in India during 2012-13 was 69,080 TMT and petrol 15,744 TMT, while diesel constitutes about 44% of total consumption of petroleum products in India, petrol accounts for about 10% [2,4]. There is 73.6% diesel consumption in transport sectors including three-wheeler passenger goods, buses, heavy commercial vehicle, light commercial vehicle, cars, and utility commercial vehicle [3,4]. Remaining consumption of diesel is in non-transport sector especially for the purpose of power generation and supply to mobile tower, industry purpose, operating agriculture pumps etc. The projected estimate of oil imports for the year 2016 stands at 190 MMT [4]. Thus, there is an urgent need to find out the alternative source of fuel to substitute mineral based fuel. In view of this, vegetable oil is a promising alternative because it has several advantages as it is renewable, environment-friendly and produced in rural areas. Obviously, the use of non-edible vegetable oils compared to edible oils is very significant because of the tremendous demand for edible oils as food and moreover they are expensive too [5,6]. New resources of non-edible oil are potential for the biodiesel preparations as substitute of diesel. India is the fastest growing economy of the world. There is a need of huge energy resources to maintain at least 8% GDP of the country. Edible oil finds its applications for various purposes as reported elsewhere [7], thus under present research work attempts were made to explore non-edible oil to be used as the potential substitute is of present day's requirement. Jatropha is one such plant that can be easily grown in the tropical regions including on Indian soil. Jatropha could be used as one of the best substitute available for production of biodiesel in India [8]. 40 % oil can be extracted from the jatropha seeds [9,10]. Physiochemical properties of jatropha is require to be improved by adding suitable additive like Di-ethyl ether. Performance and emission of compression ignition engine fuelled with JBD has the potential for improvements [11].

II. MATERIALS AND METHODS

Following materials and equipment were used to carry out the experimental work. Jatropha seeds were collected from local area of longowal. Biodiesel of Jatropha oil was produced by using the transesterification methods and fuel properties were tested in the laboratory of mechanical engineering department of SLIET, Longowal.

A. *Electric generator set coupled with C.I Engine*

Electric generator set comprising of three elements, Single cylinder 4-stroke, 7.4 kW, 1500rpm of kirloskar Compression ignition engine coupled with electric generator

Manuscript received April 10, 2017; revised April 18, 2017.
Indraj Singh, presently working as Associate Professor *in The Department of Mechanical Engineering, Sant Longowal Institute of Engineering and Technology, Longowal, (Deemed University under MHRD) Sangrur, Punjab, India 148106 (Phone number-01672253346, Email-indrajsliet@yahoo.co.in,)*

of 7.5 KVA, PF-0.8, RPM-1500 and 50Hz of Eurogen Italy and electric load.

B. Flue gas analyser kit (testo-340)

A flue gas analyzer kit, testo-340 was used. Flue gas analyzer kit has capability to measure exhaust gaseous O_2, CO, CO_2, NOx and flue gas temperature. This kit was used to measure O_2, CO, CO_2, and NOx and flue gas temperature of electric generator set for fuel mineral diesel, JBD, JBD with 4%DEE and JBD with 8% DEE at 1.5kW, 3kW, and 5kW load conditions.

C. Petroleum diesel

Mineral diesel was collected from the local petrol pump of longowal. Calorific value, density, and other physiochemical properties were tested.

D. Jatropha Biodiesel

Jatropha (Family-Euphorbiaceae, English-Purging Nut, Hindi-Bagberenda (Jatropha), Kannada- Adalu haralu, Kaadu Haralu) has been considered as most suitable for bio-diesel as the oil yields per hectare is among the highest of tree borne oil seeds. Its oil, being a potential substitute to diesel, it grows on gravely, sandy or saline soils and also on the poorest stony soils and rock crevices. Its water requirement is extremely low and withstands long periods of drought. It retains soil moisture and improves land capability and environment. The plant starts giving seeds in a maximum period of 2 years after planting. Seeds of Jatropha was collected from local area of longowal and oil was extracted by mechanical expeller. Oil of jatropha seeds was processed into biodiesel by using the transesterification methods.

E. Di Ethyl Ether

In this research work di ethyl ether is used as an additive with jatropha biodiesel to improve the fuel properties. DEE has low flash point, and viscosity. DEE contains 20% oxygen. So to enhance the performance and reduce the exhaust emission of electric generator set jatropha biodiesel was used with 4% and 8% DEE. Many sugar industries are available in India. Di ethyl ether can be produced from ethanol a by-product of sugar industry.

III. RESULTS AND DISCUSSION

Performance and exhaust emission of electric generator set coupled with compression ignition engine fuelled with Jatropha methyl ester and mineral diesel as fuels were observed and compare under 1.5kW, 3kW and 5kW load condition.

A. Fuel consumption vs power generated for jatropha biodiesel

Experiments conducted on compression ignition engine coupled with electric generator set fuelled with MD, JBD, JBD with 4%DEE and JBD with 8% DEE at load 1.5kW, 3kW and 5kW.As load increases fuel consumption also increases for fuel MD, JBD, JBD with 4%DEE and JBD with 8% DEE. Fuel consumption1465 g/h is lowest in case of mineral diesel used as fuel in comparison to JBD, JBD with 4%DEE and JBD with 8% DEE at 5kW load condition. Maximum 1610 g/h fuel consumption is observed when used JBD at 5kW load condition. Reason JBD have less calorific value as compare to mineral diesel. Calorific value of JBD with 4%DEE and JBD with 8% DEE also reported 9525kcal/Kg and 9410kcal/Kg which is also less than JBD and mineral diesel fuel as shown in fig.1. Some studies performed at the southwest research institute (USA) and described in [12] showed that fuel consumption with pure soybean biodiesel increased from 13% to 18% with respect to that with diesel fuel.

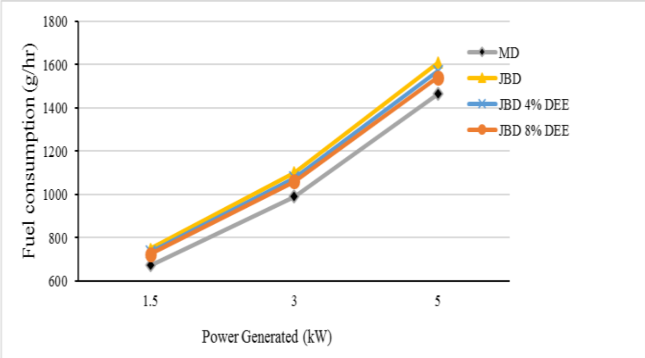

Fig. 1. Fuel consumption vs power generated

B. Bsfc vs power generated for jatropha biodiesel

It is noticed that Mineral diesel gives 293 g/kW-h least bsfc as compare to JBD, JBD with 4% DEE and JBD with 8%DEE. As DEE increases in JBD, bsfc decreased. JBD with 8% DEE gives 308 g/kW-h least bsfc as compare to JBD and JBD with 4%DEE. Justification of results with literature, Canakci and van gerpen [13] obtained about 2.5% on increases in bsfc from their test with 20% blends and 14% from those with pure biodiesel as shown in fig. 2.

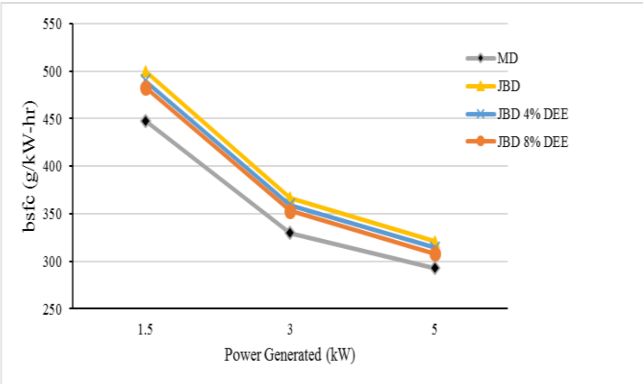

Fig. 2. Bsfc vs power generated

C. Overall efficiency vs Power generated for jatropha biodiesel

Overall efficiency of compression ignition engine coupled with electric generator was determined for 1.5kW, 3kW and 5kW load conditions by using JBD, JBD with 4% DEE and JBD with 8%DEE and compare with mineral diesel fuel. The overall efficiency of the generator operating on mineral diesel for1.5kW, 3kW and 5 kW constant loading condition were found to be 19.05%, 25.86% and 29.12% respectively.

However corresponding energy input to the generator were 673 g/h, 990 g/h and 1465g/h respectively. The overall efficiencies for JBD, JBD with 4% DEE and JBD with 8%DEE were found to be 27.82%, 28.75% and 29.67% respectively at 5kW load and shown graphically in fig. 3. However, by adding additive DEE in JBD overall efficiency increases but remain less than generator working on mineral diesel at 1.5kW, 3kW, and 5kW load condition. As DEE added in JBD from 4% to 8%, overall efficiency also increases from 28.75% to 29.67% as shown in fig. 3.

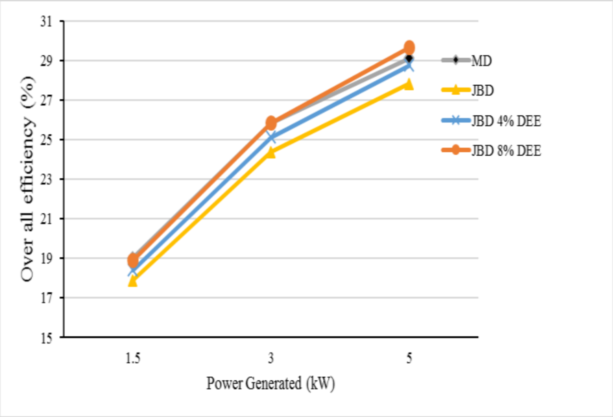

Fig. 3. Overall efficiency vs power generated

D. CO emission vs Power generated for jatropha biodiesel

CO emission of electric generator set was recorded in ppm for mineral diesel, JBD, JBD with 4%DEE and JBD with 8% DEE at 1.5kW, 3kW, and 5kW load conditions. Research revealed that CO emission decreases in case of JBD as compared to mineral diesel fuel. Maximum 92 ppm, 116ppm and 160ppm CO emitted from electric generator set used mineral diesel at 1.5 kW, 3kW and 5kW load condition respectively. Least 126 ppm CO emitted from electric generator set when used JBD with 8% DEE at 5kW load condition as shown in fig. 4. JBD contains more oxygen as compare to mineral diesel. Oxygen contains in JBD fuels increases when DEE added. Lower CO concentration in the exhaust line when oxygen in the combustion chamber was increased either with oxygenated fuels or oxygen enriched air[14].

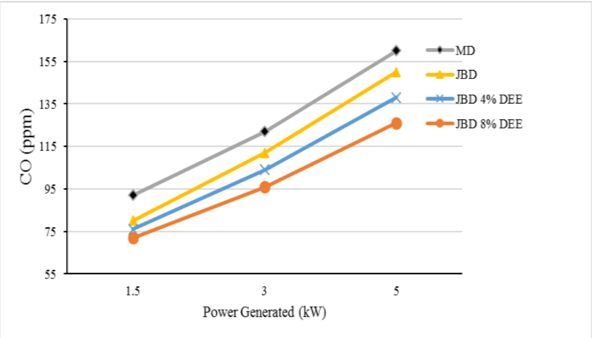

Fig. 4. CO emission vs power generated

E. CO_2 emission vs Power generated for jatropha biodiesel

CO_2 Emission from electric generator set was recorded for mineral diesel, JBD, JBD with 4% DEE and JBD with 8% DEE at 1.5 kW, 3kW and 5kW load conditions. It is observed that as load increases from 1.5kW to 5kW, CO_2 emission also increases for mineral diesel, JBD, JBD with 4% DEE, and JBD with 8%DEE.Compression ignition engine fueled with Jatropha biodiesel emits 2.37 % of CO_2 and when used mineral diesel fuel CO_2 emits 2.5% at 5kW load.

CO_2 emission from compression ignition engine coupled with electric generator set fueled with JBD increases as compare to mineral diesel from 2.5% to 2.37% at 5kW load. Research revealed that as DEE increases in JBD from 4% to 8%, CO_2 emission decreases 2.32% to 2.27% as shown in fig. 5. Reason- Oxygen present in Jatropha biodiesel is 11% and In DEE 21%. So, when 8% DEE added in Jatropha Biodiesel percentage of oxygen increases from 11% to higher and % of carbon decreases from 75% to lower. So, presence of low carbon in Jatropha biodiesel and JBD with 8% DEE responsible for decrease of CO_2.

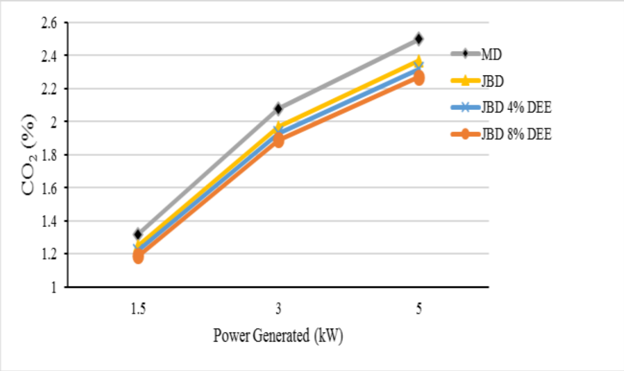

Fig. 5. CO_2 emission vs power generated

F. NOx emission vs Power generated for jatropha biodiesel

NOx emission from electric generator set was recorded for mineral diesel, JBD, JBD with 4%DEE and JBD with 8%DEE at 1.5kW, 3kW and 5kW load conditions by exhaust analyzer testo-340. It is noted, as load on electric generator set increases NO_X emission also increased for different fuels. Minimum NO_X emission recorded from electric generator set when used mineral diesel fuel as compare with JBD, JBD with 4%DEE and JBDwith8% DEE at 1.5kW, 3kW and 5kWload.Maximum NOx emission was recorded from electric generator set when used JBD with 8% DEE at all load as shown in fig. 6 JBD consume more fuel due to low calorific value. So, high temperature and high oxygen contains by biodiesel may be the reason of it. Justification of results with literature, this reasoning has been used by different author [15] to explain the resulting higher temperature peaks and NO formation rates. Some other authors are in agreements with the role of advanced injection in NOx emission increases [12].

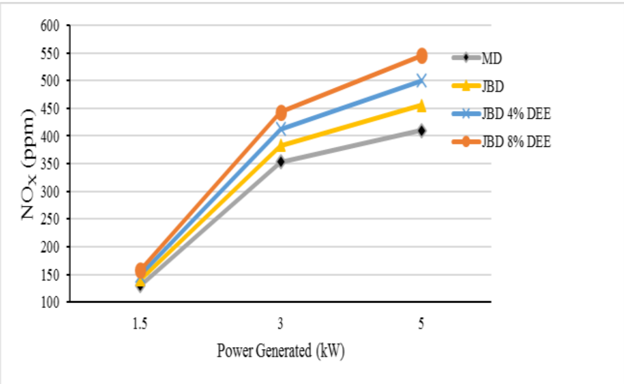

Fig. 6. NOx emission vs power generated

ISBN: 978-988-14048-9-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

G. Flue gas temperature vs Power generated for jatropha biodiesel

Flue gas temperature of electric generator set was also recorded for MD, JBD, JBD with 4% DEE and JBD with 8% DEE used as fuel at different load of 1.5kW, 3kW, and 5kW by using exhaust analyzer testo 340. Lowest 140^0C flue gas temperature of electric generator set was recorded for mineral diesel fuel as compared with 145 ^{0}C, 152 ^{0}C and 160^0C respectively for JBD, JBD with 4% DEE and JBD with 8%DEE at 5kW load condition. Calorific value of JBD diesel DEE has low viscosity and low flash point but it has low calorific value. There are more fuel consumption of JBD, JBD with 4%DEE and JBD with 8%DEE due to low calorific value. So flue gas temperature increases in case of JBD, JBD with 4%DEE and JBD with 8%DEE as shown in fig. 7.

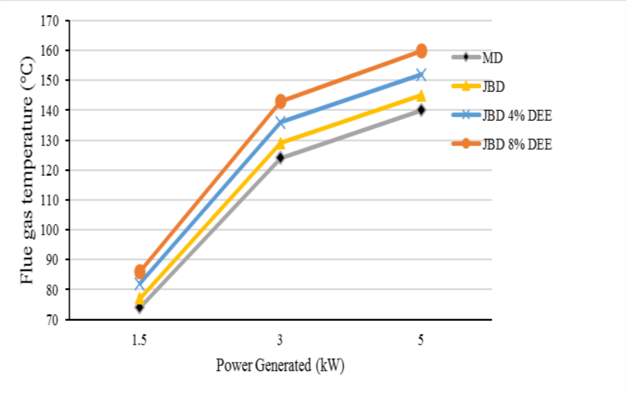

Fig. 7. Flue gas temperature vs power generated

IV. CONCLUSIONS

Lowest bsfc of 308 g/kW-hr was noted when electric generator fueled JBD with 8%DEE as compare with pure JBD at 5kW load condition. However, 295 g/kW-hr mineral diesel fuel is consumed at same load condition. There was an increasing trend in overall efficiency of electric generator was observed from 27.82%, 28.75% and 29.67% for fuel JBD, JBD with 4%DEE and JBD with 8% DEE respectively at load 5kW.CO emission from electric generator set reduces from 150 ppm to 126 ppm when 8% DEE was added in JBD for 5kW load. However electric generator emits 160 ppm CO when used mineral diesel as fuel at 5kWload. CO_2 emission from CI engine coupled with electric generator set fueled with JBD increases as compare to mineral diesel from 2.5% to 2.37% at 5kW load. It is concluded that as DEE increases in JBD from 4% to 8%, CO_2 emission decreases 2.32% to 2.27% NO_X emission from electric generator set increases from 455 ppm to 545 ppm when 8% DEE added in JBD for 5kW load. In case of mineral diesel used as fuel in electric generator set NO_X emits minimum at same load conditions. Highest 160 ^{0}C flue gas temperature of electric generator set was recorded for JBD with 8% DEE at 5 kW load condition. Lowest 140^0C flue gas temperature of electric generator set was recorded for mineral diesel fuel at 5kW load. JBD with additive DEE can be used to enhance the performance and reduce exhaust emission of electric generator set but NO_X emission increases.

Abbreviation

JBD-Jatropha biodiesel
DEE-Di-ethyl ether
Bsfc-Brake specific fuel consumption
MD-Mineral diesel
CI-Compression ignition
PPM-Part per million

REFERENCES

[1] Renewables Global Status Report, Renewable energy policy network for the 21 st century, Paris, France, 2014.
[2] BP Statistical Review of World Energy, June, 2013.
[3] Babu, M. K. Gajendra, Subramanian, K. A., "Alternative transportation fuels", Taylor &Francis, 2013.
[4] All India study on sectorial demand of diesel and petrol report, Petroleum Planning & Analysis Cell, India, 2013.
[5] Chauhan B.S., Kumar N., and Cho H.M, "Performance and emission studies on an agriculture engine on neat Jatropha oil", *Journal of Mechanical Science and Technology*, 24 (2), 529-535, 2010.
[6] Kawade G.H., Satpute S. T., and Parane K. A., "Optimization of CI Engine Performance Parameters for Jatropha Biodiesel Blending Fuel by Using ANN Software", *International Research Journal of Engineering and Technology*, 2, 1151-1156,2015,.
[7] Subramanian, M., Malhotra, R., and Kanal, P., "Performance Evaluation of Biodiesel – Diesel Blends in Passenger Car," *SAE Technical Paper* 2004-28-0088, 2004.
[8] S.N.Naik, L.M.Das, G.Sahu, M.K.Naik, "Optimization of biodiesel production from Karanja oil" *National Conference on biodiesel for IC engine technologies and strategies for rural application*, 2004.
[9] Dhar A. and Agarwal A.K., "Experimental investigations of the effect of pilot injection on performance, emissions and combustion characteristics of Karanja biodiesel fueled CRDI engine", *Energy Conversion and Management.*, 93, 357–366, 2015.
[10] Kumar N., "Jatropha curcus- A sustainable source for production of biodiesel", *Journal of scientific and industrial research*, volume 64, pp883-889, 2005.
[11] G.Sahu, S.Saha, S.Datta, Prakash, Chavan, B.K.Mall, B.K.Sharma and S.N.Naik, "Biodiesel production from jatropha curcas oil" *National Seminar on Promotion of Bio-Fuel for Sustainable Growth & its Impact on Climate Change.* Feb., 19th 2010.
[12] Senator A., Rocco V., and Prati M.V., "A comparative analysis of combustion process in D.I. Diesel engine fueled with biodiesel and diesel fuel". *SAE, paper* no 010691,2000.
[13] Canakci M, Van Gerpen JH, "Comparison of engine performance and emission for petroleum diesel fuel, yellow grease biodiesel and soybean oil biodiesel" *ASAE Annual International Meeting, 016050.*
[14] Rakopoulos, C., D., Hountalas, D., T., Zannis, T., C., Levendis, Y., A., "Operational and environmental evaluation of diesel engine burning oxygen-enriched intake air or oxygen- enriched fuels, a review", *International Society of Automotive Engineers*, 01; 29-24, 2004.
[15] Tat, M., E., Van, G., J., H. "Measurement of biodiesel speed of sound and its impact on injection timing" *National Renewable Energy lab*, NREL/SR-510-31462, 2003.

ISBN: 978-988-14048-9-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)