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Impact of Emission on Environment of Electric Generator Fuelled with Karanja (*Pongamia pinnata*) Biodiesel Adding Additive Di-Ethyl Ether

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ABSTRACT

In this research, biodiesel from karanja (*Pongamia pinnata*) oil was produced by transesterification process. Fuel properties of KBD, KBD with 4% DEE and KBD with 8% DEE were tested and compared with mineral diesel fuel. Additive DEE 4% and 8% was added in karanja biodiesel to improve the fuel properties. Electric generator set was fuelled with KBD, KBD with 4% DEE and KBD with 8% DEE operated at 1.5 kW, 3 kW and 5 kW load and performance was compared with mineral diesel fuel. Research revealed that in electric generator set increasing trend of overall efficiency and decreasing in BSFC were observed when 4% and 8% DEE was added in karanja biodiesel under different load conditions. A decreasing trend in CO and CO_2 emission of electric generator set was recorded when 4% and 8% DEE added in KBD as compared to pure KBD under different load conditions. NOx emission of electric generator set increases by adding 4% and 8% DEE in KBD at different load conditions. It is concluded that the overall efficiency of electric generator set improves, and exhaust emission reduces by adding additives in karanja biodiesel. Karanja biodiesel with additive 8% DEE is recommended as a substitute of mineral diesel for electric generator set.

INTRODUCTION

India is the fastest growing economy of the world. There is a need of huge energy resources to maintain 8% GDP of the country. Crude oil is one of the main energy resources. 80% crude oil is imported from other countries. In the transport sector, diesel consumption is maximum 32.5% in heavy commercial vehicle, light commercial vehicles followed by 15.1% private cars and utility vehicles. This huge variance in consumption is due to the large distances that are travelled by commercial vehicles vis-a-vis passenger vehicles. At all India basis, in the non-transport sector, diesel consumption is maximum 7.7% in tractors followed by 4.3% industry genset. Possible reason can be that, tractors are not necessarily used only for agricultural purposes. Today they are also used for commercial purposes, such as for transporting construction material such as bricks, stones and mined sand as well as other goods (BP 2013, REN21 2014). 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%. 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. 26.4% diesel consumption in non-transport sector including mobile tower, industry purpose, industry genset, agriculture pump, tractors and others. So researchers are forced to find out the alternate of diesel fuel for compression ignition engine (Petroleum Planning and Analysis Cell 2013). Biodiesel is one of them that can be used in compression ignition engine. Biodiesel was produced by transesterification process which is one of the popular methods of producing biodiesel (Agarwal 2015, Nizah 2014). Biodiesel can be produced by edible and non-edible oil. There is already a shortage of edible oil in India, so it is very necessary to find out the non-edible oil which has good growing potential in Indian soil. Karanja plant can be easily grown in Indian soil. Karanja is one of the best substitutes available for production of biodiesel in India. 40% oil can be extracted from the karanja seeds.

MATERIALS AND METHODS

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

Electric generator set coupled with C.I. engine: Single cylinder 4-stroke, 7.4 kW, 1500 rpm of Kirloskar compression ignition engine coupled with electric generator of 7.5 KVA, PF-0.8, RPM-1500 and 50 Hz of Eurogen Italy was used to produce the electric power. The schematic diagram of electric generator set coupled with a compression ignition engine is shown in Fig. 1.

Flue gas analyser kit (Testo-340): A flue gas analyser kit Testo-340 was used. Flue gas analyser kit has the capability to measure O_2, CO, CO_2, NOx exhaust gaseous 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, KBD, KBD with 4% DEE and KBD with 8% DEE at 1.5 kW, 3 kW, and 5 kW load conditions. The specifications of the kit, Testo-340 are presented in Table 1.

Mineral diesel: Mineral diesel was collected from the local petrol pump of Longowal. Calorific value, viscosity, flash point, fire point, cloud point, pour point were tested in laboratory and recorded.

Karanja biodiesel: Karanja (*Pongamia pinnata* Syn. *P. glabra*, *Derris indica*), Family-Papilionaceae, english-Indian beach, Hindi-karanja. *Pongamia pinnata* produces seeds containing 30-40% oil. It is often planted as an ornamental and shade tree. It is found to grow in areas with annual rainfall ranging from 500 mm to over 2500 mm. It is drought resistant. It occurs in a wide range of soil conditions, sandy and saline, clay soils, alkaline soils, but it does not grow well in very dry sand. It is indigenous throughout India from Himalayan foot-hills to Kanyakumari. Other than India, it grows in Srilanka, Malaysia, China and Tropical Australia. Fruits have a viability period of one year and seed number varies between 810 and 1410 per kilogram. Seeds of karanja were collected from local area of Longowal and oil was extracted by mechanical expeller. Oil of karanja seeds was processed into biodiesel by using the transesterification methods. Fuel properties of karanja biodiesel, viscosity and calorific value were tested and recorded as given in Table 2.

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

RESULTS AND DISCUSSION

Fuel properties: Fuel properties of mineral diesel, KBD, KBD with 4% DEE and KBD with 8% DEE are presented in Table 2. The calorific value of KBD, KBD with 4% DEE, KBD with 8% DEE was found to be 9460 kcal/kg, 9335 kcal/kg and 9225 kcal/kg. However calorific value of mineral diesel was 10080 kcal/kg and it is more than KBD, KBD with 4% DEE and KBD with 8% DEE.

Fuel consumption vs power generated: The effect of electric load on the fuel consumption for mineral diesel, KBD, KBD with 4% DEE and KBD with 8% DEE is shown in Fig. 2. There is a steady increase in fuel consumption of electric generator coupled with C.I. engine as the electric load increases to 1.5 kW, 3kW and 5kW. Maximum 1680 g/hr

Table 1: Flue gas analyzer diesel kit testo (340).

Parameters/ Technical Data	Measuring Range	Accuracy	Resolution	Reaction Time
O_2	0 to 25 Vol.%	±0.2 Vol.%	0.01 Vol.%	< 20 s
CO	0 to 10000 ppm	±10 ppm	1 ppm	< 40 s
CO_2	0 to CO, max	±0.2 Vol.%	0.1 Vol.%	< 40 s
NO	0 to 4000 ppm	±5 ppm (0 to 99 ppm) ±5 % of mv (100 to 1999 ppm)	1 ppm	< 30 s
NO_2	0 to 500 ppm	±10 ppm (0 to 199 ppm)	0.1 ppm	< 40 s
SO_2	0 to 5000 ppm	±10 ppm (0 to 99 ppm)	1 ppm	< 40 s
Temperature	-40 to +1200°C	±0.5°C (0 to +99°C)	0.1°C	-20s

Table 2: Performance and emission of electric generator for mineral diesel.

Fuel type	Calorific value (kcal/kg)	Specific gravity	Power generated load(kW)	Fuel consum-ption(g/hr)	bsfc (g/kW-hr)	Equivalent power consumption (kW-hr)	Overall efficiency (%)	CO PPM	CO_2 %	FGT °C	NOx PPM
MD	10080	0.820	1.5	673	448	7.88	19.03	92	1.32	74	130
MD	10080	0.820	3	990	330	11.60	25.86	122	2.08	124	353
MD	10080	0.820	5	1465	293	17.17	29.12	160	2.5	140	410

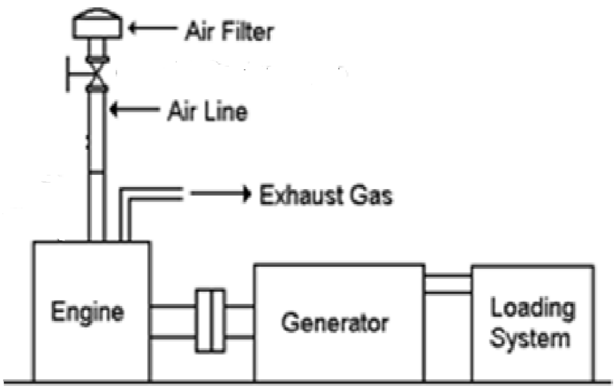

Fig. 1: Electric generator set.

karanja biodiesel fuel was consumed as compared to MD, KBD with 4% DEE and KBD with 8% DEE at 5 kW load. As 8% DEE additive was added in KBD, 4% fuel consumption decreased as compared to pure KBD at 5 kW load. The reason is that the DEE decreases viscosity and flash point, so the fuel gets atomized easily in a better way. Most of the studies found in the literature confirm that fuel consumption is on average similar to the loss of heating value, whether heavy duty or light duty engine tested. Some studies performed at the Southwest Research Institute (USA) and described in Senator (2000) showed that fuel consumption with pure soybean biodiesel increased from 13% to 18% with respect to that with diesel fuel.

Overall efficiency vs power generated: Overall efficiency of electric generator was determined for 1.5 kW, 3 kW and 5 kW constant load conditions by using KBD, KBD with 4% DEE and KBD with 8% DEE. The performance of electric generator was then compared with generator running purely on mineral diesel. The overall efficiency of the generator operating on mineral diesel for 1.5 kW, 3 kW and 5 kW constant loading conditions were found to be 19.05%, 25.86% and 29.12% respectively. However, corresponding energy input to the generator was 673 g/h, 990 g/h and 1465 g/h respectively. The overall efficiencies for KBD, KBD with 4% DEE and KBD with 8% DEE were found to be 27.05%, 27.99% and 28.86% respectively, at 5 kW load and shown graphically in Fig. 3. Overall efficiency of the generator working on pure KBD were found less than KBD with 4% DEE and KBD with 8% DEE. However by adding DEE in KBD overall efficiency increases but remains less than generator working on mineral diesel at 1.5 kW, 3 kW, and 5 kW load conditions. As DEE was added in KBD from 4% to 8%, overall efficiency also increases.

CO emission vs power generated: Exhaust analyser, Testo 340 was used to measure the exhaust emission. CO emission of electric generator set was recorded as 160 and 152 in ppm for mineral diesel and KBD at 5 kW load conditions. Research revealed that CO emission decreases in case of KBD with 8% DEE fuel as compared to mineral diesel fuel from 160 ppm to 138 ppm at 5 kW load. Least CO was emitted from electric generator set when KBD was used with 8% DEE as compared to only KBD and KBD with 4% DEE at the same load condition as shown in Fig. 4. KBD contains more oxygen as compared to mineral diesel. Oxygen contained in KBD fuels increases when DEE is added. The result is justified with the findings of Last (1995), who tested a heavy-duty engine with biodiesel from soya bean oil, and reported a slight decrease (14%) with respect to the reference diesel fuel. The reasons for the reduction of CO emission with biodiesel is that the additional oxygen content in the fuel, which enhances a complete combustion of the fuel, thus reducing emissions (Wedel 1999). For example, Rakopoulos (2004) reported lower CO concentration in the exhaust line when oxygen in the combustion chamber was increased either with oxygenated fuels or oxygen enriched air.

CO_2 emission vs power generated: CO_2 Emission from electric generator set was recorded for mineral diesel, KBD, KBD with 4% DEE and KBD with 8% DEE at different loads of 1.5 kW, 3 kW and 5 kW. It was observed that as load increases from 1.5 kW to 5 kW, CO_2 emission also increases for mineral diesel from 1.32% to 2.5%. Maximum 2.5% CO_2 was emitted from electric generator set when MD was used, as compared to KBD, KBD with 4% DEE and KBD with 8% DEE at 5 kW load condition as shown in Fig. 5. KBD with 8% DEE emits lowest 2.3% CO_2 at 5 kW load. The reason is that the karanja biodiesel with 8% di-ethyl ether contains maximum oxygen. Presence of excess O_2 in the fuel promotes complete combustion and results in increase of CO_2.

NO_x emission vs power generated: NOx emission from electric generator set was recorded for mineral diesel, KBD, KBD with 4% DEE and KBD with 8% DEE at 1.5 kW, 3 kW and 5 kW load conditions by exhaust analyser Testo-340. It is noted that, as load on electric generator set increases, NO_x emission also increases for different fuels. Minimum 410 ppm NO_x emission was recorded from electric generator set with mineral diesel fuel as compared to KBD, KBD with 4% DEE and KBD with 8% DEE at 5 kW load. Maximum 537 ppm NOx emission was recorded from electric generator set when KBD with 8% DEE at 5 kW load was used as shown in Fig. 6. Marshall et al. (1995) tested a Cummins L10E engine with pure biodiesel under steady condition reaching a 16% increase with respect to diesel fuel NO_x emissions. Reasons for the increase in NOx emission with biodiesel are that the combustion process is advanced and as a consequence of the advanced injection derived from the physical properties of biodiesel (viscosity, density, compressibility, sound velocity). Higher viscosity reduces leakages in the

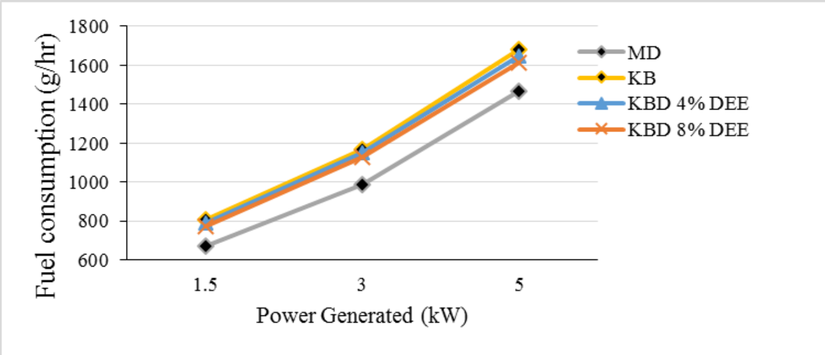

Fig. 2: Fuel consumption vs power generated.

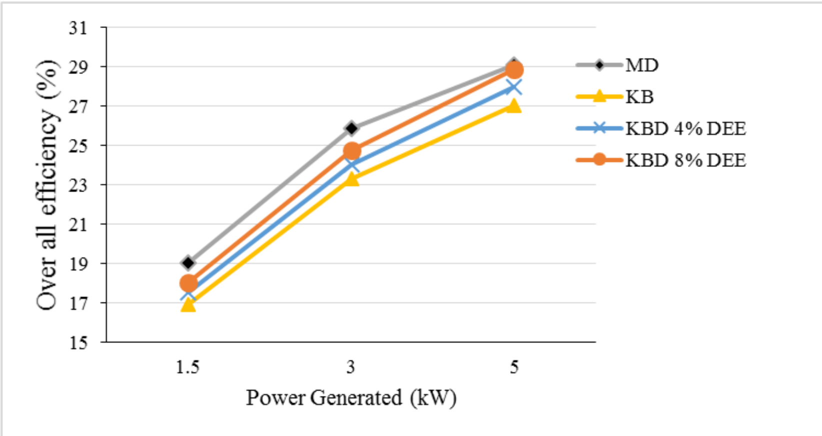

Fig. 3: Overall efficiency vs power generated.

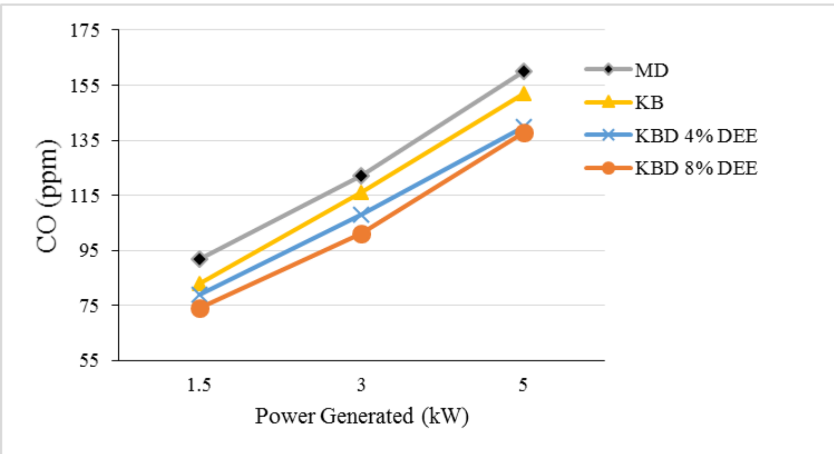

Fig. 4: CO emission vs power generated.

pump leading to an increase in the injection line pressure. Therefore, a quicker and earlier needle opening is observed with respect to the case of diesel fuel. This reasoning has been used by different authors (Tat 2003, Moneyem 2001) to explain the resulting higher temperature peaks and NO formation rates. Some other authors are in agreement with the role of advanced injection in NOx emission increase (Senator 2000).

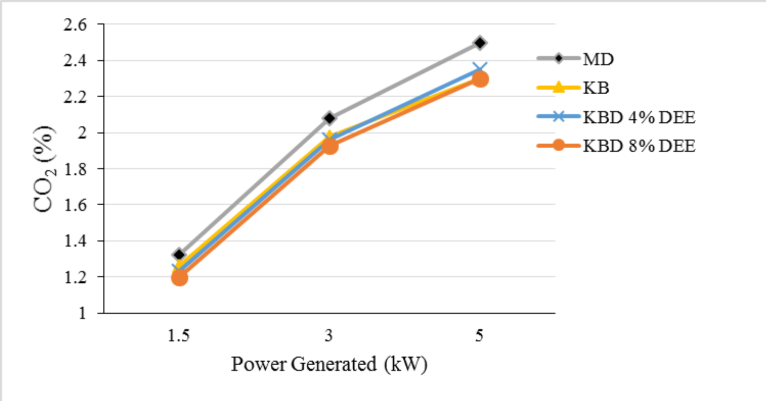

Fig. 5: CO_2 emission vs power generated.

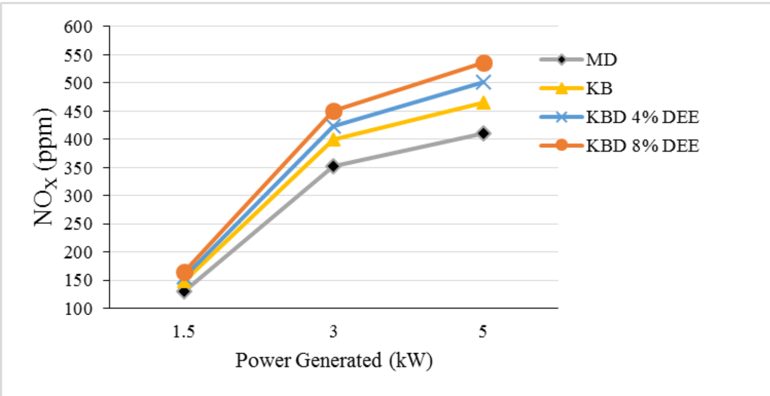

Fig. 6: NO_X emission vs power generated.

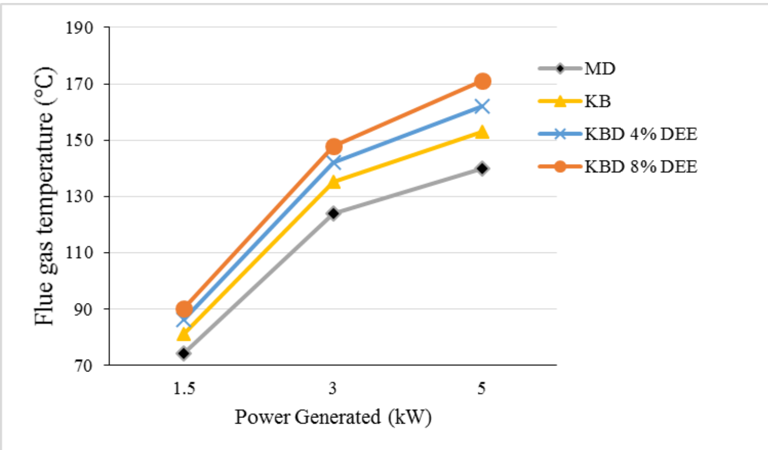

Fig. 7: Flue gas temperature vs power generated.

Flue gas temperature vs power generated: Flue gas temperature of the electric generator set was also recorded for MD, KBD, KBD with 4% DEE and KBD with 8% DEE at different loads of 1.5 kW, 3 kW and 5 kW by exhaust analyser Testo-340. Lowest 140°C flue gas temperature of electric generator set was recorded for mineral diesel fuel as compared to KBD, KBD with 4% DEE and KBD with 8% DEE at 5 kW load. Maximum 171°C flue gas temperature of the electric generator set was recorded for KBD with 8% DEE at 5 kW load condition. There are good physico-chemical properties of KBD with DEE i.e., low viscosity and low flash point. There is more fuel consumption of KBD, KBD with 4% DEE and KBD with 8% DEE due to low calorific value. So flue gas temperature increases in case of KBD, KBD with 4% DEE and KBD with 8% DEE as shown in Fig. 7.

Lower BSFC of 323 g/kW-hr was noted when electric generator fuelled with KBD with 8% DEE as compared to pure KBD at 5 kW 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 the electric generator observed from 27.05%, 27.99% and 28.86% for fuel KBD, KBD with 4% DEE and KBD with 8% DEE respectively, at same load of 5kW. CO emission from electric generator set reduces from 152 ppm to 138 ppm when 8% DEE was added in KBD for 5 kW load. However, electric generator emits 160 ppm CO when used with mineral diesel as fuel at 5 kW load. NO_X emission from electric generator set increases from 465 ppm to 537 ppm when 8% DEE was added in KBD for 5 kW load. In case of mineral diesel used as fuel in electric generator set, NO_X emits maximum at same load conditions. Highest 171°C flue gas temperature of electric generator set was recorded for KBD with 8% DEE at 5 kW load condition. Lowest 140°C flue gas temperature of electric generator set was recorded for mineral diesel fuel at 5 kW load. KBD with additive DEE can be used to enhance the performance and reduce the exhaust emissions of electric generator set, but the NO_X emission increases.

ABBREVIATIONS

MD- Mineral Diesel
KBD- Karanja biodiesel
DEE- Di-ethyl Ether
BSFC- Brake specific fuel consumption
PPM-Part Per Million
CI-Compression ignition

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