Indian Journal of Science and Technology, Vol 9(33), DOI: 10.17485/ijst/2016/v9i33/98071, September 2016
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Performance and Emission Analysis of Compression Ignition Engine Coupled with Electric Generator Set used Bakain Methyl Ester as Fuel

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Abstract

Objective: In this research article performance and exhaust emission of compression ignition engine coupled with electric generator set was analysed by using fuel bakain methyl ester as a new renewable energy source. **Methods/Statistical Analysis:** Seeds of Bakain, Family- Meliaceae, English-Persian lilac, Hindi- bakain were collected from local area of longowal and oil was extracted. Oil collected from Bakain seeds was transesterificated into Biodiesel. Fuel properties viscosity, calorific value, flash point and fire point of Bakain methyl ester were tested and recorded as per ASTM D. Electric generator set operated by compression ignition engine used Bakain methyl ester as fuel under different loading condition. **Findings:** Performance and exhaust emission of electric generator set operated by compression ignition engine used bakain methyl ester and mineral diesel were compared under 0.1 kW ,1.5 kW, 3kW and 5 kW load condition. There was slightly drop in overall efficiency of electric generator set when used bakain methyl ester as compare to mineral diesel fuel under same load condition. 2.77% less of overall efficiency drop of electric generator set was observed when used Bakain methyl ester as compare to mineral diesel fuel at 5 kW load. Electric generator set coupled with compression ignition engine consumed more bakain methyl ester as compare to mineral diesel fuel at same load condition. There was 96 gm/kW quantity of fuel consumed more when used bakain methyl ester as compare to mineral diesel fuel. Exhaust emission of CO, CO_2, NO_x and flue gas temperature of electric generator set were also recorded for bakain methyl ester and mineral diesel fuel under different load condition. Electric power generator set emitted 4 % more NO_x when used bakain methyl ester as fuel in comparison to mineral diesel at 5 kW load.8 % less carbon dioxide CO_2 emitted from electric generator set when used bakain methyl ester as fuel in comparisons to mineral diesel operated at 5 kW load condition. Higher flue gas temperature of electric generator set was recorded when used bakain methyl ester as compare to mineral diesel as a fuel at same load condition. **Application/Improvement:** Biodiesel from bakain seeds new renewable energy source can be produced and use as a fuel in compression ignition engine to generate electric power with slightly compromising power and less impact on exhaust emission.

Keywords: Bakain methyl ester, Emission, Fuel Property, Overall Efficiency, Transesterification

1. Introduction

There are limited resources of petroleum reservoirs available on the earth. Petroleum reservoirs are expected to be exhausted in next 50 years. Petroleum fuel increases exhaust emission and has impact on environment. India imports 80% of petroleum from other countries[1]. In India, there is five times mineral diesel consumes as compare to gasoline fuel. Mineral diesel is also used to generate electric power. In India there is a shortage of electric power[2,3]. So there is an urgent need for suitable alternative fuels available from local resources for use in compression ignition engine. Indian government planned to use up to 20% blend biodiesel with mineral diesel. Biodiesel can be

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produced by edible and non-edible oil[4,5]. In India there is already shortage of edible oil. In view of this, nonedible vegetable oil is a good option as an alternative fuel because it has several advantages[6]. It is renewable, environment friendly and can be produced easily in rural areas, where there is an acute need for modern forms of energy[7,8]. There are different methods for reducing viscosity of vegetable oils such as preheating, blending and transesterification[9].

Bakain is one of new resource of energy. Bakain trees are distributed all over from arid to moist tropics. It grows on a variety of soils, from sandy to clay including black cotton soils[10]. It grows well on flat ground with high subsoil water level. It tolerates temperature ranging from 0 °Cto 40°C. It also possesses certain amount of drought hardiness and thrive in extremely low rainfall of 130 mm annually. It is medium sized tree, upto12 m in height. Fruits one seeded drupes 1 cm with woody endocarp, greenish yellow when ripe. As the edible oil prices are increasing day by day so that researchers are focussing on non-edible oils[11,12]. It is a plant growing almost throughout Asia.

2. Material and Methodology

Following materials and equipment were used to carry out the experimental work. bakain seeds were collected from local area of Longowal. Biodiesel of bakain oil was produced by using the transesterification methods and fuel properties were tested. Experiments were performed in the month of March 2016, local temperature 27°C was recorded.

2.1Electric generator set coupled with Compression Ignition Engine

Electric generator set of 7.5kVA, PF-0.8,RPM-1500 and 50 Hz specification coupled with Single cylinder 4-stroke, 7.4 kW, 1500rpm, air cooled kirloskar compression ignition engine was used to conduct the experiments. The schematic diagram of experimental set up is shown in Figure 1.

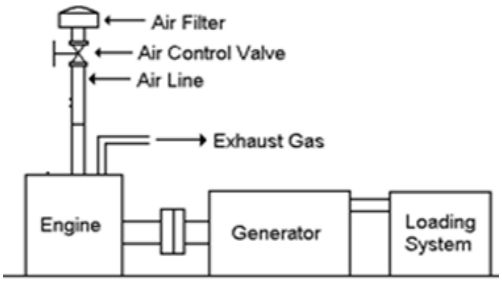

Figure 1. Schematic diagram of Electric generator set.

2.2 Flue Gas Analyser Kit (testo-340)

To observe the environment impact of electric generator set coupled with compression ignition engine, a flue gas analyser kit testo-340 was used. Flue gas analyser kit has capability to measure O_2, CO, CO_2, NO_x exhaust gaseous and flue gas temperature. Specification of flue gas analyser kit is shown in Table 1.

2.3 Mineral Diesel

In India consumption of mineral diesel observes five times more as compare to gasoline. Maximum consump-

Table 1. Flue gas analyser (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 max CO_2	±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	-20 s

tion of mineral diesel is being used in transport, irrigation and power sector. Mineral diesel was collected from the local petrol pump Longowal. Fuel properties were tested and recorded as shown in Table 2.

2.4 Bakain methyl ester

Family- Meliaceae, English-Persian lilac, Hindi- Bakain. It grows on a variety of soils, from sandy to clay including black cotton soils. It grows well on flat ground with high sub-soil water level. It tolerates temperature ranging from 0°C to 40°C. It also possesses certain amount of drought hardiness and thrive in extremely low rainfall of 130 mm annually. It is medium sized tree, upto12 m in height. Fruits one seed drupes 1 cm with woody endocarp, greenish yellow when ripe. Seeds of bakain were collected and moisture removed. To extract oil from seeds of bakain oil mechanical expeller was used. Transesterification methods of biodiesel production was used to produce biodiesel from the oil of bakain seeds. Physiochemical properties of bakain methyl ester and mineral diesel were tested as per ASTM D. Viscosity, density, flash point, fire point and calorific value of bakain methyl ester were recorded and found comparable to mineral diesel as shown in Table 2.

3. Result and Discussion

Performance analysis of electric generator set coupled with compression ignition engine fuelledwith bakain methyl ester and mineral diesel as fuels were observed and compare under different load condition.

3.1 Performance and Exhaust Analysis of Electric Generator Set

Electric generator set attached with compression ignition engine fuelled with mineral diesel and bakain methyl ester was run on ideal load condition till the system reach in steady state position. Experiments were conducted on electric generator set attached with compression ignition engine for electric power generation at 0.1, 1.5 kW, 3 kW and 5 kW load conditions

Performance and exhaust emission of electric generator set coupled with compression ignition engine used mineral diesel and bakain methyl ester were compare and analyses under different load condition. Data of overall efficiency and fuel consumption of electric generator set coupled with compression ignition engine used mineral diesel and bakain methyl ester as fuel were recorded under 0.1 kW ,1.5 kW, 3kW and 5 kW load condition. Exhaust emission O_2, CO, CO_2, NO_x and flue gas temperature of electric generator set coupled with compression ignition engine fuelled with mineral diesel and bakain methyl ester as fuel were also recorded under same load conditions.

3.1.1 Power generated vs Overall Efficiency

Experiments were conducted to produce electric power from electric generator set coupled with compression ignition engine used mineral diesel and bakain methyl ester as fuel and operated at different load. Equivalent amount of energy spent in terms of fuel consumed by compression ignition engine to produce electric power was recorded and overall efficiency. Overall efficiency of the electric generated set decreases in case of bakain methyl ester used as fuel as compare to mineral diesel at different load condition as shown in Figure 2. Research revealed, There is a drop of 2.77% overall efficiency of the electric generator set when used bakain methyl ester as fuel in comparison to mineral diesel as shown in Figure 2. Less calorific value and high viscosity may be reason of it.

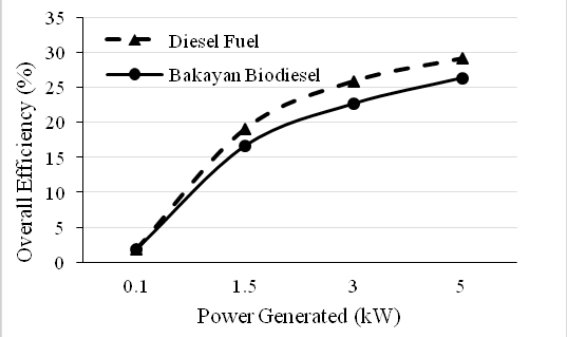

Figure 2. Overall Efficiency vs electric power generated.

Table 2. Physiochemical properties

Fuel/Properties	Viscosity (cst) ASTM D 445	Density (Kg/m^3) ASTM D 941	Flash Point (°C) ASTM D 92	Fire Point (°C) ASTM D 92	Calorific Value (kcal/kg) ASTM D 240
Mineral Diesel	2.91	820	58	64	10080
Bakain Oil	35	950	205	214	9250
Bakain Methyl Ester	5.5	890	176	180	9125

3.1.2 Power Generated vs Fuel Consumption

Electric power produce by electric generator set coupled with compression ignition engine used mineral diesel and bakain methyl ester as fuel and operated at different load condition. Fuel consumption recorded and compare for mineral diesel and bakain methyl ester. It is observed that fuel consumption increases as load increased at different load as shown in Figure 3.

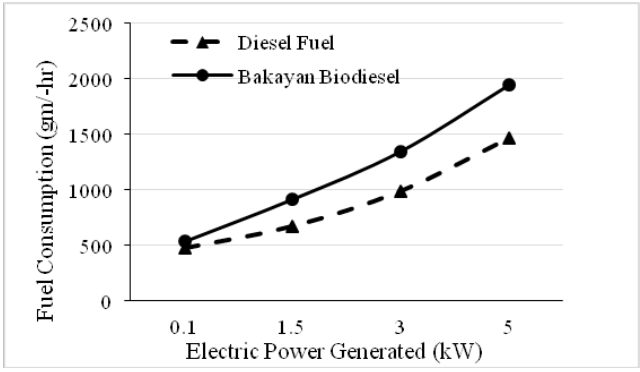

Figure 3. Fuel Consumption (gm/-hr) vs electric power generated.

Specific fuel consumption of bakain biodiesel and mineral diesel decreases when load increased. Research revealed that there is a 389 g/kW-hr specific fuel of bakain methyl ester consumed at 5 kW load conditions. More bakain biodiesel was consumed as compare to mineral diesel when used in compression ignition engine coupled with generator set at 5 kW load as shown in Figure 3. It is due to low calorific value of bakain methyl ester.

3.1.3 Power Generated vs CO_2 Emission

To observe the impact on environment, exhaust emission of electric generator set fuelled with mineral diesel and bakain methyl ester. Flue gas analyser (testo-340) was used to measure exhaust emission CO_2, CO, NO_x and flue gas temperature. It is observed that CO_2 pollutant increases as load increased in both cases when bakain methyl ester and mineral diesel used as fuel under different load condition as shown in Figure 4. % of CO_2 emission per kW-hr decreases as load increased from 0.1 kW to 5kW on electric generator set when fuelled with mineral diesel and bakain methyl ester as fuel.CO_2 emission per kW-hr is less when bakain methyl ester used as fuel as compare with mineral diesel. In case of bakain methyl ester used as fuel, lowest CO_2 0.46%per kW emitted from electric generator set at 5 kW load condition as shown in Figure 4.

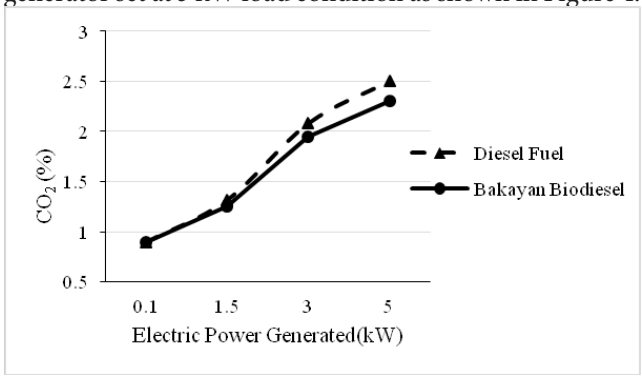

Figure 4. Emission of Carbon dioxide vs electric power generated.

3.1.4 Power generated vs CO emission

It is shown in Figure 5. that emission of carbon monoxide increases as electric load increased on compression ignition engine coupled with generator set. Further research revealed that emission of carbon monoxide in case of bakain methyl ester used as fuel in electric generator set increases less as compare to mineral diesel. It observed that emission of carbon monoxide was 6% less when bakain methyl ester used as a fuel in compression ignition engine coupled with generator set in comparison to mineral diesel at 5 kW load conditions. Carbon monoxide is emitted due to less oxygen present during combustion

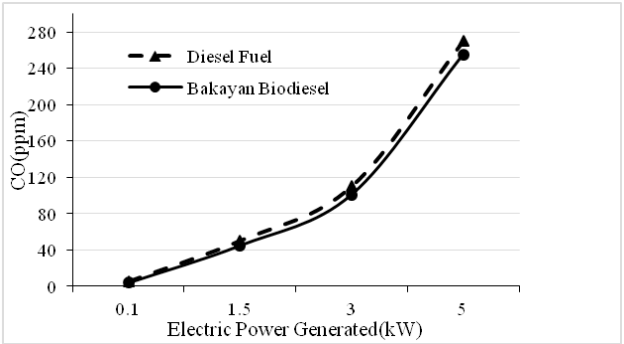

Figure 5. Emission of Carbon monoxide vs electric power generated.

process. Present of oxygen in bakain methyl ester may be the reason of less carbon monoxide emission.

3.1.5 Power Generated vs NO_x Emission

Emission of NO_x from electric generator set was recorded by flue gas analyser kit. It was noticed that as load increases emission of NO_x also increased in both fuel case. More NO_x emitted in case of bakain methyl ester used as fuel in electric generator set as compare to mineral diesel. It was observed that compression ignition engine coupled with generator set emitted415ppmof NO_x when used bakain methyl ester as a fuel at 5kW load conditions as shown in Figure 6. Interesting data ppm/kW was also observed and found lowest value 83ppm/kW at 5 kW load condition when used bakain methyl ester as a fuel.

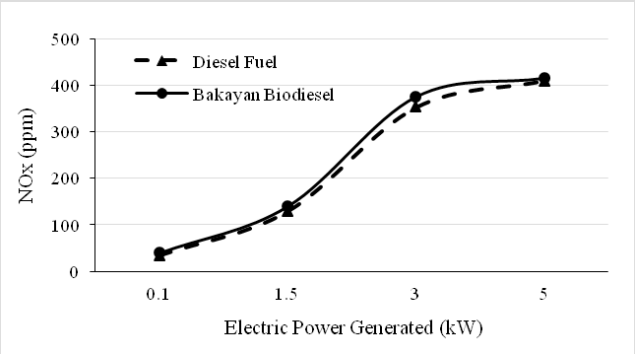

Figure 6. Emission of NOx vs electric power generated.

3.1.6 Power generated vs Flue Gas Temperature

Flue gas temperatures of compression ignition engine coupled with generator set was also recorded for using of bakain methyl ester and mineral diesel as a fuel under different loading condition. As load increased flue gas temperature also increases for bakain methyl ester and mineral diesel as trend shown in Figure 7. Higher flue gas temperatures of 145℃ was observed when used bakain methyl ester as fuel as compare to 130 ℃ temperature of mineral diesel used as a fuel in compression ignition engine coupled with generator set at 5kW load condition as shown in Figure 7. Lower calorific value of bakain methyl ester and more fuel consumption is the reason of higher flue gas temperature.

4. Conclusion

Based on the results of the research work carried out on used of bakain methyl ester and mineral diesel as fuel in compression ignition engine coupled with electric generator set for production of electric power, the following specific conclusions were drawn. The fuel properties of bakain methyl ester such as, viscosity, flash point, fire point, specific gravity and calorific value were found within the limits and comparable to mineral diesel.

Slightly drop in overall efficiency of electric generator set were recorded when used bakain methyl ester as compare to mineral diesel under different load. There was a 2.77 % of overall efficiency drop in case of bakain methyl ester used as fuel in comparison to mineral diesel at 5 kW load condition.

It is concluded that fuel consumption of electric generator set used bakain methyl ester and mineral diesel increases when load increased. Specific fuel consumption decreases on increased of electric load. Research revealed that specific fuel consumption 389 g/kW-hr was noted when used bakain methyl ester as fuel at 5 kW load conditions.

8 % less carbon dioxide was emitted from compression ignition engine coupled with generator set used bakain methyl ester as a fuel in comparison to mineral

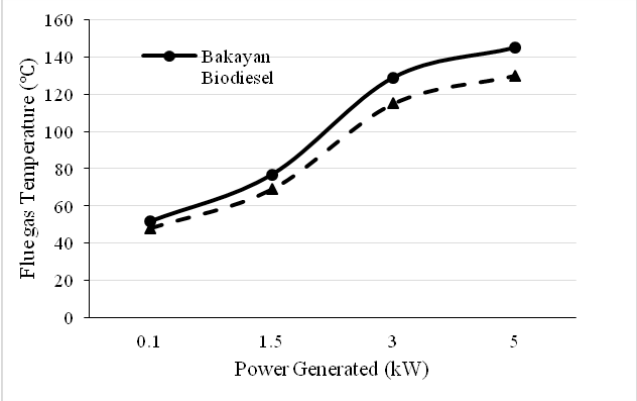

Figure 7. Flue gas temperature vs electric power generated.

diesel at 5 kW load condition. Less emission rate of carbon dioxide0.46 % per kilowatt (CO_2%/kW) is observed for bakain methyl ester as compare to 0.5 for mineral diesel from electric generator set at 5 kW load condition.

6% less carbon monoxide emitted into atmosphere from electric generator set used bakain methyl ester as compare to mineral diesel fuel at 5 kW load.

Electric generator set emitted 4 % more NOx when used bakain methyl ester as compare to mineral diesel fuel at 5 kW load condition.

Higher flue gas temperature of compression ignition engine coupled with electric generator set was recorded 145℃ when used bakain methyl ester as compare to mineral diesel as a fuel at 5 kW load condition.

It is concluded that electricity can be generated by using of bakain methyl ester as a local renewable energy source in compression ignition engine coupled with electric generator set without modification in engine with small sacrificing power output and less impact of exhaust emission on environment .It can be used as an option to generate the power especially in rural area of south east Asia with less impact on environment. However overall efficiency drop can be improved by use of suitable additive in bakain methyl ester.

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