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Performance and Emission Characteristics of Karanja (*Pongamia Pinnata*) Biodiesel and Its Blends in a Diesel Engine

KEYWORDS: Alternate fuel, diesel engine, karanja biodiesel, exhaust emissions

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ABSTRACT *A 3.7 kW diesel engine was fuelled with diesel and karanja biodiesel blends and its performance and emission characteristics were studied. The parameters such as specific fuel consumption (SFC), brake thermal efficiency (BTE) and exhaust emissions of carbon dioxide (CO2), carbon monoxide (CO), oxides of nitrogen (NOx) and oxygen were measured and compared with diesel. With 100% biodiesel, the specific fuel consumption was 340, 304 and 287 g/kWh at 1.5, 2.0 and 2.5 kW load conditions. The per cent increase in brake thermal efficiency of engine with karanja biodiesel blends (B20 to B80) ranged from 0.94 to 5.83% higher than diesel fuel. The exhaust gas temperature increased with increase in loads and quantity of biodiesel in its blends. The CO2 emission from 100 % biodiesel was slightly higher than that of diesel. The CO reduction and increase in NOx emission by biodiesel were 15 to 17 % and 19 to 29 % respectively as compared to diesel at tested load conditions.*

Biodiesel contains oxygen, which leads to complete combustion in internal combustion (IC) engines. Biodiesel can be used in the existing diesel engines without any modification and can mix readily with diesel at any blending level (Srivastava & Prasad, 2000). Certain edible oils such as cottonseed, palm, sunflower, rapeseed, and safflower can be used in diesel engines. For longer life of the engines these oils cannot be used straightway. These oils are not cost effective to be used as an alternate fuel in diesel engines at present. Some of the non-edible oils such as castor, rice bran, linseed, karanja, jatropha, neem, madhuca, rubber, etc. can be used in diesel engines after some chemical treatment. The viscosity and volatility of these vegetable oils is higher, and these can be brought down by a process known as "transesterification".

Many researchers have used biodiesel of madhua oil (Puhan et al., 2005), linseed oil (Deepa et al., 2007), cottonseed (Ali et al., 2008), Hazelnut oil (Ceviz et al., 2011) and reported the performance and emission characteristics in diesel engines. The objective of this paper is to investigate the performance and emission characteristics of a single cylinder, 4 stroke, constant speed, water cooled diesel engine with karanja biodiesel and four different blends of karanja biodiesel with diesel (B_{20}, B_{40}, B_{60} and B_{80}) and compared with diesel fuel.

EXPERIMENTAL SET-UP

A 3.7 kW diesel engine (4-stroke, constant speed, water cooled, direct injection) was selected for investigation to evaluate the performance and emissions for selected fuels. The engine was coupled with a DC compound generator. Experiments were conducted using diesel and biodiesel blends at 1.5, 2.0 and 2.5 kW generator output at the rated speed of 1500 rpm. The parameters selected for the study were specific fuel consumption (SFC), brake thermal efficiency (BTE) and exhaust emissions like carbon dioxide (CO_2), carbon monoxide (CO), oxides of nitrogen (NO_x) and oxygen (O_2) and results compared with diesel fuel. A KM900 exhaust gas analyzer was used to determine the composition of exhaust gases. The ambient and exhaust gas temperatures were recorded using a k-type thermocouple attached with KM900 exhaust gas analyzer.

RESULTS AND DISCUSSIONS

i. Specific fuel consumption

The SFC for karanja biodiesel alone (B_{100}) were found to be 340, 304 and 287 g/kWh at 1.5, 2.0 and 2.5 kW load conditions respectively. The increase in SFC of biodiesel blends (B_{20} to B_{80}) ranged from 1 to 8, 1 to 6 and 1 to 10% higher than that of diesel at 1.5, 2.0 and 2.5 kW loads (Figure 1). The percent increase in SFC increased with decreased quantity of diesel in the blended fuels. The reason for increase in fuel consumption is due to higher density and lower heating value of the biodiesel as compared with diesel fuel.

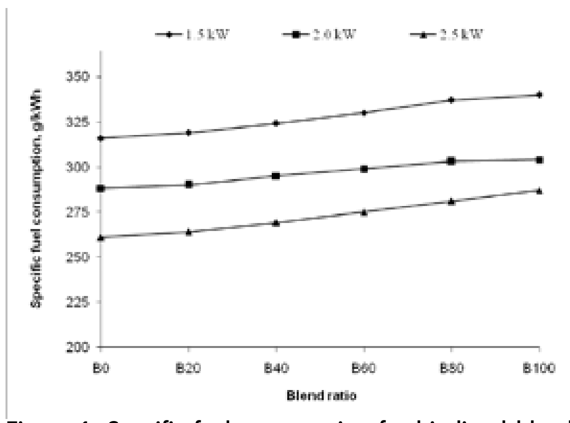

Figure 1. Specific fuel consumption for biodiesel blended fuels at different loads

ii. Brake thermal efficiency

The BTE of the engine when operating with karanja biodiesel alone (B_{100}) were 26.59, 29.78 and 31.56% at three load conditions tested (Figure 2). Maximum BTE of 31.56% was noted for biodiesel, which was 31.05% for diesel. The BTE of biodiesels was found to be 1 to 6% higher than that of diesel and there was no significant difference between the biodiesel and its blended fuel efficiencies.

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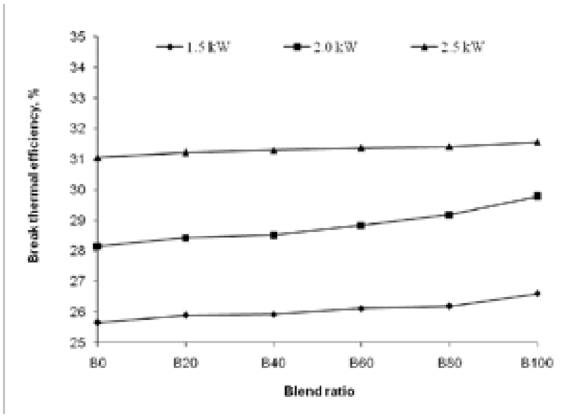

Figure 2. Brake thermal efficiency for biodiesel blended fuels at different loads

iii. Emission profile

The exhaust emission of diesel engine with different blends of karanja biodiesel was monitored with exhaust gas analyzer and results are presented in the table 1.

Fuel type	Exhaust gas temperature, °C			Carbon dioxide (CO_2) emission, %			Carbon monoxide (CO) emission, ppm			NOx emission, ppm			Oxygen (O_2) emission, %		
	1.5 kW	2.0 kW	2.5 kW	1.5 kW	2.0 kW	2.5 kW	1.5 kW	2.0 kW	2.5 kW	1.5 kW	2.0 kW	2.5 kW	1.5 kW	2.0 kW	2.5 kW
B_0	184	220	280	8.5	7.7	6.3	748	701	514	1850	1888	1935	14.8	13.1	11.5
B_{20}	187	245	292	8.7	8.1	6.4	662	648	499	1918	1929	2016	14.8	13.2	11.7
B_{40}	189	258	293	8.8	8.3	6.4	652	628	485	2002	2071	2162	14.8	13.3	11.7
B_{60}	189	286	320	9.4	8.4	6.5	646	620	454	2140	2186	2221	14.9	13.3	11.7
B_{80}	190	298	330	9.6	8.5	6.7	644	611	445	2183	2257	2272	14.9	13.4	11.8
B_{100}	201	308	347	10.1	8.9	6.9	637	596	428	2202	2313	2487	15.0	13.5	11.9

Table 2. The exhaust emission of diesel engine with different blends of karanja biodiesel and loads

From the table 1, the exhaust gas temperature was observed to be higher in karanja biodiesel fuel mode by 17, 88 and 67°C as compared with diesel fuel mode and rise in temperature found with increase in quantity of biodiesel in blends. The exhaust gas temperature varied between 187 and 201, 245 and 308 and 292 and 347°C for karanja biodiesel blends (B_{20} to B_{80}) at 1.5, 2.0 and 2.5 kW loads. The exhaust gas temperature increased with increase in load and quantity of biodiesel in blended fuels. This may due to higher ignition delay, which may results in delayed combustion of the fuels.

The CO_2 emission at 1.5, 2.0 and 2.5 kW loads was noted as 10.1, 8.9 and 6.9% for biodiesel whereas that of diesel fuel was 8.5, 7.7 and 6.3 %. For the biodiesel blended (B_{20} to B_{80}) fuels, CO_2 emission increased from 2 to 19, 5 to 16 and 2 to 10% at 1.5, 2.0 and 2.5 kW load conditions. For 1.5, 2.0 and 2.5 kW loading conditions, the CO emission was noted as 637, 596 and 428 ppm for biodiesel whereas it was 748, 701 and 514 ppm for diesel fuel. For the biodiesel blended (B_{20} to B_{80}) fuels, CO emission decreased from 662 to 637, 648 to 596 and 499 to 428 ppm at 1.5, 2.0 and 2.5 kW load conditions.

The NO_x emissions increased with increase in biodiesel quantity in the blends and also the NO_x emission from the biodiesel alone was found to be higher than diesel. NO_x emissions under selected tested load conditions were noted as 2202, 2313 and 2487 ppm for karanja biodiesel, whereas it was 1850, 1888 and 1935 ppm for diesel fuel. For the biodiesel blended (B_{20} to B_{80}) fuels, the NO_x emission increased from 1918 to 2202, 1929 to 2313 and 2016 to 2287 ppm at 1.5, 2.0 and 2.5 kW load conditions. It is seen that with increase in the quantity of biodiesel in the blends, there was an increase in NO_x emission. Several reasons associated for the increased NO_x emission from biodiesel, i) formation of NO_x depends upon the oxygen availability and combustion temperatures (Sharma *et al.*, 2009) and ii) During combustion of biodiesel in the engine, the oxygen present in fuel oxidizes the nitrogen, which led increasing NO_x emissions (Serdari *et al.,* 2000).

The O_2 emissions from the diesel engine were reduced with increase in load. Maximum O_2 emission was noted as 15% for karanja biodiesels alone (B_{100}) at 1.5 kW whereas that of diesel fuel was 14.8%. For the biodiesel blends (B_{20} to B_{80}), the O_2 emission increased from 14.8 to 15.0, 13.2 to 13.5 and 11.7 to 11.9 % at 1.5, 2.0 and 2.5 kW load conditions.

CONCLUSIONS

Performance and emission characteristics were conducted on karanja biodiesel fuelled diesel engine at an injection pressure 240 bar, the following conclusions are drawn based on the test results:

- Karanja biodiesel alone, the SFC was 8, 6 and 10% higher than that of diesel at 1.5, 2.0 and 2.5 kW loads. The corresponding BTE were found to be slightly higher than that of diesel fuel at tested load conditions and there was no significant difference between the biodiesel and its blended fuels efficiencies.
- For karanja biodiesel and its blended fuels, the exhaust gas temperature increased with increase in loads and biodiesel quantity. The highest exhaust gas temperature was observed as 201, 308 and 347°C for biodiesel alone at 1.5, 2.0 and 2.5 kW loads.
- The CO_2 emission from the biodiesel fuelled engine was slightly higher than that of diesel fuel. The carbon monoxide reduction by biodiesel was 15, 15 and 17% respectively at 1.5, 2.0 and 2.5 kW load conditions.
- The NOx emission from biodiesel was 19 to 29 % higher than that of the diesel fuel at the tested three load conditions.

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