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Research Paper :

Performance study of diesel engine by using karanja methyl ester (biodiesel) and its blends with diesel fuel

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ABSTRACT

The results of the performance of a compression ignition engine (direct injected, 4-stroke 2-cylinder engine) by using karanja methyl ester from non-edible vegetable oil (*Pongamia glabra*) and its blends with diesel fuel have been presented in this paper. Short-term engine performance tests were conducted using four different blends of karanja methyl ester oil with diesel fuel from 20% to 100% by volume at three fuel temperatures (30, 50 and 70^0-C) and at two injection pressures (17640 kPa and 24010 kPa). The engine performance parameters studied were power output, brake specific fuel consumption (BSFC), brake thermal efficiency (BThE) and exhaust gas temperature (ExGT) by using diesel fuel alone and the above mentioned blend fuels. The performance of engine with blend fuel (20% karanja methyl ester and 80% diesel) was found to be better than the other blend fuels. But the values of power output, BSFC, BThE and ExGT in case of blend fuel B20 (20% karanja methyl ester and 80% diesel) were observed to be, respectively 3% more, 9% more, 12%more and 0.5% less than the diesel fuel at 70^0-C temperature and 24010 kPa pressure. The karanja methyl ester (blends of B20) can be used as an alternative diesel fuel replacement with little sacrifice in brake specific fuel consumption.

Key words : Vegetable oil fuel, Alternative fuel, *Pongamia glabra*, Karanja methyl ester (biodiesel), Diesel blend

Among the alternate fuels for the petroleum fuel, vegetable oil esters (biodiesel) have gained good promise and suitability for their use in compression ignition engine (Srivastava and Prasad, 2004). Biodiesel is a 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. According to the report entitled "comprehensive analysis of biodiesel impacts on exhaust emissions" published by Environmental Protection Agency, US (2002), biodiesel fuel burns up to 70% cleaner with 93% lower total HC, 50% lower CO and 45% lower particulate matter in comparison with conventional diesel fuel (China *et al*., 2005).

The 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 vegetable oils for diesel engine (Bhatt, 1987). With the abundance of forest and tree-borne non-edible oils available in India, not much attempt has been made to use the esters of these non-edible oils as the alternative fuels for diesel engine. Karanja (*Pongamia glabra*) is one of the forest based tree-borne non-edible oils with large production potential of about 90 million tones per annum in India (Das,2005). The karanja tree belongs to the genus *Pongamia*. The tree, its seed and flowers have been very useful in Indian economy for a long time. The flowering season extends from February to April. The kernel of karanja fruit contains about 30-40% of oil. The oil yield is 20-30 % in village ghanis (indigenous mill) and 25 to 35 % in expeller. The fresh extracted oil is yellowish orange to brown and rapidly darkens on storage. It has a disagreeable odour and bitter taste. As this tree grows mainly in forest area and also in waste and fallow land, its cultivation would not produce any impact on food production but would in long way improve the environmental condition by massive aforestation. Therefore, an attempt is made in this paper to study the feasibility of karanja methyl ester and its blends with diesel fuel for a compression ignition engine.

METHODOLOGY

Tests were conducted at the Department of Farm Machinery and Power, Orissa University of Agriculture and Technology, Bhubnaneswar, Orissa, India. A 2-cylinder, four stroke, direct injected, water cooled and 7.4 kW power at 1500 rpm with injector pressure of 17640 kPa diesel engine was selected for the test. Tests were done on a laboratory test bench which consisted of a hydraulic dynamometer, a water tank, exhaust gas temperature measuring system and engine mounting elements as shown in Fig.1.

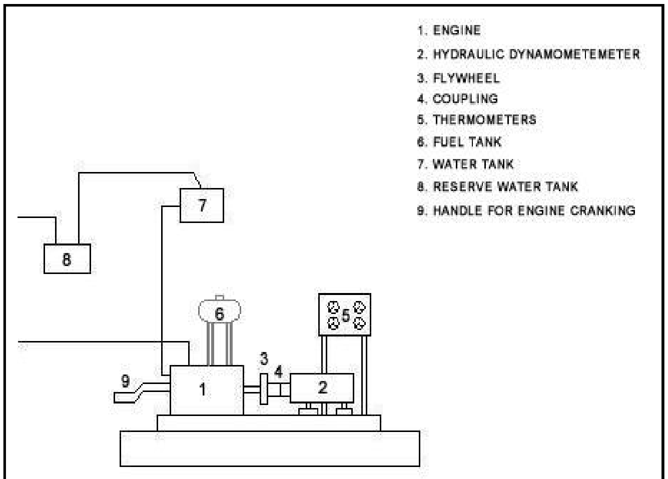

Fig. 1 : Schematic layout of experimental set up

Karanja methyl ester from non-edible karanja oil (*Pongamia glabra*) was selected for the study. Esterification of karanja oil is composed of heating of oil, addition of KOH and methyl alcohol, stirring of mixture, separation of glycerol, washing with distilled water and heating for removal of water. Karanja oil was esterified using the esterification system developed in the laboratory of Farm Machinery and Power Department, O.U.A.T., Bhubaneswar. The fuel properties of karanja oil, karanja methyl ester and diesel have been presented in Table 1. The basic composition of any vegetable oil is triglyceride, which is ester of three fatty acids and one glycerol. Blends of karanja methyl ester with diesel fuel were prepared on volume basis. The ester was mixed with the diesel in the proportion of 20, 40, 60 and 100 % on volume basis. For example, B0 indicates blend karanja methyl ester (0%); diesel (100 %), B20 (Karanja methyl ester 20% and diesel 80%), etc. and B100 (Karanja methyl ester 100% and diesel 0 %) on volume basis. An electrical heating unit was used to heat the fuel and its blends to the desired temperature to reduce the viscosity of vegetable oil which is more viscous than diesel resulting in poorer atomization. Constant speed short-term performances tests were conducted to compare the suitability of the blend fuels with diesel fuel. The baseline test was conducted using diesel fuel alone for its comparison with the performance of alternative fuel blends. The following parameters were selected for the study: engine speed, 1500 r/min; fuel temperature, 30^0C, 50^0C and 70^0C; injection pressure, 17640 kPa and 24010 kPa. The three ranges of fuel temperatures like low (30^0C), medium (50^0C) and high (70^0C) were taken to study the engine performance with the increasing fuel temperatures as viscosity of vegetable oil decreases with increase in temperature resulting good atomization of fuel. The engine was started and run till it attained the speed little higher than 1500 rpm. Then the speed was adjusted exactly to 1500 rpm by adjusting the fuel control lever. The load on the engine was gradually applied with the help of a spring balance (100 g x 20 kg). The speed for all the observations was kept constant at 1500 r/min. For the stabilization of measuring parameters at each load change and at the start of each test a time period of 10 minutes and 20 minutes was, respectively allowed. Three readings were taken for each set of observations at minimum of three load settings to get a reasonable value. One set of observations consists of measurements relating to (i) net weight on the torque arm, (ii) time for 50 cc of fuel consumption, (iii) reading for the exhaust temperature, (iv) coolant temperature, (v) fuel temperature and fuel injection pressure. The ambient air temperature and barometric pressure were also recorded. From the recorded set of observations, the following parameters were calculated to predict and compare the engine performance such as (i) brake power output in kW, (ii) engine specific fuel consumption (ESFC) in kg/kW-h and (iii) exhaust gas temperature (ExGT) in ^{0}C. These performance parameters were compared for all fuel blends at three-fuel temperatures and two- injection pressures. The original injection pressure of the injector of the engine is 17640 kPa. The engine created problem in proper atomization of the fuel during testing and that was why the injection pressure was changed to 24010 kPa for improved atomization. The engine test was done according to BIS: 5994-11 (Anon, 1979).

Table 1 : Fuel properties of karanja oil, karanja methyl ester and diesel (IS: 548). 1997

Fuel	Kinematic viscosity at 38 ^{0}C (cS)	Density at 21 ^{0}C (kg/m^3)	Flash point (^{0}C)	Pour point (^{0}C)	Heating value (MJ/kg)
Karanja oil	45.3	0.941	256	13	38.3
Karanja methyl ester	12.4	0.881	160	11	40.7
Diesel	6.8	0.849	74	- 4	47.4

RESULTS AND DISCUSSION

The power output for the blends (B_0, B_{20}, B_{40}, B_{60} and B_{100}) at two different fuel injection pressures (17640 kPa and 24010 kPa) has been presented in Fig. 2 and 3. The power output increased with the increase of operating temperatures and pressures for all the blends. But the power output showed a decreasing trend from B_{20} to B_{100} at a particular temperature and pressure. The maximum power output at 70^{0}C and 24010 kPa was found to be 7.20 kW in B_{20} followed by 7.13 kW for B_{40}, 7.10 kW for B_{60}, 7.0 kW for B_0 and minimum (6.90 kW) for B_{100}. However, the power outputs in case of B20 and B_{100} were found to be 3% more and 1.5% less than the reference diesel fuel, respectively. The increased power output with the increase of temperatures may be due to the better atomization of the blends because of their reduced viscosities at higher temperatures. The increase in power output with the increase in injection pressure may be due to the improved atomization. The decreasing trends in power output is from B_{20} to B_{100} for the increase in the percentage of karanja methyl ester oil in diesel because of lower energy input of vegetable oils than that of diesel. It may also be due to poor atomization of vegetable ester for its higher viscosity.

Similarly the effect of fuel temperatures on engine specific fuel consumption (ESFC) for the blends at above mentioned injection pressures has been depicted in Fig. 4 and 5. The results showed that with the increase in the fuel temperatures and injection pressures, ESFC decreased in all the blends of fuel. But ESFC showed a increasing trend from B_{20} to B_{100} at a particular temperature and pressure. The minimum ESFC at 70^{0}C and 24010 kPa was found to be 0.23 kg/kWh in pure diesel followed by 0.25 kg/kWh for B_{20}, 0.26 kg/kWh for B_{40}, 0.26 kg/kWh for B_{60} and maximum (0.27 kg/kWh) for B_{100}. Similarly the ESFC in case of B_{20} and B_{100} were

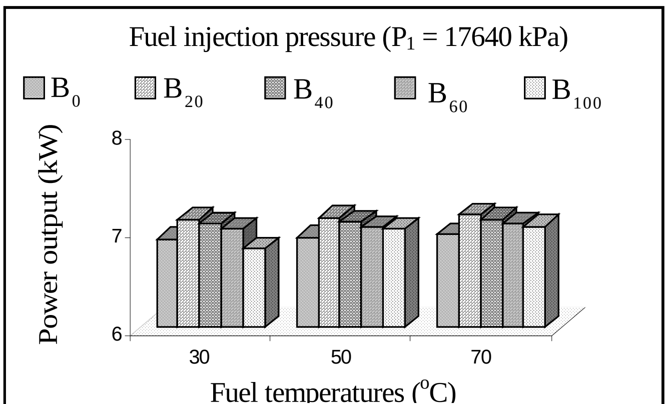

Fig. 2 : Effect of fuel temperature on power output for different blends of karanja methyl ester with diesel at 17640 kPa injection pressure

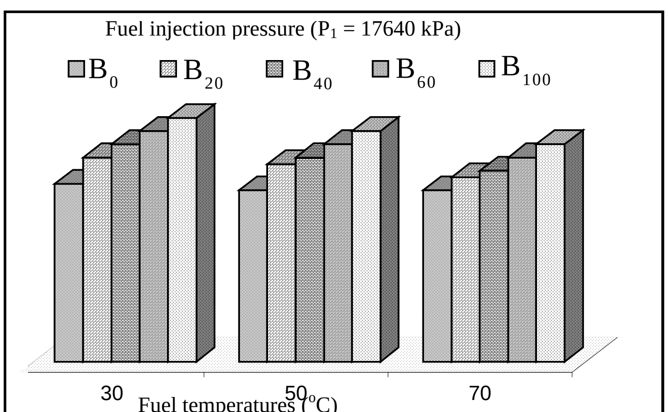

Fig. 3 : Effect of fuel temperature on power output for different blends of karanja methyl ester with diesel at 24010 kPa injection pressure

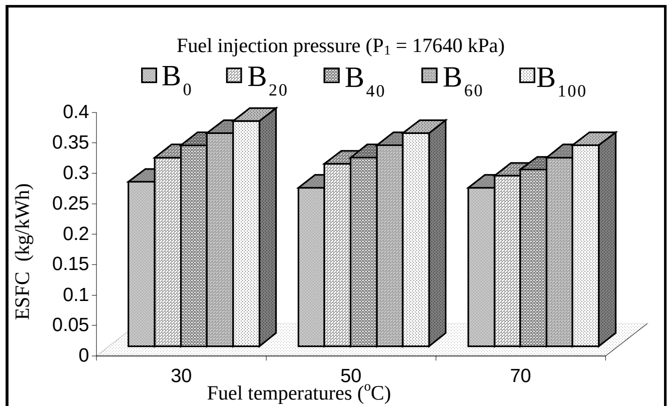

Fig. 4 : Effect of fuel temperature on engine specific fuel consumption for different blends of karanja methyl ester with diesel at 17640 kPa injection pressure

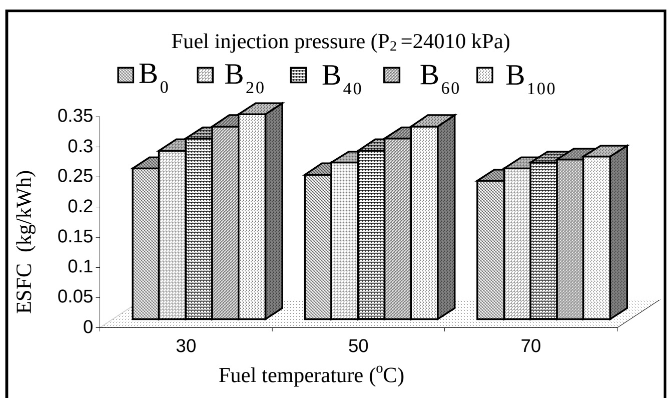

Fig. 5 : Effect of fuel temperature on engine specific fuel consumption for different blends of karanja methyl ester with diesel at 24010 kPa injection pressure

found to be 9% and 17% more than the reference diesel fuel, respectively. The ESFC increase may be due to the lower heat content of the karanja methyl ester oil than diesel fuel. Increasing in injection pressure decreased the ESFC and it might be due to the improved burning quality of finer injection sprays. By increasing the fuel temperatures, viscosity decreased and enhanced flowability and finer atomization of blends, which results in decreased ESFC.

The relationship between exhaust gas temperature (ExGT) and fuel temperatures for different blends at different fuel injection pressures has been shown in Fig. 6 and 7. The results showed that with the increase in the fuel temperatures and injection pressures, ExGT increased in all the blends of fuel. But ExGT showed an increasing trend from B_{20} to B_{100} at a particular temperature and pressure. The minimum ExGT at 70^0C and 24010 kPa was found to be 156.8^0C in B_{20} followed by 157.5 ^{0}C for B_0, 159.3^0C for B_{40}, 160.5 ^{0}C for B_{60} and maximum (162^0C) for B100. Similarly the ExGT in case of B_{20} and B_{100} were found to be 0.5% less and 4% more than the reference diesel fuel, respectively. The increase in ExGT with increase in fuel temperature and pressure may be attributed to the increased cylinder pressure due to improved combustion of fuel as a result of improved atomization. The increase in ExGT with increase in the proportion of karanja methyl ester may be due to the delayed combustion. This may also be due to the slower combustion characteristics of karanja methyl ester. The results obtained in this study are in confirmation with the results reported by Shyam *et al.* (1984).

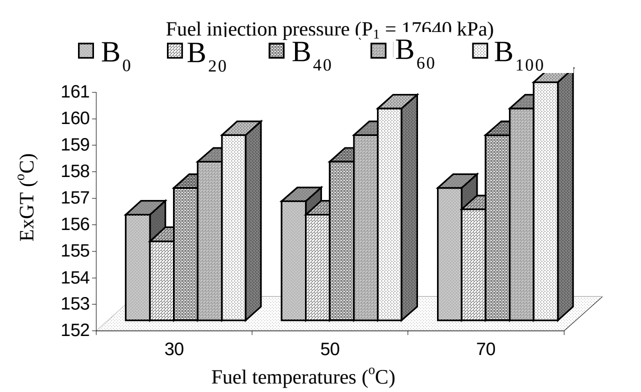

Fig. 6 : Effect of fuel temperature on exhaust gas temperature for different blends of karanja methyl ester with diesel at 17640 kPa injection pressure

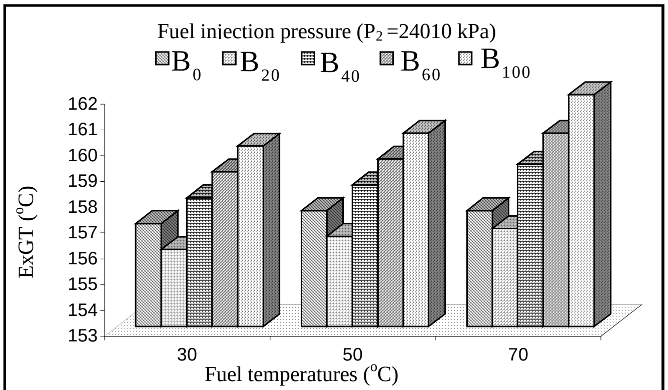

Fig. 7 : Effect of fuel temperature on exhaust gas temperature for different blends of karanja methyl ester with diesel at 24010 kPa injection pressure

Conclusion:

From the results of the experimental investigation, the following conclusions are drawn:

– Injection pressure and fuel temperature were found to have significant effects on the engine performance.

– The power output, engine specific fuel consumption (ESFC) and exhaust gas temperature (ExGT) of the engine under test increased with the decrease, increase and increase, respectively of the concentration of karanja methyl ester in the blends.

– The power output, ESFC and ExGT of the engine increased with the increase, decrease and decrease (but non-significant), respectively of the fuel temperatures and operating pressures.

– The performance of the engine with B_{20} blend fuel was found to be at par with the diesel fuel for short-term engine test.

– On an average, the values of power output, ESFC and ExGT of the blend B_{20} were found to 3% more, 9% more and 0.5 % less than the pure diesel fuel, respectively.

– Karanja methyl ester can be used as a substitute for diesel fuel in compression ignition engine with lower percentage of emissions and engine wear compared to diesel.

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