Performance and emission characteristics of diesel engine using custard apple seed oil methyl ester and blends

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Abstract - *In the last few decades, depletion of the energy source has become major concern. The need for the alternate source of energy is must to solve the problem of energy scarcity. The need to develop alternate fuel from renewable sources has gained more importance. Vegetable oils have emerged as one of the promising fuel that can be used commercially in coming years. These oils produce less emission and are renewable in nature. Crude oils derived from custard apple seeds have high viscosity, hence transesterification process is used to reduce the viscosity and custard apple methyl ester is obtained by the technique.*
Initially tests are conducted using diesel on 3.6kW, water cooled, single cylinder, 4 stroke, dual ignition diesel engine. Custard apple methyl ester blends are prepared to test on same engine. The results of custard apple methyl ester and prepared blends are compared with diesel. The study revealed that the biodiesel of custard apple seed oil can be used as an alternate fuel without any engine modifications. Slight increase in brake thermal efficiency is observed with 50% blend. Exhaust emissions of the biodiesel are reduced compared diesel fuel.

***Key Words*: Transesterification, Custard apple methyl ester, Biodiesel, Brake thermal efficiency, Emissions.**

1. INTRODUCTION

Energy is the most fundamental requirement for human existence. Consumption of fossil fuels has highly increased and the use of these energy resources has major environmental impact as well [1-4]. Diesel fuel is largely used in transport, agriculture, commercial, domestic and industrial sectors for the generation of mechanical energy and electricity. Finding suitable sustainable fuel alternatives has become a high priority for many countries. Also, it will play major role in various industries in the near future. Out of all the alternative fuels available, the bio-diesel obtained from vegetable oils and animal fatty acids are promising to be more eco-friendly when compared to diesel fuel. Biofuels are liquid or gaseous fuels made from agricultural crops, municipal wastes, and forestry by-products [5]. Liquid biofuels are categorized as vegetable oils, biodiesels, alcohols, and synthetic oils. Bio-diesel is one of these sustainable fuels that is a non-petroleum based, obtained from vegetable oils [6-8]. It has many advantages that include low emissions, biodegradable, non-toxic, environment friendly and better lubricity [9]. Petroleum fuel supply has become scarce, and its use has been associated with the increase in environmental problems. Diesel engines are widely used as power sources for medium and heavy duty applications [10]. The viscosity of vegetable oils is many times higher than that of diesel fuel. The viscosity is reduced when triglycerides are converted into esters by transesterification reaction. Thus, three smaller molecules of ester and one molecule of glycerin are obtained from one molecule of fat/oil [11].

1.1 Custard apple

Custard apple is a common name for a fruit, and the tree which bears it, Annona reticulata. It is sometimes erroneously termed sugar apple, sweetsop and, by Spanish-speaking people, anon or rinon, in India, ramphal. It is erect, with a rounded or spreading crown and trunk 10 to 14 in (25-35 cm) thick. The custard apple is believed to be a native of the West Indies but it was carried in early times through Central America to southern Mexico. It has long been cultivated and naturalized as far south as Peru and Brazil. It is commonly grown in the Bahamas and occasionally in Bermuda and southern Florida. Apparently it was introduced into tropical Africa early in the 17th century and it is grown in South Africa as a dooryard fruit tree. In India the tree is cultivated, especially around Calcutta, and runs wild in many areas.

Figure 1 shows the custard apple fruit. The fruit is greenish in color and contains 20-30 seeds in each fruit.

Figure 1: Custard apple fruit

2. MATERIALS AND METHODS

The engine used in study is 3.6kW, computerized, vertical, single cylinder, 4 stroke, water cooled, naturally aspirated, dual ignition diesel engine. An eddy current dynamometer is fixed for loading of the engine. To measure the exhaust emissions AVL DIGAS 444 (5 gas analyzer) is used.

Seeds of custard apple are collected and the oil from the seeds is extracted. Crude custard apple oil undergoes transesterification process to obtain the custard apple seed oil methyl ester (CASOME). 7 grams of sodium hydroxide and 150 ml of methanol are mixed with 1 liter of custard apple oil. The mixture is heated about 65^{o}C for 90 minutes. After transesterification process, the mixture is poured into the separating funnel. After settling of biodiesel, two layers are observed biodiesel and glycerin. Drain the glycerin from bottom of funnel. The obtained biodiesel is washed with warm water to remove the traces of methanol and sodium hydroxide residuals. It is then heated upto 110^{o}C to remove the water particles in biodiesel. The biodiesel obtained is used to prepare the various blends such as 25% blend (25% CASOME + 75% diesel), 50% blend (50% CASOME + 50% diesel), and 75% blend (75% CASOME + 25% diesel). The properties of the diesel, CASOME and prepared blends are determined with the help of standard procedures. Table 1 shows the properties of the test fuels.

Table -1: Properties of the fuels

Property	Diesel	25% blend	50% blend	75% blend	CASOME
Flash point ^{o}C	54	54	60	67	138
Fire point ^{o}C	63	70	74	81	167
Kinematic viscosity cSt	2.54	3.26	4.45	4.9	5.7
Density kg/m^3	835	825	846	852	875
Calorific value KJ/kg	42500	41276	40030	38764	37525

3. RESULTS AND DISCUSSIONS

The main objective of the work is to investigate the performance and emission characteristics of diesel engine using custard apple seed oil methyl ester (CASOME), its blends and diesel. The results obtained from the test are compared with the diesel fuel.

3.1 Performance analysis

The engine performance parameters such as brake thermal efficiency, brake specific fuel consumption, brake specific energy consumption and exhaust gas temperature are calculated, and represented graphically.

Brake thermal efficiency

The variation of brake thermal efficiency with brake power is shown in figure 2. From the figure, it is observed that the brake thermal efficiency of 50% blend is slight higher compared to diesel. This may be due to the presence of excess oxygen in the blend. The maximum values of brake thermal efficiency obtained for CASOME, 25%, 50%, 75% blends are 28.49%, 30.85%, 30.96%, 28.96% respectively against 29.02% of diesel. However 75% blend has the lower value of brake thermal efficiency.

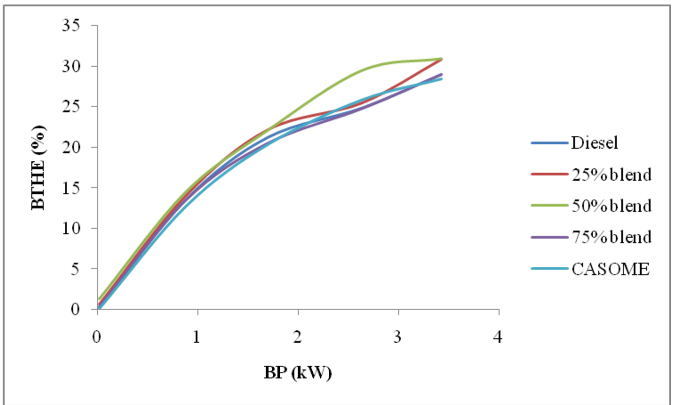

Figure 2: Variation of brake thermal efficiency with brake power

Brake specific fuel consumption

From figure 3 it is observed that with the increasing load value of brake specific fuel consumption declines. The results shows that the brake specific fuel consumption obtained for all the blends and CASOME are closer to diesel. The brake specific fuel is governed by the density, viscosity and the heating values. The minimum value of brake specific fuel consumption obtained for CASOME, 25%, 50%, 75% blends are 0.30, 0.28, 0.29 and 0.29 kg/kWh respectively against 0.29 kg/kWh of the diesel .

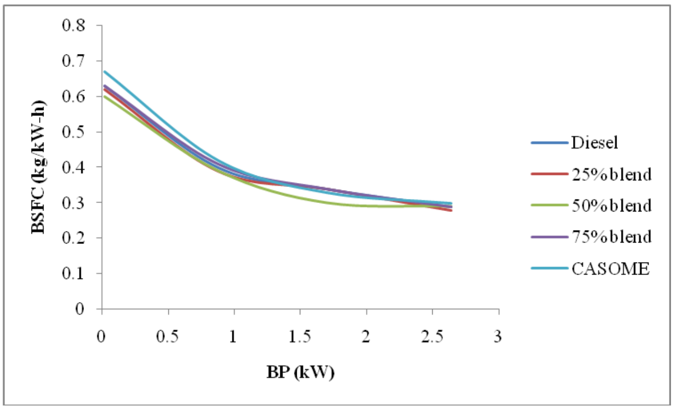

Figure 3: Variation of brake specific fuel consumption with brake power

Brake specific energy consumption

Figure 4 depicts the values of brake specific energy consumption plotted against brake power. The brake specific fuel is not a reliable parameter. Hence brake specific energy consumption is calculated. The brake specific fuel consumption of all the fuels tested in the engine is low at high loads. The values of brake specific energy consumption obtained for all the blends are well comparable to diesel. The obtained values of the brake specific energy consumption are 11257.5, 11557.28, 11608.7, and 11241.56 kW/ kg h for CASOME, 25%, 50%, 75% blends respectively against 12325 kW/kg h for diesel fuel.

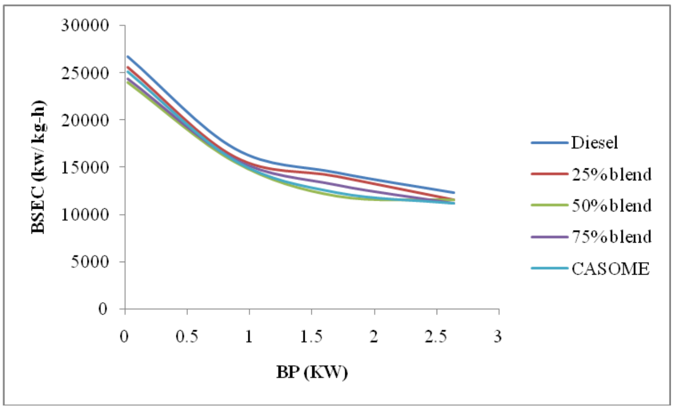

Figure 4: Variation of brake specific energy consumption with brake power

Exhaust gas temperature

The figure 5 indicates the values of exhaust gas temperature plotted against brake power. As the load on engine increases temperature of the exhaust gas also increases. The reason is that the viscosity and flash point of the biodiesel blends are high compared diesel. The Maximum value of exhaust gas temperature of 50% blend is 159°C against 152.58°C of diesel. The values of CASOME, 25%, 75% blends are 147.47, 154.96, 148.36°C respectively.

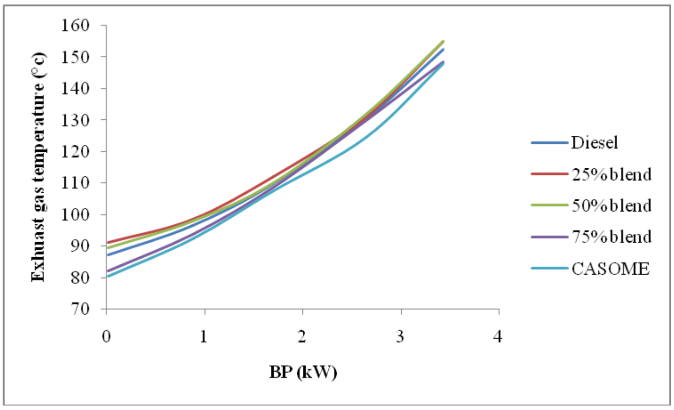

Figure 5: Variation of exhaust gas temperature with brake power

3.2 Emission analysis

The emission analysis includes the study of carbon monoxide, unburnt hydrocarbons and nitrogen oxides. As these parameters play an important role in the environment pollution. The results of the emission parameters with the brake power are plotted and results are analyzed and compared to the results of diesel.

Carbon Monoxide

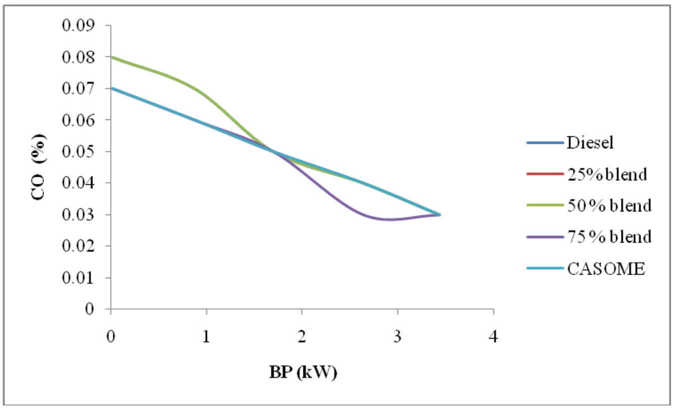

Figure 6: Variation of carbon monoxide with brake power

The variations of carbon monoxide plotted against brake power for the test fuels are shown in Figure 6. The plot indicates that the values of carbon monoxide decreases with the increasing load for all the test fuels. The values of the carbon monoxide obtained for the biodiesel blends are closer to the values of diesel fuel. The value of the carbon monoxide at full load for 50% blend is 0.03% against 0.03% of diesel.

Hydrocarbons

From figure 7 it is observed that the values of unburnt hydrocarbon decreases slightly with the increasing loads. The reason for this is reduction in the quantity of unburnt hydrocarbons at high loads due to complete combustion. The minimum value of the unburnt hydrocarbon obtained for 50% blend is 16ppm compared to 19ppm of diesel.

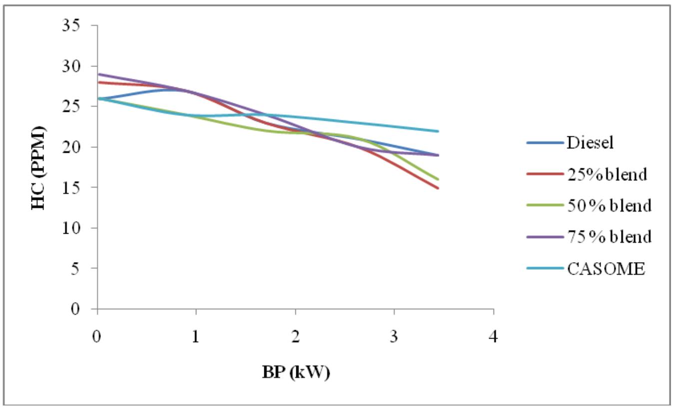

Figure 7: Variation of unburnt hydrocarbon with brake power

Oxides of nitrogen

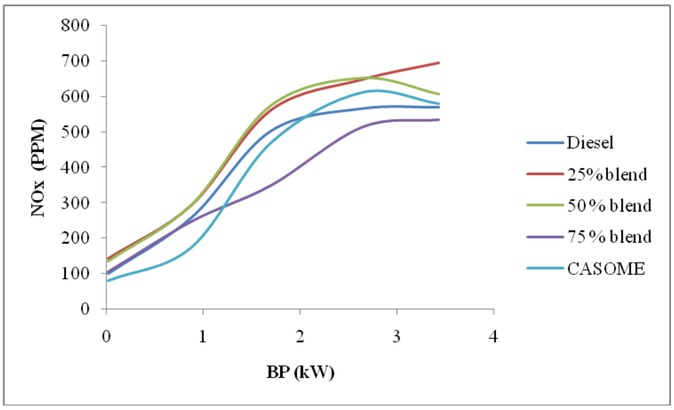

Figure 8: Variation of oxides of nitrogen with brake power

Figure 8 shows the variations of oxides of nitrogen obtained for the test fuels plotted against the brake power. The value of nitrogen oxides increases with increasing loads. The reason for this is at high temperatures, excess oxygen present in biodiesel reacts with nitrogen and forms nitrogen oxides. The maximum value of nitrogen oxide obtained for 50% blend is 608 ppm compared to 571ppm of diesel.

3. CONCLUSIONS

In the present work, the experiments are conducted with custard apple seed oil methyl ester and blends for performance and emission characteristics of diesel engine. The obtained results of CASOME and its blends are compared with diesel.

- The values of the physical properties obtained for biodiesel and blends are close to diesel.
- The prepared fuel samples are tested in diesel engine without any modifications.
- The test results of biodiesel are closer to the diesel.
- Maximum brake thermal efficiency of the 50% blend is 30.96% against 29.02% of the diesel. This is greater by 6.22%. From this it can be concluded that 50% blend has high brake thermal efficiency.
- The results shows that the brake specific fuel consumption obtained for all the blends and biodiesel are closer to diesel.
- The brake specific energy consumption of all the fuels tested in the engine is low at high loads. The values of brake specific energy consumption obtained for all the blends are well comparable to diesel.
- The values of carbon monoxide decreases with the increasing load for all the test fuels. The values of the carbon monoxide obtained for the biodiesel are closer to the values of diesel fuel.
- The values of unburnt hydrocarbon decreases slightly with the increasing loads. The reason for this is reduction in the quantity of unburnt hydrocarbons at high loads due to complete combustion. The minimum value of the unburnt hydrocarbon obtained for 50% blend is 16ppm compared to 19ppm of diesel.
- The value of nitrogen oxides increases with increasing loads. The maximum value of nitrogen oxide obtained for 50% blend is 608 ppm compared to 571ppm of diesel.

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