Performance and Emission Analysis of C.I.Engine with Kapok Methyl Ester and Its Blends

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Abstract

Current demands on renewable alternative fuel, biodiesel claims considerable significance. Biodiesel can be produced from any type of vegetable oils but yielding is determined by its free fatty acid (FFA) content. The alkaline-catalyzed esterification is not suitable for the unrefined vegetable oil which has high acid content. Hence, two-step esterification process is used to derive the kapok methyl ester due to its high FFA value. The biodiesel production in the two step process consists of acid-catalyzed pretreatment followed by an alkaline-catalyzed transesterificatin. In this study, experimental investigations are carried out in compression ignition engine to analyze the properties, performance and emissions characteristics of different blends of kapok methyl ester and compared with diesel. The exhaust gas temperature and specific fuel consumption are increased with increase of load and amount of biodiesel. The CO_2 emission is slightly higher and NO_x emission is about 22 percentage higher than that of the diesel at all the loads of engine. However, lower biodiesel blends showed reasonable efficiencies, lower value of smoke, CO and HC emissions.

Keywords— *Kapok seed oil, Kapok Methyl Esters (KME), Biodiesel, Performance, Emission*

1. Introduction

Environment concern, increasing of fuel prices and fast depletion of the fossil fuels urges us to search for some alternative fuels like biogas, methanol, ethanol and vegetable oils. The cost of petroleum products depend on international markets and petroleum reserves are limited to nearly next 30 years. The main reasons for developing and utilizing biofuels are to reprieve the greenhouse gas, aiming for energy security, local electricity generation, domestic market utilization and transportation [1].

The biodiesel can be derived from both edible and non-edible oils like Soybean, coconut, sunflower, Jatropha Curcus, Pongamia Pinnata, Kapok (silk cotton), Neem, Rubber seed oil, etc. Biodiesel production from edible oils would not be viable for developing country like India. Hence, non-edible oil is better to use for biodiesel purposes, moreover, the non-edible plants can grow in semi-arid or arid and wastelands. The additional benefits are green cover to waste land, support to agriculture and rural economy, lower dependence on imported crude oil and reduction in air pollution [2].

Biodiesel is a long-chain fatty acid made through a chemical process called esterification, vegetable oil or animal fats reacts with methanol in the presence of catalyst KaOH or NaOH and yields mono alkyl esters (biodiesel) and glycerin. [1-4]. Recently, multiple efforts being carried out by many researchers to find the suitability to convert the raw vegetable oil into biodiesel; blending, emulsification, thermal cracking and transesterification are the common methods used [5].

Biodiesel and its blends can be used in diesel engines without any design modification. The performance and emission characteristics compared with diesel fueled engine. CO, HC emissions were significantly decreased at high loads, but it was observed that slightly higher CO_2 and NO_x emission for higher ratio of biodiesel at all the load conditions. [5-7]

This study is mainly focused on kapok (Ceiba Pentandra) which is also known as silk-cotton tree. The Kapok tree grows to 60-70m tall and adult trees produce several hundred 15 cm seed pods and seed contains 24 % oil content. The pods contain seeds surrounded by a fluffy, yellowish fiber. The oil colour is yellow and pleasant mild odor.

2. Materials and Methods

2.1 Characters of kapok seed oil

The significant properties of kapok seed oil are compared with other oils which are given in the table.1 [6]. The kinematic viscosity of kapok seed oil is several times higher than that of diesel fuel. This will cause the problems in pumping and atomization in injection system in engine. Hence, fuel modification is mainly focused to reduce the viscosity and flow related problems.

Table 1: comparison of kapok seed oil with other oils

Property	Kapok Seed oil	Rubber Seed oil	Rapeseed oil	Cotton Seed oil	Soybean oil
Specific gravity	0.9218	0.91	0.914	0.912	0.92
Kinematic Viscosity at 40°C in CST	31.13	66.2	39.5	50	65
Flash point (°C)	296	198	280	210	230
Calorific value (MJ/kg)	42.0	37.5	37.6	39.6	39.6
Acid value	2.82	17	1.14	0.11	0.2

The FFA content in the raw kapok seed oil is about 3%. The maximum amount of FFA acceptable in a base catalyzed system is less than 2 percent, and preferably less than 1 percent. [7]. Therefore, the acid-catalyzed treatment is to be done first in order to reduce the acid value, then the alkaline-catalyzed transesterification process is suitable to yield maximum quantity of kapok methyl ester.

2.2 Esterification of Kapok seed oil

Biodiesel production from low-cost and high FFA feed stock like kapok seed oil consists of the following two steps,

Step I: Acid-esterification: Sulphuric acid is used as catalyst in the acid-catalyzed pretreatment. It reduces FFA content of the raw oil into even less than 1 percent.

Step II: Alkaline-esterification: The products from the first step are used as the input of the alkaline-esterification process. Here, sodium hydroxide or potassium hydroxide is used as catalyst.

The sulphuric acid 0.5% by volume was first dissolved completely in 75g methanol and added to the 250g of kapok oil and stirred continuously by magnetic stirrer, it was necessary to heat till the phases are distinguished clearly. The second step was taken up with catalyst 0.5% by weight of NaOH/ KOH and after the reaction is completed, the products are allowed to separates in two layers. The important factors that affect the transesterification process are the amount of methanol, sodium or potassium hydroxide, reaction time and temperature [5, 8-10]. Most researches have used 15 to 30 % of methanol and up to 5% of sodium hydroxide or potassium hydroxide by weight of vegetable oil for better yield of biodiesel.

3. Experimental Setup

This study was carried out to investigate the performance and emission characteristics of kapok methyl esters in a stationary single cylinder diesel engine without any modifications. The engine testing setup is depicted in Fig.1. The engine was tested with three electrical load levels *viz.*, no load, half load and full load. The three levels of kapok biodiesel blends at 40, 80 and 100 percent (B_{40}, B_{80} and B_{100}) with diesel were used for engine testing. The performance data of all blends in terms of thermal efficiency, brake specific fuel consumption and emission parameters CO_2, CO, NO_x, HC and smoke density were then analyzed from the graphs.

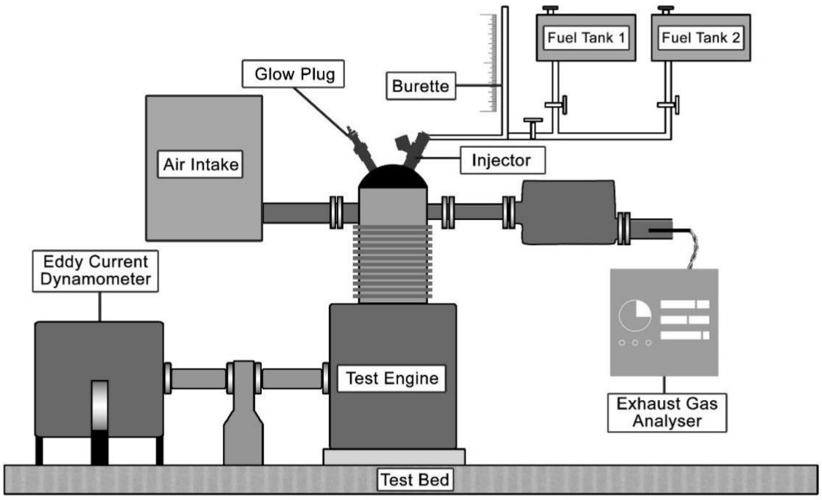


Fig.1: Experimental Setup

4. Results and Discussions

The results obtained in the experimental investigations for different ratio of biodiesel blends are compared to diesel, and are presented.

Brake Thermal Efficiency

The brake thermal efficiency of biodiesel and its blends was found to be slightly higher than that of diesel fuel. There was no difference between the biodiesel and its blended fuels on efficiencies. The brake thermal efficiencies of engine operating with biodiesel mode were 9.2, 20.9 and 24.4 percent at three different load conditions.

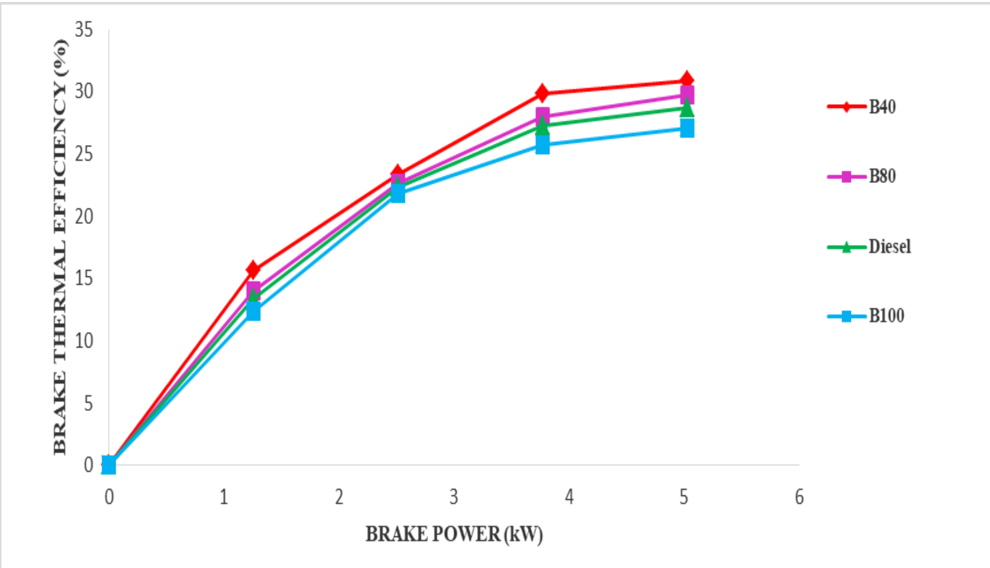


Figure 1 BP vs BTE

Specific Fuel Consumption

The variation in specific fuel consumption with brake power is shown in Fig. 2. The percentage of specific fuel consumption was increased with increase the amount of biodiesel in the blends. The specific fuel consumption for all blends of biodiesel increased ranged from 4 to15 percent.

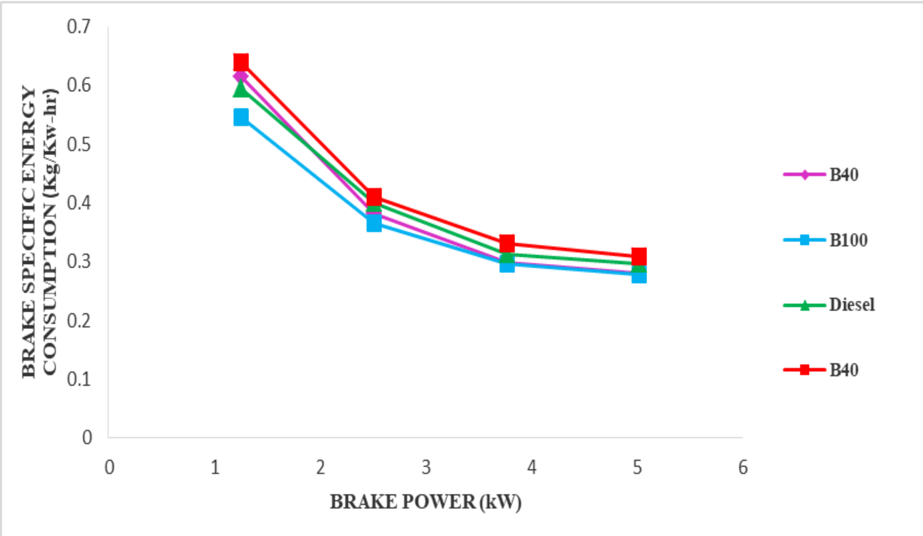


Fig.2: Fuel consumption and Brake power

Exhaust Gas Temperature.

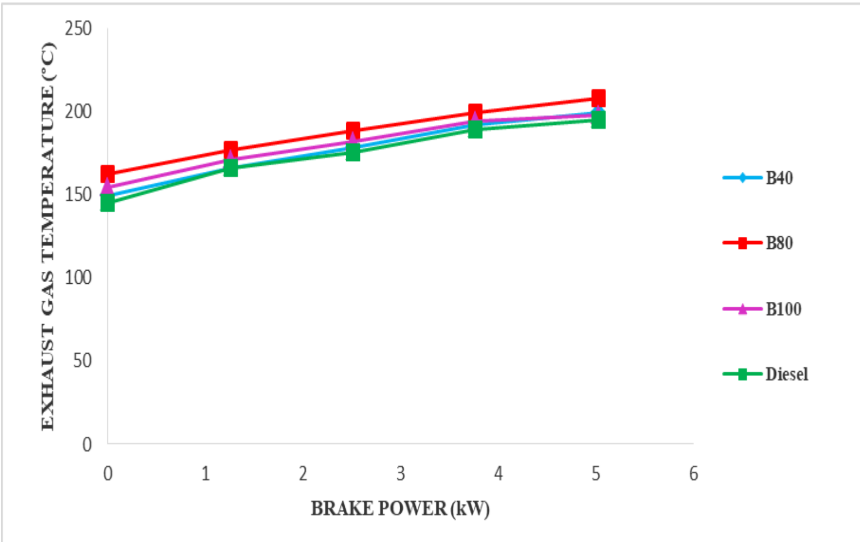


Fig.3: Exhaust gas temperature with BP

Fig.3 shows the variation of exhaust gas temperature of the different biodiesel blends against the load. The increases in exhaust gas temperature are noticed throughout engine operation with different biodiesel modes. The highest temperature was 482^0C for biodiesel blends at all three load conditions, it ranges from 225^0C. The diesel mode operation shows a variation from 214^0C to 412^0C.

CO Emissions

Fig.4 shows the carbon monoxide emissions for different blends of biodiesel and diesel against load. The CO emission is reduced by biodiesel about 17 to 14 percent than compared to diesel. The ranges from 1.12 g/kW-h to 0.17 g/kW-h for the biodiesel blends, whereas the CO emission for the diesel fuel varies from 0.28 g/kW-h to 0.13 g/kW-h. The CO emission appreciably increased for B80 and B100 blends due to incomplete combustion.

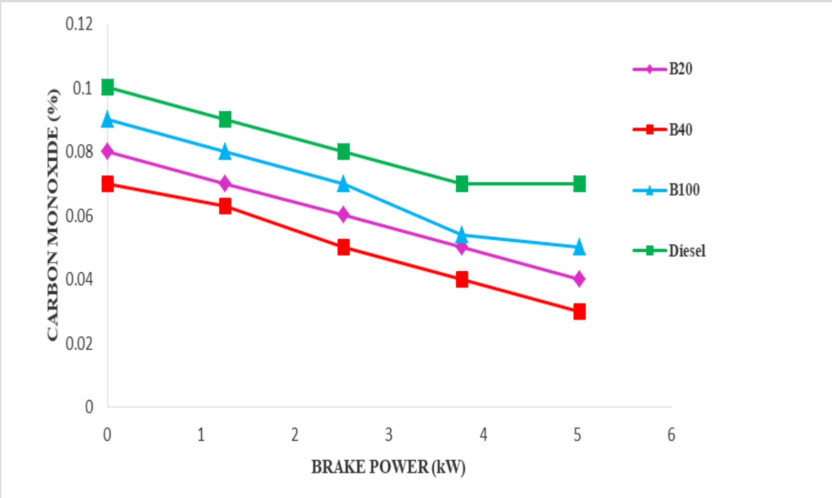


Fig.4: Carbon monoxide variation with load

NOx Emission. Fig.5 depicts the variation of NOx emissions from engine with different ratios of biodiesel blends. The NOx emission for biodiesel was 22 % higher than diesel fuel. The NOx emission increased with increase in amount of biodiesel in the blended fuel. It was observed that the increase of NOx formation is caused by high combustion temperature and less availability of oxygen when the rich biodiesel blends involves in the combustion process. However, the increase in NOx concentration is the main problem in biodiesel and can be reduced by suitable change in the engine parameters. NOx ranges from 7.75 g/kW-h to 6.28 g/kW-h for diesel fuel.

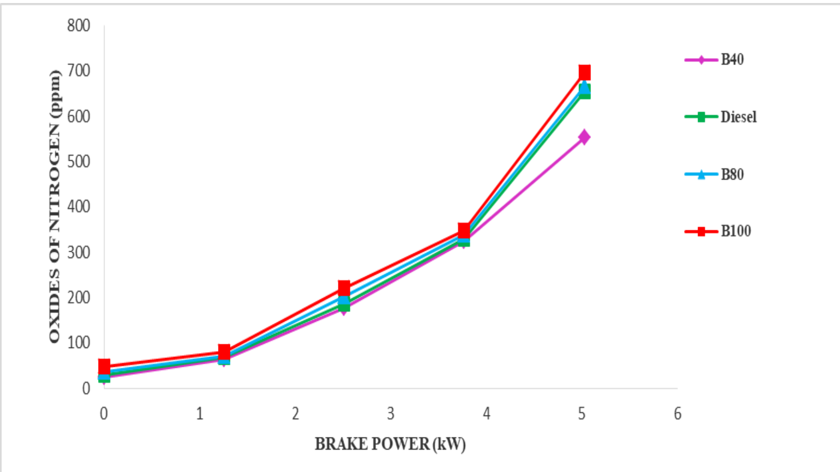
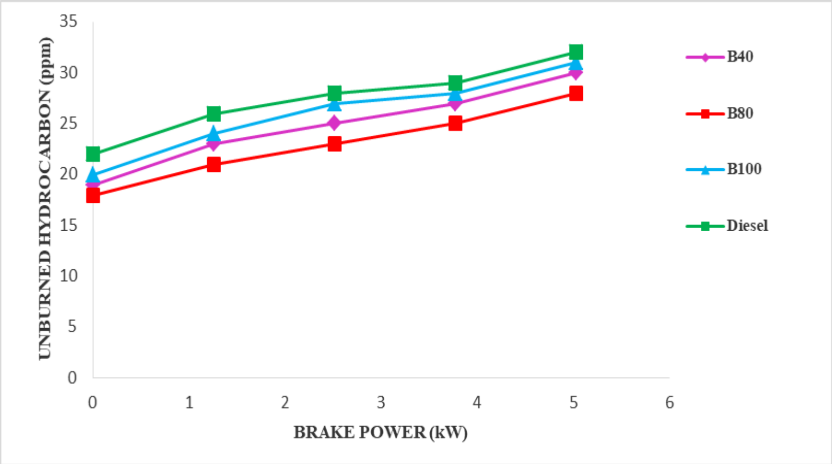


Fig. 5: NO_x Emission with load

HC Emission

The variation of HC emission against load was also observed. The hydrocarbon emission slightly increased when load increases for biodiesel blends B_{60}, B_{80} and B_{100} due to insufficient combustion. But lower ratio of biodiesel blend shows lesser value of HC emission than diesel.



Smoke.The variation of smoke density for the different biodiesel blends against load is shown Fig.6. It was observed that biodiesel has less smoke density compared to diesel. But smoke density increases for B_{80} and B_{100} due to insufficient combustion. Smoke density also increases when load increases.

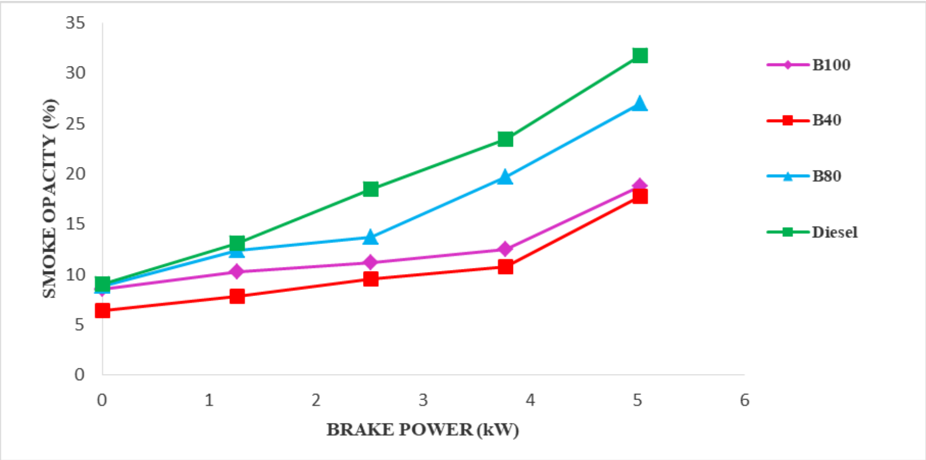


Fig.6: Variation of smoke with BP

4. Conclusions

The following conclusions were made based on the results obtained from the experimental investigations of single cylinder diesel engine operating with different kapok biodiesel blends.

- Kapok methyl ester can be directly used in the diesel engines without any engine modifications and it is a viable alternative to diesel.
- The exhaust gas temperature has increased about 5 % to 17 % in biodiesel blends compared to diesel.
- Brake thermal efficiency for biodiesel and its blends has slightly higher than diesel fuel tested at all load conditions, but there was no appreciable change among biodiesel blends.

- HC and CO emissions for biodiesel blends B_{20} and B_{40} were found to be 16 % lower than diesel fuel operation.
- The NO_x emission for biodiesel was increased by 22 % higher than diesel fuel. The NO_x emission increased with increase in load conditions and amount of biodiesel in the blended fuel.
- The emission of smoke is reduced by 11 % for B_{20} and B_{40} biodiesel blends.

In general B_{20} and B_{40} kapok biodiesel blends improves the overall performance of the engine with a significant reduction in emissions.

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