Performance and Emission Evaluation of Diesel Engine Fueled with Karanja Methyl Ester

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Abstract. Petroleum based fuels are the main source of energy for the transportation vehicles. It is consumed in a very faster rate due to continuous use. Major drawback of fossil fuel usage is exhaust gas emission and it is non-renewable. The search for alternate energy source has been increasing; one of the better alternatives is biodiesel. The biodiesel can be effectively used as an alternate fuel instead of diesel as its properties is very close to diesel. The biodiesel extracted from Karanja oil is tested in diesel engine as B100 and B20 blend and its results were compared with diesel. It was found that the brake thermal efficiency is low for biodiesel and its blend compared to diesel. The specific fuel consumption increases for B100 and B20 than diesel due to its reduced heating value. Carbon monoxide and hydrocarbon emission is reduced considerably for B100 compared to B20 and neat diesel. At the same time the NOx emission is also observed to be decreasing for B100 and the NOx of B20 is closer to diesel. From the results obtained the Karanja oil biodiesel can be directly used in direct injection diesel engines and can be a better alternate fuel for the conventional one.

Keywords: Karanja oil, methyl ester, biodiesel, transesterification, performance, emission

1. Introduction

Due to increasing population and transport requirement there is huge demand for petroleum-based fuels. Many works have been carried out to find a better alternative to the existing problem. There are many alternative energy sources like LPG, alcohol, natural gas, hydrogen, biodiesel, etc. Among these biodiesel stands as a best solution for replacing diesel fuel. The properties of the biodiesel are comparable with diesel. Major advantage of biodiesel is renewable, easily available, production of biodiesel won’t affect environment like diesel, and biodiesel can be extracted from any type of vegetable oil, lower emission rates compared to diesel [1]. All over the world many researches are going on biodiesel aiming to replace the fossil fuel to reduce the dependency on the fossil fuels. Many non-edible oils are available for the production of biodiesel fuel. Some of the oils are Neem Oil, Mahua oil, cotton seed, Karanja oil, Jatropha oil, Castor oil, Rape seed oil, linseed oil, punnai oil, Acid oil, jojoba oil, rice bran oil, rubber seed oil, grape seed oil etc.

Even though biodiesel has comparable properties to be used in engines there is significant difference in properties like viscosity of the oil which lead to poor spray of fuel during injection and incomplete combustion resulting in unwanted emissions. To overcome the issues related to viscosity
methods like transesterification, pyrolysis, micro emulsion, de-polymerization is used to produce biodiesel. Generally, transesterification process method is used to produce biodiesel. Based on the free acid content of the oil, esterification and transesterification or direct transesterification is carried out to extract biodiesel. Use of biodiesel extracted from vegetable oils such as karanja, jatropha, neem, Karanja, rapeseed, soybean as fuel resulted in lower efficiency and higher smoke for diesel.

Karanja (Pongamia Pinnata) and jatropha are abundantly available in India and researchers study the performance characteristics of karanja oil in diesel engines. Moreover, Karanja oil is non-edible and finds no food versus scarcity problem. Many literatures indicate the use of biodiesel from karanja oil and its effective use in direct injection diesel engines. Yehliu et al. reported that the BSFC of biodiesel is increased by 15% compared to diesel which is due to 15% lower calorific value and observed in some cases increase in particulate matter emission due to unburned hydrocarbon emissions [2]. Godhiganur et al. discussed the effect of mahua biodiesel and its blends in diesel engine. It is found that for maximum blend of mahua biodiesel resulted in reduced emissions of hydrocarbon and Carbon monoxide emissions but nitrous oxide emission and BSFC were higher [3].

Muralidharan et al. recorded the performance of waste cooking oil with diesel. They observed that brake thermal efficiency of B40 blend is marginally higher than diesel. Also, biodiesel and its blends resulted in higher combustion pressure and lower HRR in comparison with diesel [4]. The observation of other researchers indicates that use of biodiesel as fuel in diesel engines results in increased BSFC due to lower calorific value and NOx emission due to higher oxygen content and better combustion. [5-8]. In this present work karanja oil biodiesel is used for running the single cylinder diesel engine and to study the performance and emissions by running the fuel.

2. Materials and Methodology

2.1 Materials and experimental design

Karanja oil was purchased from a dealer shop, 99.9% pure analytical grade methanol, Sulphuric acid and potassium hydroxide in lead shot form of above 85% pure were used in the production of biodiesel. The apparatus required for the experiment are half a litre spherical glass beaker, a speed controlled mechanical stirrer, a temperature-controlled heater and a digital thermometer.

2.2 Transesterification process

Karanja biodiesel is extracted by two stage process. The first stage is esterification to produce ester and the next stage is alkaline transesterification process to produce biodiesel. The conversion process is done to reduce the viscosity of the oil. If the viscosity is higher than it may lead to poor atomization and improper combustion [9]. If the FFA content of the oil is minimal of 2.5%, then one step transesterification process with a base catalyst should be done and if it exceeds 2.5%, then esterification and transesterification processes should be preferred. In this study as the FFA content of Karanja oil was 5.45%, thus two stage transesterification method is employed.

The FFA content in oil is decided by titration test. For this test, oil sample of 2-5g is taken in a conical flask and 25ml of ethanol is added to the oil and 4-5 drops of phenolphthalein indicator was added to the flask. It was heated for about 4-5min and then allowed to cool down. Following it is titrated against 0.1N of KOH solution. The KOH solution is added until permanent pink colour appears. The FFA content is calculated based on the burette solution during titration. In Karanja oil, the FFA content is around 5.45%. Thus, two step transesterification process is carried out. In acid transesterification process methanol to oil ratio of 8:1 and 2% of concentrated sulphuric acid to the volume of oil is taken. The esterification process carried on for a period of 90 minutes at a temperature of 60°C. After the process the FFA is checked to move on with the alkaline esterification.

In alkaline transesterification process, oil is pre-heated and the solution is mixed by stirrer for constant mixing 500rpm is maintained. By dissolving KOH pellets in methanol (molar ratio 8:1) the methoxide solution is prepared. When the oil reaches certain temperature, in the reactor the prepared methoxide solution is poured slowly. The reaction was maintained at 60°C with a time period of 60
minutes. The by-product glycerine is removed and then to remove the soap content from the biodiesel, it is washed with distilled water.

3. Experimental setup and Measurements

The experiment was performed in Kirloskar AV1 make four stroke water cooled diesel engine. The rated power is 5.20 kW at a constant speed of 1500 rpm. Engine is connected to the swinging field electrical generator with the load bank. The engine experimental setup is shown in figure 1 and specification is given in the table 1. AVL-444 gas analyser is used to measure the amount HC, CO and NOx emissions. The pressure at in-cylinder is measured using Piezoelectric pressure sensor at every crank angle using a charge amplifier transducer. Variables such as engine speed, fuel flow, and emission characteristics were acquired from the data acquisition system connected with the engine. Specific fuel consumption, Brake thermal efficiency, and brake power were evaluated from study of performance of the engine.

| Table 1. Engine Specifications |
|--------------------------------|
| Engine Parameters             | Specifications               |
| Make                          | Kirloskar AV 1, Water cooled, Four Stroke |
| Number of cylinders           | Single                       |
| Bore                          | 87.5 mm                      |
| Compression ratio             | 17.5:1                       |
| Maximum power                 | 5.20 kW                      |
| Speed                         | 1500 rpm                     |
| Dynamometer                   | Electrical                   |
| Injection pressure            | 200 bar                      |

![Figure 1: Experimental Setup of test engine](image-url)
4. Result and Discussions

4.1 Properties of Karanja oil

Karanja oil property has been studied before carrying out the esterification and transesterification process for biodiesel production. Its physicochemical properties have been studied to find the suitability as feed stock for biodiesel production. Table 3 depicts the physicochemical properties of Karanja oil. The properties like density, free fatty acid content (FFA), kinematic viscosity, Acid value, Iodine value, molecular weight was studied.

| PARAMETRS                                        | VALUES |
|--------------------------------------------------|--------|
| Density at 15 ℃ (Kg/m³)                         | 930    |
| Kinematic viscosity at 40 ℃ (mm²/s)              | 12.5   |
| Free fatty acid (% FFA as oleic acid)            | 1.5%   |
| Acid value (mg KOH/g)                            | 5.06   |
| Iodine value (g Iodine/100 g)                    | 86.5   |
| Molecular weight (g/mol)                         | 876.16 |

Table 3. Properties of karanja oil methyl ester

| PROPERTIES                                      | DIESEL | BIODIESEL |
|-------------------------------------------------|--------|-----------|
| Density(15 ℃) (Kg/m³)                          | 833    | 886       |
| Kinematic viscosity(40 ℃) in cST                | 2.67   | 4.3       |
| Flash point(℃)                                  | 65     | 157       |
| Calorific Value (MJ/kg)                         | 43.06  | 41.07     |

4.2 Performance Characteristics

4.2.1 Specific fuel consumption

![Figure 2. Specific fuel consumption against load](image-url)
The specific fuel is defined as the ratio of fuel consumed to the brake power. Consumption of diesel, biodiesel and its blend are shown in the figure 2. The Karanja oil biodiesel has higher specific fuel consumption compared to diesel for all load conditions. Karanja biodiesel has low calorific value compared to diesel, hence more amount of fuel was consumed to produce same power output [10]. It is observed that specific fuel consumption increases by 19% and 12.85% for biodiesel and B20 blend compared to that of diesel at full load.

4.2.2 Brake Thermal Efficiency

The brake thermal efficiency of diesel, biodiesel and its blend are shown in the figure 3. The Karanja oil biodiesel has lower BTE compared to that of diesel. The drop in brake thermal efficiency for biodiesel and diesel blends is due to reduced calorific value and higher viscosity [10]. The higher viscosity of the fuel affects the atomization and vaporization of biodiesel. It is observed that BTE decreases by 16% and 9% for biodiesel and B20 blend compared to that of diesel at full load.

4.3 Emission Characteristics

4.3.1 Carbon monoxide
The figure 4 shows the variation of carbon monoxide (CO) emission of diesel, biodiesel and its blend with respect to load. By using biodiesel, reduction in CO is observed which is due to the increased proportion of oxygen in biodiesel compared to diesel which promotes oxidation and results in complete combustion [11]. Thus, there is a decrease of 33.5% and 20.2% for biodiesel and B20 blend compared to that of diesel at full load.

4.3.2 Hydrocarbon (HC)

The figure 5 shows the variation of Hydrocarbon (HC) emission of diesel, biodiesel and its blend with respect to load. Since, biodiesel has higher oxygen content which results in complete combustion of fuel. Thus, HC is less compared to that of diesel. The increased gas temperature and higher cetane number of biodiesel and their blends were responsible for this decrease [11]. Thus, there is a decrease of 26.5% and 14.7% for biodiesel and B20 blend compared to that of diesel at full load.

4.3.3 Oxides of Nitrogen (NOx)

The figure 6 shows the variation of Oxides of Nitrogen (NOx) emission diesel and biodiesel blends with respect to load. The NOx from biodiesel is higher compared to that diesel. This is mainly due to better combustion and improved cetane number of biodiesel blends. Hence the ignition delay is reduced which leads to better combustion resulting higher operating temperature. The inert nitrogen reacts with oxygen at higher temperature to form NOx [12]. Thus, there is an increase of 16.2% and 11.5% for biodiesel and B20 blend compared to that of diesel at full load.
5. Conclusions
This paper investigates on the production of Karanja oil Methyl Ester (KOME) and its performance characteristics in diesel engine.

- The parameter condition used for production of Karanja Methyl Ester (KOM) are for esterification 8:1 Molar ratio of Methanol to oil, 90 min Reaction time, 60°C Reaction temperature and 2% (H₂SO₄) (w/w) Catalyst concentration.
- For transesterification 8:1 Molar ratio, 60 min Reaction time, 60°C Reaction temperature and 1% (KOH) (w/w) Catalyst concentration and obtained yield is 92.36%.
- There is a slight increase of specific fuel consumption for B20 blend and biodiesel than that of diesel
- Brake thermal efficiency decreases by 16% and 9% for biodiesel and B20 blend than that of diesel
- There is a significant reduction in CO and HC emission than that of diesel
- There is a slight increase in NOx emission due to high oxygen content in biodiesel.

From the conclusion it is clear that the karanja oil biodiesel and its blends can be used as a substantial fuel for direction injection diesel engines

6. References
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