# Emission Characteristics of using Different Alternative Fuels with Petroleum Diesel in a Compression Ignition (CI) Engine

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**Abstract**

Stringent emission norms and depletion of oil resources have led the researchers to find alternative fuels for internal combustion engines. The main objectives of this study are to investigate the effects of using different types of fuel samples interns of emission characteristics and feasibility of using alternative fuels. Therefore, in this study five fuel samples (FSs) such as: 100% diesel fuel (FS1); 5% palm diesel and 95% diesel fuel (FS2); 5% jatropha oil and 95% diesel fuel (FS3); 5% jatropha oil, 5% palm diesel and 90% diesel fuel (FS4); and 10% jatropha oil, 10% palm diesel and 80% diesel fuel (FS5) respectively were used to analyze the exhaust emissions which are included carbon monoxide, carbon dioxide, nitrogen oxide and also exhaust gas temperature. All tests were carried out on a single cylinder DI YANMAR engine model YF120-M at constant speed of 2000 rpm at varied load conditions between 5 Nm and 17.5 Nm with intervals of 2.5 Nm. The results presented in this study showed that the FS2 and FS3 have a potential to reduce emissions compared to diesel fuel (FS1). Therefore, in conclusion the FS2 and FS3 can be feasible alternative fuels for the CI diesel engine without any engine modification.

Keywords: emission charcteristics, alternative fuel, CI engine

## 1. Introduction

Diesel engine sector forms a vital part of transportation systems in all the developed and developing countries of the world. Globally, the increasing use of fossil fuels has resulted in enormous increase of global environmental degradation effects. These impacts include global warming, air quality deterioration, ozone depletion, oil spills, and acid. In several studies, it has been experimentally investigated that the human health hazards are associated with exposure to diesel exhaust emissions [1 – 5]. Interests in emission control systems, alternative fuels and new fuel formulations for diesel engines have significantly increased around the world regarding the new regulations and increasing demands on diesel engine manufacturers. Therefore, with limited fossil fuels, and intensified environment pollution, it is increasingly necessary to develop alternative clean fuel which is technically feasible, economically competitive, environmentally acceptable and readily available [6, 7]. Experimental use of blends of vegetable oils with diesel has been examined successfully by various researchers in several countries [8–11]. Similarly, the combustion of biodiesel compared to standard diesel fuel has also resulted in lower smoke, particulate matter, carbon monoxide and hydrocarbon emissions while the engine efficiency is either unaffected or improved [12-18]. The idea of using vegetable oil as the fuel for diesel engine is not new. Rudolf Diesel first used peanut oil as a fuel for demonstration of his newly developed compression ignition (CI) engine in year 1910. But soon afterwards, the application of vegetable oils as fuel was dropped due to the cheap supply of petroleum based fossil fuels available in the world. During the period of World War-II, vegetable oils were again used as fuel in emergency situations when fuel availability became scarce [19]. Crops, which produce oil directly, are one of alternative sources of fuel. In this study, the blends of Palm diesel and Jatropha oil with petroleum diesel have been used. Malaysia is the largest producers of palm oil in the world. Tropical climate and cheap man power of this region is another beneficial point for growing of this plant. Malaysia's biodiesel production is mainly palm oil based though it has taken some initiative to introduce Jatropha production in mass level [20]. It has been reported that among the vegetable oils, Jatropha oil exhibits very good properties. It is a non-edible oil, its calorific value and cetane number are higher compared to many others. The Jatropha plant can grow almost anywhere, even on gravely, sandy and saline soils. Its water requirement is extremely low [21].

This paper presents the effects of using five samples of the fuels: FS1 (100% Petroleum Diesel), FS2 (5% PO + 95% PD), FS3 (5% JO + 95% PD), FS4(5% JO + 5% PO + 90% PD) and FS5 (10% JO + 10% PO + 80% PD) respectively interns of emission characteristics. Emission parameters for all fuels samples were measured under a range of varying loads (torque) applied to the engine at one constant speed of 2000 rpm.

## 2. Experimental set up and test plan

Fig. 1 shows the test rig set up for the experimental study. It consists of a test-bed, a diesel engine, a dynamometer, a fuel tank, an operation panel, exhaust emission analyzers, etc.

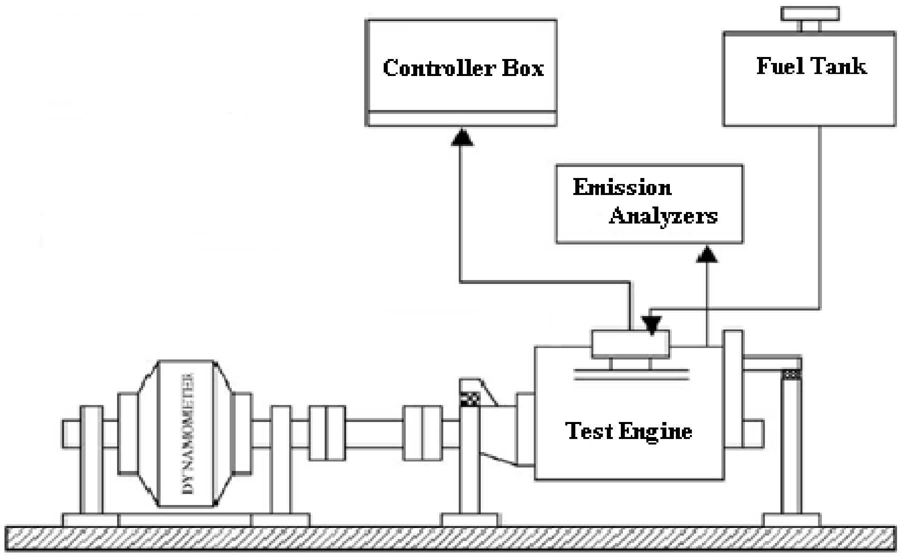


Fig.1. Schematic diagram of the engine test ring

### 2.1. The engine

A YANMAR diesel engine model TF120 -M shown in Fig. 2 is selected for the study and is mounted on a test-bed. It is a water-cooled, direct injection diesel engine. Its specifications are shown in Table 1.

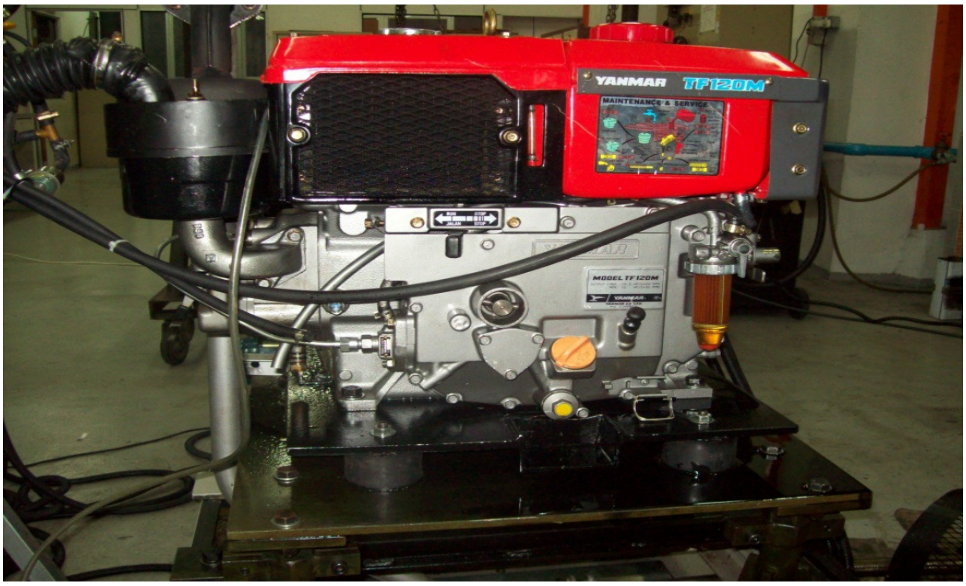


Fig. 2. YANMAR Test Engine

Table 1

Specifications of the test engine

| Engine type | | 4 – stroke DI diesel engine |
|---|---|---|
| Number of cylinders | | One |
| Aspiration | | Natural aspiration |
| Cylinder bore x stroke | mm | 92 x 96 |
| Displacement | L | 0.638 |
| Continuous rated output | rpm | 2400 |
| | kW | 7.7 |
| At 1 – hr rated output | rpm | 2400 |
| | kW | 8.8 |
| Power take – off position | | Flywheel side |
| Cooling system | | Radiator cooling |

### 2.2. Emission analyzers

Two exhaust gas analyzers named Bacharach and Bosch gas analyzers are used to analyze the exhaust emissions from the engine, i.e, carbon monoxide, carbon dioxide, oxides of nitrogen and also exhaust gas temperatures.

### 2.3. Experimental plan

A plan was designed for the experimental investigation. Five fuel samples were tested as shown in Table 2. For each of the fuel samples, the engine ran on five different load conditions between 5 Nm and 17.5 Nm with intervals of 2.5 Nm. at constant speed of 2000. The engine load was controlled by the control panel.

Table 2

Five fuel samples of different compositions

| Fuel sample (FS) | Composition (by vol.%) |
|---|---|
| 1 | 100% diesel fuel |
| 2 | 5% palm diesel and 95% diesel fuel |
| 3 | 5% jatropha oil and 95% diesel fuel |
| 4 | 5% jatropha oil, 5% palm diesel and 90% diesel fuel |
| 5 | 10% jatropha oil, 10% palm diesel and 80% diesel fuel |

### 2.4. The fuel properties

The properties of the fuel tested are shown in Table 3. As shown in the table, diesel fuel has the lowest viscosity at both 40°C and 100°C temperature respectively. When diesel mixed with palm oil and jatropha oil to make blends, it is found that the more percentage of these oils in the blends increased the viscosity.

Table 3

Fuel sample properties

| Fuel sample (FS) | Viscosity at 40°C (cSt) | Viscosity at 100°C (cSt) | Density (g/ml) | Cloud Point (°C) | Pour Point (°C) |
|---|---|---|---|---|---|
| 1 | 3.602 | 1.486 | 0.8305 | 14-16 | 12 |
| 2 | 4.612 | 1.745 | 0.8315 | 17 | 12 |
| 3 | 4.617 | 1.748 | 0.8269 | 17 | 12 |
| 4 | 4.922 | 1.819 | 0.8346 | 16 | 12 |
| 5 | 7.362 | 2.123 | 0.8498 | 18 | 12 |

## 3. Engine test results and discussion

The diesel engine ran well on all the fuel samples mentioned above. There were no faults happening during the whole experiment process. The test results obtained from the comprehensive experimental investigations are analyzed and described below.

### 3.1 Carbon monoxide (CO) emission

CO is formed during the combustion process with rich air–fuel mixtures regions and when there is insufficient oxygen to fully burn all the carbon in the fuel to $CO_2$. Fig. 3 shows the comparison of the CO emissions of different fuel samples at different engine load. It can be seen that CO for FS2, FS3, FS4, and FS5 were less than the petroleum diesel (FS1) over the entire range of load. It is found that among all the fuels, FS3 produced the lowest level of CO emissions within the experimental range. FS2 seems to have a lower emission of CO as compared to diesel and almost found to be the same as shown by FS3 up to 15 Nm. It can be observed that the CO initially decreased with load and later increased sharply beyond 15 Nm loads. This trend was observed for all the fuel blends tested. Initially, at low load conditions cylinder temperatures might be low, which increased with loading due to more fuel injected inside the cylinder. At elevated temperature, performance of the engine improved with relatively better burning of the fuel resulting in decreased CO. However, on further loading, it might be observed that the excess fuel required led to formation of more smoke, which might have prevented oxidation of CO into $CO_2$, consequently increasing the CO emissions sharply.

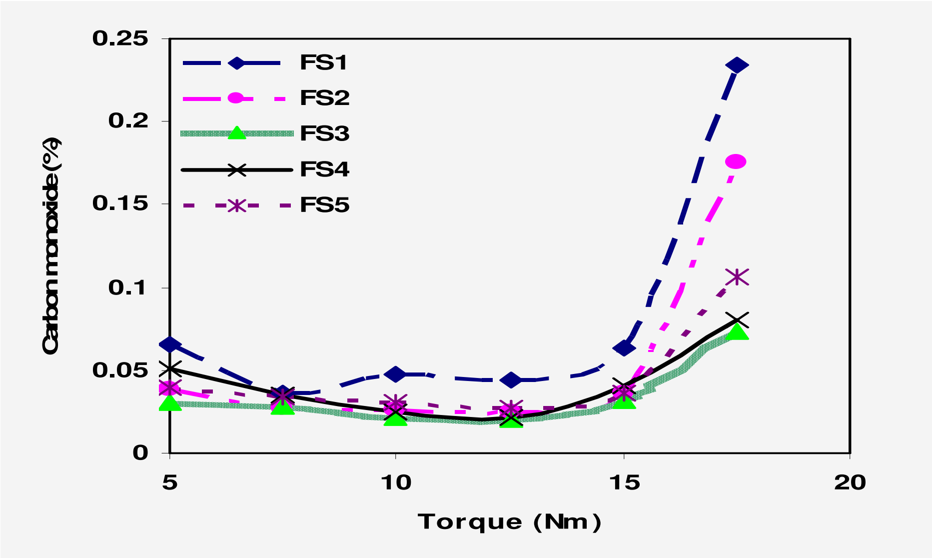


Fig. 3. CO emission versus torque.

### 3.2 Carbon dioxide ($CO_2$) emission

Fig. 4 compares the $CO_2$ emissions of various fuel samples used in the diesel engine. Overall, there was not much difference found in all the fuel samples. However, it has been found that FS3 produced the lowest level of $CO_2$ emissions and FS2 produced the highest level of $CO_2$ emissions throughout the range of the load among all the fuels. The $CO_2$ emissions increase with increases in load, as expected. More amount of $CO_2$ in exhaust emission is an indication of the complete combustion of fuel. It should be mentioned here that the formation of $CO_2$ is an exothermic reaction. Therefore, it supports the higher value of exhaust gas temperature.

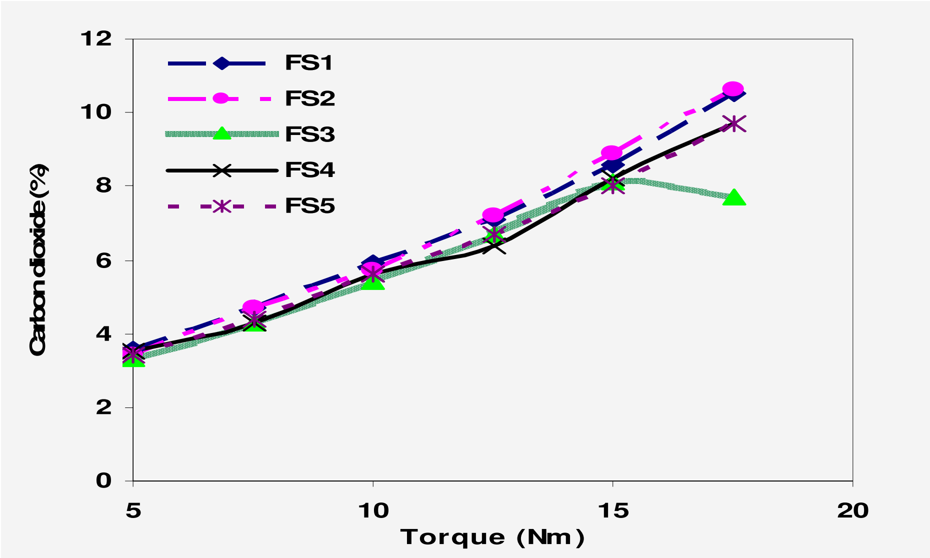


Fig. 4. $CO_2$ emission versus torque.

### 3.3 Oxides of nitrogen ($NO_x$) emission

The $NO_x$ values as parts per million (ppm) for different fuel samples in exhaust emissions are plotted as a function of load in Fig. 5. Generally, there was not much difference found in all the fuel samples within the experimental range. However two important observations were made from the $NO_x$ curves presented in Fig. 5. First, NOx emissions were a direct function of engine loading. This was expected because with increasing load the temperature of the combustion chamber increased and the $NO_x$ emission is directly related to the engine combustion chamber temperatures, which in turn indicated by the prevailing exhaust gas temperature. With increase in the value of exhaust gas temperature, NOx emission also increases. The second important observation was that $NO_x$ emissions reduction for the case of FS3 which decreased about 13.85% compared to petroleum diesel (FS1) at 17.5 Nm load. These lower NOx emissions could be due to lower temperatures in the combustion chamber using Jatropha oil blend. However FS2 shows better over all performance among all fuel blends over the entire range of load.

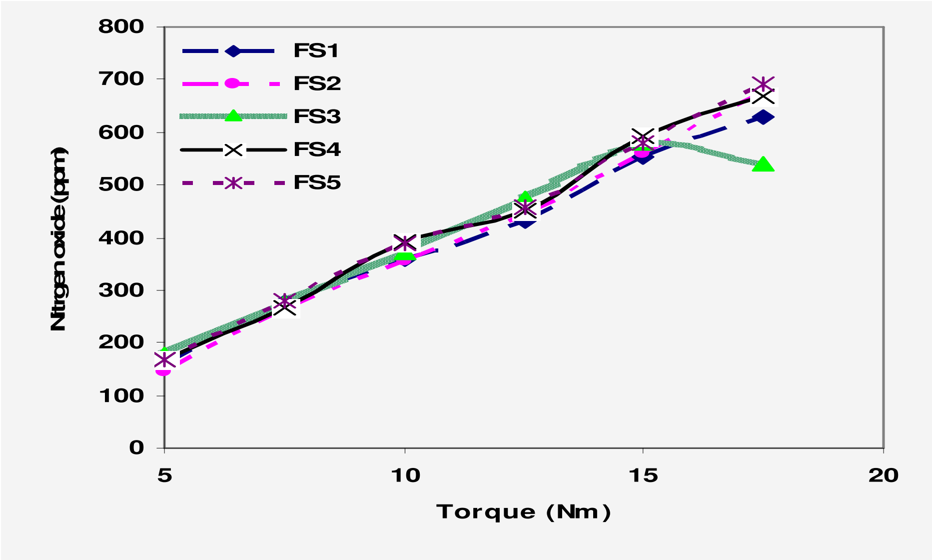


Fig. 5. $NO_x$ emission versus torque.

### 3.4 Exhaust gas temperature (EGT)

With respect to engine loading, the exhaust gas temperatures for all fuel samples are compared in Fig. 6. Generally, the trend of EGT increases with the increase in engine loading for all the fuel samples tested. The increase in exhaust gas temperature with load is obvious from the simple fact that more amount of fuel was required in the engine to generate that extra power needed to take up the additional loading. The burning of diesel fuel (FS1) was found to have the highest exhaust gas temperature value among these five fuel samples. This may be attributed due to its highest heating value among all fuel samples. Furthermore it can be seen that for the case of FS3 at 17.5 Nm load, lower exhaust gas temperature supported $NO_x$ emissions reduction (ref. Fig. 5) under same load condition.

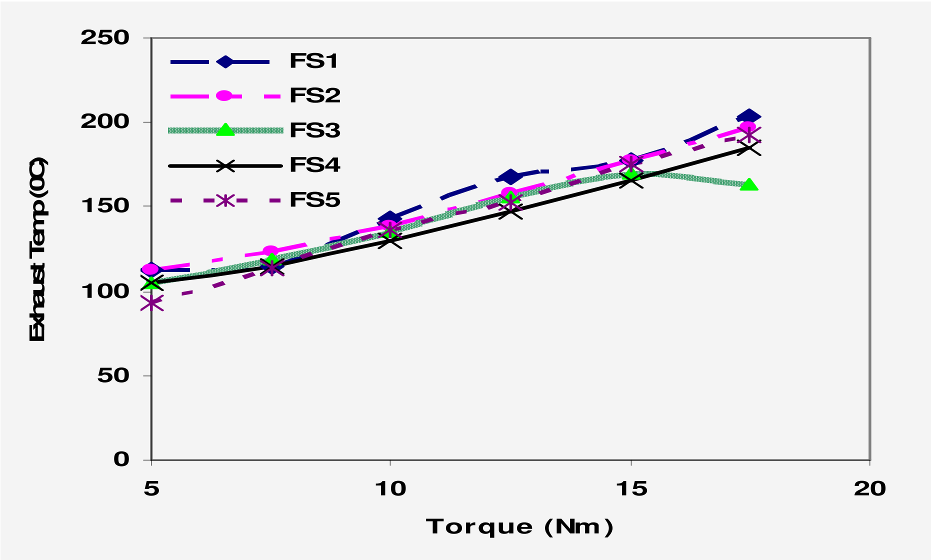


Fig. 6. Exhaust temperature versus torque.

## 4. Conclusion

Experimental results of using blends of palm diesel and jatropha oil with petroleum diesel engine fuel have been conducted in the present work. The results obtained from this study may be summarized as follows.

- It was found that CO for all fuel blends (FS2 to FS5) was lower than the petroleum diesel (FS1). However FS3 produced the lowest level of CO emissions followed by FS2.
- More amount of $CO_2$ in exhaust emission is an indication of the complete combustion of fuel. Therefore, FS2 produced the highest level of $CO_2$ emissions throughout the range of the load among all the fuel samples.
- For the case of FS3, $NO_x$ emissions were decreased about 13.85% compared to petroleum diesel (FS1) at 17.5 Nm load. However FS2 showed better over all performance.
- Under same load condition, lower exhaust gas temperature supported $NO_x$ emissions reduction.

Finally, the present analysis revealed that FS2 and FS3 are fund to be quite suitable as an alternative to petroleum diesel.

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