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# The Effect of Biodiesel, Ethanol and Diesel Fuel Blends on The Performance and Exhaust Emissions in A DI Diesel Engine

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**ABSTRACT**

In this study, blends of No. 2 diesel fuel and ethanol with rapeseed oil and soybean oil methyl esters were tested in a four-stroke, four-cylinder, direct injection (DI) diesel engine. Tests were performed using diesel fuel + rapeseed oil + ethanol (DRE) blends and diesel fuel + soybean oil + ethanol (DSE) blends at different engine speeds and full load operating conditions and the results were compared with neat diesel fuel. In each test, brake torque, brake specific fuel consumption (BSFC), smoke level, carbon monoxide (CO), unburned hydrocarbons (HC) and nitrogen oxides (NOx) emissions were measured. The experimental results indicated that blends of No. 2 diesel fuel and ethanol with rapeseed oil or soybean oil methyl esters can be used in a DI diesel engine without any modification. According to obtained results, brake torque was decreased and the BSFC was increased with DRE and DSE fuel blends because of their lower heating value. Smoke level and CO and HC emissions were decreased. However, NOx emissions were increased with blends of DRE and DSE compared to neat diesel fuel.

**Key Words**: *Diesel engine, alternative fuels, rapeseed oil, soybean oil, ethanol.*

## 1. INTRODUCTION

The rapid depletion of oil reserves and environmental pollutions created an incentive to study and evaluate alternative fuels, which are renewable and cleaner than fossil fuels [1]. One of the alternative renewable fuels is biodiesel which can be used in diesel engines few or no modifications due to its close properties to diesel fuel [2]. Biodiesel can be produced through transesterifikasyon from a variety of vegetable oils including soybean, rapeseed, sunflower, peanut and palm. Biodiesel has higher cetane number and higher lubricity than diesel fuel [3-6] Biodiesel contains about 11% of oxygen by weight, minimal sulfur and does not contain any aromatic hydrocarbons. On the other hand, its lower heating value is less than diesel fuel, therefore to produce the same amount of power; the quantity of fuel is increased [7].

Rakopoulos et al. investigated the use of a high variety of vegetable oils or biodiesels of various origins as supplements to conventional diesel fuel in a DI Diesel

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engine. The use of biodiesels reduced the smoke density and CO emissions [4].

Lapuerta et al investigated the effect of No. 1 and No. 2 diesel fuels and biodiesel from soybean oil on the combustion characteristics and emissions in a turbocharged diesel engine. He found that, using biodiesels leads to an increase in BSFC and $NO_x$ emissions. However, a significant reduction obtained in particulate matter (PM) and CO emissions [8].

Ethanol is a biomass based renewable fuel, which can be produced from vegetable materials, such as corn, sugar cane, sugar beets, sorghum, barley and cassava, and it has higher miscibility with diesel fuel [9-11]. The use of ethanol in diesel engines has received considerable attention. It is regarded as one of the promising alternative fuels or an oxygen additive in diesel engines with its advantages of low price and high oxygen fraction [12]. In an experimental study carried out by Can et al. [9]. The effects of ethanol addition to No. 2 diesel fuel on the performance and emissions were investigated in an IDI injection diesel engine. The addition of ethanol reduced CO, soot and sulfur dioxides ($SO_2$) emissions while it caused an increase in $NO_x$ emissions.

Ethanol blended gasoline has been widely used as an alternative fuel in Brazil, USA and Canada. On the other hand, biodiesel, ethanol and diesel blends are new renewable alternative energy sources with environmentally friendly characteristics comparable to fossil fuels [10]. In an experimental study, carried out by Pang et al. effects of using biodiesel - ethanol – diesel fuel blends on carbonyls emissions were investigated in a diesel engine. The blended fuels reduced PM emissions, while increased $NO_x$ emissions [13]. Kowalewicz investigated the effect of diesel fuel-ethanol blends and rapeseed oil methyl ester-ethanol blends in a DI diesel engine. Rapeseed oil methyl ester decreased smoke and CO emissions [14].

The objective of the present study is to investigate the effect of using blends of No. 2 diesel fuel, ethanol and biodiesels from rapeseed oil and soybean oil methyl esters on the performance and exhaust emissions in a DI diesel engine. The tests were performed at different engine speeds and full load operating conditions.

In this study, different proportions of diesel, ethanol and the use of isoproaponal purpose in the market by 5% ethanol and 20% biodiesel, alternative fuel use as a result of the contribution of the country's economy and reducing engine emissions is thought to form. The purpose of the use of 1% isoproaponal the phase difference and facilitate the formation of ethanol is to prevent confusion as homogeneous.

## 2. MATERIAL AND METHODS

Experiments were conducted on a DI diesel engine. Technical specifications of the engine are shown in Table 1.

Table 1. Technical specifications of the test engine.

| Item | Specification |
|---|---|
| Engine type | DI Diesel engine |
| Cycle | 4 |
| Number of cylinder | 4 |
| Bore (mm) | 100 |
| Stroke (mm) | 100 |
| Compression ratio | 16:1 |
| Injection pressure (bar) | 250 |
| Max. power output | 46 kW (2400 rpm) |
| Max. torque | 216 Nm (1400 rpm) |

The torque of the engine was measured by a hydraulic dynamometer (type Go-Power). Fuel consumption was measured by using a scale (type Ohaus GT 8000) with an accuracy of 0.1 g and a stopwatch (type Robic SC-700) with an accuracy of 0.01 s. The schematic view of the test equipment is shown in Figure 1.

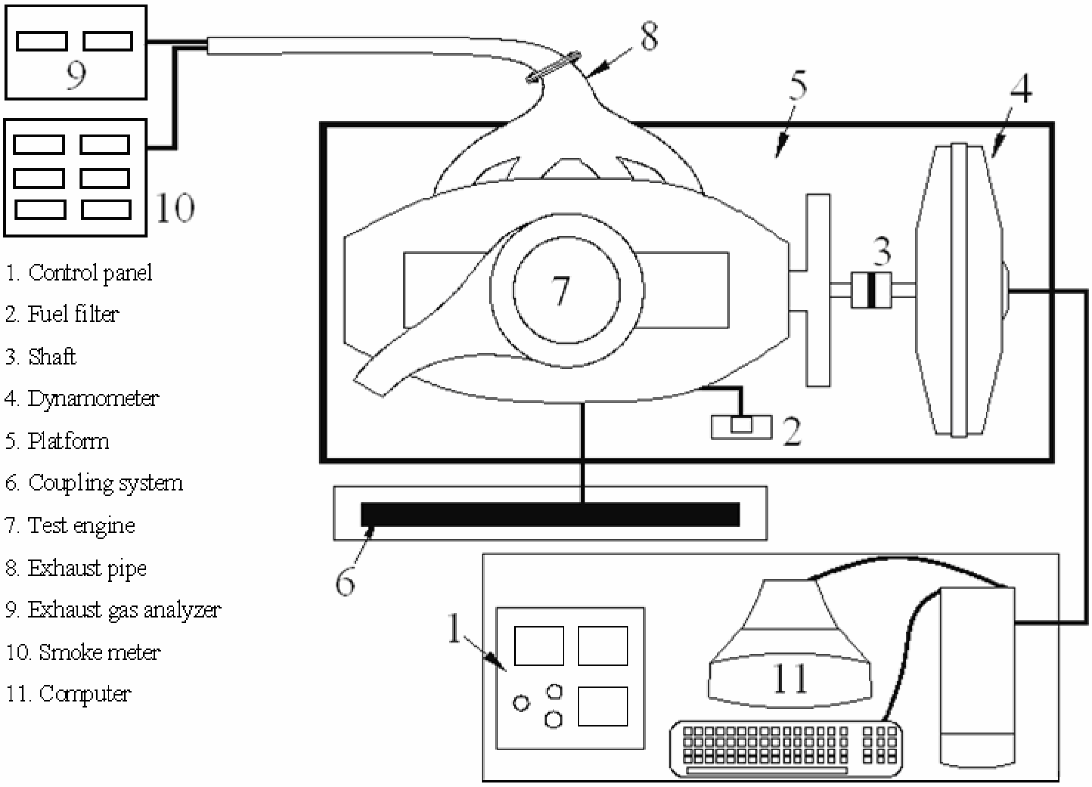


Figure 1. Schematic view of the test equipment.

Exhaust emissions were measured with a MRU Delta 1600L exhaust gas analyzer. Smoke level was measured with VLT 2600 S smoke meter. Analyzers were calibrated before the experiments. The specifications of MRU Delta 1600 L and VLT 2600 S were given in Table 2.

Table 2. Technical specifications of MRU Delta1600-L and VLT 2600-S.

| | Measurement range | Accuracy |
|---|---|---|
| **MRU DELTA1600** | | |
| CO (% vol) | 0 – 15 | 0.01 |
| $CO_2$ (% vol) | 0 – 20 | 0.01 |
| HC (ppm) | 0 – 20000 | 1 |
| $NO_x$ (ppm) | 0 – 4000 | 1 |
| $O_2$ (% vol) | 0 – 25 | 0.1 |
| **VLT 2600-S** | | |
| Opacity (%) | 0 – 100 | 1 |
| Absorption (k) ($m^{-1}$) | 0 – 99.99 | 0.01 |

The effects of using No. 2 diesel fuel (D), rapeseed oil (R), soybean oil (S) biodiesels and ethanol (E) blends on engine performance and exhaust emissions have been investigated. In the experiments, 74% diesel fuel + 20% rapeseed oil + 5% ethanol + 1% isopropanol blends (DRE) and 74% diesel + 20% soybean oil + 5% ethanol + 1% isopropanol blends (DSE) were used and the results were compared with neat No. 2 diesel fuel.

Properties of No. 2 diesel fuel, rapeseed oil, soybean oil biodiesels and ethanol are shown in Table 3 [4,14]. Isopropanol was added to the mixtures to satisfy homogeneity and prevent phase separation.

Table 3. Physical and chemical properties of test fuels [4,14].

| Fuel | Viscosity (40°C) ($mm^2$/sn) | Calorific value (kJ/kg) | Cetane number | Density (25°C) (g/$cm^3$) |
|---|---|---|---|---|
| Diesel fuel | 3.9 | 43300 | 54 | 0.837 |
| Rapeseed methyl ester | 4.7 | 39900 | 58 | 0.877 |
| Soybean methyl ester | 4.9 | 39760 | 54–55 | 0.878 |
| Ethanol | 3.4 | 29772 | | 0.765 |
| Isopropanol | 1.7 | 30447 | | 0.785 |

Before the tests, oil and water levels of the test engine were controlled and the fuel pump and injection pressures were adjusted. The injection pressure was adjusted to 250 bar. Fuel filter was changed and fuel lines were cleaned when the test fuel was changed. Tests were performed at four different engine speeds (1100, 1600, 2000 and 2400 rpm) and full-load operating conditions. In each test, the same procedure was repeated.

**3. RESULTS**

In this study, effects of 74% diesel fuel + 20% rapeseed oil + 5% ethanol + 1% isopropanol blends (DRE) and 74% diesel fuel + 20% soybean oil + 5% ethanol + 1% isopropanol blends (DSE) on the performance and exhaust emissions were investigated and results were compared to neat No. 2 diesel fuel. Blends of No. 2 diesel fuel and ethanol with rapeseed oil or soybean oil methyl esters can be used in a diesel engine without any modification.

The variations of brake torque (BT) and brake specific fuel consumption (BSFC) with engine speed are shown in Figure 2. Maximum brake torque (MBT) was obtained as 192 Nm at the engine speed of 1600 rpm with No. 2 diesel fuel (D). The brake torque was decreased by 5.7% and 10.2% with DRE and DSE fuel blends respectively compared to No. 2 diesel fuel. The results also showed that, DRE and DSE fuel blends increased the BSFC because the lower heating value of DRE and DSE is less than No. 2 diesel fuel. The increase in the BSFC with DRE and DSE blends was approximately 4% and 10% compared to neat No. 2 diesel fuel, respectively.

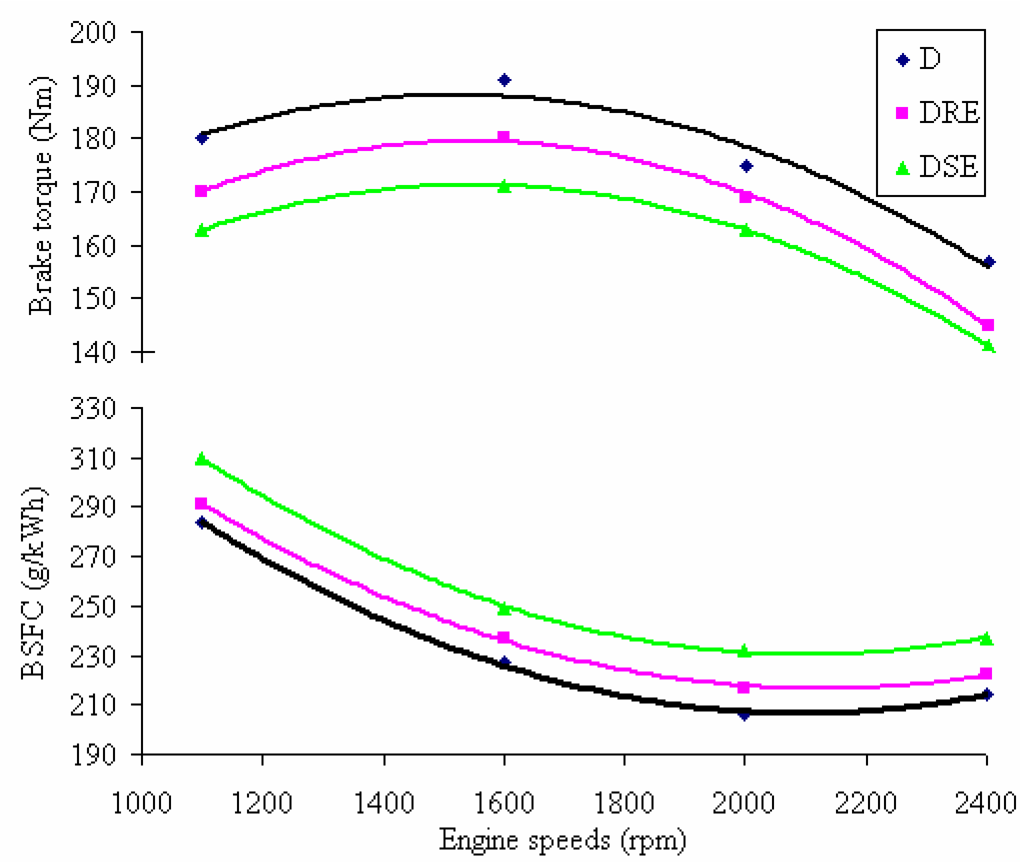


Figure 2. The variation of brake torque and BSFC with engine speed.

The variation of smoke level, CO, HC and $NO_x$ emissions with engine speed for DRE and DSE fuel blends corresponding neat diesel fuel are shown in Figure 3. As shown in Figure 3, smoke level was reduced by 36% and 43% with DRE and DSE fuel blends compared to No. 2 diesel fuel, respectively.

The CO and HC emissions of the DRE and DSE blends were also decreased by 20% and 8%, 7% and 13% compared to No. 2 diesel fuel, respectively.

As shown in Figure 3, the $NO_x$ emissions of the No. 2 diesel fuel were less than DRE and DSE blends. HC emissions were decreased by 7% and 13% with DRE and DSE blends compared to No. 2 diesel fuel, respectively. Compared with No. 2 diesel fuel, the $NO_x$ emissions of DRE and DSE blends were also increased by 53% and 73%. The increase in the $NO_x$ emissions may be related to the oxygen content of DRE and DSE blends.

Considerable decrease of smoke level was obtained and-for high load-also CO and HC emission. At low loads, NOx emission was reduced.

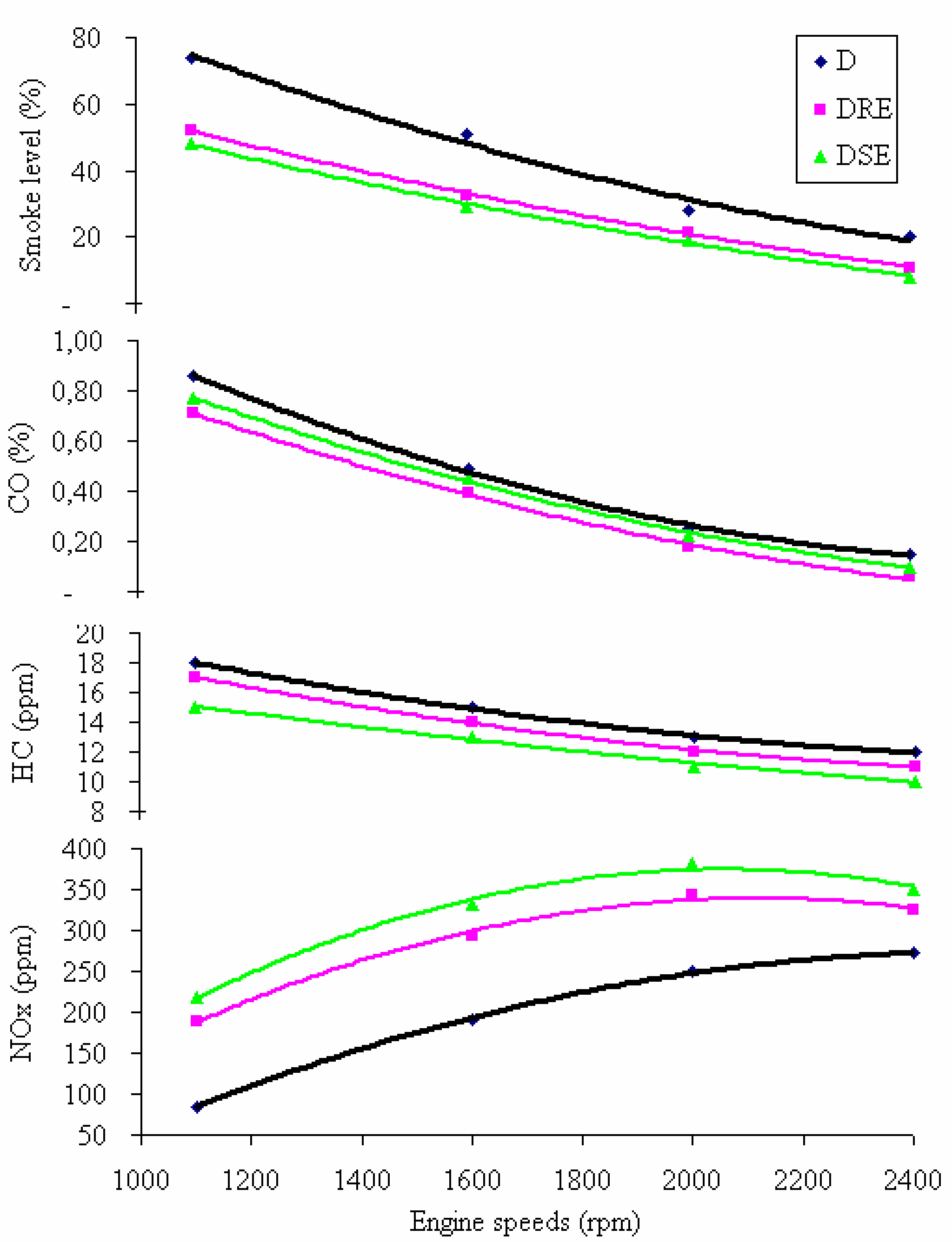


Figure 3. The variation of exhaust emissions with engine speed.

## 4. DISCUSSION

Based on the experimental study, the following results were obtained:

1. The brake torque was decreased by 7.6% and 10% with DRE and DSE blends respectively, compared to No.2 diesel fuel.

2. BSFC was increased by 3.7% and 10.7% with DRE and DSE blends respectively, compared to No. 2 diesel fuel.

3. Significant reductions were obtained in smoke level, CO and HC emissions with DRE and DSE fuels. Smoke level was decreased by 60% with DSE fuel compared to No.2 diesel fuel at maximum torque speed of the engine. The highest decrease in CO emissions was obtained with DRE fuels as 67% compared to neat diesel fuel.

4. On the other hand, $NO_x$ emissions were increased with DRE and DSE fuels compared to neat diesel fuel. $NO_x$ emissions were increased by 19% and 29% with DRE and DSE fuels respectively, compared to neat diesel fuel.

5. As a result, DRE and DSE fuels decreased the engine performance and increased HC and $NO_x$ emissions. However, better smoke level and CO emissions were obtained with DRE and DSE fuels, compared to neat diesel fuel.

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