The influence of ethanol and biodiesel blends on diesel engine performance and emissions

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Abstract. This paper presents the variation of energy parameters and pollutant emissions of the diesel engine for different types of diesel-biodiesel-ethanol blends. The biofuels added in fossil fuels influence the mentioned characteristics. Ethanol is a renewable fuel, which is obtained from plant biomass, sugar and starch. The tests were performed on a 4-cylinder engine, water cooled with pure diesel (D), 10% ethanol (D90E10), 10% ethanol 10% biodiesel (D80B10E10), and 15% ethanol 10% biodiesel (D75B10E15). The comparative results of the engine operation with these fuels for the evaluation of performance and pollutant emissions were presented. Nitrogen oxides (NOx) decreased moderately for fuel blends compared to pure diesel. A slight increase in hydrocarbon (HC) and carbon monoxide (CO) emissions was observed with fuel blends due to low combustion temperature inside the engine cylinder. It can be concluded that the engine power has a small variation compared to diesel operation, and the pollutant emissions are lower when the engine runs on fuel mixtures.

1. Introduction

Compression ignition engines are widely used in industry, agriculture, transportation and as stationary engines. They have high reliability and low fuel consumption. Among the disadvantages presented by CI engines are: high emissions of NOx, particulate matter and other polycyclic aromatic hydrocarbons. Due to the increasingly demanding pollution norms have been developed: high-performance injection systems, gas recirculation systems (EGR), systems to reduce NOx emissions (AdBlue), the use of biofuels.

Biofuels have the advantage of being renewable, reducing dependence on oil resources [1]. At the same time, being oxygenated compounds, mixed with diesel can reduce pollutant emissions. Alternative fuels that mix with diesel must be soluble in diesel and have high cetane numbers, and the raw material for obtaining them must be cheap, easy to produce and the production process must be clean [2]. Currently, the most common biofuel used for diesel engines is biodiesel (alkyl ester of fatty acids from plants and animal fats) [3]. Biodiesel is a renewable fuel that can be produced from vegetable oils, waste oils, and animal fats. Biodiesel has about 10% oxygen in its structure, contributing to a more complete combustion [4].

Ethanol is less toxic, has a higher volatility and a higher oxygen content, which can offer a high potential to reduce pollutant emissions from the engine. Ethanol is a renewable fuel and can be obtained at a fairly low price on the market, which makes it an attractive alternative fuel. It is widely used in ethanol / gasoline blended fuel mode for gasoline engines. There are some problems with applying ethanol-diesel mixtures to the diesel engine. The solubility of ethanol in diesel is poor [5], which makes it difficult to mix ethanol in diesel with a high ethanol ratio. Ethanol can be used in diesel engines in several ways such as mixing ethanol and diesel before injecting it into the combustion chamber. Another method is fumigation [6]; in this case, the ethanol will be injected into the intake manifold and mixed with the intake air. A third technique is to inject fuel (diesel and ethanol) through a separate injection system into a combustion chamber. In the case of this work, the first method was used, blending ethanol with diesel because it does not require any modification of the engine equipment.

2. Method

The tests were made on a Renault K9K engine. A schematic diagram of the engine test bed is presented in figure 1. The engine specifications are presented in table 1.

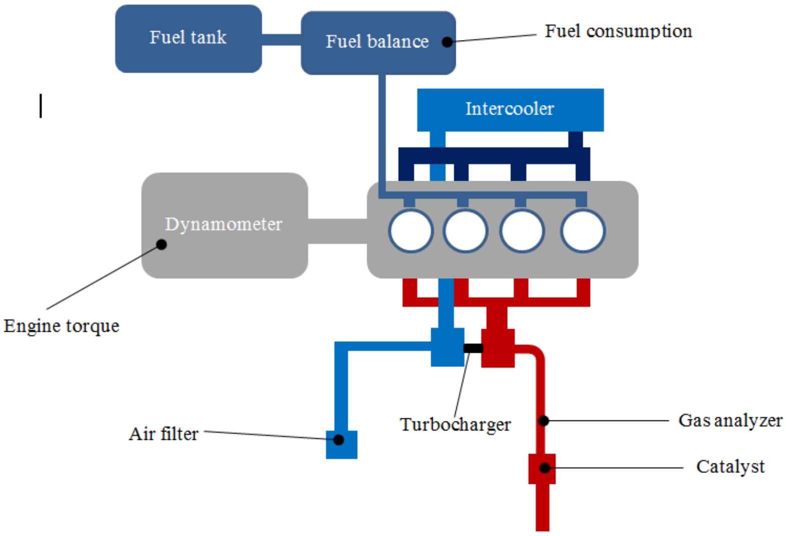

Figure 1. Schematic diagram of the engine test bed.

Table 1. Engine properties.

Engine type	Renault K9K four stroke
Number of cylinders	4
Bore (mm)	76
Stroke (mm)	80.5
Total displacement (cm^3)	1451
Compression ratio	15.3
Maximum power	72 kW at 3700 rpm
Maximum torque	200 Nm at 2700 rpm
Fueling	Common-rail direct injection

The engine was mounted on a Horiba Titan 250 test bench. The engine test bed is equipped with an electric Dynas3 LI250 dynamometer, which is designed for operated within a range of 0-8000 rotations per minute. It can measure engine power up to 250 kW with an accuracy of ±2%.

The engine was fuelled with a blend from mineral diesel and 10%/15% of ethanol and 10% of biodiesel obtained from waste oil. The characteristics of fuel are presented in table 2.

The Pierburg Hermann HGA 400 analyser was used to measure pollutant emissions. The analyser specifications are presented in table 3.

Table 2. Fuels properties.

Properties	Diesel	Biodiesel	Ethanol
Density (at 20ºC), kg/m^3	840.2	862.3	796.3
Viscosity (at 20ºC), mm^2/s	5.34	6.49	3.53
Cetane number	51.1	65.2	8.4
Flash point, ºC	67	171	17.5
Net calorific value, MJ/kg	43.16	38.56	24.89

Table 3. Fuels properties.

Components	Measuring range	Accuracy
Carbon monoxide (CO)	0 – 10% vol	<1,2%vol±0,06% vol
Hydrocarbon (HC)	0 – 20000 ppm	< 220 ppm ±11 ppm
NO_x	0 – 5000 ppm	< 450 ppm ±4 ppm

The tests were done at an ambient temperature of 23ºC and a relative humidity of 62%. The tests were performed at an engine speed of 3900 rpm (maximum engine power speed) for 25%, 50%, 75% and 100% engine load.

3. Results

3.1 Brake Power

Figure 4 shows the increase in brake power when the engine is running with a mixture of ethanol and biodiesel, at higher engine loads, while at low loads the power differences developed by the engine are insignificant

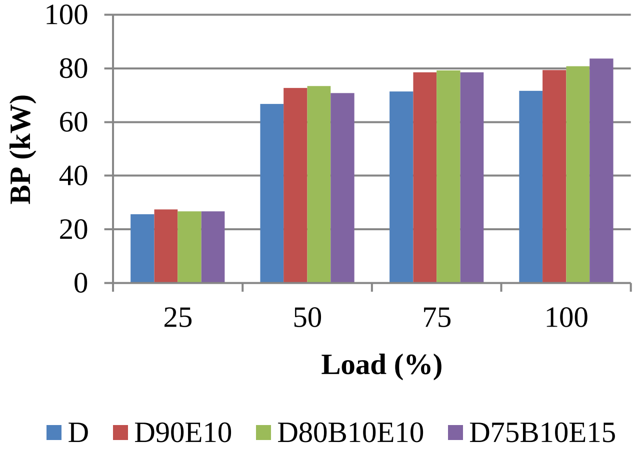

Figure 2. Brake power at different loads.

3.2 Carbon monoxide emissions (CO)

As shown in figure 5, CO emissions with combined fuels are higher than those of pure diesel. Increased emissions are caused by inefficient combustion, which is also observed by the variation of HC emissions (figure 6). Usually, any engine is most prone to CO emissions when the engine is running on a rich mixture or when the proper air-fuel mixture is not being made.

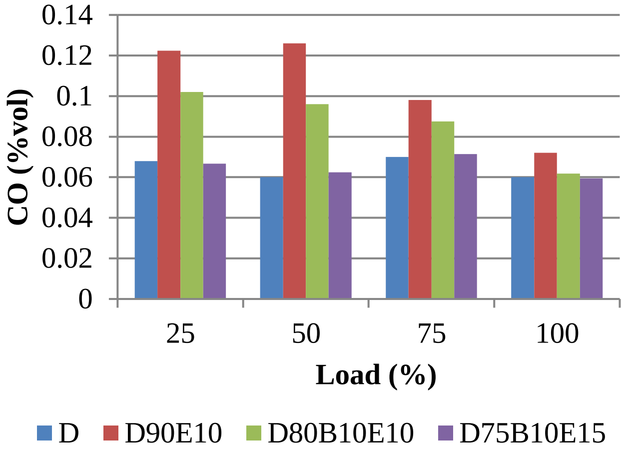

Figure 3. CO emissions.

3.3 Hydrocarbons emissions (HC)

Hydrocarbon (HC) emissions are considerably higher at all operating modes, as shown in figure 6. Unburned hydrocarbon emissions are due to improper injection process. Due to the low cetane number of ethanol, the ignition delay increases, producing an accumulation of unburned fuel in the cylinder. Due to this, areas with a rich mixture appear which burn incompletely, leading to an increase in hydrocarbon emissions.

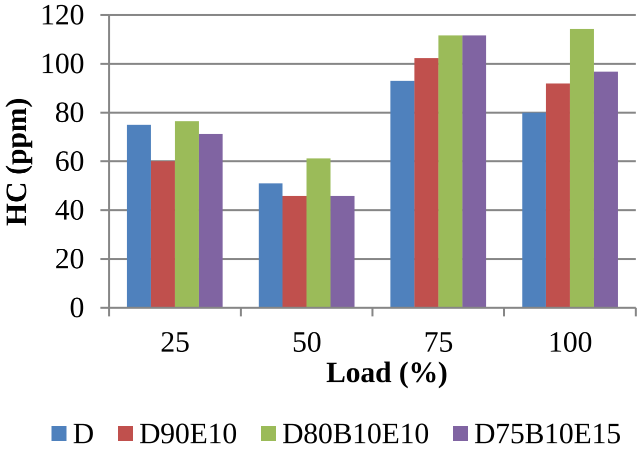

Figure 4. HC emissions.

3.4. NO_x emissions

The NOx formation rate decreased with the operation of the engine with ethanol-based mixtures compared to the operation with simple diesel. This can be attributed to the addition of ethanol, which possesses high latent heat of vaporization. During vaporization ethanol absorbs amount of heat from cylinder and drops the in-cylinder temperature. The formation of NOx emissions is favoured by the temperature and the presence of nitrogen in the cylinder. By decreasing the temperature in the cylinder, the rate of NOx formation also decreased.

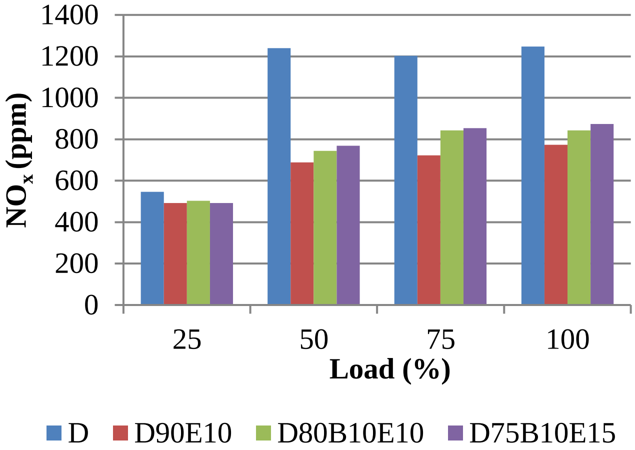

Figure 5. NO_x emissions.

4. Conclusions

In this study, the power generated, CO, HC and NOx emissions resulting from the addition of ethanol and bioethanol in a concentration of 10% and 15% to diesel fuel were investigated. For this purpose, a 4-cylinder engine in line was used at loads of 25%, 50%, 75% and 100%, at maximum power speed.

At higher engine loads, the engine's brake power (BP) increased with the ethanol-diesel-biodiesel mixture. A decrease in the power at low loads of the engine powered by an ethanol mixture was observed.

Hydrocarbon emissions (HC) are considerably higher at all engine tests regimes. Carbon monoxide (CO) emissions are higher than diesel fuel due to incomplete combustion, which certainly reflects an inhomogeneous air-fuel mixture.

The rate of formation of nitrogen oxides (NOx) emissions decreased when the engine was supplied with ethanol mixtures compared to the operation with mineral diesel. This is mainly due to the addition of ethanol which possesses high heat of vaporization.

5. References

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