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Experimental Study of Alcohol Blending Effects on the Operating Characteristics of a Diesel Engine

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Abstract

The main objective of this research work is to study, experimentally, the effects of alcohol blending of diesel and biodiesel fuels on the mechanical and thermochemical characteristics of a diesel engine. This experimental study was carried out on a single cylinder four-stroke and air-cooled diesel engine. As a first step, we have investigated the effect of adding small quantities of different types of alcohol on the diesel engine performances. In this paper, we present only the results obtained for 2.5% of ethanol added to pure diesel fuel. The comparison was made between pure diesel D100 and a mixture between 97.5% of pure diesel and 2.5% of ethanol (D97.5E2.5). The tests were carried out under four different loads 1/4, 1/2, 3/4 and full load. Experimental results showed a decrease in the specific fuel consumption (SFC) of the D97.5E2.5 compared to the D100. The decay margin increases as the load increases and starts from about 5% at 1/2 load up to 27% at full load for an engine speed at the vicinity of 2100 rpm. The effect of the ethanol addition on engine power (BTP) was remarkable. An increase in the BTP was observed under full load and for all engine speed range. İn the case of other loads, the increase on BTP was observed only at speeds above 2500 rpm.

Keywords: Diesel engine, Alcohol, Ethanol, SFC, BTP

Research Article

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1. Introduction

Air pollution, caused by exhaust gases from industrial activities and road traffic, often manifests itself in the form of pollutant haze or smog. The density of microparticles, the gradual increase in the amount of CO2 and other pollutants in the environment, contributes to global warming and causes respiratory diseases [1]. In large urban areas of developed countries, exhaust gases have become the primary source of pollution, particularly nitrogen dioxide, fine particles, and unburned hydrocarbons. According to recent statistics of the World Health Organization (WHO), air pollution is responsible of the death of 4.2 million people per year over the world. Hence, air pollution become the fourth factor of premature death on earth [2].

Many scientific investigations have taken as primary objectives the reduction of polluting emissions from combustion either by intervening after combustion on the exhaust gas (catalysts systems, EGR or other devices), or by intervening before combustion by seeking other alternative fuels or by adding other additives. In this context, our objective is to study the effects of the fuel composition variation, by adding ethanol, on the mechanical and thermochemical characteristics of a diesel engine.

In general, alcohol-based fuels are promising fuels for diesel engines, thanks to their low emissions and their easy adaptability to engine technologies. This kind of fuel blending are competitive due to their liquid nature, high oxygen content which reduce combustion chamber temperature and harmful emissions.

Addition of higher alcohols to biodiesel may reduce density, viscosity, improve atomization characteristics, exhibited a longer ignition delay and longer burning time. [3]

Primary alcohols (methanol, ethanol) are characterized by a hydroxyl radical linked to a primary carbon, leading to a low opacity, especially at high engine operating loads, but despite their high oxygen content, the low cetane number and viscosity of this kind of alcohols make the auto ignition in diesel engines bit difficult. [4]

Several studies have been performed on the application of alcohols, especially ethanol, to diesel engines that have confirmed their positive effect on the engine's performance [5-8].

The main results that concluded from prior experimental studies are:

- ✓ The use of methanol as an additive resulted in a decrease in carbon oxides but a slight increase in unburned hydrocarbons (UHC) and NOx.[9]
- ✓ Using isoamyl alcohol generates a reduction up to 52% of CO and 20% of NOx but an increase in UHC of about 40%. [10]
- ✓ The addition of ethanol or methanol improves the fuel air mixture and the temperature inside the cylinder giving a considerable reduction in the fuel consumption and UHC emission but an increase in NOx.
- ✓ The adding of higher alcohols (butanol, octanol, heptanol, propanol, n-butanol, 1-pentanol) generates a reduction in specific consumption reaching 9.3%, exhaust gas temperature, NOx emissions but an increase in UHC. [3]

The objective of this research work is to study the effect of substituting diesel fuel by small quantities of ethanol on the operating characteristics of the engine.

2. Experimental Setup

The experimental device (Figure 1) essentially consists of a single-cylinder four-strokes air cooled diesel engine (table 1). The engine is coupled to a dynamometer which is used at first to start the engine then as a generator to determine the engine performance. The dynamometer is linked to an electric load rheostat allowing to choose the specific load (1/4, 1/2, 3/4 and full load). The fuel consumption is measured by a graduated burette connected to a fuel tank supply. The engine speed is measured using a typical optical tachometer (VT-8204). The airflow through the air filter as well as its temperature are determined by a Pitot tube anemometer model VPT-100.

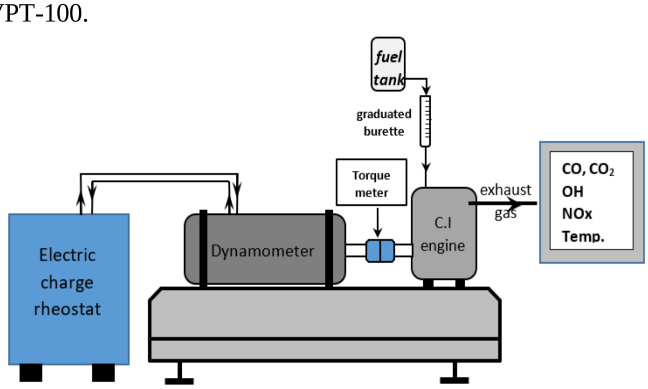

Fig. 1. Experimental Setup

Before doing measurements, the engine must run for at least fifteen minutes so that it reaches its stable operating conditions, and so that the transient phase does not affect the results.

For each test all the experimental values are taken three times then the average value is calculated.

Table 1. Engine characteristics

Type	Lombardini 6LD325N
Cylinder	1
Stroke	4
Displacement (cc)	325
Compression ratio	18:1
Power (kW)@ (rpm)	5 @ 3500

3. Experimental Results and Discussion

To understand the effects of alcohol blending on diesel engine characteristics, we have compared the results obtained by adding small quantities of ethanol on the mechanical and thermochemical characteristics to those obtained for pure diesel fuel. In order to avoid homogeneity mixing issues as reported by Abu-Qudais et al. [11] and knocking problems as reported by Xing-Cai et al. [12], especially at high speeds causing the abruptly stop of engine, the percentage of ethanol has been limited to 2.5%. The studied fuel (D97.5E2.5) is composed by 97.5% of pure diesel and 2.5% of ethanol. Measurements were carried out at the whole speed range {1000-3200 rpm} and under different loads {1/4, 1/2, 3/4 and full load}.

In this paper, presented results are limited to fuel consumption (SFC), engine developed power (BTP) and torque, function of directly measured engine speeds and at various loads applied by the electric load rheostat through the dynamometer. Exhaust emission measurements have not yet been carried out.

Figure 2 shows the specific fuel consumption, for pure diesel D100 and for a mixture D97.5E2.5, in which, we substitute 2.5% of diesel fuel by ethanol. Globally, figure 2 shows a decrease in the specific fuel consumption of D97.5E2.5 compared to D100 at the whole range of speeds and loads.

The mean SFC reduction rises as the load increases: it starts from about 5% at 1/2 load up to 27% at full load for an engine speed in the vicinity of 2100 rpm. This was mainly due to the evaporation temperature of ethanol which is about 2-3 times lower than that of diesel, speeding up the preparation of the air-fuel mixture. More complete and improved combustion was also obtained using D97.5E2.5 and it is due to the combined effect of the ethanol properties and the availability of oxygen in the fuel. The same result was observed by Zare et al. [13] for ethanol blends less than 10%.

Figure 3 shows the evolution of the BTP as a function of the rotation speed for D100 and for D97.5E2.5. One can notice that under 1/4, 1/2 and 3/4 loads, the addition of a small quantity of ethanol does not affect the engine BTP delivered at speeds below 2500 rpm. Notable effect appeared only behind 2500 rpm. An improvement of about 12% in BTP was observed.

In the case of full load, the effect of ethanol addition is more obvious even at low speeds. An enhancement on BTP of about 35% was observed throw the whole range of engine speeds. This result was also obtained by Putrasari et al. [14] for a similar percentage of ethanol. They explained this result by the fact that when the small quantity of ethanol burns due to the high compression rate it accelerates the evaporation and then the dispersion-mixing phase of the fuel, hence the whole combustion process becomes more efficient which affects positively SFC and mainly BTP.

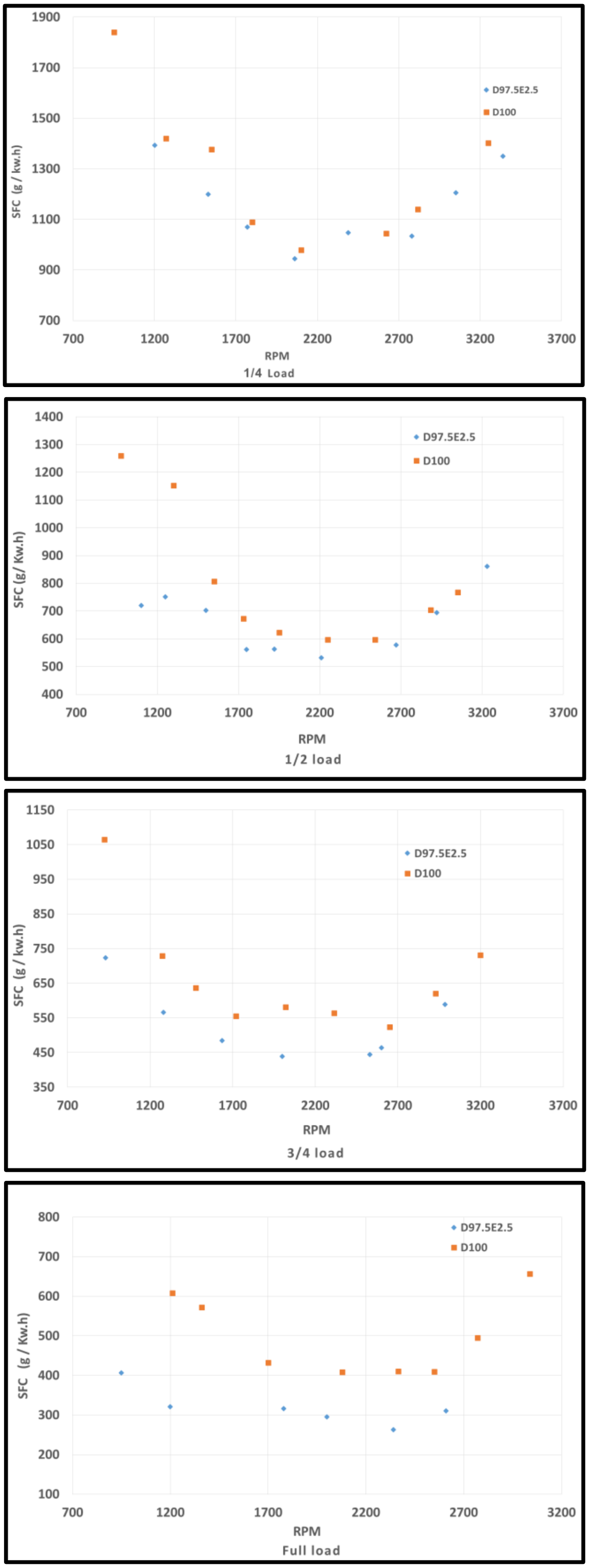

Fig. 2. Effect of ethanol addition on SFC under different loads

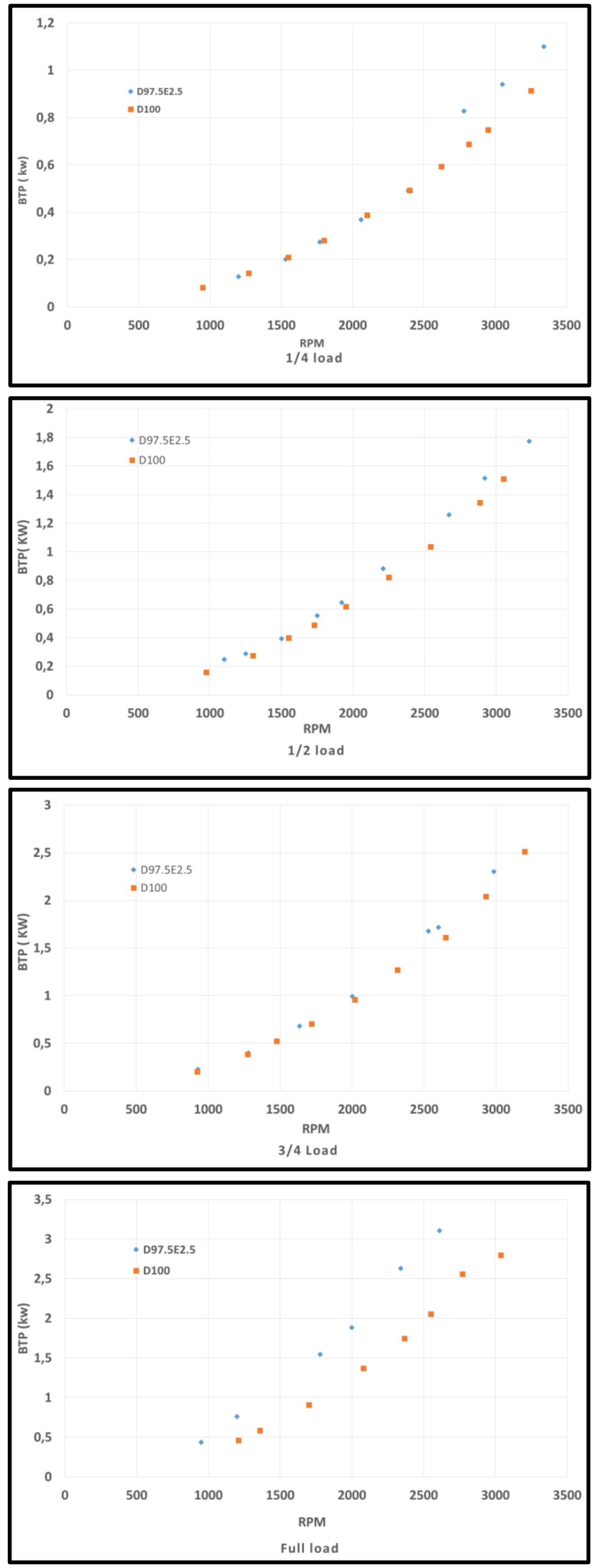

Fig. 3. Effect of ethanol addition on BTP under different loads

Figure 4 shows the evolution of the engine torque as a function of the engine speed for D100 and for D97.5E2.5.
Except for full load, the mean torque enhancement is about 8%, for the different loads and at all speed ranges.
Adding a small quantity of ethanol to diesel gives better and important results, in terms of developed torque, comparatively to that obtained for pure diesel, at different engine speeds and, especially under full load, but this effect declines as the load decreases.

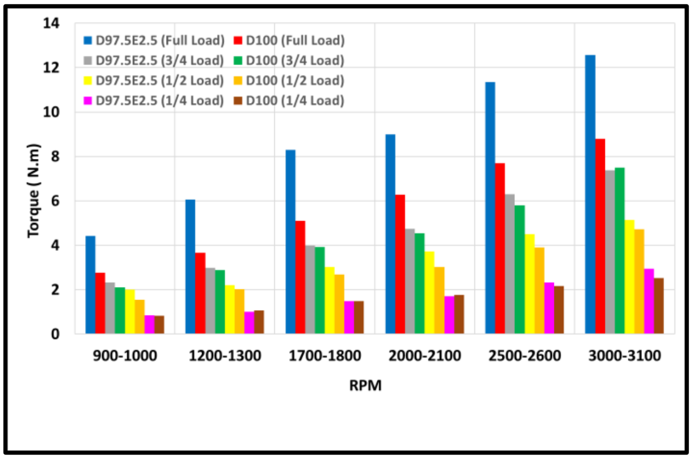

Fig. 4. Effect of ethanol addition on torque under different loads

Our results are confirmed by previous experimental studies. Bilgin et al. [15] studied, experimentally, the effects of diesel-ethanol blends (2, 4, and 6 % by volume) on a variable compression ratio (19, 21, and 23), compression-ignition engine performance. This study demonstrated that the addition of 4% ethanol to diesel fuel gives the best results by increasing the brake thermal efficiency, brake torque, and brake power, while decreasing the brake specific fuel consumption.

Taghizadeh-Alisaraei and Rezaei-Asl [16] investigated the effects of adding ethanol (by 2, 4, 6, 8, 10, and 12%) to pure diesel fuel on performance, vibration, combustion and knocking of a 6 -cylinders CI engine at full load. They found that the addition of ethanol, for example by 6%, has increased the engine torque by an average of 8.3% at engine speeds ranging from 1600 to 1900 rpm. This value reached 13.2 % at 2000 rpm.

4. Conclusions

The main objective of this research was to investigate experimentally, the effect of the addition of a small quantity of ethanol on a diesel engine performance.

The experiment was carried out using a single cylinder air-cooled diesel engine.

Comparisons between pure diesel fuel D100 and D97.5E2.5, in which 2.5% of the diesel fuel are substituted by ethanol, was made for SFC, BTP and torque.

Measurements were obtained by varying the engine speeds and under various loads.

The experimental results have demonstrated that:

- adding a small quantity of ethanol in CI engine has an important enhancement in engine performance especially under full load.
- a gradually decrease was observed in the SFC as loads increase. It starts from 5% at 1/2 load up to 27% at full load for an engine speed in the vicinity of 2100 rpm
- An enhancement of the BTP was obtained: a mean of 12% under low loads behind 2500 rpm but a mean of 35% was obtained at full load and throw the whole speed range.
- An obvious increase in the developed torque was also observed at full load in the whole range of engine speed.

This work represents the first step of a more developed research which will be carried out using further quantities and different types of alcohols and biofuels.

Nomenclature

BTP	break thermal power
SFC	specific fuel consumption
RPM	revolution per minute
CI	compression ignition

Conflict of Interest Statement

The authors declare that there is no conflict of interest in the study.

Credit Author Statement

Fakher Hamdi: Investigation, Writing-original draft, Writing - review & editing,
Mehrez Gassoumi: Investigation, Visualizatio,
Zouhaier Boutar: Validation, Formal analysis,
Ridha Ennetta: Conceptualization, Supervision, Project administration,
Hakan Serhad Soyhan: Conceptualization, Supervision

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