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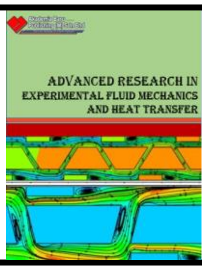

Experimental Evaluation of the Performance of a Diesel Engine Feeding with Ethanol/Diesel and Methanol/Diesel

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ABSTRACT

Article history:

Nowadays, decreasing sources of petroleum fuel has led to innovation of other resources. Alternative fuel can be produced from biomass such as alcohol. In this work, an experimental study on the feasibility and the effects of using Diesel-ethanol and Diesel-methanol blends as alternative fuel for Diesel engine was carried out. Pure Diesel, Diesel-ethanol, D95E5, D90E10 and D85E15 as well as Diesel-methanol, D95M5, D90M10 and D85M15 on Farymann four stroke monocylinder Diesel engine performances was completed. The engine was tested at full load with engine speed ranged from 700 to 3000 tr/min. The effects of ethanol and methanol fraction on diesel engine power, torque, brake specific fuel consumption (BSFC), brake thermal efficiency and exhaust temperature were experimentally investigated. The results showed that mixing ethanol and methanol at different fractions with Diesel fuel have a significant effect on the engine performance, as well as the nature of alcohol, which constitutes a combustion catalyst. Fuel mixtures, D85E15 and D85M15 have the highest improvement rates compared to pure Diesel and other examined fuel mixtures. It has been shown, that, the lowest BSFC than that of pure Diesel, which is an advantage for our proposed fuels, is recorded with D95E5 and D95M5 blends. The different mixtures provide higher exhaust gas and outlet temperature of the coolant proportional to the mixing ratio, which explains why the addition of biofuel improves the calorific value of the fuel. The combustion of the different mixtures increases the outlet temperature of the coolant in proportion to the mixing rates.

Keywords:
Diesel engine; engine performance; Ethanol-Diesel blend, Methanol-Diesel blend

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1. Introduction

The increase in fuel consumption and the unstable rates of their prices have direct impacts on consumers and cause them to suffer various problems, which has triggered a great attraction towards alternative and low-cost biofuels. Excessive fossil fuel consumption has led to a reduction in underground carbon resources. The search for alternative fuels, which promise a harmonious

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correlation with sustainable development, energy conservation, efficiency and environmental preservation, has become very pronounced nowadays. Fuels of biological origin can provide a feasible solution to this problem. In addition, petrol and diesel cars are the main sources of greenhouse gas emissions. In addition, the intensive use of crude oil has also increased air pollution by exhaust emissions [1]. These vehicle exhaust emissions have dangerous effects on human health [2-5]. Scientific research in recent years has explored several alternative energy resources, which have the potential to meet the ever-increasing energy needs of today's consumers [6-9]. As a result, several researches promote the use of methanol and ethanol as alternative fuels for internal combustion engines due to their richness in oxygen to produce energy with less emissions. The use of alcohols as additives to conventional combustion engine fuels improves thermal efficiency and reduces CO and HC emissions [10]. Ethanol and methanol contain a high oxygen content compared to pure diesel; thus, they improve the combustion process in the cylinder [11,12]. From the above, we see that there is a need and motivation to explore the potential of using Diesel-Ethanol and Diesel-Methanol blends in compression ignition (CI) engines. This work aims to study by experimentation the potential to improve the performance of the diesel engine running on this type of alcohol-based blended fuels. The performance of an IC engine at different blending ratios of ethanol and methanol with pure diesel was studied on a single-cylinder four-stroke diesel engine.

2. Properties of Biofuels and Preparation of Mixtures

Several oxygenated fuel additives that were used are methanol, ethanol, tertiary butyl alcohol and tertiary butyl methyl ether [13,14]. According to Simeon Iliev [14], the use of oxygen-containing (oxygenated) alternative fuels is very important as an additive fuel as it can increase engine performance and efficiency. Dasilva *et al.,* [15], deduced that ethanol and methanol had a higher octane number than diesel as well as gasoline. This allows ethanol-Diesel and methanol-Diesel blends to have much higher compression ratios and increases thermal efficiency according to Thangavelu *et al.,* [16]. The blended fuels were obtained by mixing ethanol and then methanol with Algeria Diesel fuel, which was obtained from a local gas station in Chlef. Ethanol and methanol were obtained from the Process Engineering Laboratory at Chlef University. The mixtures were made in the ratios E5D95, E10D90, E15D85, and M5D95, M10D90, M15D85 on a volumetric basis. For example, an E10D90 mixture contains 10% ethanol and 90% diesel fuel. Mixtures were made simply by pouring the two fuels into a container of the correct proportions and mixing them until the mixture was homogeneous. Table 1 below describes the fuel properties of ethanol and methanol compared to pure diesel [13].

Table 1
Comparative properties of fuels

Properties	Diesel	Ethanol	Methanol
Molecular formula	C_{14}-C_{30}	C_2H_5OH	CH_3OH
Molecular weight -	-	46	32
Oxygen Level (%) -	-	34.7	49.9
Density (kg/m3)	845	785	792
Cetane number	>50	108	111
Stoichiometric air/fuel ratio	14.96	9.0	6.47
Auto-ignition temperature (°C)	220	425	465
Lower calorific value (MJ/kg)	43.45	27.00	20.10

This study was performed to test the performance of a Farymann P604 direct-injection air-cooled four-stroke single-cylinder diesel engine. Table 2 presents the specifications of the engine used. The engine is connected to a hydraulic dynamometer via a connection and the dynamometer relinquishes the load on the engine to measure the braking power (Figure 1). The experimental study is carried out using the different fuel mixtures prepared, for engine speeds ranging from 700 rpm to 3000 rpm under constant engine load.

Table 2
Test Engine Specifications

Description	Characteristics
Carburant	P604
Fuel	Diesel
No. of cylinders	1
Boron (mm)	95
Stroke (mm)	100
Cylinder capacity (cm^3)	708
Rated speed, rpm (max)	3,000
Volumetric ratio	21±1.5 to 1
Compression pressure (bar)	25 to 30
Engine oil consumption	1.0 g/kWh

In the present study, different percentages of Diesel-ethanol and Diesel-methanol blends (0%, 5% 10% and 15%) were tested to study the effects of alcohol blends on diesel engine performance (braking power, BSFC and BTE) without any modification on the original engine.

The main objectives were to address the problem of the depletion of fossil fuels and consequently reduce their harmful effects in addition to the idea of using biofuels (ethanol and methanol) as an alternative fuel less harmful to the environment. At the end of this research, the results obtained were compared with those of the literature.

3. Materials and Methods

The engine was started for about 10 minutes as a warm-up period for the engine operation stability to be reached. The fuel blending test then began with ethanol-Diesel blends, followed by methanol-diesel blends. Pure Diesel is used after each fuel mixture use to clean traces of fuel mixtures in the fuel lines. The engine was tested approximately 15 min for each mixing test with engine speed in the range of 700 to 3000 rpm at full throttle.

Figure 1 shows the configuration of the experimental test bench. The motor is coupled to an eddy current dynamometer (model Froude Hoffman AG150) with a maximum power of 150 kW to measure the torque and power of the motor. A graduated burette and stopwatch are used to measure the flow of fuel consumed. The temperatures of the fluids (exhaust gases, coolant, glycol water) are measured by thermocouples, the coolant is measured by two mercury-based graduated thermometers, the first measures the water temperature at the inlet and the second measures the water temperature at the outlet. The intake air flow rate is measured by a flow meter based on the air box method. The temperature of the exhaust gases is measured by a Testo 925 type thermometer.

4. Performance Calculation

Braking power is used to indicate the power actually delivered by the engine. Braking power is defined as follows [17]:

$$P = \frac{2\pi NT}{60000}\ [kW] \quad (1)$$

With, N: engine speed (rpm)
T: engine torque (N.m)

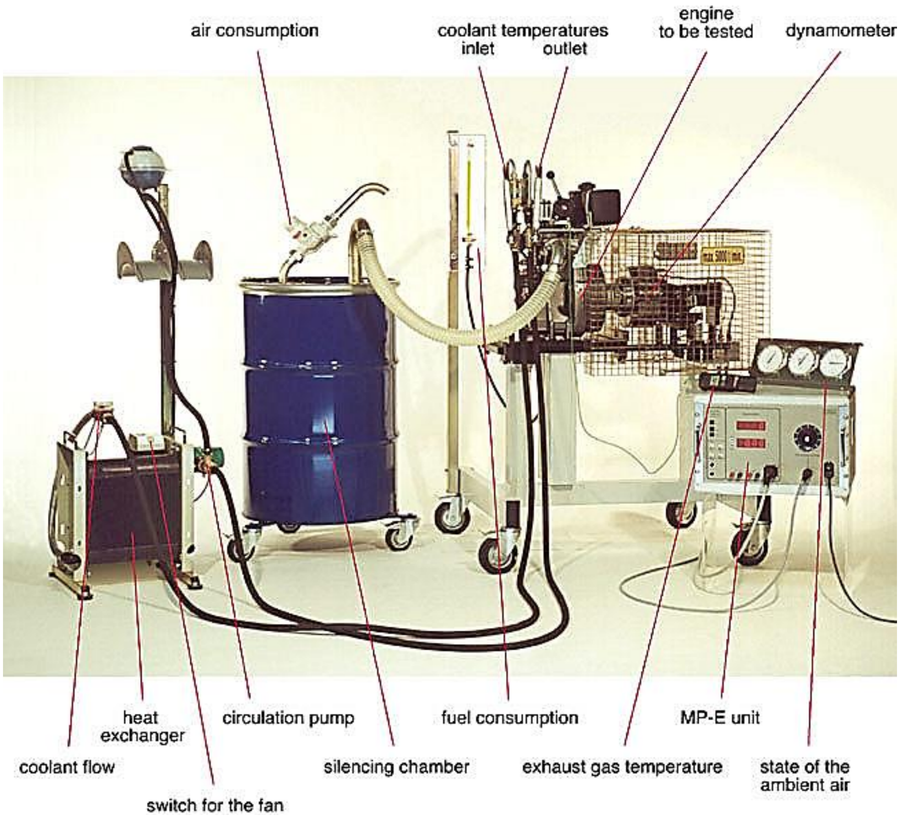

Fig. 1. Experimental test bench

BSFC is the fuel consumption characteristic of an engine. It is expressed as fuel consumption in kilograms of fuel per kilowatt-hour [18].

$$BCFC = \frac{\dot{m}}{B_p}\ [\frac{g}{kW.h}] \quad (2)$$

With,
$\dot{m}$: fuel mass flow $\left(\frac{\mathrm{g}}{\mathrm{h}}\right)$
B_p: engine braking power (kW)

BTE is the ratio of braking power to input fuel thermal energy in appropriate units [9].

$$BTE = \frac{B_p}{CV.360} \ [\%] \qquad (3)$$

where,
B_p : engine braking power (kW)
CV: calorific value of the fuel $\left[\frac{kJ}{kg}\right]$.

5. Results and Discussion

This section includes the results of the experiment conducted on the Farymann P604 diesel engine. The behaviour of blended fuels; Diesel, Diesel-Ethanol, D95E5, D90E10 and D85E15 as well as Diesel-Methanol, D95M5, D90M10 and D85M15 is shown in their relative graphs with discussion.

The results illustrate the engine torque, the braking torque, the useful power, the specific fuel consumption, the braking thermal efficiency, the energy consumption specific to braking, the engine coolant temperature and the exhaust gas temperature and finally the engine efficiency.

By virtue of the experimental results presented in Figure 2 and 3, for diesel-ethanol fuel mixtures compared to pure diesel, the engine torque is higher than that in the case of pure diesel, the torque increases with the increase in engine speed as well as with the rate of the diesel-ethanol mixture.

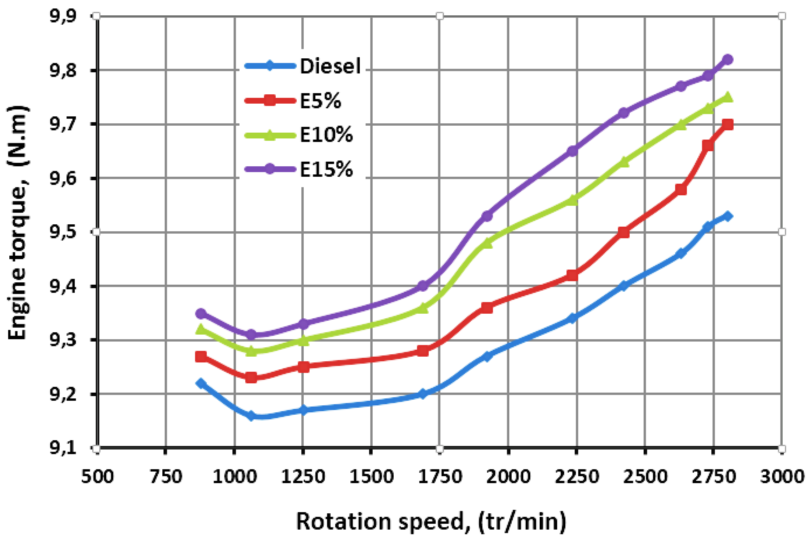

Fig. 2. Engine torque versus engine rotational speed for different Diesel-ethanol blends

For the braking torque shown in Figure 3, the improvement is less important but the trend is maintained.

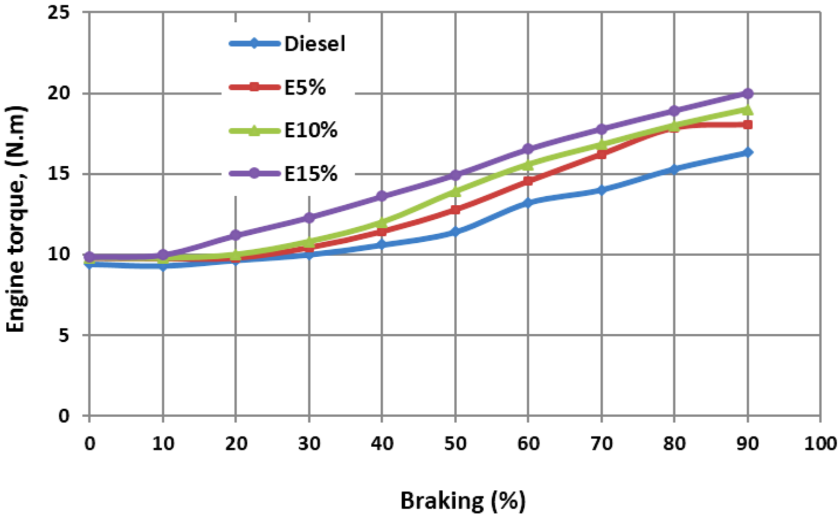

Fig. 3. Braking torque for different Diesel-Ethanol blends

According to Figure 4, ethanol blends significantly improve engine power, i.e. power is a key performance for any engine. In addition, this improvement follows the increase in the mixing rate. This explains the high power of the D85E15 mixture compared to other low ethanol mixtures.

Conferring to the results in Figure 5, the specific consumption of brake fuel mixtures is much higher than that of pure Diesel, which is a disadvantage for the proposed fuels and this may be due to the engine originally designed to run on pure Diesel and the nature of ethanol, which is a combustion catalyst. On the other hand, ethanol improves the rest of the engine's performance, which is very appreciable. The lowest BSFC is recorded with the D95E5 blend. According to the literature, this disadvantage can be overcome by adding certain additives.

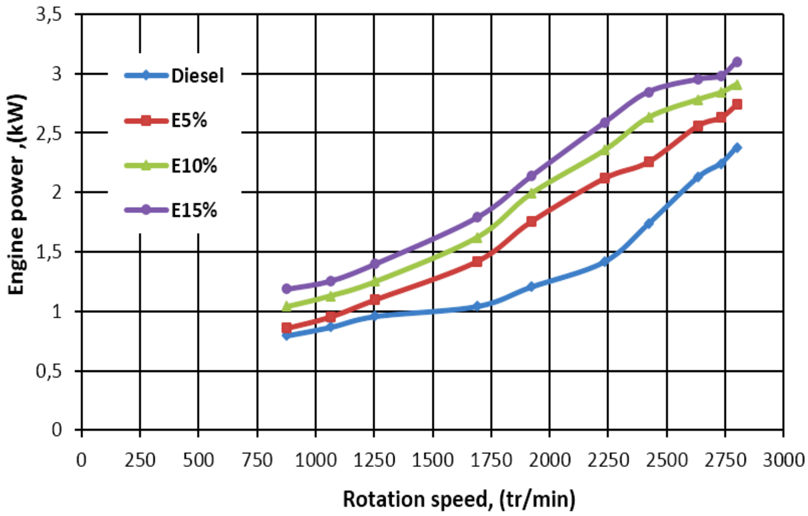

Fig. 4. Engine power versus rotation speed for different Diesel-Ethanolblends

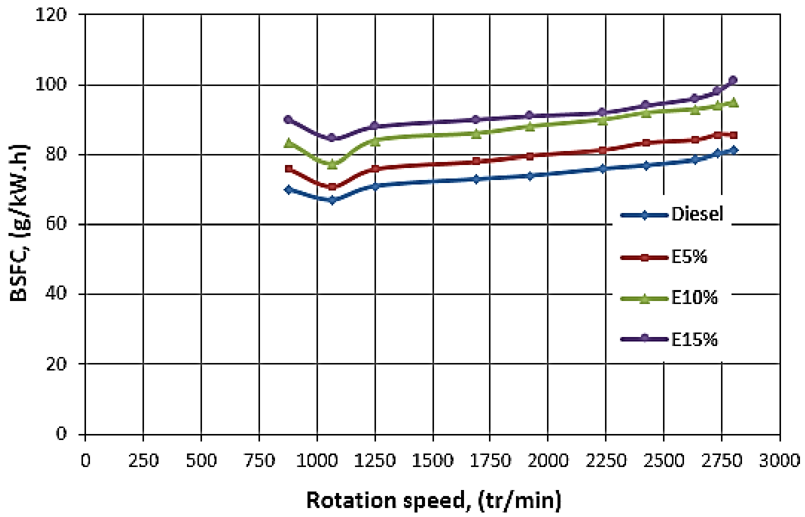

Fig. 5. CSCF depending on engine speed for different Diesel-Ethanol blends

According to the results of Figure 6, the increase in the temperature of the exhaust gases is all the greater and proportional to the increase in the ethanol content of the mixture. The highest exhaust gas temperature corresponds to the D85E15 mixture.

From the results presented in Figure 7, it is clear that the use of ethanol in this test led to better thermal braking efficiency compared to other fuel mixtures. This is due to the complete combustion resulting from the use of ethanol in the fuel mixture. It was found that increasing the ethanol level in the Diesel engine is less beneficial at high speeds around 3000 rpm, as shown in Figure 7, adding more than 10% ethanol does not further improve the thermal braking efficiency unlike pure Diesel.

According to the results presented in Figure 8, the use of ethanol in these tests led to a better yield compared to that of pure Diesel with about 20% for the D85E15 mixture. Figure 8 clearly shows the proportional increase between the engine efficiency and the engine speed as well as the efficiency with the ethanol mixing rate. It is observed that for operating speeds above 2400 rpm, the efficiency is delayed and this in relation to the mixing rate.

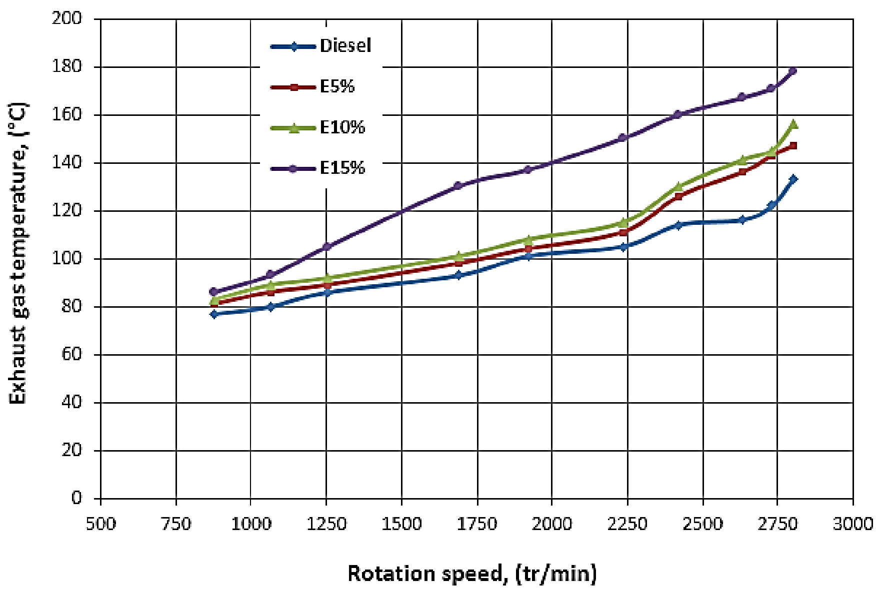

Fig. 6. Exhaust Gas Temperature for Different Diesel-Ethanol Mixtures

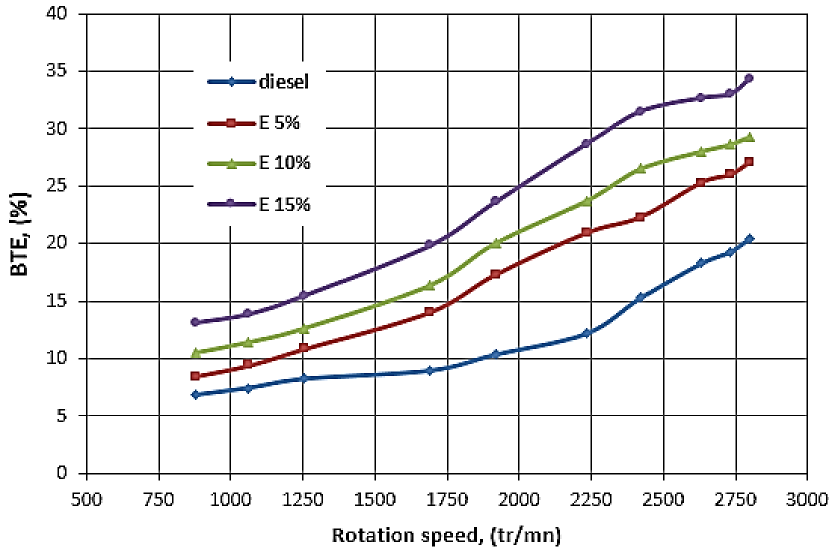

Fig. 7. Thermal braking efficiency for different Diesel-Ethanol blends

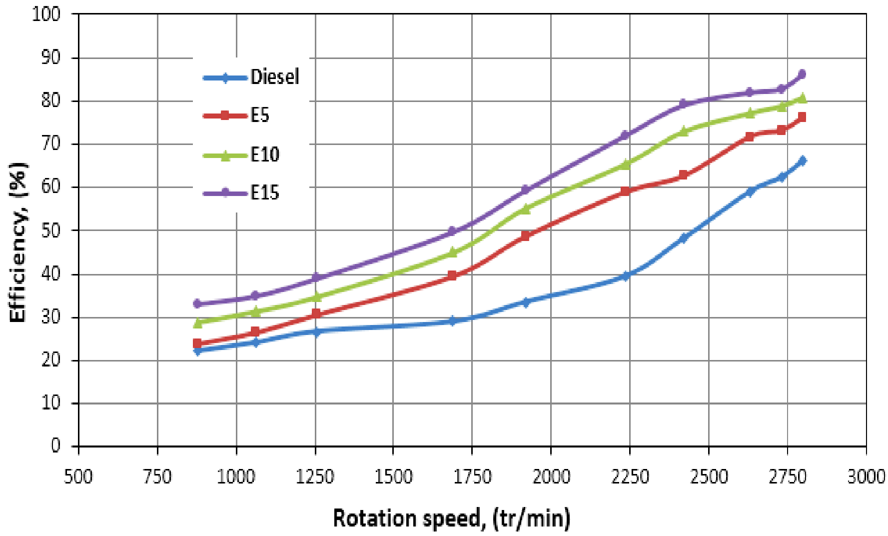

Fig. 8. Engine efficiency based on different Diesel-Ethanol blends

The evolution of the engine torque with respect to the engine speed at different Diesel-methanol mixing ratios is shown in Figure 9. It is well recorded that, the starting torque is high at low rpm, this is due to the high starting resistance, but once it is overcome, the torque decreases then increases with increasing engine rpm. The experimental results obtained show that the rate of the methanol mixture further improves the engine torque.

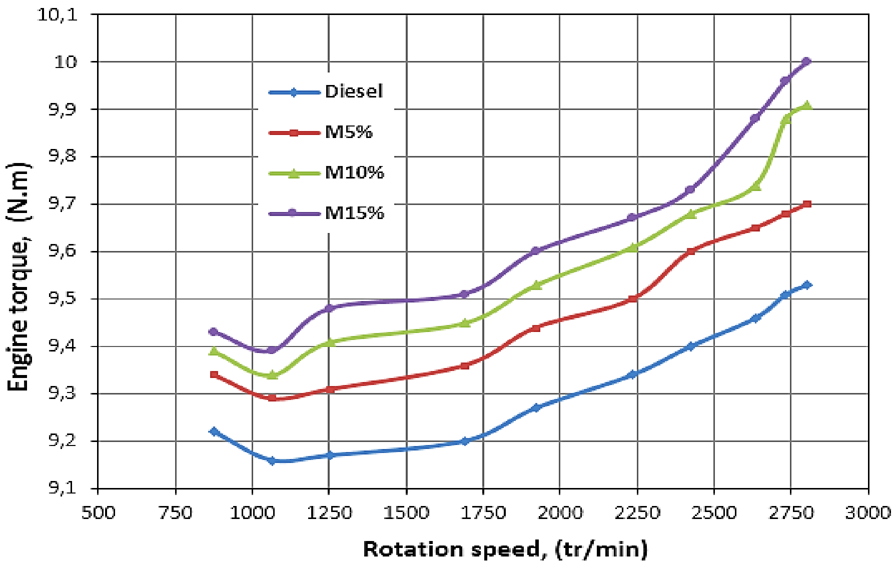

Fig. 9. Torque as a function of engine speed for different Diesel-Methanol blends

However, the trends in the results are the same. For pure diesel, the curve is fairly constant with a difference between the maximum and minimum values. Meanwhile, mixing Diesel-methanol shows an increase in torque at higher speeds. However, at all engine speeds, Diesel-methanol blended fuels in all ratios have a higher torque than pure Diesel fuel, which means that the use of methanol has the potential to improve the performance of the Diesel engine.

For the braking torque shown in Figure 10, the improvement is less important but the trend is maintained.

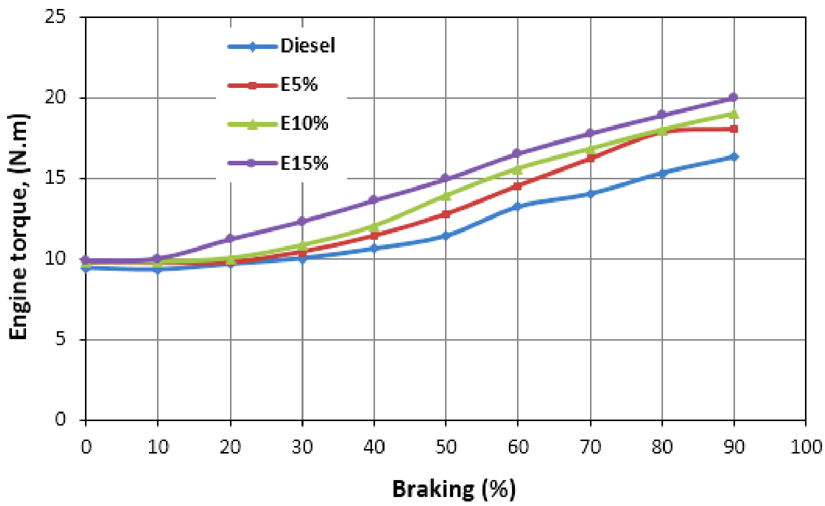

Fig. 10. Braking motor torque comparison for different Diesel-Methanol blends

The input power of the engine can be estimated by the amount of fuel injected into it. Theoretically, it is determined on the basis of the flow rate and the net calorific value of the blended or pure fuels.

The net calorific value of methanol is about half that of diesel, with values of 23.8 MJ/kg and 44.5 MJ/kg for methanol and diesel respectively. It is well known that engine power is strongly controlled by combustion efficiency. The experimental results obtained, Figure 11 shows the effect of the various fuel mixtures on the engine power.

In general, it can be seen that the power output from blended fuels gives a higher power output than pure diesel. The improvement in power output from blends is significantly greater than that of pure diesel.

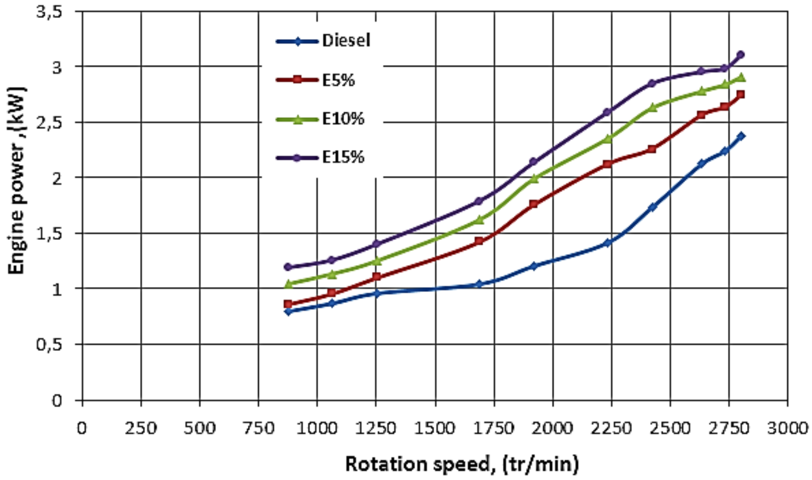

Fig. 11. Engine power as a function of engine speed for different Diesel-Methanol blends

Brake Specific Fuel Consumption (BSFC), which is defined as the fuel flow rate per hour (kg/hr) divided by engine braking power (kW), is a measure of engine efficiency. The CFSO based on engine speed is shown in Figure 12, which represents the CFSO at maximum operating conditions. A significant difference between blended fuels and pure diesel fuel can be seen in Figure 12.

In addition, the specific consumption of pure diesel fuel is the lowest compared to other diesel-methanol blends, these results fit well with those obtained by Sayin *et al.,* [19]. This is due to the difference in the lower calorific values of the different types of fuels compared.

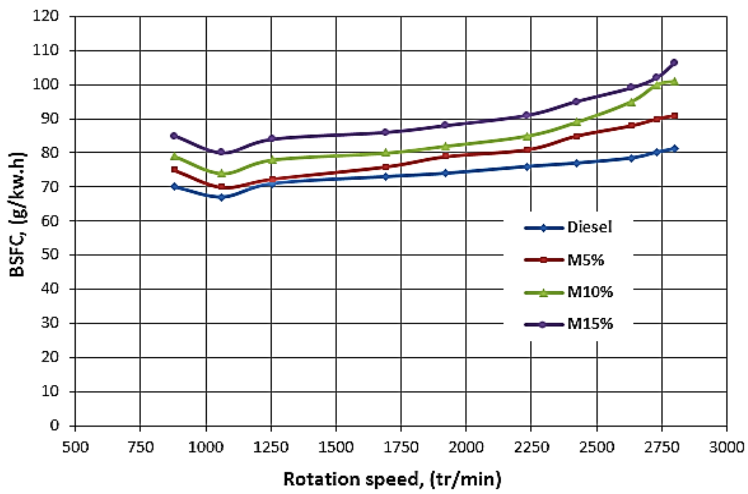

Fig. 12. CSCF as a function of engine speed for different Diesel-Methanol blends

It should be noted that the specific consumptions relating to diesel-methanol mixtures are certainly much higher than that of pure Diesel but deliver greater powers than that derived from pure Diesel (see Figure 11). In order to obtain the same input power, the amount of fuel mixture must be decreased.

Figure 13 shows the evolution of the exhaust gas temperature with respect to the engine speed at full load. At all engine rpm ranges, the best mixing ratio that produces the lowest exhaust temperature is 10% methanol and 90% diesel. The greater the amount of methanol injected into the combustion chamber, the more oxygen will be available, which will lead to complete combustion.

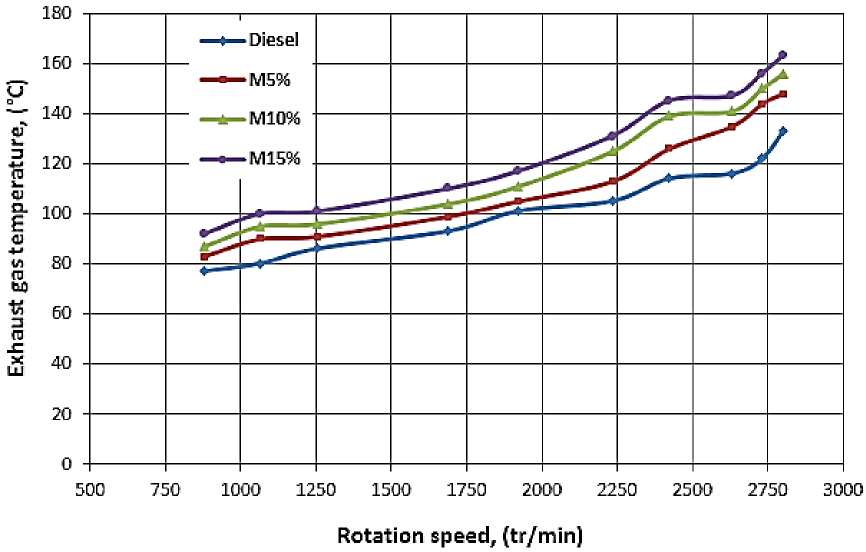

Fig. 13. Exhaust Gas Temperature for Different Diesel-Methanol Blends

Thermal braking efficiency is the percentage ratio of braking output power and input power. From the results presented in Figure 14, it is clear that the use of methanol in this test led to better thermal braking efficiency compared to pure diesel. This is due to complete combustion when methanol is used.

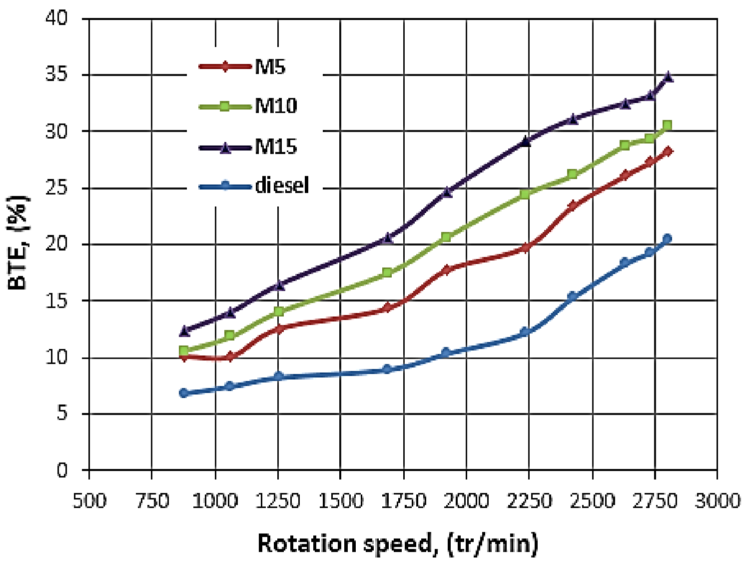

Fig. 14. Evolution of the thermal braking efficiency for different Diesel-Methanol blends

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According to the results presented in Figure 15, the use of methanol in the present study led to a better yield compared to that of pure Diesel with an improvement of around 20% for the D85M15 mixture compared to pure Diesel. The results obtained show that the yield is proportional to the ethanol content of the mixture as well as to the engine speed.

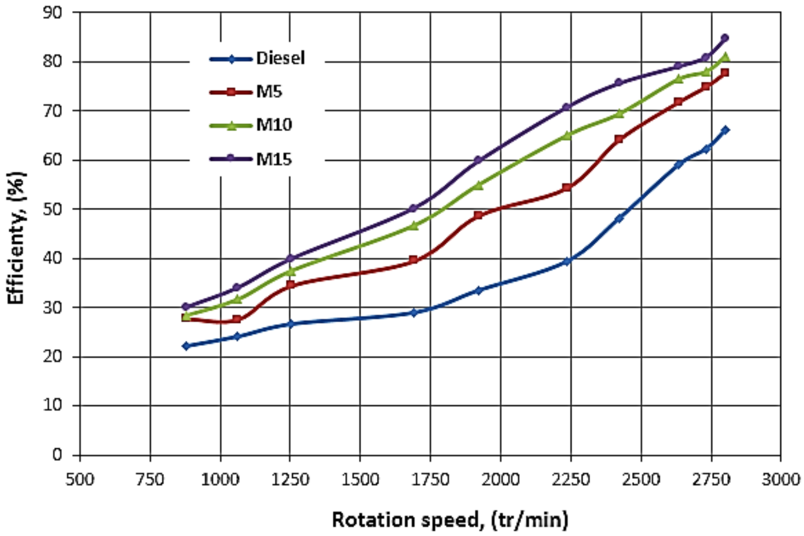

Fig. 15. Engine efficiency based on different Diesel-Methanol blends

6. Conclusion

This study is part of the research objective to evaluate the impact of new generation fuel on the performance of diesel engines. Among the fuels envisaged, the Diesel-Ethanol and Diesel-Methanol mixtures seem to have significant potential. Indeed, they are alternative fuels with physic-chemical properties relatively close to those of a traditional diesel fuel. In addition, their high oxygen content allows an improvement in the combustion process as well as the drastic reduction of particulate emissions at the exhaust. The main objective of this work was therefore to understand the behaviour of fuel mixtures on the performance of the diesel engine. This approach is considered better because it does not affect the cost of the engine by a possible modification and will allow existing engines to remain in use.

The following conclusions can be drawn on the performance of the P604 single-cylinder Farymann Diesel engine without any engine modification at different speeds. The conclusions are as follows:

- Engine torque, braking power and engine efficiency from the combustion of Diesel-Ethanol fuel blends, and Diesel-Methanol fuel blends are higher than those from pure Diesel fuel.
- Fuel blends, D85E15 and D85M15 have the highest improvement rates compared to pure diesel as well as other fuel blends tested on our engine.
- The specific braking fuel consumption for blended fuels is significantly higher than that from pure Diesel, which is a disadvantage for our proposed fuels, this may be due to the engine originally designed to run on pure Diesel as well as the nature of ethanol, which is a combustion catalyst. On the other hand, ethanol improves the rest of the engine's performance. The lowest CSCF is recorded with mixtures D95E5 and D95M5.

- The different blends provide higher exhaust gas temperatures and are proportional to the blending rates in the Diesel. This explains why the addition of biofuel improves the calorific value of the fuel, which is highly sought after.
- Combustion of the different mixtures increases the outlet temperature of the coolant in proportion to the mixing rates. This is explained by the high calorific value of blends compared to that of pure Diesel.

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