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EXPERIMENTAL INVESTIGATION ON EMISSIONS AND PERFORMANCE OF A SPARK-IGNITION ENGINE FUELED WITH GASOLINE–ETHANOL BLENDS

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Abstract— The latest European regulations require the use of biofuels by at least 10% as energy source in transport by 2020 to reduce the worldwide pollutant emissions. The combination between ethanol and gasoline provides a promising and in a same time a challenging approach. Ethanol has attractive properties based on the fact that this fuel can be produced from renewable energy sources without any modification on the engine. This biofuel was used as an alternative fuel due his higher evaporation heat, octane number and flammability temperature. In this study the pollutant emission (CO, CO_2, HC, NO_X) of a gasoline direct injection engine was investigated with an LPS 3000 chassis dynamometer together with the STARGAS 898 gas analyzer. Different studies for traffic operations were analyzed by using the LPS 3000 stand maintaining a constant traction.

Keywords— bioethanol, chassis dynamometer, emissions, gas analyzer.

I. INTRODUCTION

THE world consumption of energy has a raising trend specially due to two main reasons: changes in lifestyles of the consumers and growth of the population in the undeveloped countries. Fossil fuels are predominantly used for the production of energy supply; however they are limited on Earth. In the last century the researches was done to the development of coal, natural gas and fossil crude oil based on any cheaply available fossil feedstock to satisfy the need for energy due to the increase of energy from industrial activities [1]-[2]. Currently, a key issue in the transportation sector is expanding the use of alternative and renewable fuels. Interest in alternative fuels has grown as they continue to play an important role not only in meeting the growing global demand for transportation energy but also in reducing greenhouse gas emissions [3]. To help promote the development and expansion of alternative transportation fuels, a number of government initiatives have been implemented at the regional, national, and local levels [4]–[5]. The principal alternative fuels that are used are oxygenates (alcohol, ether), gaseous fuel (hydrogen, liquefied petroleum gas), vegetable oils and animal fats and their esters, gas to liquids (GTL) and coal products. Bioethanol has attracted the attention especially in the countries which have a large feedstock such as Brazil [6]. Ethanol now provides a significant contribution to road transportation fuel in the US and Brazil. Most expect that the use of renewable fuels including ethanol will increase in the US, EU, and elsewhere, driven by the multiple potential benefits from the use of ethanol as a transportation fuel: decreased petroleum usage and imports, improved air quality in older vehicles, economic stimulus for agriculture and rural areas [7]. Actually the blends of bioethanol and gasoline are used in auto vehicles with direct injection. Ethanol and bioethanol in essence is the same product with the same molecular and structural formula produced from various feedstock's' [8]. In this paper are studied the pollutant emission of blends of gasoline-ethanol.

II. LITERATURE SURVEY

From the literature survey, ethanol–gasoline blended fuels can be used effectively in spark-ignition engine with little or no modifications. Ethanol has higher evaporation heat, higher octane number and the low evaporation pressure compared with gasoline, and contains 34.7% oxygen by weight. There are many points on engine performance when ethanol is used as fuel. The heating values decrease if the amount of ethanol is increased in the fuel blend. Currently the increase of bioethanol in blended fuels enables to decrease of air–fuel ratio, so is needed more fuel in the period of intake processes. Other parameters which influence the engine performance are compression ratio, ignition timing, latent heat of vaporization, excess air ratios and flame speed [8]. Several researchers used ethanol fuel, which benefits from a low cetane number, in a two stroke diesel engine with exhaust gas recirculation (EGR). They showed that ethanol makes lower soot and NOx, and also causes 2-3% increase in thermal efficiency. Several researchers studied the ethanol addition (10% and 15% in volume) and his effects on the performance and emissions on a turbocharged indirect injection diesel engine with four cylinder at different fuel injection pressures (150, 200, 250 bar) at full load. Their results showed that the ethanol addition reduces SO_2, soot and CO emissions, but it caused a rise in NOx emission and power reductions of approximately 20% (for 15% ethanol addition) and 12.5% (for 10% ethanol addition). Also was investigated the effects of ethanol-gasoline blends on cyclic cylinder pressure variation in a production spark ignition engine. Fuel blends with up to 20% of ethanol content were used in the investigation. The authors found that the fuel blend containing 10% ethanol (E10) produced the lowest variation of indicated mean effective pressure for fifty consecutive cycles. Additionally, E10 fuel blend also produced the lowest carbon monoxide (CO) and hydrocarbon (HC) emission levels [11]. Investigations were done at an air-cooled, four-stroke, spark ignition motorcycle engine originally designed for gasoline to operate with ethanol fuel. Fuel injection duration was increased by 62% to comply with the lower heating value of ethanol. The results showed increased peak torque and peak output power by 1.9% and 5.4%, respectively, when ethanol was used instead of gasoline. Fuel consumption for ethanol operation was increased by about 50% in the entire engine speed range investigated. Advanced ignition timing was shown to improve output power for ethanol fuel operation [12]. Other researchers suggested that the anti-knock characteristic of alcohols as one of the main advantages over hydrocarbon fuels, allowing for the use of higher compression ratios and, consequently, the production of higher engine output power. Also, the higher heat of vaporization of alcohols under high temperatures and the faster flame speed permit increased fuel conversion efficiency in comparison with gasoline. Moreover, alcohol combustion generates higher product volume, thus increasing cylinder pressure and the work done on the piston. On the other hand, the smaller low heating value of alcohols results in increased specific fuel consumption in comparison with gasoline, that is, a higher mass amount of alcohol is required per unit power produced. Cold start is also a problem for alcohol fuels, due to their low vapor pressure [13].

III. Comparison of Physical-Chemical Properties

The physical-chemical properties of the fuel indicate the quality and the behavior of the fuel in the engine. Performance, combustion and emission characteristics are dependent on them. The fuel's integrity was preserved throughout the multiple drains and fill sequence by maintaining it at or slightly below room temperature in a temperature-controlled facility until the time the fuel was actually used. The physical properties of ethanol provide important benefits when added to gasoline. Ethanol has both a higher octane rating and a higher heat of vaporization than typical gasoline. A content of oxygen of 7.36 wt% in ethanol promotes combustion efficiency as well as high combustion temperature. Physical and chemical properties of the fuels are shown in table I [14].

Inspection	Method	Gasoline (reference)	Ethanol 20%
Sulfur content, ppm	ASTM D 5453	9.0	4.0
Distillation temperatures	ASTM D 86		
IBP		38.8	40.5
10% Evaporated		68.5	62.4
50% Evaporated		109.6	79.2
90% Evaporated		161.5	155.1
End point, ^{0}C		206.3	201.4
Reid vapor pressure, psi	ASTM D4953	7.06	7.3
Composition, vol.%	ASTM D 6729		
Olefins		4.2	4.7
Aromatics		26.5	24.7
Paraffins		11.4	9.5
Isoparaffins		52.6	35.6
Naphtenes		4.7	5.1
Oxygenate		0.0	19.8
Oxygen, wt.%	ASTM D 4814	0.00	7.36
Research octane number	ASTM D 2699	91.3	93
Motor octane number	ASTM D 2700	84.0	83.4
Net heating value, MJ/kg	ASTM D 240	42.54	39.47
Relative density	ASTM D 1298	0.7454	0.7597
Driveability index	ASTM D 4814	593	513
Carbon fraction		0.8630	0.8112
Atomic ratio H/C		1.923	1.962
Atomic ratio O/C		0.000	0.102

TABLE I
Fuel Properties

IV. Methods and Material

Ethanol was blended with pure gasoline to prepare fuel blends on a volume basis. The tests were conducted on a vehicle placed on a chassis dynamometer MAHA LPS 3000. The schematic view of the experimental stand is presented in Fig. 1. The tester actually measures Pw (wheel power) and the software calculates Pe (engine output) by measuring drag power in the additional stage following full load acceleration. After the vehicle is accelerated at WOT from 50 km/h up to maximum engine speed, the clutch is disengaged and the transmission is decelerated from maximum speed down to 50 km/h, while the rig measures drag power.

Measuring power using this method ensures increased accuracy of 2% [16]-[17]. The engine specifications of the test vehicle are shown in Table II. All fuel tests were performed without any modifications on the test engine. The relative humidity, ambient temperature and pressure of the test room were measured using a hygrometer, a thermometer and a barometer, respectively.

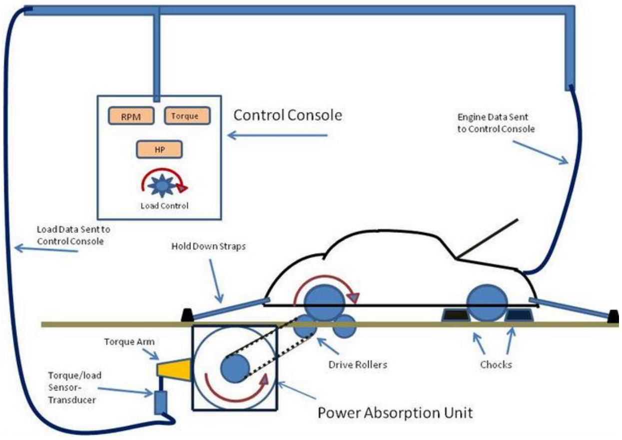

Fig. 1. Chassis dynamometer setup [15]

The engine from table II was sufficiently warmed up at each test and the engine oil temperature was maintained at 70-80°C. The engine was allowed to run for a few minutes until it reached to steady-state conditions, and then, the data were collected subsequently. The engine was warmed with the blend for at least one hour to purge any of the remaining reference fuel from the engine fuelling system. For sampling the exhausted emissions during the experimental tests, STARGAS 898 analyzer from the laboratory instrumentation was used.

TABLE II
TECHNICAL DATA FOR TEST CAR

Passenger car engine specifications	
The total cylinder capacity	1390 cm^3
Gearbox	5M
The maximum power	75@5.500
The maximum torque	112@3000
The maximum speed	162 km/h
Fuel	gasoline
Standard emission	Euro 4
The urban consumption	9.6 L
The extra urban consumption	5.4 L
The mixt consumption	7.0 L

V. RESULTS AND DISCUSSION

Experimental researches are based on the measured value of major pollutants resulted from combustion of the engine which equips the tested vehicle. The simulation was done fallowing the next steps:
- Setting the speed in constant speed module;
- Setting the force in constant traction module (Fig. 2).

The experimental stand allows the recording of atmospheric conditions which correspond to measurements moment:
- The ambient temperature ta=15.3 C
- The intake air temperature ti=14.5 C
- The air humidity φ=23.8%
- The air pressure pa=1018.7 hPa
- The steam pressure ps=14.8 hPa

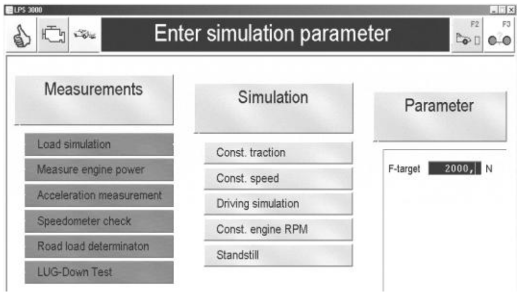

Fig. 2. Introduction of the value of traction force F=210N

As a result of the urban traffic conditions simulation on the test stand, the values of the vehicle emissions were recorded depending both on the engine speed and excess air coefficient (λ). With the operating mode Constant Speed the dynamometer stand is regulated in a way that the driving speed remains almost constant independent from the traction (between low to full throttle), i.e. only the speed of the car which was pre-set can be driven. In this way only the eddy current brake effectiveness rises up to full throttle but not the speed of the vehicle. The eddy-current brake is activated immediately by a pre-set value of traction which keeps a constant traction during the experiments [16].

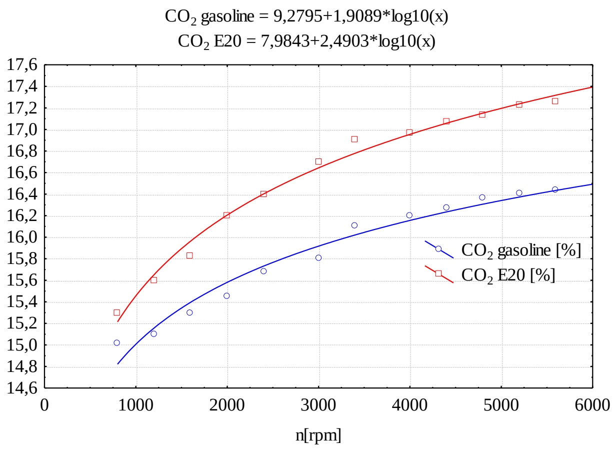

Fig. 3. CO_2 variation law versus the speed, F=210N (constant speed)

Results of the engine test showed that using ethanol–gasoline blended fuel, carbon monoxide (Fig. 5) and hydrocarbons (Fig. 4) emissions decrease significant as a result of the leaning effect produced by the ethanol presence in the blend; and carbon dioxide (Fig. 3) emission increases because of the improved combustion.

Also the level of oxygen (Fig.6) increase due to the higher oxygen content of ethanol fuel.

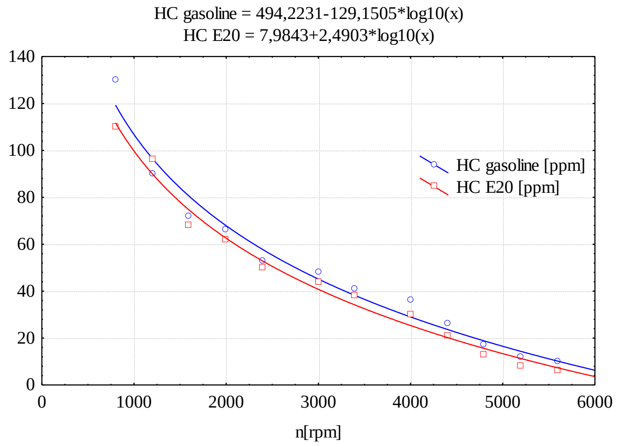

Fig. 4. HC variation law versus the speed, F=210N (constant speed)

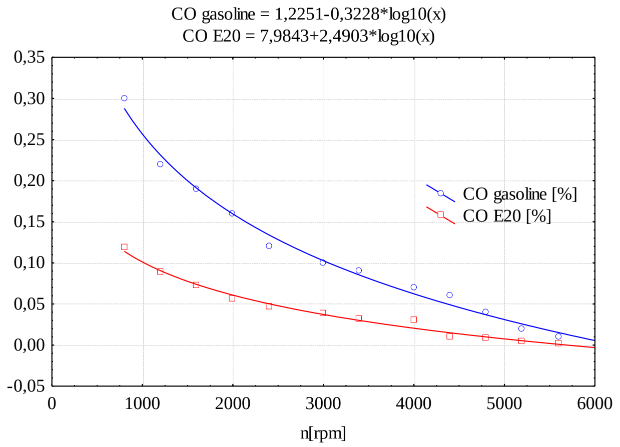

Fig. 5. CO variation law versus the speed, F=210N (constant speed)

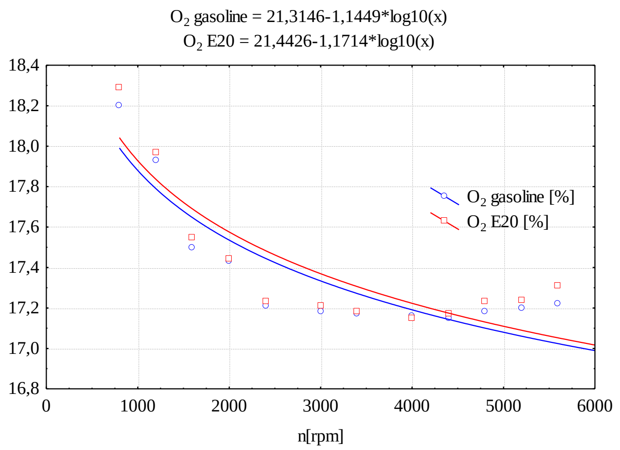

Fig. 6. O_2 variation law versus the speed, F=210N (constant speed)

By the speed limitation in accordance to the urban traffic one and by maintaining the traction constant, F=210N, real traffic conditions were simulated and pollutant emissions were controlled in order to evaluate the vehicle operation for load case.

VI. Conclusion

The result obtained in this study show that E20 is a better suited replacement for gasoline because has lower pollutant emissions.

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