Use of E20 in a Spark Ignition Supercharged Engine

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Bioethanol is very similar to gasoline in many aspects and can be used in internal combustion engines without any changes in their structure. It has advantage that is produced from biomass and can be delivered to users by the same infrastructures. The paper present results of the experimental investigations of an A15MF supercharged engine fuelled with E20 gasoline-ethanol blend. Using this fuel an increase of the engine power was obtained comparative with gasoline at the same air fuel ratio. Also, it was obtained a decrease of the brake specific fuel consumption and a decrease of CO and HC emissions level.

Keywords: gasoline, ethanol, supercharged, emissions, performances

Currently, there is a worldwide growing interest, regarding the use of alternative fuels in spark ignition engines in order to reduce pollutant emissions, consumption of petroleum fuels and to increase the energy performance of engines [1].

Biofuels such as ethanol, biodiesel and biohydrogen are the main alternative fuels of the future [2].

Bioresources raw materials used to ethanol manufacture were diverse: biomass energy production plants, agroindustrial residues, wood residues from forest materials [3, 4].

The researches carried out on alternative fuels have led to the use of ethanol as automotive fuel, especially when mixed with gasoline, due to its attractive properties.

Therefore, appeared increasingly more studies based on experimental investigations or numerical modeling [5-12], papers that have evaluated the effect of properties and characteristics of the ethanol on engine performance and on the environment.

For example, M. Gogos et al. [13] have tested the fuels E0, E10, E20 and E50 on a Ford Escort car by old technology without a catalytic converter and a displacement of 1287 cc. The obtained results showed that increasing the percentage of ethanol from the mixture has decreased CO and HC emissions level but increased the NOx percentage of ethanol from the mixture had decreased cc. The obtained results showed that increasing the E0, E10, E20 and E50 on a Ford Escort car by old technology the environment.

The researchers studied the experimental investigation of the engine performance and pollutant emission of a commercial S.I. engine using ethanol–gasoline blended fuels with various blended rates (0, 5, 10, 20, 30%) [15]. Results showed that with increasing the ethanol content, the torque output and fuel consumption of the engine slightly increase while CO and HC emissions decrease dramatically as a result of the leaning effect caused by the ethanol addition. CO emission increases because of the improved combustion and NOx emission depends on the engine operating condition rather than the ethanol content.

It was also compared the performance and emissions from an engine 1.0 liter, eight-valve, in four-stroke fuelled by E22 (78% gasoline-22% ethanol) blend [16]. The results showed that torque and brake mean effective pressure were higher when the E22 was used as fuel on low engine speeds. The fuel E22 produced higher thermal efficiency and higher BSFC than the gasoline throughout all the engine speed range studied. With regard to exhaust emissions E22 reduced CO and HC, but increased CO2 and NOx levels.

Paper objectives

To obtain better performance in terms of energetic and economic, the A15MF engine has been supercharged by using a variable geometry turbine, aiming at obtaining a similar power of the engine with normal intake but at lower engine speeds and partial loads, based on downspeeding concept. Furthermore, supplying gasoline-ethanol blend of supercharged engine expects to achieve the desired goals.

Properties

Comparative to gasoline, ethanol contains more oxygen in its chemical composition (table I). This allows the use of a leaner air-fuel mixture, and as a result, a better combustion is achieved. This fact further causes fewer emissions of CO and unburned HC.

Ethanol flammability range is much wider for air-ethanol mixtures comparative to gasoline (0, 3...1, 56 versus 0, 4...1, 4) providing engine run stability in the area of lean mixtures [5].

Ethanol has a higher octane rating (RON=106) than gasoline and because of its anti-knock properties, engines with a higher compression ratio, and subsequently more power, can be designed [6].

The heat of vaporization of ethanol is 854 kJ/kg, higher than the value of 290-335 kJ/kg of the gasoline. This property can

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Contribute to the increase of engine power and thermal efficiency because of higher density of the mixture and the engine cylinder filling improvement [17].

Ethanol has higher burning speeds comparative with gasoline. It has a much longer delay between spark ignition timing and a fully-formed flame (the "ignition delay"). This means that the spark timing may need to be advanced.

Experimental investigations

The experimental investigations were carried on A15MF supercharged engine which was coupled with an eddy current dynamometer, 160 kW, water cooled. The engine specifications are provided in table 1.

For measuring the parameters which are required in the proposed experimental study, the engine was equipped with several sensors and instruments:

- Air flow meter
- Flow meter Krohne Optimass 3050 C for measuring fuel consumption
- Manometer
- Thermocouple and thermo resistances for measuring exhaust gases temperature, intake air temperature, cooling liquid and oil temperature
- Throttle position feedback
- AVL GU12P piezoelectric pressure transducer
- AVL 3067A01 charge amplifier
- AVL 365CC speed incremental transducer
- AVL Indimodule 621 data acquisition system
- PC computer for data processing
- AVL DiCom 4000 gas analyzer

The experimental investigations were carried out at engine speed 2500 rpm, 85% load and different excess air-fuel ratio values for two fuels: gasoline and E20 (80% gasoline blend with 20% ethanol), and 1.2 bar supercharging pressure.

Excess air-fuel ratio is the amount of air available per kilogram of fuel reported to the amount of air required for stoichiometric combustion of this fuel quantity.

Knowing the consumption of air, of fuel and of ethanol, the excess air-fuel ratio is calculated with relations:

$$\lambda = \frac{\rho_{\text{air}} \cdot Q_{\text{air}}}{Ch_{\text{fuel}} \cdot \left(\frac{A}{F}\right)_{\text{fuel}}}$$

In this paper $\rho_{\text{air}}$ is density of air, [kg/m$^3$]

$Q_{\text{air}}$ - air flow, [m$^3$/h]

$Ch_{\text{fuel}}$ - gasoline consumption, [kg/h]

$(A/F)_{\text{fuel}} = 14.5$ stoichiometric air-fuel ratio for gasoline and $13.4$ stoichiometric air-fuel ratio for E20.

For E20 the investigations were carried out for excess air-fuel ratio $\lambda > 1$ in order to emphasize the main advantages of using ethanol in the lean mixtures field. Spark ignition timing was adjusted for each operating regime at optimum value. In case of ethanol fueling the optimum spark ignition timing is smaller comparative to gasoline S.I. engine due to a much higher burning rate of the ethanol.

Experimental results

Figure 2 presents the variation of engine power versus excess air-fuel ratio, to fuelling the engine with gasoline and E20. It can be seen that for the same excess air-fuel ratio, the engine power increased with 16 % for E20 compared to gasoline, at 85% load and 2500 rpm. The higher effective power of the engine obtained at the use of gasoline-bioethanol mixtures is due to better combustion properties of bioethanol and due to shorter duration of combustion.
When the engine was fuelled with E20, the brake thermal efficiency (BTE) increased with 3-5% compared to gasoline at 85% load, 2500 rot/min and at the same excess air fuel ratio (fig. 3).

The brake thermal efficiency is calculated with the relation:
\[
BTE = \frac{3.6 \times 1000}{Ce}
\]

In this paper Ce is energetic fuel consumption [kJ/kWh].

Pollutant emissions from exhaust gases were collected and analyzed as gross emissions, because the engine is not equipped with a catalytic post-processing of exhaust gases.

Figure 4 and 5 show the percentage evolution of the emissions of carbon monoxide and hydrocarbons contained in exhaust gases. CO emissions level is not significantly different at fuelling with E20 compared with gasoline (only 12%). Concentration of HC emissions at the engine operating with E20 blend is significantly lower than for gasoline, registering values up to 46% lower at 2500 rpm and 85% load. Reduction of carbon monoxide and hydrocarbons emissions are mainly due to the presence of oxygen in the chemical composition of ethanol resulting an improved combustion to increase the ethanol content from the mixture.

Presence of oxygen in chemical composition of ethanol and higher combustion temperatures when the engine was fuelled with E20, led to a significant increase in the level of nitrogen oxides in exhaust gases (fig. 6). The decrease of NOx emission level is possible by using of leaner mixtures (qualitative adjustment of the engine load) or by passive gas treatment methods. The use of the leaner mixtures is a better solution because the brake specific fuel consumption is smaller.
Fig. 6. NOx emissions level versus excess air fuel ratio for 85% load and 2500 rpm

Conclusions
At the use of E20 fuel was obtained an increase of the effective power of the engine compared to gasoline by 1% at engine speed 2500 rpm, 85% load and the same excess air fuel ratio, similar results to those from literature. For example, the paper [13] presents the results of experimental investigations at supply an engine with gasoline-ethanol blends (E10, E20), obtained an increase of effective power by 10-12% higher compared to gasoline.

The brake thermal efficiency at engine operation with E20, increased by 3-5% compared to gasoline at the same operating regimes, decreasing the fuel consumption. This downward trend in consumption was highlighted in the paper [18] at the mixtures used E20, E50 and E75 on a single cylinder engine in four stroke.

In mixtures with gasoline, ethanol presents good anti-pollution properties. Thus, compared to gasoline, were obtained HC emission reductions of about 37-46% and a slight decrease of CO emissions, approximately 12%. Similar results are found in the paper [15].

Compared to gasoline, at the using E20 fuel the NOx emissions increased significantly with 33% mainly due to higher combustion temperature, being recommended the engine operation at the leaner dosages for decrease the nitrogen oxides emission level. This undesirable effect of increasing NOx emissions at the engine fuelled with gasoline-ethanol mixtures was reported [19].

Nomenclature
BTE - brake thermal efficiency
CO - carbon monoxide
E20 - ethanol-gasoline blend (20% ethanol, 80% gasoline)
HC - hydrocarbons
MPI - multipoint injection
NOx - nitrogen oxides
Pe - effective power
RON - research octane number
rpm - revolutions per minute
S.I. - spark ignition engine
Greek symbols
\( \lambda \) - excess air fuel ratio

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