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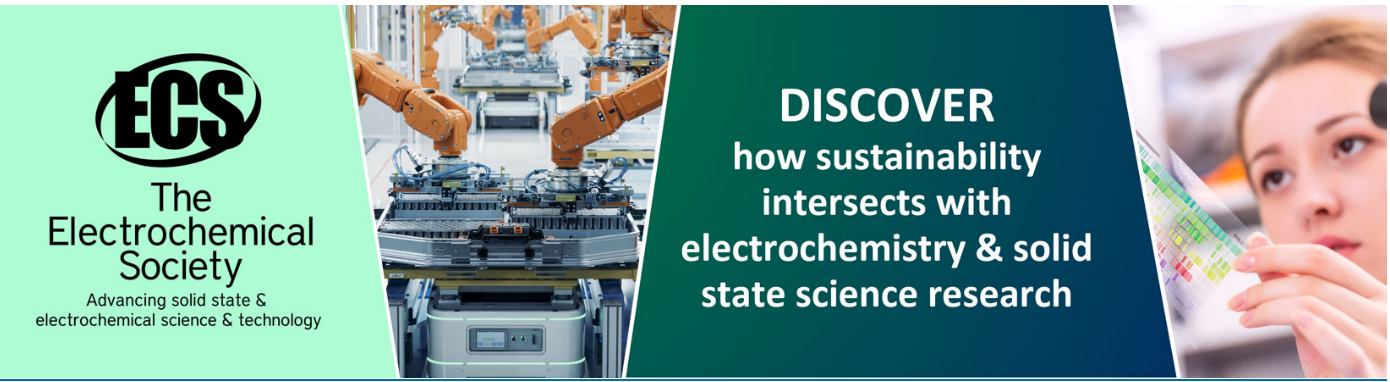

Analysis of the impact of using additional injectors in the intake manifold on utility and ecological parameters enforced ignition engine

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Abstract. The article presents the results of comparative research on the utility and ecological parameters of the FSO 1.6 GSi engine, which are the effect of using additional injectors in the intake manifold. In the future, these injectors will be responsible for supplying the engine with alternative fuels. Engine parameters such as: cylinder filling factor, torque, unit fuel consumption and exhaust composition were analyzed. The tests were carried out with both standard and modified collector, in which additional injectors were installed.

1. Introduction

The strategy of using additional injectors results from problems that are associated with the use of alcohols as an intrinsic fuel to power spark ignition engines. In view of the above, the more convenient solution consist in using mixtures of ethyl alcohol and gasoline. In such configuration, up to 30% ethanol can be used. Above the value, it becomes necessary to increase the fuel supply rate because of lower calorific value of ethanol [3]. With much higher alcohol content reaching 85%, it is necessary to have expensive modifications to the power supply system and it is difficult or impossible to start the engine at low temperatures [2].

To avoid problems relating to fuelling the engine with gasoline-ethanol mixtures, it is possible to use two separate fuel supply systems, of which one is responsible for injecting gasoline and the other for supplying the engine with ethanol. Although such solution still requires a costly modification of the fuel supply system, it offers a wider range of ways in which ethanol can be used. It is even possible to employ an engine fuelling method similar to this typical for LPG systems, where in the engine starting and heating-up phase, the engine would be fuelled with gasoline and then with ethanol alone.

The paper presents results of a comparative study on FSO 1.6 GSi engine aimed at determination of the effect of installing additional injectors responsible in the future for supplying the engine with ethanol operating parameters of the engine such as: the cylinders filling ratio, the output torque, the specific fuel consumption, and exhaust gas composition.

2. The research set-up and methodology

The comparative study was carried out in the laboratory operated by the Department of Combustion Engines and Transport (KSSiT). As the test engine, FSO 1.6 GSi engine was used equipped with additional injectors in the intake manifold. A view of the manifold on the engine with the additional injectors mounted is shown in Fig. 1.

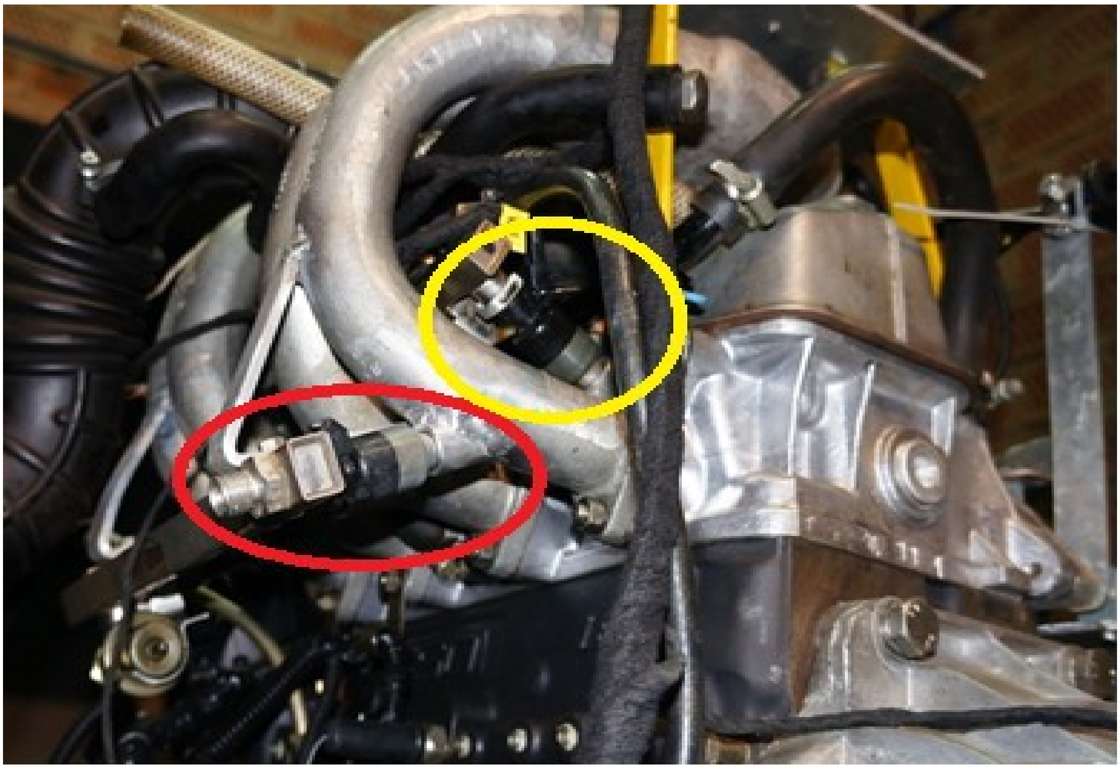

Figure 1. A view of the intake manifold mounted on engine with gasoline injectors (marked in yellow) and additional ethanol injectors (marked in red)

During the tests, the engine was supplied with 95 octane commercial gasoline which was supplied via the original injector marked in yellow colour in Fig. 1. The additional engine injectors, marked with red colour in the figure, was inactive.

The engine was mounted on a test bench schematic diagram of which is presented in Fig. 2. The set-up is equipped with SCHENCK DYNAS$_2$ 220 AC-machine brake shown in Fig. 3. The brake, constituting a load for the engine, allowed also to control precisely position of the throttle by means of SCHENCK LFM 2003 actuator.

The research covered also the fuel consumption which was measured with the use of the gravimetric method by a prototype instrument developed in KSSiT. Schematic diagram of the measuring system is presented in Fig. 4, and a view of its interface is shown in Fig. 5. The device is designed so that it performs three 30 second fuel consumption measurements and calculates the average value on this basis. This type of work ensures that the obtained fuel consumption results are subject to a measurement error below 1%. The measuring system is described in detail in [4]. The stream of air flowing into the engine was also measured by means of a drop in pressure at the inlet nozzle of the engine, described in [1]. The layout of the system is shown in Figure 6.

The research was carried out for the throttle in fully open position which corresponds to the combustion engine performance characteristic. The fuel dosage was controlled with the use of a prototype engine controller governing both injection and ignition. The controller allowed to set freely the ignition advance angle and regulate accordingly the fuel doses in a feedback loop with the use of the lambda sensor. The controller is built in microprocessor technology based on the ATMEGA 1284P microcontroller. The controller analyses engine operating parameters such as:

• rotational speed of the crankshaft,
• coolant temperature,

• intake air temperature,
• throttle position,
• absolute air pressure,
• reading the signal from the lambda probe,
• device power supply,
• Crankshaft position.
The controller can perform the following functions of operating the parameters of the drive unit:
• ignition timing,
• leading angle of the fuel injection start,
• sometimes fuel injection,
• switching off the fuel supply and ignition on individual cylinders.
By using a n-coder with a resolution of 720 chips, it is possible to more precisely determine the injection and ignition advance angle than in the original controller. The exact description of the controller can be found in [5, 6]

The research covered also the environmental parameters measured with the use of Bosch BEA 350 emissions analyser shown in Fig. 7.

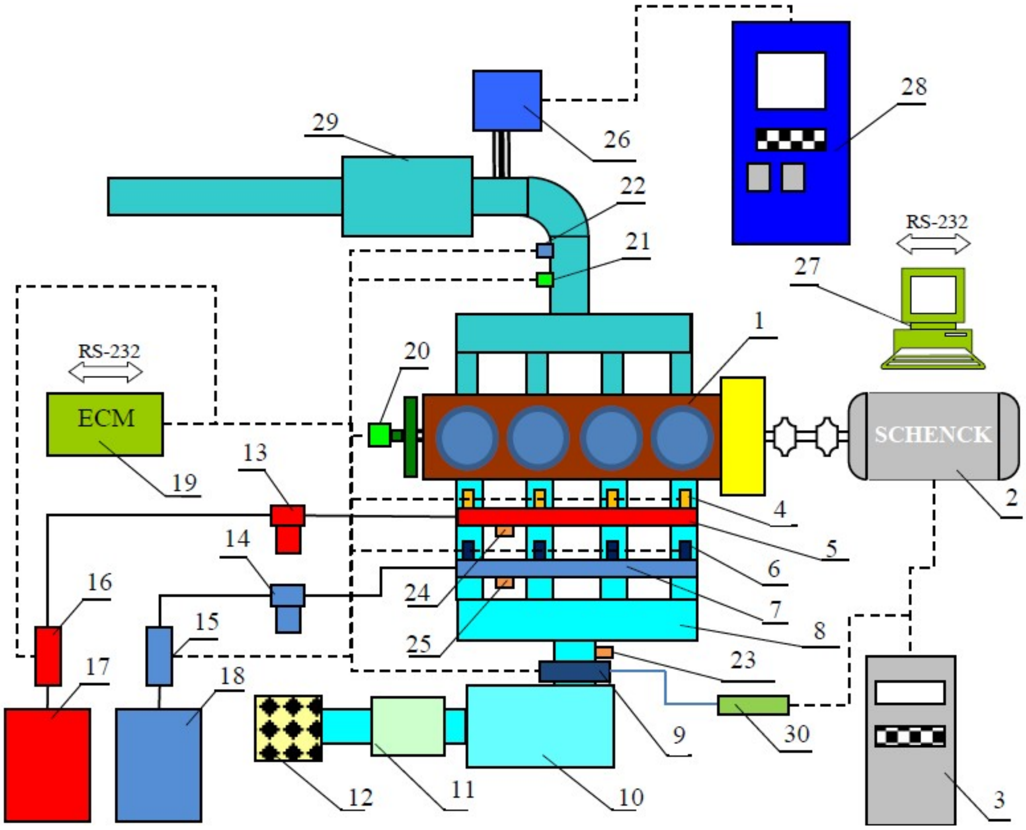

Figure 2. Schematic diagram of the measuring setup: 1 — test engine FSO 1.6 GSi; 2 — AC-machine brake; 3 — brake control panel; 4 — gasoline injectors; 5 — gasoline fuel rail; 6 — ethanol injectors; 7 — gasoline fuel rail; 8 — modernized intake manifold; 9 — air throttle with position sensor; 10 — compensation vessel; 11 — air flowmeter; 12 — air filter; 13 — fuel (gasoline) filter; 14 — fuel (ethanol) filter, 15 — fuel (ethanol) pump; 16 — fuel (gasoline) pump, 17 — fuel (gasoline) consumption measuring system; 18 — fuel (ethanol) consumption measuring system; 19 — electronic system controller; 20 — encoder; 21 — lambda sensor; 22 — exhaust gas temperature measuring thermocouple; 23 — absolute pressure sensor; 24 — pressure regulator in fuel (gasoline) rail; 25 — pressure regulator in fuel (ethanol) rail; 26 — probe with a filter for exhaust gas sample taking; 27 —

injection parameters controlling computer; 28 — control panel of the exhaust gas harmful emissions measurement system; 29 — muffler; 30 — throttle position actuator SCHENCK LFM 2003

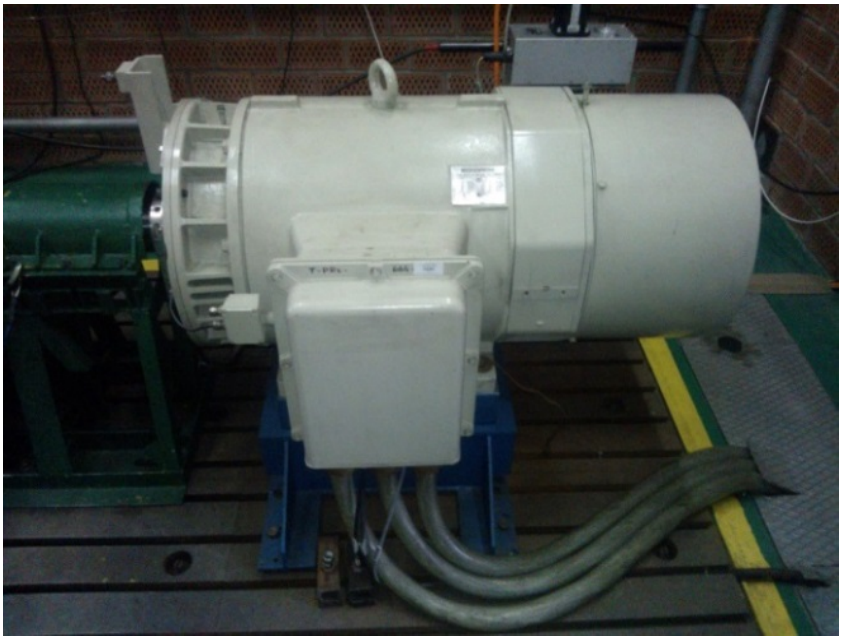

Figure 3. A view of SCHENCK DYNAS$_2$ 220 AC-machine brake

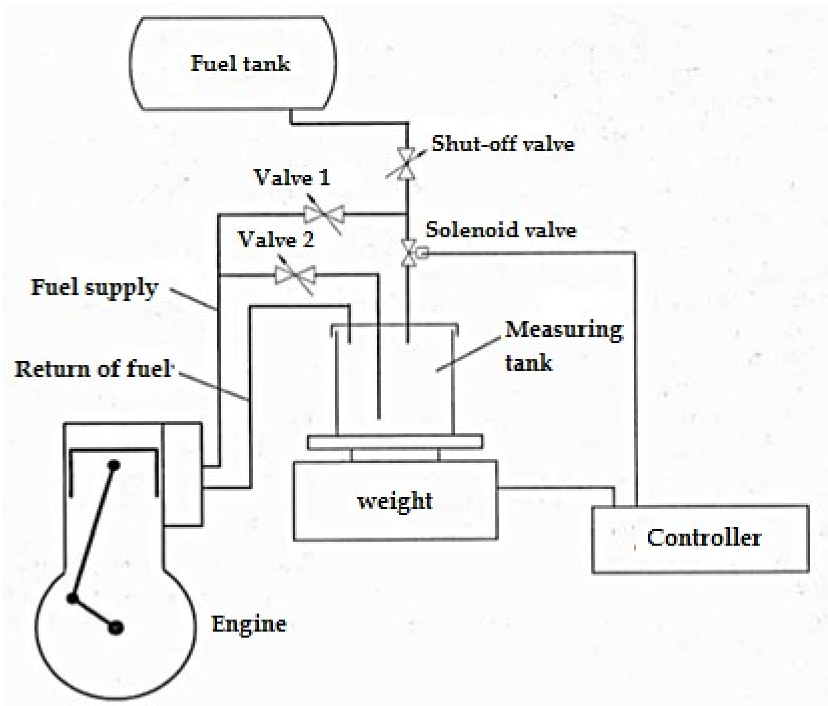

Figure 4. A schematic diagram of the system for fuel consumption measurement with the use of gravimetric method [1]

Figure 5. A view of the fuel consumption measuring system user's interface

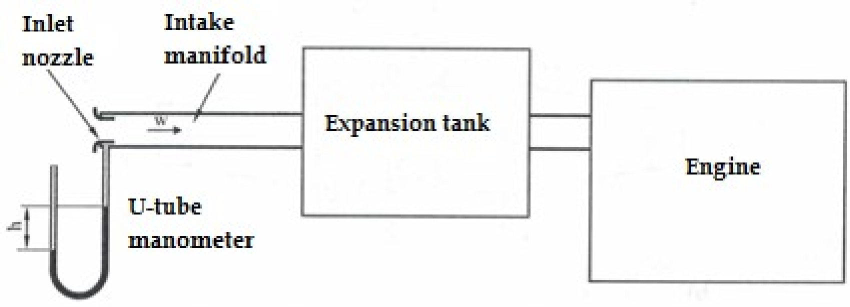

Figure 6. A schematic diagram of the filling ratio measuring system [1]

Figure 7. A view of Bosch BEA 350 emissions analyser

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3. Research results

The comparative study proved that installing an additional injector, which represents an obstacle in intake manifold channel, hand no significant effect on the measured parameters of the examined combustion engine. Analysing the performance parameters presented in Fig. 8, one can note a change in the filling ratio value, which up to 3500 rpm is slightly higher a maximum of 2.29%. Above that value, one can observe a decrease of value of the parameter of 0,84 % due to flow disturbances.

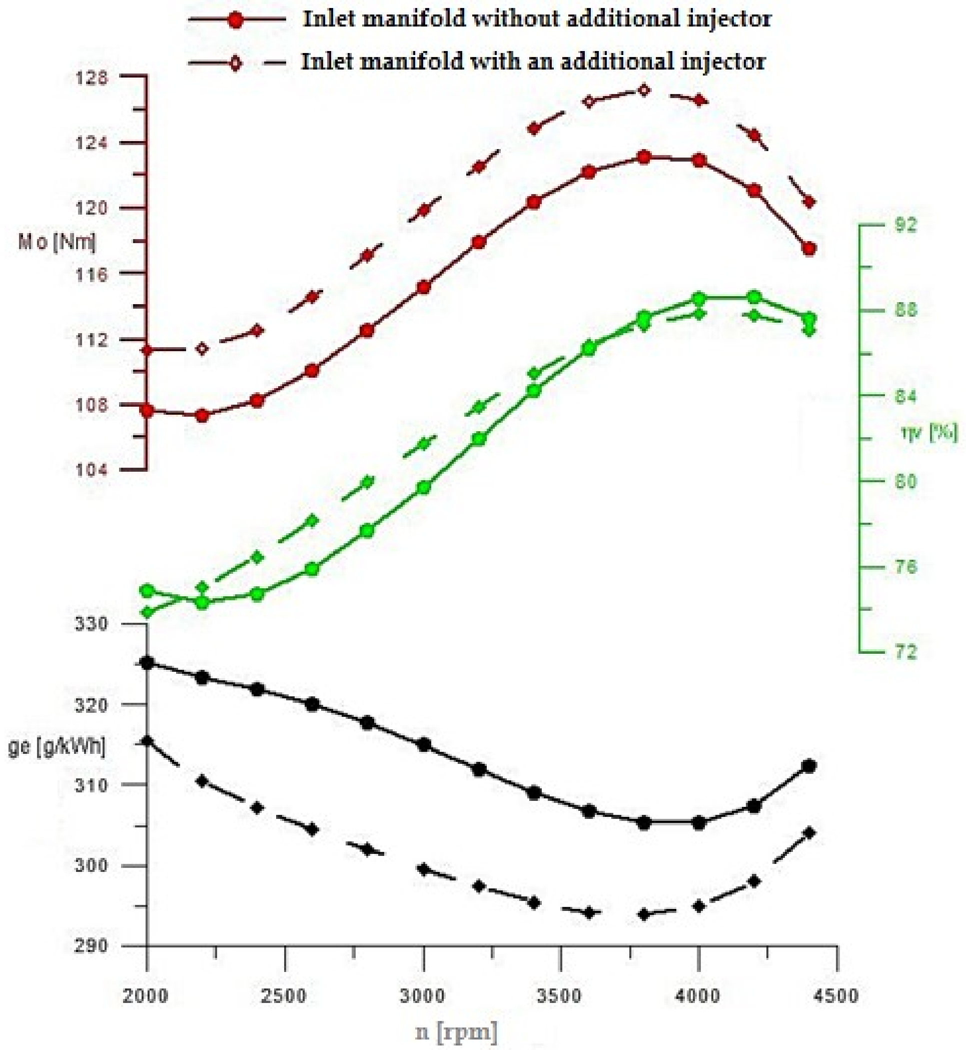

Figure 8. A comparison of performance parameters of the engine before and after employing an additional injector in the intake manifold

Comparing the output torque value, which is by about 5 Nm higher in the whole examined range of engine speed, and the specific fuel consumption, which decreased by about 10 g/kWh as an average, one can note a slight increase of the overall efficiency by about 0.7%.

The cause of such changes could be whirls generated by the additional injector in the intake channel which result in better evaporation of fuel and improve homogeneity of the fuel-air mixture. In support of the hypothesis, Fig. 9 shows plots representing the exhaust gas composition. One can note a distinct decrease of hydrocarbons content in the exhaust gas within the whole engine speed range, which is maximally reduced by 80 ppm, a similar change characterizing also the exhaust gas temperature depending on the measuring point, it was reduced by 30°C to 80°C, which unambiguously evidences an improvement of the combustion process through better utilization of the supplied fuel.

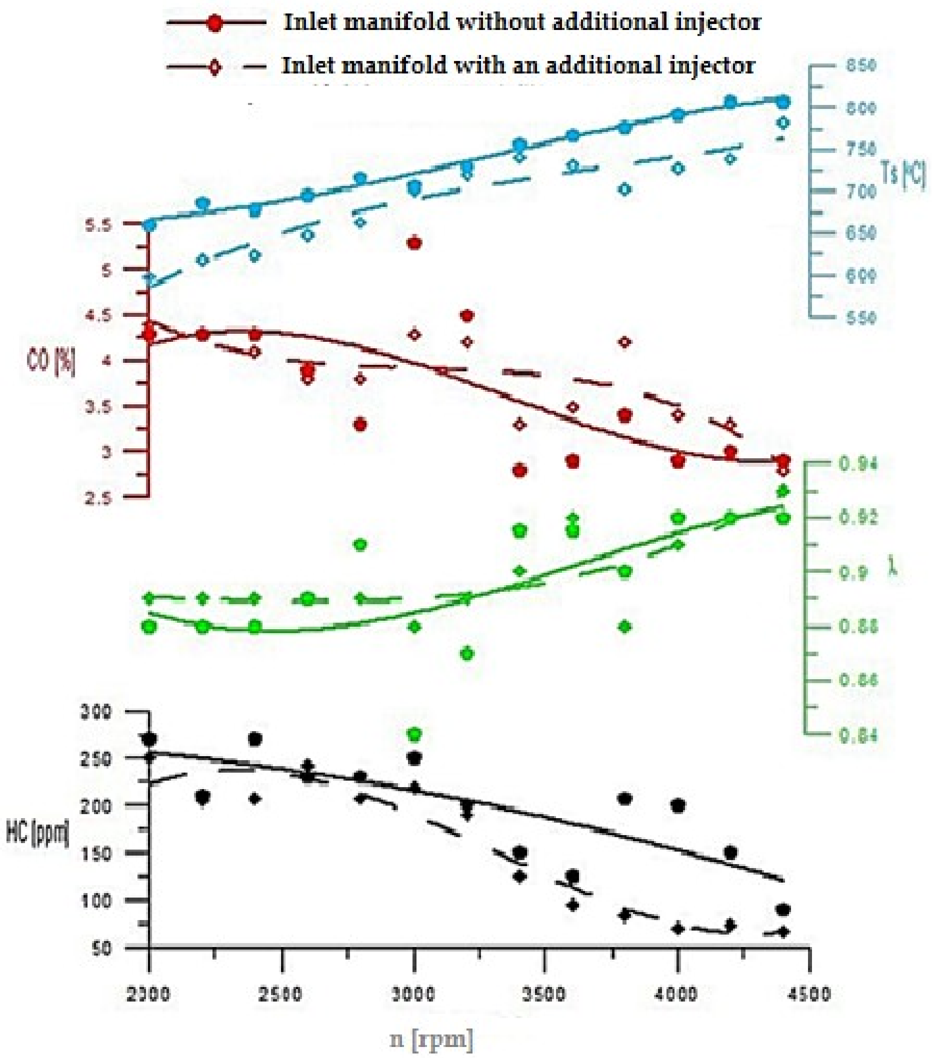

Figure 9. A comparison of the engine exhaust gas composition before and after employing an additional injector in the intake channel

The comparative tests were carried out at constant value of the air-fuel equivalence ratio λ of about 0.9, which is also presented in Fig. 9. The change of the parameter remains on the level of 0.02 from which it follows that it could not affect significantly the analyzed parameters.

4. Summary and conclusions

The comparative analysis of results obtained before and after introduction of additional injectors (one for each of the two cylinders) was carried out to determine the effect of the modification on performance and environmental parameters of the test engine.

By offering the possibility to maintain injection and ignition parameters on identical levels and control precisely both composition of the fuel-air mixture and the ignition advance angle, the prototype controller developed and constructed in KSSiT allowed to perform a comparative analysis of the effect of the manifold modification of engine parameters. After modification of the intake manifold, the filling ratio value remained almost unchanged throughout the whole examined engine speed range.

Before and after the modification, value of the air-fuel equivalence ratio remained almost unchanged assuring thus identical composition of fuel-air mixture on the level of $\lambda = 0.9$.

Although the additional injectors did not supply any fuel, they still had a slight effect on engine performance consisting in reduction of the specific fuel consumption accompanied by an increase of output torque, which resulted in improvement of environmental parameters, namely reduction of hydrocarbons content, slight increase of the overall efficiency, and a decrease of the exhaust temperature within the whole examined engine speed range.

The exhaust gas was not treated in any catalytic reactor and therefore it was impossible to analyze the fumes from the point of view of meeting applicable standards in scope of toxic compound content.

The changes introduced to the intake manifold consisting in installing additional injectors did not affect parameters of the test engine in any significant way, as a consequence of which it will be possible to continue the research on the use of dual-fuel system and compare the obtained results directly with currently observed performance parameters of the engine fueled solely with gasoline or with gasoline-alcohol mixtures.

Nomenclature

CO	carbon oxides quantity
FSO	Motor Car Factory (the company *Fabryka Samochodów Osobowych*)
ge	specific fuel consumption
HC	hydrocarbons content
KSSiT	Department of Combustion Engines and Transport (Katedra Silników Spalinowych I Transportu)
Mo	engine output torque
Ts	exhaust gas temperature
SI	spark ignition
ηv	engine filling ratio
λ	air-fuel equivalence ratio

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