# TESTING OF AN IGNITION SYSTEM IN A CAR RUN ON VARIOUS FUELS

## Mieczysław Dziubiński\*, Stanisław Walusiak\*\*, Wiktor Pietrzyk\*\*

\*Department of Automotive Vehicles, \*\*Department of Computer and Electrical Engineering Lublin University of Technology Nadbystrzycka Str. 38A, 20-618 Lublin, Poland, e-mail: swal@elektron.pol.lublin.pl

**Summary**. An analysis of operating states of ignition system elements in cars fitted with LPG installations was an objective of the study. Tests were performed on a car of Mazda 323 F make. Measurements were taken to establish a dependence of ignition system input voltage on the kind of spark plugs, spark plug electrode gap size, and ignition coil load at engine fueling with gasoline and LPG.

Key words: ignition system, spark plug, secondary voltage, LPG fueling

## **INTRODUCTION**

Installations that fit spark-ignition engines to be run on other kinds of fuel than ethyl gasoline have been known for a long time. Presently, a comeback of the issue can be observed for two reasons: an economical one following from ever growing petroleum prices and an ecologic one resulting from stricter and stricter environment protection standards.

In Poland for many years the fuel selection question has been mainly a cost-benefit issue with environment protection regulations and engine requirements being of lesser importance. LPG (Liquefied Petroleum Gas) is one of hydrocarbon fuels, whose engine-fueling history extends over fifty years back. The first LPG-fueled systems were elaborated in Italy for the shortage of commonly used fuels after the WWII outbreak.

Fuel purchase cost decrease by 50–60% as compared to the gasoline cost made an economic foundation for the development of autogas installations and the whole infrastructure related to the use of LPG-fueled cars. It is estimated that over the last 3 years the number of LPG-fueled automobiles has increased by some-hundred percent. In the year 2002 the number of such cars in Poland already exceeded 1 million.

Regardless of the kind of autogas installation used in a car a gasoline system remains its basic driving source. It is related to the need of using compromise solutions, especially for the engine fueling system A vehicle that is fitted with an LPG installation uses common air-feed line and "gasoline" ignition system. It poses obvious problems following from combustion differences of those two fuels.

## THE PERFORMED TESTING

An objective of the study was to analyze operating states of ignition system elements in cars equipped with LPG installations. The testing was performed on a car of the Mazda 323 F (1,6116 V) make.

The car has been fitted with a carburetor LPG feed system (Fig. 1). The ignition coil was of the Hanshin company make. Spark plugs of the NGK BPR6-ES11 type, recommended gap of 1.1 mm and of the Iskra SFE65 PRS GAZ type, producer-recommended inter-electrode gap of 0.9 mm were used to the testing.



Fig. 1. Connection diagram of a LPGII feed system of the BAS generation in a car of the Mazda 323 1,6 16V make [Krupa 2006]

A spark plug of the NGK BPR6-ES11 type contains one side electrode, 19 mm long thread M14x1,25 with flat seal, internal 3,8 k $\Omega$  resistor, and a central cored electrode.

A spark plug GAZ SFE65 PRS contains one side electrode, 19 mm long thread M14x1,25, with flat seal, internal 1,7 k $\Omega$  resistor and a central cored electrode.

Fig. 2 presents a block diagram of the test stand. The following kinds of tests have been performed at the test stand:

- measurements of firing voltage at spark plugs,
- measurements of the ignition system current,
- analysis of the rpm sensor signal waveforms by an oscilloscope.



Fig. 2. The test stand

Voltage measurements at the secondary circuit of an ignition coil were performed with the application of an instrument meant to measure high voltage of a KR 8005A car ignition system, whose measuring range is 30 kV. The measurements concerned spark plugs of the NGK BPR6-ES11 and Iskra SFE65 PRS GAZ types. They were performed on a hot engine at the ambient temperature of 15°C. Four sizes of the spark plug electrode gaps were tested - from 0.8 mm to 1.1 mm, every 0,1 mm. Results of secondary voltage measurements done with the use of NGK spark plugs for an engine fueled with gasoline are presented in Fig. 3 and for a LPG-fueled engine – in Fig. 4.

In the case of a gasoline-fueled engine and NGK spark plugs when the spark plug electrode gap decreases, a secondary circuit voltage grows. Rated characteristic of the Uw voltage vs. engine speed occurs at the gap size of 1.1 mm Similar values can also be obtained at setting of the gap size for 0.8 mm.

In the case of LPG fueling the results are similar. From the viewpoint of the ignition system voltage load and the related life of its elements electrode gaps of 1.1 and 0.8 mm seem to be optimal for NGK spark plugs at the LPG fueling of an engine.

Secondary voltage  $U_w = f(n)$  at the Iskra GAZ spark plug electrodes for various electrode gap sizes for a gasoline-fueled engine is shown in Fig. 5 and for the LPG fueling – in Fig. 6.

At gasoline fueling and the Iskra GAZ spark plug application, the results are reverse to the ones obtained with NGK spark plugs. Along with the electrode gap decrease voltage in the ignition system secondary circuit also decreases. The most advantageous characteristic of Uw voltage vs. engine speed occurs at electrode gaps of 1 and 0.9 mm. Attention should be paid to a very specific, at many ranges - even linear, characteristic of the Uw voltage for the 0.9 mm gap size. Such a gap size is recommended by the producer of that engine type.

In the case of LPG fueling and the Iskra GAZ spark plug application, the highest Uw voltage value occurs at the electrode gap sizes of 0.9 and 1.1 mm.







Fig. 4. Secondary voltage  $U_w = f(n)$  at NGK spark plug electrodes for various electrode gap sizes in a LPG fueled engine



Fig. 5. Secondary voltage  $U_w = f(n)$  at Iskra GAZ spark plug electrodes for various electrode gap sizes in a gasoline-fueled engine







Fig. 7. Secondary voltage  $U_w = f(n)$  at the electrodes of NGK and Iskra GAZ spark plugs at the engine fueled with gasoline and LPG and the electrode gap of 0.9 mm



Fig. 8. Ignition system primary current  $I_p = f(n)$  for spark plugs of the NGK and –Iskra GAZ types at engine fueling with gasoline and LPG and the spark plug electrode gap of 1 mm

Variations of secondary voltage Uw at the application of LPG fuel and NGK spark plugs amounted up to ca 30% for the rotation speed not exceeding 1500 rpm and over the whole range of the engine rotation variability the level of voltage variation rate was of 20% as compared to values obtained at the engine idling.

For Iskra GAZ spark plugs, within the low rpm range, Uw voltage variations do not exceed 10%. Within the high engine rotation range no significant secondary voltage variations can be observed, which can be considered as an advantage of the spark plug type operation at the LPG mixture combustion. Insignificant variability of the Uw voltage over the whole range of the engine speed regardless of the applied fuel kind is advantageous for proper combustion of the fuel/air mixture.



Fig. 9. Secondary voltage  $U_w = f(n)$  with the NGK spark plug electrodes and gasoline and LPG engine fueling for worn and new ignition wiring



Fig. 10. Secondary voltage Uw = f(n) with the Iskra GAZ spark plug electrodes and gasoline and LPG engine fueling for worn and new ignition wiring

The next kind of testing aimed at determining variability of the ignition system primary current depending on the engine rpm for both the above-discussed types of spark plugs and both kinds of fuels. The testing was performed on a hot engine at the ambient temperature of ca 20°C and the electrode gap ranging from 0.8 to 1 mm. Voltage of the ignition coil primary circuit remained at a constant level 13.5 V. Fig. 8 presents testing results for the electrode gap of 1 mm.

The presented results of measuring primary current of an ignition coil for both fuel kinds and spark plug types do not show any distinctive differences. At the change of an electrode gap size current variations do not exceed 6% for individual values of the engine speed regardless of the applied fuel kind. It should be also noted that primary current grows together with an increase of rotational speed (unlike the classical ignition system), which follows from the application of an electronic amplifier in the tested ignition system.

The next kind of testing was performed to determine variations of the ignition coil load with worn ignition wiring (100 000 km mileage) replaced by new silicon-insulated wires Fig. 9 presents testing results for both fuel kinds and the NGK spark plug and Fig. 10 – for the Iskra GAZ spark plug.

Measurement results indicate the need of wiring replacement and its effect on the ignition system load. In the case when in NGK spark plugs and gasoline fueling were applied, the quality of high-voltage wiring makes no difference, which means that performance requirements for the ignition system elements are lower when gasoline is used to fuel an engine. The requirements in the case of LPG fueling are distinctly higher. The difference in most of the engine rotation ranges is of ca 10% as compared to the values obtained at the idle. For the Iskra GAZ spark plugs, the measurements show considerable differences in voltage values of the ignition coil secondary circuit in favor of the new ignition wiring.. At the LPG mixture combustion and a low rpm range the difference is even up to 30% in favor of the new wiring. It confirms the need of frequenter replacement of ignition system elements (wiring, spark plugs) when LPG is used as an alternative fuel.

### CONCLUSIONS

1. Small changes in the ignition system secondary circuit voltage Uw, over the whole range of the engine rotational speed indicate preference for the Iskra GAZ spark plug application regardless of the fuel kind, which is advantageous for proper combustion of the air/fuel mixture. When NGK spark plugs are applied, changes (drop) of the secondary voltage Uw, as compared to the values obtained at the idle, can be observed when LPG fueling is applied. The changes are considerable (up to 30%) for the rotation not exceeding 1500 rpm, while over the whole range of the engine rotation variations voltage changes reach ca 20%. The differences follow from the composition and physical-chemical properties of both the discussed fuels. The air-LPG mixture is more homogenous, which follows from the way the gas vaporizes and mixes with air.

2. The presented results of measuring the ignition coil primary circuit voltage for both the fuel kinds and spark plug types do not show any distinct differences. Current variations at changing of the spark plug electrode gap sizes do not exceed 6% for individual rotational speed values, regardless of the applied fuel kind.

3. The performed testing results show how important for the ignition system performance is the condition of high voltage wiring and that it should be more frequently replaced when an engine is fueled with LPG. Hence, it can be concluded that spark plugs produced specifically for autogas fueled engines make a better option for cars fitted with LPG installations than general-purpose spark plugs.

4. Results of the NGK spark plug measurements prove that a reduction of the spark plug electrode gap that is recommended by many "experts" to enhance the ignition system performance, in specific cases can produce the reverse effect. The best solution is to follow the tips of spark plug producers and remember of the periodic replacement of wearable elements of the ignition system.

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