PRACE NAUKOWE POLITECHNIKI WARSZAWSKIEJ
z. 112 Transport 2016

Mieczysław Dziubiński, Artur Drozd, Ewa Siemionek
Politechnika Lubelska, Wydział Mechaniczny

Mieczysław Plich
Politechnika Warszawska, Wydział Transportu

EXPERIMENTAL COMPARATIVE STUDIES OF INJECTION SYSTEMS

The manuscript delivered: May 2016

Abstract: Modern cars have engines equipped with multi point fuel injection system electronically controlled. These system co-operate with a series of sensors and actors. The purpose of this study was to show the most common electric defects and to evaluate the reliability of selected elements of petrol fuel electric injections system Motronic and Simos during driving. The benches make it possible to realize the control of injection and ignition systems thanks to the connection of all elements sensors and actuators with ECU (Electronic Control Unit). The simulation of work was carried out thanks to the power transmission systems, in which the rotational speed of the ignition system was controlled, sensors of rotational speed and crankshaft position and also the sensor of timing phases. Te bench was connected to the computer through the diagnostic connector OBD (On Board Diagnostics). The simulations of other sensors work, e.g. the flowmeter, were realized by changing air flow and temperature by changing the resistance of the sensor for different temperatures. The cooperation of particular sensors and execution elements with the driver was monitored by the diagnostic block of Audi-VW interface software. The designed and made-up bench made it possible to control engine work and carry out tests and the analysis of particular parameters of engine work in order to identify error codes.
Keywords: injection system, diagnostics, Motronic system, injection time, ignition advance angle

1. INTRODUCTION

Currently, electronic integrated systems controlling injection and ignition are used to control spark ignition (SI) engines. The purpose of injection systems is to control the size of the fuel dose and to regulate and produce air-fuel mixture; ignition systems are responsible for forming an ignition spark in the combustion chamber at the appropriate moment. To accomplish these tasks, it is necessary to monitor the operation of the engine by means of signals coming from various sensors on the vehicle. Due to the fact that ignition and injection systems require similar information, combining both systems into one control unit came as a logical consequence. These systems are called Motronic and are used by Bosch as units.

There are many design solutions for integrated injection-ignition systems for particular car models [3, 4, 9, 14]. In subsequent solutions, new functions are introduced so that the control unit can control and regulate the operation of the engine in a more precise way. The systems co-operate with other systems of the car, such as air-conditioning, automatic transmission, ABS, ESP, SRS, etc.

Such a beneficial combination, applied due to the use of the same signals both in the supply system and the ignition system, resulted in more adaptive possibilities in the control system. Consequently, greater reliability and lower production cost were obtained. In the ignition system, mechanical or pneumatic devices for controlling ignition advance angle were eliminated and replaced with contactless, fully electronic microprocessor ignition which makes use of inductive sensors of rotational speed and crankshaft position. Characteristics of ignition advance angle which take into account rotational speed and current load on the car engine are stored in the memory of the electronic control device.

To achieve the best control possibilities, the following signals for analysing the work of particular systems are necessary:

– turning the ignition on and off,
– camshaft position,
– vehicle speed signal,
– signal of cooperation with the automatic transmission,
– switching on the air conditioner,
– signal of battery charge voltage,
– temperature of the sucked air,
– quantity of the sucked air,
– throttle opening angle ,
– amount of oxygen in exhaust fumes,
– signal from the knock combustion sensor,
– engine rotational speed.

Drivers made by Siemens realize similar functions. They are presented in the block diagram in Figure 1.

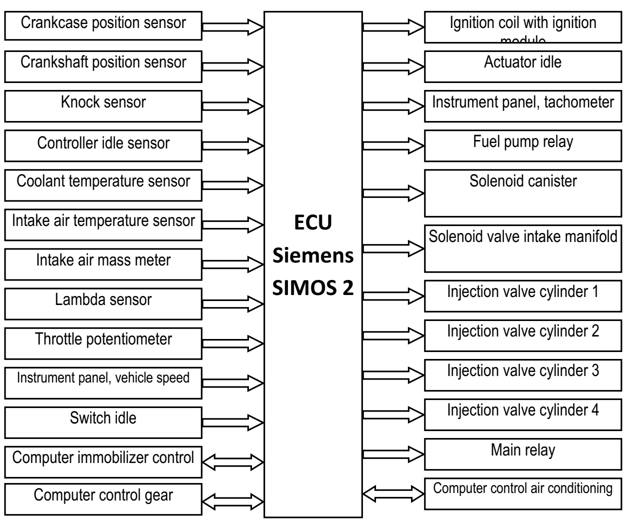

Fig. 1. Block diagram of SIMOS 2 injection system made by Siemens

2. EXPERIMENTAL TESTS

In order to observe the system parameters and to simulate the work of actuators [1, 2, 5, 6, 10, 11], the bench (Fig. 2) was connected to the computer through the diagnostic connector OBD. The possibilities of the diagnostic program are shown in Figure 3.

By means of this program, the following tasks can be performed in the driver system: the identification of the driver, the readout of error codes, the control of particular signals, the simulation of selected actuators and the adaptation of the throttle. In order to carry out the adaptation of the throttle, the following conditions must be fulfilled: the battery needs to be charged min. 12 V, and engine temperature should be min. 80 °C.

In order to carry out the adaptation of the throttle, the measurement program ("Meas.Block - 08") and the subprogram 098 should be chosen.

In the diagnostic program, four pieces of information can be read. The first one is about the voltage of the throttle regulator, the second one is about the reference voltage, the third piece of information is about the throttle position (idle - closed throttle, Part Throttle - partially open, Full Throttle - completely open) and the fourth piece of information is about the adaptation state of the throttle.

When the test is completed, exit the program by pressing "Done, Go Back".

Fig. 2. The view of the test bench

In order to observe the actual parameters (Fig. 4) on the basis of which instantaneous values can be read, an appropriate button in the program "Meas.Blocks – 08" should be selected: rotational speed of the engine crankshaft, engine temperature, air temperature in the intake manifold, voltage of vehicle electric system supply, throttle opening angle, signal from the lambda sensor, injector opening time, ignition advance angle.

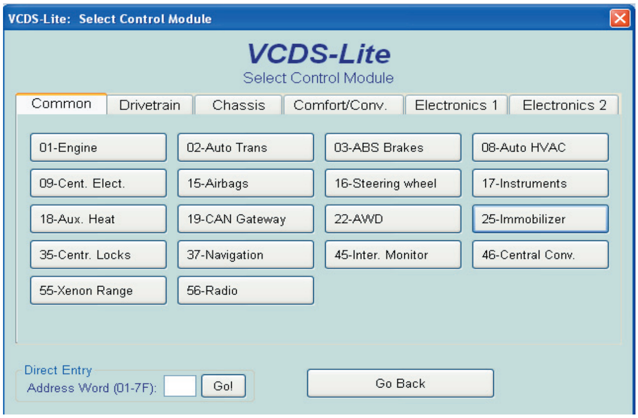

Fig. 3. Diagnostic program of the Motronic system

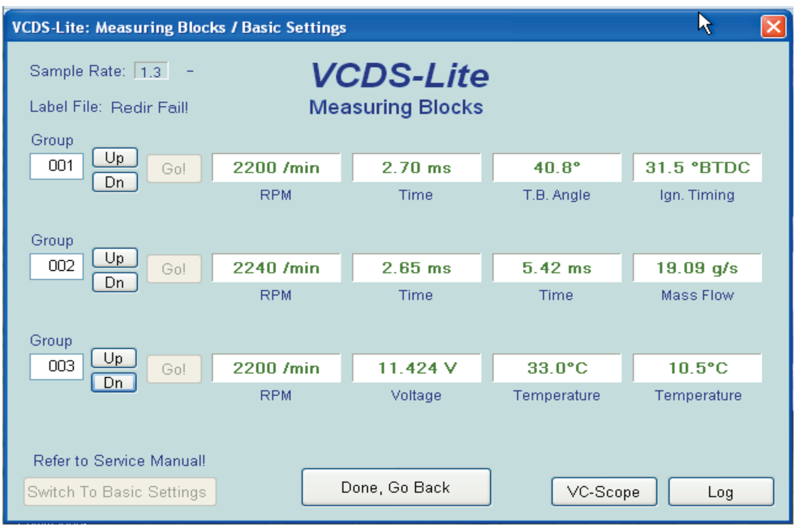

Fig. 4. Window of the diagnostic program – measuring blocks

During the study, throttle opening angle was simulated and fuel injection time was read in milliseconds. Fig. 5 presents the graph showing how injection time depends on throttle opening angle at constant parameters: engine temperature 85 ° C, the flowmeter 26.67 g / stroke (blower second gear), rotational speed 2000 rpm.

However, the simulation for different values of ignition advance angle was realized by changing engine rotational speed. The graph showing how ignition advance angle depends on engine rotational speed was realized at constant parameters: throttle opening angle 60 °, constant air flow 26.67 g / stroke (blower second gear), engine temperature 90 °C (Fig. 6).

Comparative tests were carried out on the designed ignition bench SIMOS 2 made by Siemens. The test bench consists of mechatronic elements of the injection system and was made on the basis of Audi engine whose engine capacity is 1600 cm^3. The components of the bench together with the computer are shown in Fig. 7.

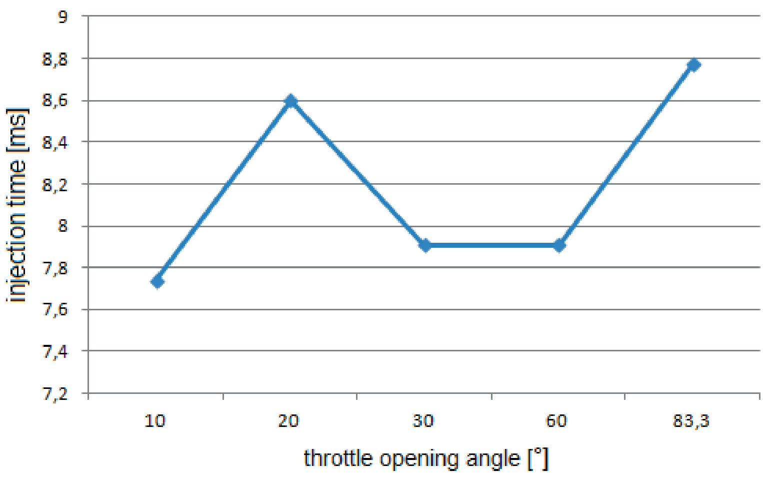

Fig. 5. Graph showing how injection time depends on throttle opening angle

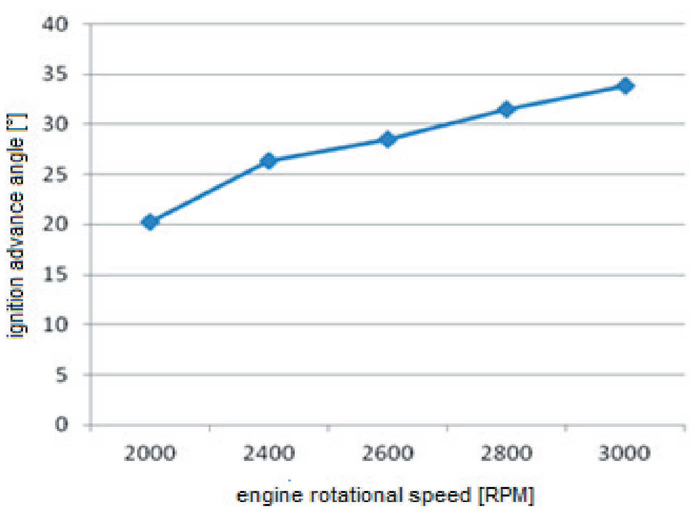

Fig. 6. Change of ignition advance angle as a function of engine rotational speed

For the purpose of simulating the work of injection system mechatronic elements, smooth adjustment of the following values was realized:

– Rotational speed,

– Engine temperature,
– Sucked air temperature,
– Air flow intensity,
– Throttle position,
– Lambda sensor signal.

Fig. 7. General view of the bench

During the simulation tests, the diagnostic program VWTOOL presented in Fig. 8, 9, 10 was used.

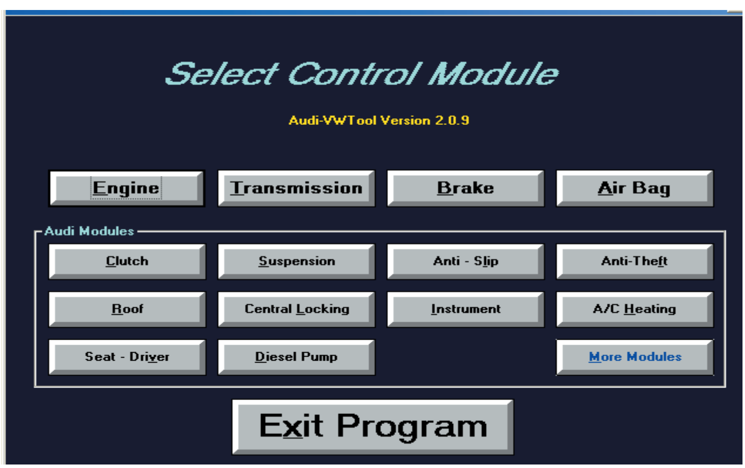

Fig. 8. The choice of the diagnostic program VWTOOL functions

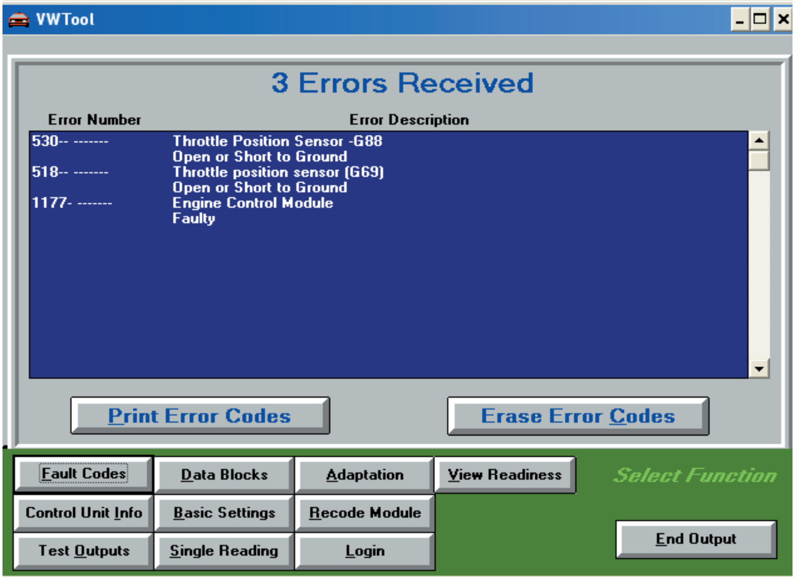

Fig. 9. Reading error codes in the diagnostic program VWTOOL

In order to verify the correctness of set parameters of engine work, the bookmarker "Main Functions" and then the bookmarker "Fault Codes." should be selected. After error codes have been read, the bookmarker "Erase Error Codes" should be chosen, then the previously recorded codes will be erased from the driver memory and new codes will be read.

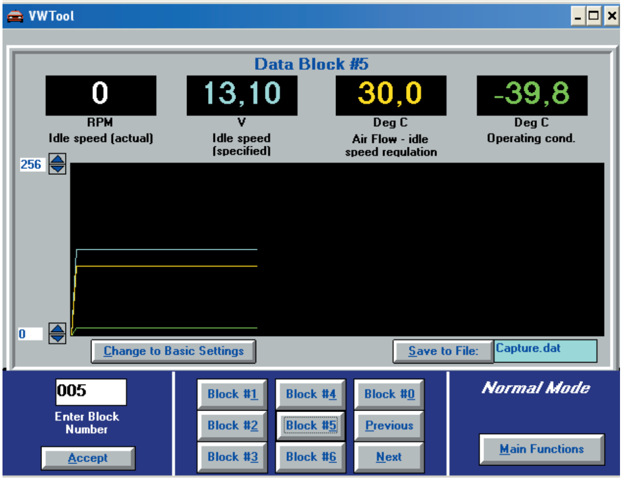

Fig. 10. Diagnostic program which enables reading the selected parameters

On the basis of the conducted measurements of injector opening time as a function of rotational speed and as a function of air flow intensity at constant liquid temperature 84 ° C, air temperature 33 ° C, throttle opening angle 12 °, 50 °, 92 °, the results were recorded and presented in Fig. 11 and Fig. 12.

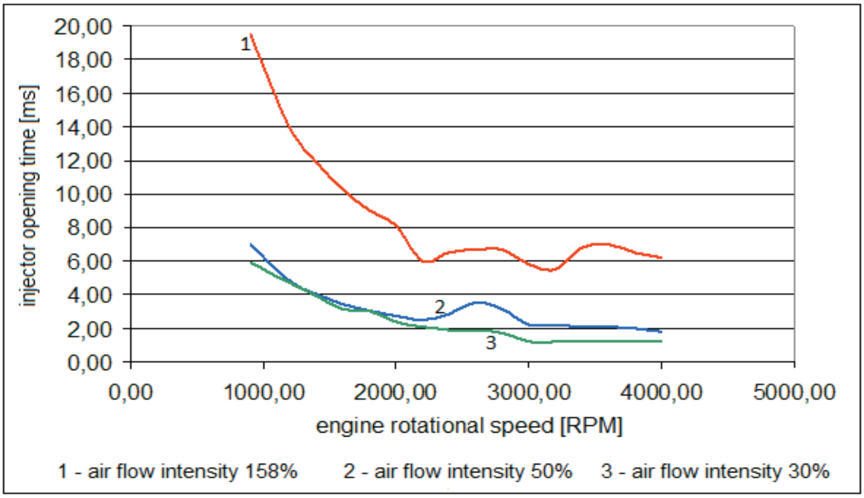

Fig. 11. Characteristics of injector opening time as a function of engine rotational speed at different values of air flow intensity

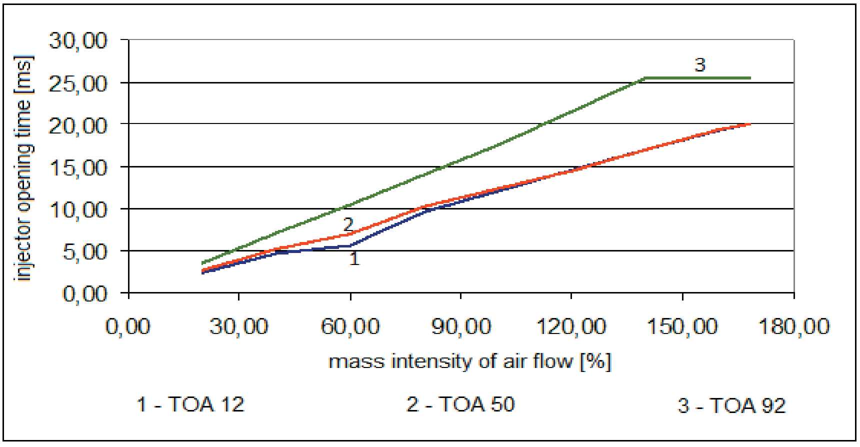

Fig. 12. Characteristics of injector opening time as a function of mass intensity of air flow at different throttle opening angles (TOA)

3. SUMMARY

The cooperation of particular sensors and execution elements with the driver was monitored by the diagnostic block of Audi-VW interface software.

The simulation carried out in the ignition and injection systems was recognized by the diagnostics blocks of the drivers.

The diagnostic software made it possible to carry out procedures simulating the work of execution elements and the adaptation of the throttle.

The designed and made-up bench made it possible to control engine work and carry out tests and the analysis of particular parameters of engine work in order to identify error codes.

The simulation of execution elements faults was carried out by adjusting control values and breaks in the circuits of particular sensors.

Measurements of electrical values of particular signals on the driver connectors were carried out on the test bench in order to determine the level of the signal at which a particular error code occurs.

References

1. Chłopek Z., Testing of hazards to the environment caused by particulate matter during use of vehicles, Maintenance and reliability, Vol. 14, No. 2., 2012.
2. Chłopek Z., The assessment of the pollutant emission from the self ignition engine in its different operating states, The Archives of Transport, Vol. 29, Issue 1, 2014.
3. Dziubiński M., Plich M., Metoda symulacji uszkodzeń układów wtryskowych. XXXIII Ogólnopolskie Sympozjum "Diagnostyka Maszyn" (ISBN 83-86923-88-1), Politechnika Śląska Wydział Transportu, s. 76, Węgierska Górka 2006,
4. Dziubiński M., Plich M., Bezstykowy układ zapłonowy z czujnikiem Halla. Materiały na IV Konferencję Naukową „ Nauka i praktyka w transporcie”, VII Eksploatacja i utrzymanie technicznych środków transportu, VIII Trakcja elektryczna i energetyka w transporcie, Politechnika Warszawska Instytut Transportu, tom. 4, s. 281-291, Warszawa 1985.
5. Dziubiński M., Plich M., Drozd A., Modelling and simulation characteristics of starting system, Zimowa Szkoła Niezawodności, Szczyrk 2016.
6. Dziubiński M., Plich M., Modelowanie i symulacja stanów niezdatności układu zasilania elektrycznego pojazdu. Materiały XL Jubileuszowej Zimowej Szkoły Niezawodności, Niezawodność Procesów i systemów technicznych, Szczyrk 8-14 stycznia 2012.
7. Issermann R., Model-based fault-detection and diagnosis – status and applications, Annual Reviews in Control, Vol. 29, Issue 1, 2005, s.71-75.
8. Jianmin L., Yupeng S., Xiaoming Z., Shiyong X., Lijun D., Fuel Injection System Fault Diagnosis Based on Cylinder Head Vibration Signal, International Workshop on Automobile, Power and Energy Engineering, Procedia Engineering, 16, 2011, p.218-223.
9. Kasedorf J, Woisetschlgäer E.: Układy wtryskowe benzyny, Wydanie 2, Wydawnictwo WKŁ, Warszawa 2000.
10. Merkisz J., Lijewski P., Fuć P., Exhaust emissions measured under Real traffic conditions from vehicles fitted with spark igniton and compression ignitron engines, The Archives of Transport, Vol. XXIII, NO 2., 2011, p. 165-173.
11. Merkisz J., Pielecha J., Emission of particulates from automotive source, the publishing house of Poznań University of Technology, ISBN 978-83-7775-325-5, Poznań 2014.
12. Patton R., Chen J., Design methods for robust fault diagnosis, Control system, Robotics and Automation, Vol. XVI, 2005.

13. Payri R., Salvador F., Manin J., Viera A.; Diesel ignition delay and lift-off length through different methodologies using a multi-hole injector; Applied Energy; Volume 162, 15 January 2016; Pages 541-550.
14. Robert Bosh Gmbh, "The technical manual – Control of spark ignition engines. Motronic systems", 2004.
15. Wang Z., Ding H., Ma X., Xu H., Wyszynski M., Ultra-high speed imaging study of the diesel spray close to the injector tip at the initial opening stage with split injection; Applied Energy; Volume 163, 1 February 2016, Pages 105-117.
16. Yang B., Xi Ch., Wei X., Zeng K., Chia Lai M.; Parametric investigation of natural gas port injection and diesel pilot injection on the combustion and emissions of a turbocharged common rail dual-fuel engine at low load; Applied Energy; Volume 143; 1 April 2015; Pages 130-137.