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POSSIBILITIES OF RESEARCH ELECTROMAGNETIC FUEL INJECTORS

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Abstract

Article discusses issues concerning researching electromagnetic fuel injectors. These fuel system is using in automobiles all the time. Bosch Company declined piezoelectric fuel injectors and reverted to electromagnetic. There are known Denso, Delphi and Bosch electromagnetic fuel injectors. Article describes how to diagnose and repair it. Denso and Bosch fuel injectors have almost the same construction. These objects have very similar repair technology. Despite Denso fuel injectors has not manufacturer official repair technology it is possibility to regenerate it because there are tools and many spare parts available on the market. Article discusses construction and operation presented fuel injectors. There has been shown diagnostic parameters and how to analysis it. Researches have been made in laboratory handle; to research and repair Diesel injection systems. Article describes construction, operating testing and repairing of electromagnetic fuel injectors. The aim of the article is to present the possibilities of researching and repairing electromagnetic fuel injectors. The fuel unit injector testing and repair process is carried out. The tests were conducted in a specialist laboratory where fuel injectors, fuel unit injectors and fuel injection pumps are being regenerated. The setting of the opening pressure of fuel unit injector is a very important stage because it affects the volume of injection doses. The opening pressure of fuel unit injector should amount to 28 MPa. F

Keywords: *fuel injector, CI – engine, diagnosing procedure, Common Rail system*

1. Introduction

Design requirements for modern internal combustion engines refer, among others, to limitation of the emissions of toxic substances into the atmosphere and reduction of fuel consumption. A system being responsible for fuel delivery at the appropriate time and at a specific pressure to the engine's combustion chamber is the fuel supply system. Fuel supply systems (Common Rail) of modern compression ignition engines (CI) are composed of two systems: low-pressure system and high-pressure system. In order to ensure proper engine operation, both systems must be technically efficient and function smoothly. The purpose of low-pressure system is continuously to supply fuel at an appropriate pressure to the high-pressure section of fuel injection pump where the high-pressure zone begins. The last element of high pressure system, and at the same time the most precise and exposed to defects one, are fuel injectors [3]. The main task of fuel injectors is to distribute and spray an adequate fuel dose in the combustion chamber of compression ignition engine. There are known two sorts of Common Rail fuel injector: electromagnetic and piezoelectric. Piezoelectric fuel injectors are manufactured by Continental VDO Siemens Company mostly. Denso, Delphi and Bosch companies withdrew piezoelectric fuel injectors from production. Electromagnetic fuel injector is composed of two assemblies: nozzle section and valve solenoid section. The valve solenoid section is an element controlling the operation of fuel injector and being responsible for the volume of fuel injection doses and back leakage. Nozzle section answers for spraying and injection dosages quality. The advantages of electromagnetic fuel injectors are possibilities for testing and potential repairs for its. There are research fuel injector parameters like full load dosage (VL), emission dosage (EM), idle speed dosage (LL), initial

dosage (VE) and back leakage during standard test. All parameters should have own range of work. If one of dosage is out of range, fuel injector will classify as faulty [12]. All dosages could be regulate.

Article describes construction, operating testing and repairing of electromagnetic fuel injectors.

2. Electromagnetic fuel injector construction and operation

A fuel injector is composed of two assemblies: nozzle and solenoid elements [12]. Bosch and Denso electromagnetic fuel injectors are very similar at an angle construction and operation. Fig. 1 presents Denso and Fig. 2 presents Bosch generation 2.1 fuel injectors subdivided into these assemblies.

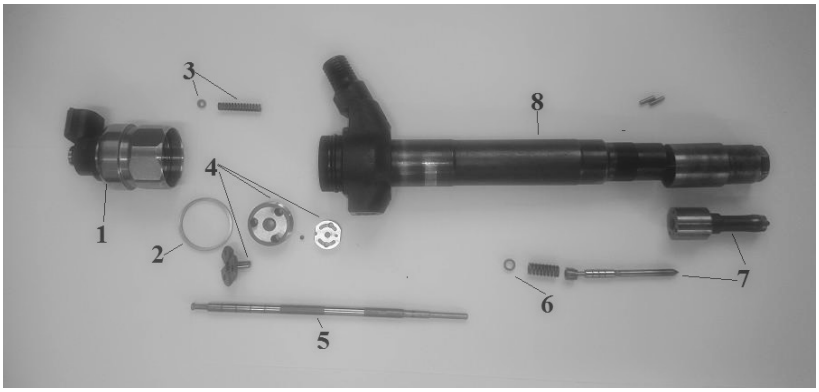

Fig. 1. Denso fuel injector subdivided into its components: 1 – solenoid section, 2 – RLS slit regulation washer, 3 – solenoid section elements, 4 – steering valve section, 5 – piston section, 6 – regulation washer, 7 – nozzle unit, 8 – injector body

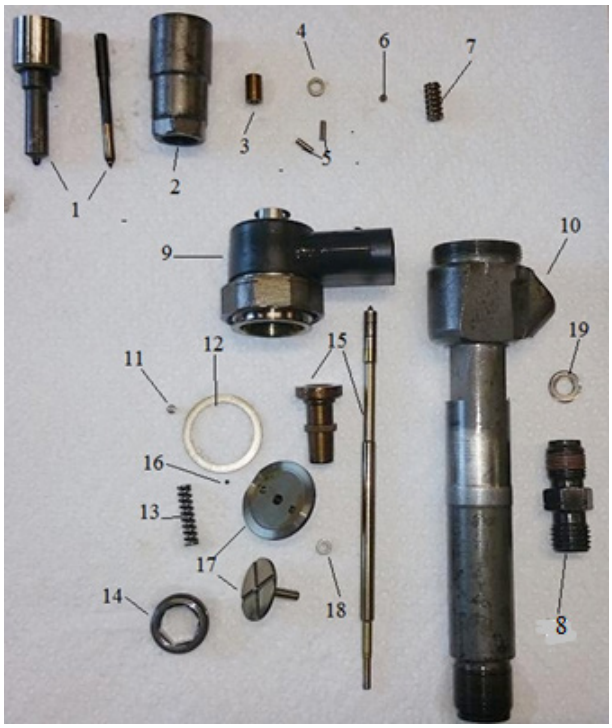

Fig. 2. Bosch gen. 2.1 fuel injector subdivided into its components: 1 – nozzle unit, 2 – nozzle cap, 3 – regulation tab bush, 4 – regulation washer, 5 – steady peg, 6 – regulation tab, 7 – nozzle spring, 8 – injector feed ampler, 9 – electromagnetic solenoid, 10 – injector body, 11 – valve ball runner, 12 – RLS slit regulation washer, 13 – electromagnetic solenoid spring, 14 – valve cap, 15 – fuel injector valve, fuel injector ball, 17 – steering valve section, 18 – back leakage regulation washer, 19 – injector feed ampler sealer

Electromagnetic fuel injectors could be divided on two zones: injector nozzle and steering zone. Figure 3 presents Bosch electromagnetic fuel injectors (gen. 1.0, 2.0, 2.1, 2.2) divided on the zones [11].

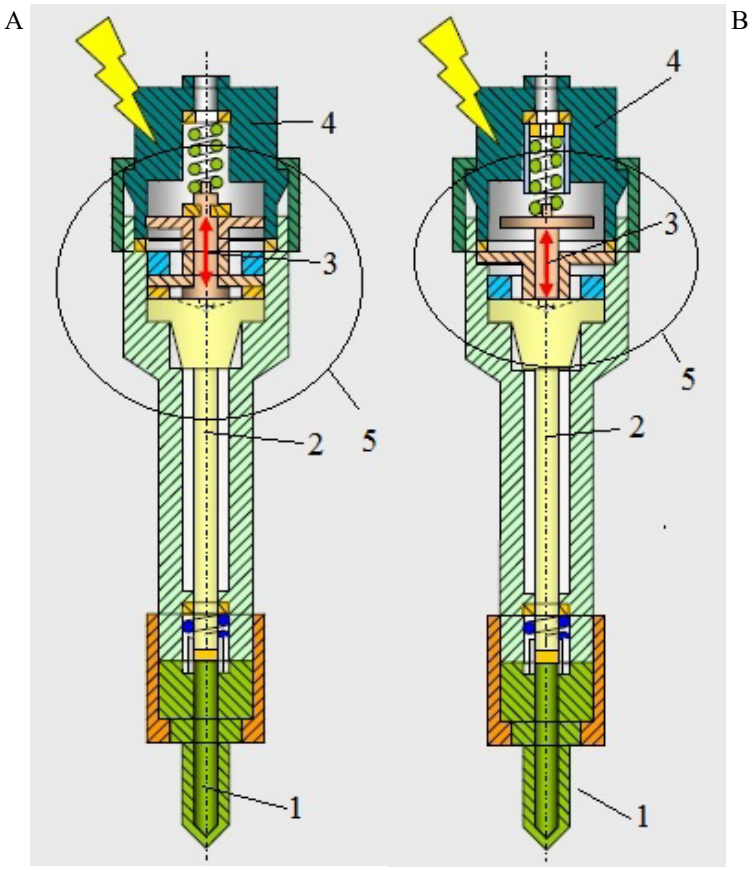

Fig. 3. Bosch gen. 1.0, 2.0, 2.2 (A), gen. 2.1 (B) fuel injector subdivided into its areas: 1 – nozzle unit, 2 – fuel injector valve, 3, 4 – electromagnetic solenoid, 5 – injector steering area [11]

Nozzle unit consists with injector nozzle and needle, regulation tab and bush, spring and regulation washer. Thickness of regulation tab influences on full load dosage. To make regulation tab 0.02 mm smaller increasing dosage about 2 mm^3/H. Thickness of washer over spring influences on idle speed dosage. The same situation is like by VL dosage. To make washer smaller 0.1 mm increasing dosage about 1 mm^3/H. It is very important, that differences between dosages of injectors from the same engine were not higher than 0.5 mm^3/H. Initial dosage is regulated by washer under solenoid. Increasing about 0.02 mm washer increases dosage about 1 mm^3/H. Emission load depends from all dosages [3]. If every dosages are in norms, EM dosage will be in standard too. There is very important to regulate range of valve work (AHE) for Bosch fuel injectors gen. 1.0, 2.0, 2.2 and AHE and slit in the injection steering area for Bosch fuel injectors gen. 2.1. AHE is regulated by washer under plate in the steering section for Bosch fuel injectors' gen. 1.0, 2.0, 2.2 and for gen. 2.1 by washer under solenoid. RLS slit is regulate by thickness of washer over bush in the solenoid. To small washer increases, RLS slit. This described technology concerns Bosch fuel injectors. Regulation of Denso fuel injectors is similar. VL and LL dosage are regulate by washer under idle spring the same like in Bosch fuel injectors. Initial dosage and range of valve work are regulated by washer under solenoid. Increasing washer increases initial dosage and range of valve work. Electromagnetic fuel injector works thanks to difference pressures between nozzle unit and steering valve section [5-10]. The higher range of valve works the bigger injector power, so that AHE regulation is so important step. Regulation AHE and RLS slit is possible only for electromagnetic Bosch fuel injectors. Denso and Delphi do not have such repair

technology. The first research and regulate is initial dosage. Denso fuel injectors are regulated similar like Bosch gen. 2.1. If initial dosage is in norm, it is possible to find that range of injector valve work is correct. Remained dosages are regulated by washer over nozzle spring [2].

Other situation is with electromagnetic Delphi fuel injectors. Fig. 4 presents Delphi fuel injector subdivided on components.

All dosages have been regulated only by clot in solenoid. To make clot smaller increases all dosages.

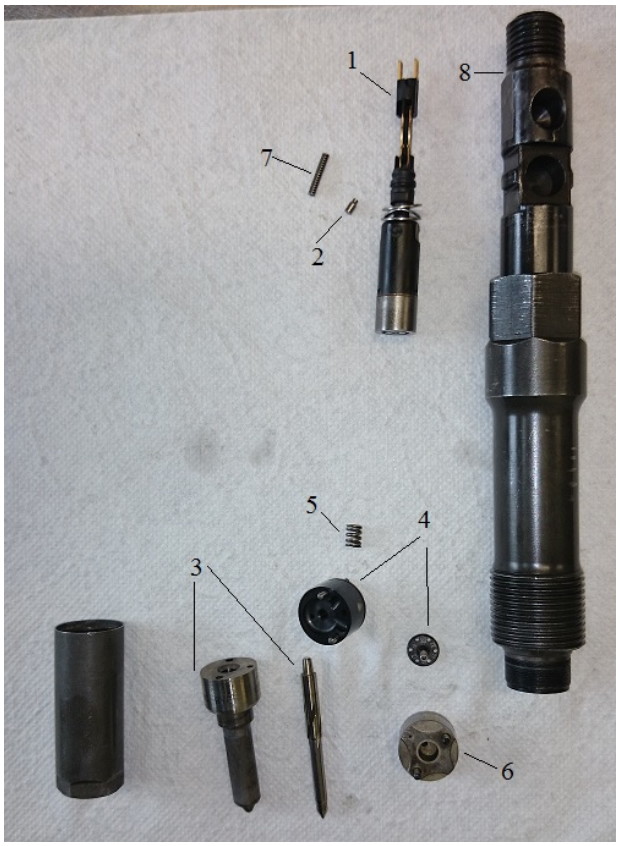

Fig. 4. Delphi fuel injector subdivided into its components: 1 – solenoid, 2 –regulation all dosages clot in solenoid, 3 – nozzle, 4 – steering valve, 5 – spring over needle, 6 – washer over nozzle unit, 7 – spring in solenoid, 8 – injector body

3. Study objective and scope

The aim of this article is to present the possibilities of researching and repairing electromagnetic fuel injectors. The fuel unit injector testing and repair process is carried out according to the scheme being presented in Fig 5.

4. Presentation of test bad and test object

The tests were conducted in a specialist laboratory where fuel injectors, fuel unit injectors and fuel injection pumps are being regenerated. Fig. 6 presents a test bench for testing the volume of fuel injection doses in fuel injectors STPiW 3 (Fuel Injection Pump and Fuel Injector Test Bench). The setting of the opening pressure of fuel unit injector is a very important stage because it affects the volume of injection doses. The opening pressure of fuel unit injector should amount to 28 MPa. Fig. 7 presents instruments to repair fuel injectors.

Figure 8 presents the Bosch manufactured solenoid – controlled fuel injector being tested, with a catalogue number 0445110083. This is electromagnetic fuel injector generation 1.0.

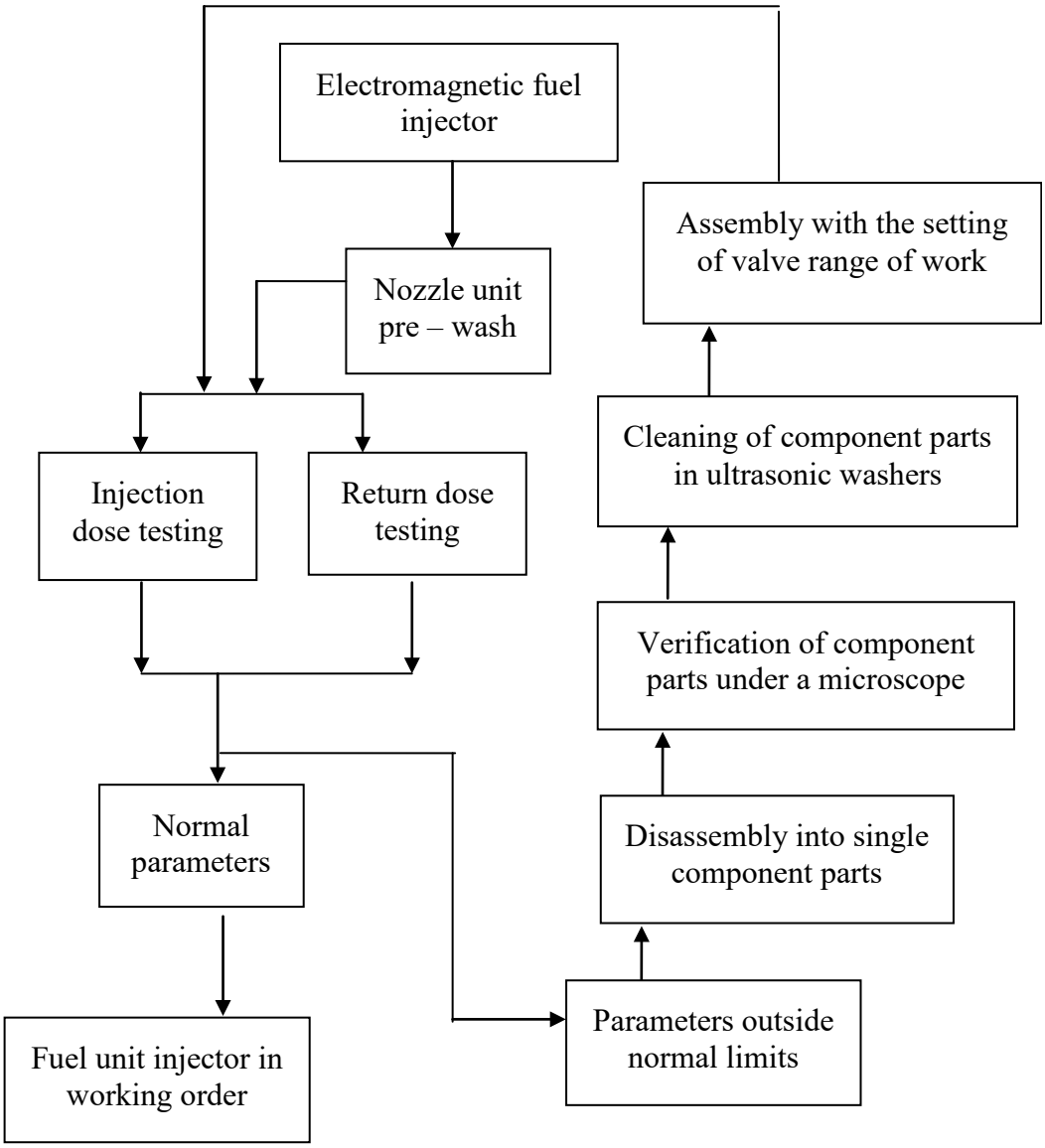

Fig. 5. Fuel unit injector testing and repair procedure

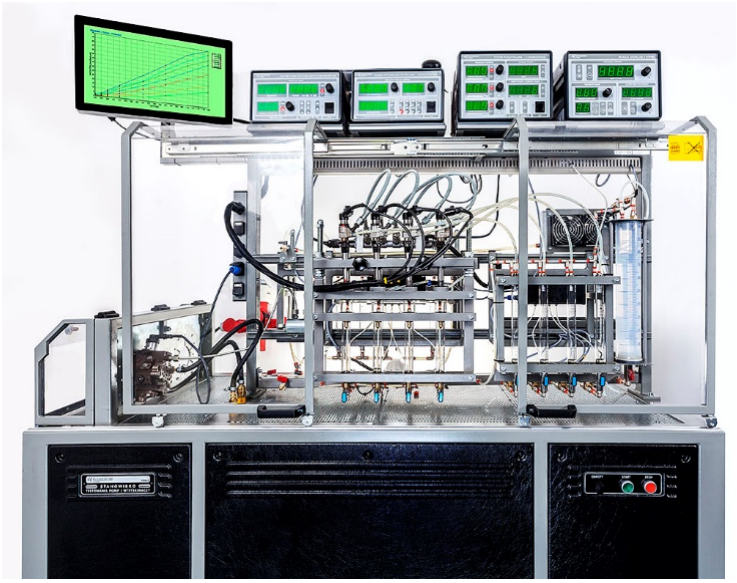

Fig. 6. Test bench for testing fuel injectors STPiW – 3

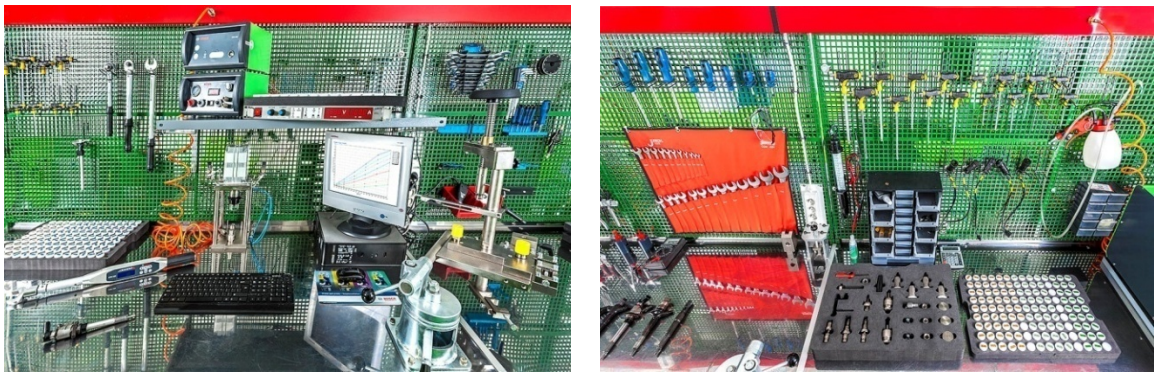

Fig. 7. Instruments to repair fuel injectors

Fig. 8. Researched fuel injector

5. Presentation of test results

The laboratory test involved testing the volume of fuel injection doses before disassembly, determining whether a fuel injector is in working order, and a possible attempt to repair it. After the initial test, it appeared that the volumes of fuel injection doses in the fuel injector being tested were too small. Measurements of the volumes of fuel injection doses were made at various parameters of fuel injector. The first measurement was made at a fuel pressure 135 MPa and injection time 780 µs (VL dosage), the second at 30 MPa and 420 µs (LL dosage) and the third at 26 MPa and 800 µs (VE dosage). Leak test is the internal tightness fuel injector research. It was made at 145 MPa fuel pressure; fuel injector did not work. The time of test is 89 second. There was measured back leakage (internal tightness) and if the fuel injector is nozzle, solenoid and thread connection will be tight.

A very important measurement is the LL test because it reflects the engine idling. It is important that all volumes of fuel injection doses in fuel injectors at the same rotational speed vary by a maximum of 0.5 mm^3/H. If a fuel injector is dosing properly at maximum or average pressures, while at low pressure the doses are small, it means that the elements of the plunger and barrel assembly may be slightly seized or the fuel injector may be dirty inside or corroded. It should be dismounted then, tested under a microscope, and cleaned next, and its operating parameters should return to normal. Tab. 1 presents fuel injector work parameters.

Tab. 1. Fuel injector work parameters

Electromagnetic Bosch fuel injector no. 0445110083				
Electric parameters	Resistance [0.3-0.7 Ω]		Inductance [115-375 µH]	
	0.6		288	
Test	Injection dosage		Return dosage	
Leak test [mm^3/H] | 145 MPa, 89 s	0		0-72	42.72
VL [mm^3/H] | 135 MPa, 780 µs	34.71-49.69	35.16	5-82	56.12
LL [mm^3/H] | 30 MPa, 420 µs	0.31-3.89	0.72	0-58	29.93
VE [mm^3/H] | 26 MPa, 800 µs	0.31-4.01	0.25	0-58	27.32

The research analysis shows that tested electromagnetic fuel injector has to low all dosages especial initial dosage. The reason of it was to low range of work fuel injector valve. The correct range of work fuel injector valve is 0.046-0.056 µm. The result of measurement was 0.045 µm. Used fuel injector nozzle, steering valve and decrease valve range of work caused lower injection dosages. To reset all parameters it should be made the procedure like on Fig. 5. Researched fuel injector was dismounted on spare parts. It was washed in ultrasonic cleaner, assembled and adjusted. Figure 9 presents adjustment process of work range the steering valve. This is very important operation because appropriate range of valve work influences on fuel injector work parameters. To small scope of valve, operation causes lower dosages to high increase its [4].

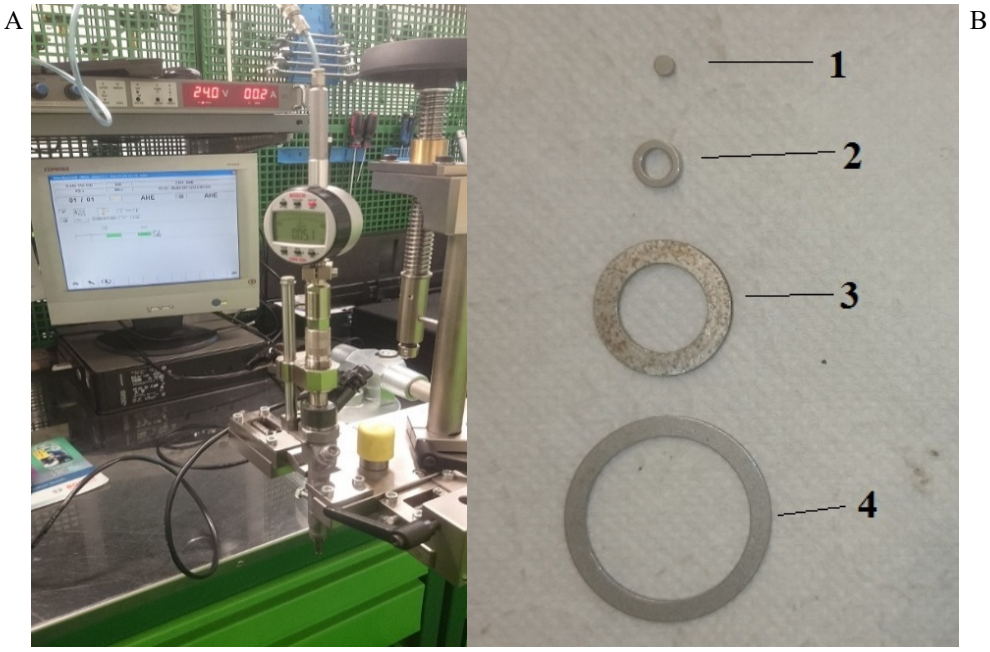

Fig. 9. Steering valve adjust process (A). Adjust pads (B): 1 – VL dosage, 2 – LL dosage, 3 – AHE (range of work injector valve), 4 – initial dosage

The first step was adjust AHE. The initial measure was 0.045 µm. It has been changed adjustment washer from 1.246 µm to 1.254 µm. The second measuration of AHE was 0.051 µm. Then, it has been made fuel injector test. The result of test presents Tab. 2.

The fuel injector work parameters were in norm but it was necessary to readjust fuel injector because idle speed and full load dosages were small. The LL dosage washer has been changed from 1.480 µm to 1.380 µm, and VL pad from 1.140 µm to 1.08 µm. Tab. 3 presents the results of research after electromagnetic fuel injector regulation process [1].

Figure 10 presents the volumes of fuel injection doses for a fuel injector before and after repair and Fig. 11 back leakage.

Tab. 2. Fuel injector work parameters after AHE adjustment

Electromagnetic Bosch fuel injector no. 0445110083				
Electric parameters	Resistance [0.3-0.7 Ω]		Inductance [115-375 µH]	
	0.5		286	
Test	Injection dosage		Return dosage	
Leak test [mm^3/H] | 145 MPa, 89 s	0		0-72	9.44
VL [mm^3/H] | 135 MPa, 780 µs	34.71-49.69	36.25	5-82	21.59
LL [mm^3/H] | 30 MPa, 420 µs	0.31-3.89	1.18	0-58	11.75
VE [mm^3/H] | 26 MPa, 800 µs	0.31-4.01	0.53	0-58	9.18

Tab. 3. Fuel injector work parameters after adjustment

Electromagnetic Bosch fuel injector no. 0445110083				
Electric parameters	Resistance [0.3-0.7 Ω]		Inductance [115-375 µH]	
	0.5		286	
Test	Injection dosage		Return dosage	
Leak test [mm^3/H] | 145 MPa, 89 s	0		0-72	9.44
VL [mm^3/H] | 135 MPa, 780 µs	34.71-49.69	44.72	5-82	21.59
LL [mm^3/H] | 30 MPa, 420 µs	0.31-3.89	2.76	0-58	11.75
VE [mm^3/H] | 26 MPa, 800 µs	0.31-4.01	1.15	0-58	9.18

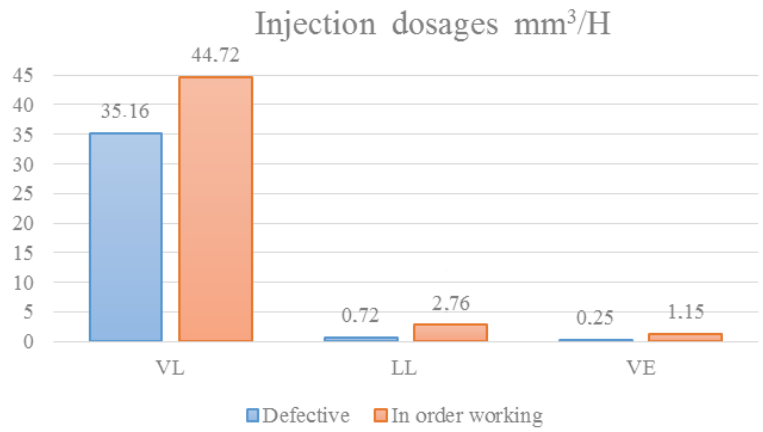

Fig. 10. Injection dosages

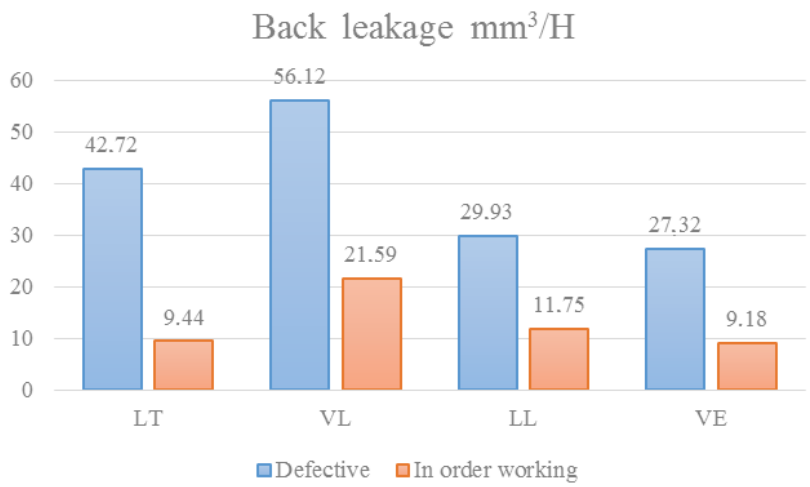

Fig. 11. Back leakage test

There is noticeable that defective fuel injector has higher back leakage and lower injection dosages especial initial. The reason of it are used and polluted precision elements on injector nozzle and steering valve, to low range of work fuel injector valve and usage of fuel injector elements (springs, washers, sealing).

6. Conclusion

The laboratory tests showed that it is possible to disassemble, clean and adjust electromagnetic fuel injectors, and possibly replace the faulty elements. The main cause of the troubles of all fuel injectors are impurities inside them, especially those on the elements of the nozzle unit and steering valve assemblies and wear of them, springs, washers and sealing. During the research, the volumes of fuel injection doses were too small especially initial dosage. This was affected by many factors. The researched electromagnetic fuel injector was thoroughly washed in an ultrasonic washer, and then dried. The range of injector valve operation was adjusted from 0.045 μm to 0.051 μm. After assembly, the volumes of fuel injection dosages were tested. This measure improves initial dosage (Tab. 2). It was necessary to readjust researched fuel injector because idle speed and full load dosages were low. After change VL pad and LL washer, the parameters were correct. It is noticeable that AHE and other dosages (VL, LL) adjustment influence on initial dosage (VE). So during adjustment electromagnetic fuel injectors it is necessary starting from research range of work fuel injector valve and then setting initial and other parameters.

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