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Evaluation of Modern Diesel Engine Fuel Injectors

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Summary. The article describes methods of evaluation of modern Diesel engine fuel injectors. The analysis was carried out in a specialist laboratory taking up researching and repairing injection systems in combustion engines. The subject of scientific study was Bosch electromagnetic Diesel engine injector with a catalogue number 0445110083. The scientific object was evaluated and verified. There was made the microscopic specification sheet of elements exposed to wear and tear and tests were performed.
Key words: Diesel engine, fuel injector, Common Rail system, engine evaluation and repair.

INTRODUCTION

Diesel engine fuel injection is used to distribute and spray fuel in combustion chamber. High pressures and temperatures inside engine cause disruptions in its correct work due to overstrains [5, 7].

At present in Common Rail systems electromagnetic and piezoelectric injectors are applied [11]. Electromagnetic injectors were introduced in 1997 and have been used successfully till the present time. The largest producer of Diesel system injectors in the world is Bosch company. Bosch company makes the following injectors of Common Rail system [11]. Electromagnetic are 1.0; 2.0; 2.1; 2.2 generations: as well as 2.5 and piezoelectric 1; 2; 3. Nowadays fully repairing are: 1.0; 2.0; 2.1; 2.2 generations [17, 18]. Generation 2.5 and all piezoelectric injection could not be repaired because of shortage technology and originals spare parts [6]. However there is a possibility to diagnose them. The others producers of Common Rail piezoelectric and electromagnetic injectors are Delphi and Denso only piezoelectric Continental – Siemens [12, 13, 15]. Delphi electromagnetic injectors are completely repaired whereas Denso because of shortage of original spare parts are partly repaired. Bosch, Delphi and Denso piezoelectric injectors could not be repaired nowadays because of shortage of technology and original spare parts [14, 19]. There are producers on the market who sell substitution parts but it is made with low quality. Siemens piezoelectric injectors are fully available to repair and to diagnose. It is possible to regulate them. There is only one problem with access to spare parts and information of instruction database [3, 8].

Generally piezoelectric injectors could be cleaned on the surface and thermo-chemically internally with the help of special detergent and next they can be diagnosed. Because of unreliability of piezoelectric crystals producers started removing them and coming back to electromagnetic injectors of modern generations.

THE RULE OF COMMON RAIL ELECTROMAGNETIC INJECTOR'S OPERATION

Picture 1 presents the rule of Common Rail electromagnetic injector's work.

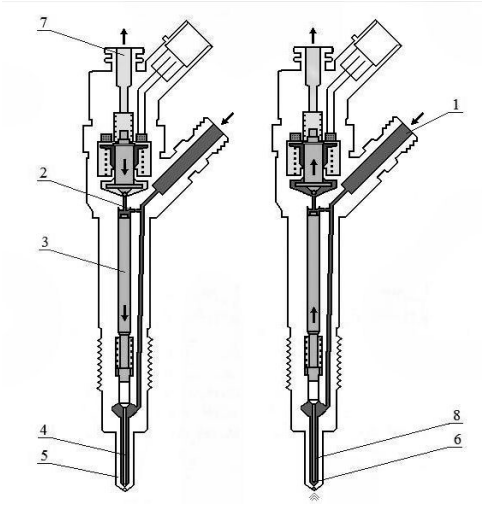

Fig. 1. The rule of Common Rail electromagnetic injector's work

Fuel is supplied to injector under high pressure by inlet pipe screwed to injector body whose magnitude depends on engine load and rotation speed. Next, it flows through inlet channel (1) through the body of injector to atomizer and combine channel (2) with steering chamber of injector work. If the pressure in valve chamber and in atomizer is the same at the time, the ending part of atomizer (6) is closed and injector does not break up into a spray into combustion chamber. But when coil obtains voltage under the influence of electromagnetic field, raises unit shaft is raised and the valve starts to open (2). A the time difference of pressure appears in the lower and upper part of injector. Higher pressure in the nozzle causes lifts the needle (8) and begins injection of fuel to the combustion chamber. When the voltage disappears in the coil unit shaft comes back to the down position and closes the steering injector valve. Pressure in lower and upper part of the injector adjustment and the needle under pressure the spring closes nozzle and finishes work of the injector.

METHODS OF DIAGNOSING MODERN FUEL INJECTORS AND THEIR PROBLEMS

Diagnose process of modern fuel injectors begins already in the vehicle with working engine. There are researched two parameters: dosage compensation on every cylinder and dosage return magnitude on neutral gear. Engine parameters on neutral gear are the injection fuel pressure between 25 – 30 MPa and injection time from 250 μs for pilots dosage to circa 800 μs for main dosage. These conditions are ideal to make diagnose of injector. With low pressures and injection times the first symptoms of faulty operation can be noticed. B reconstruction analysis of dosage compensation it can be determined which injector gives more fuel and which less. Too big differences between injectors indicate that it should be dismantled and diagnosed. Return dosage is discharge of working fluid during injector work. Every well-working injector has the determined value of it. If the discharge values are higher than the established standards it means that separate spare parts and seals are damaged and they should be replaced or repaired if it is possible.

Second stage of evaluating fuel injectors should be made in a special laboratory with suitable equipment. The first is cleaning injector nozzle in the sonic washer and installation of injector to the testing machine in order to research fluid tightness, injection and return dosage as well as the spraying stream of fuel. It should be remarked that all the injectors have to be taken out from the engine because in another situation our diagnose will be faulty. Research on the testing machine shows which injector works incorrectly.

The third stage of diagnose relies on the disassembly of the injector into spare parts, analysis under microscope, washing all elements in ultrasonic washer, their assembly according to special procedures, their regulation and, finally, research on the testing machine. It should be remembered that even if only one injector differs from another it has to be taken out, examined under microscope and cleaned in sonic washer [16, 18]. Then we will be sure that the verification process and eventual repair were correct. A very important element during the research is verification using a microscope. It allows us to check if there are some iron filings inside the injector coming from high pressure in the injection pump [1, 2].

The greatest number of malfunctions of fuel injectors occur in the surface of precision vapour needle injector piston, steering valve, nozzle and insulation [9, 10, 20].

THE AIM AND SCOPE OF EXPERIMENTAL RESEARCH

Experimental research concerned diagnose of electromagnetic Bosch Common Rail injector with catalog number 0445110083. The aim of researches was to make correct diagnose and eventually regeneration process of the researched injector. Researches were made by using special instruments and testing machines in a laboratory research unit and then repairing injection systems of combustion engines.

CHARACTERISTICS OF RESEARCH OBJECT AND WORKSTATION

The research object was Common Rail electromagnetic Bosch injector generation 1.0 with catalog number 0445110083. Picture 2 shows the disassemble of the injector into spare parts.

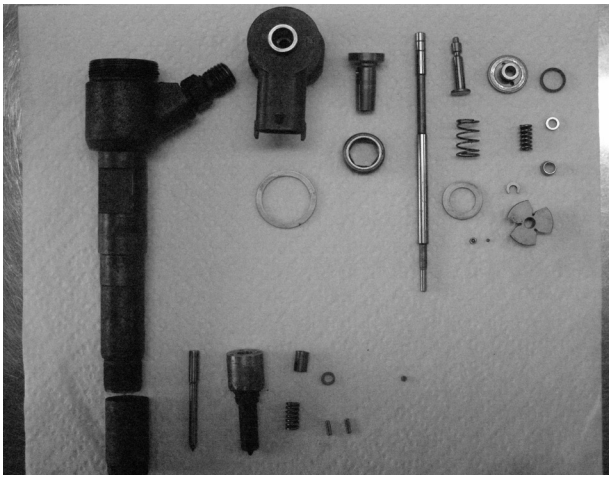

Fig. 2. Electromagnetic Bosch generation 1.0 injector disassembled into spare parts

Laboratory researches were made by using test machine STPiW 3 and stereoscope microscope. On the testing machine injection dosage and discharge were measured and visual condition of spare parts responsible for the injector's correct work was examined by using a microscope. Picture 3 shows STPiW 3 testing machine as the workstation of researches.

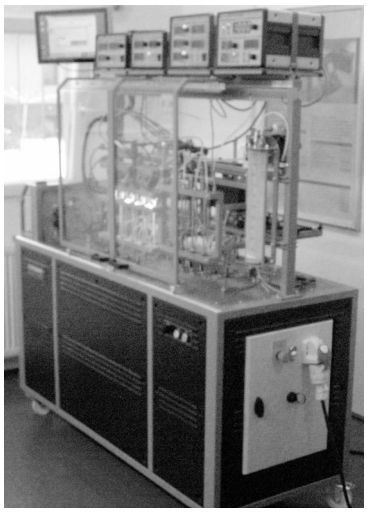

Fig. 3. Research workstation

RESEARCH RESULTS

Experimental researches were made according to the following procedure: the injector was disassembled into spare parts and subjected to verification by using stereoscope microscope. Picture 4 shows elements of needle precision vapour which open and close at fuel spraying. There are visible marks of intensive wear of the vapour stream nozzle in picture 4a. It is easy to notice little marks of corrosion in picture 4b but it has no influence on nozzle work [20]. As it can be visible in the picture, the needle is a little bit dirty with wastes coming from fuel. There are no marks of metal filings.

a) b)

Fig. 4a. Element of injector precision vapour, **b)** Injector nozzle needle

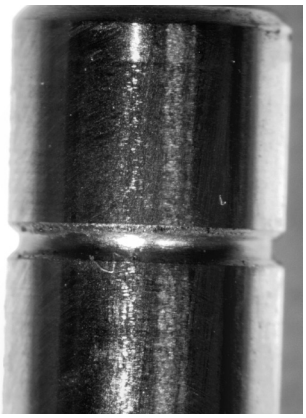

Fig. 5. Piston precision vapour steering valve of fuel injector

There is the element of piston steering injector valve precision vapour in picture 5. The dark surface means intensive use of precision vapour element. It has influence on the amount of fuel discharge.

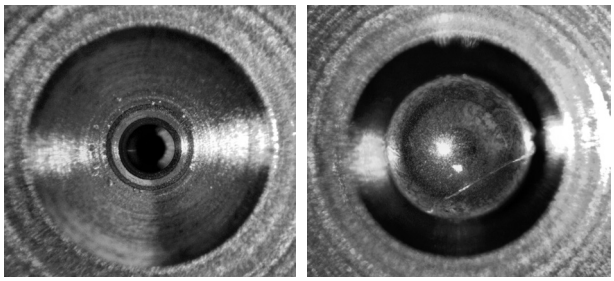

Fig. 6. Steering valve of Common Rail Bosch injector – left without a ball, right with a ball

Picture 6 presents a section of steering valve electromagnetic Common Rail Bosch injector. It shows the section without a ball in picture 6a and the section with a ball in picture 6b. Steering valve is in good condition. Picture 6b shows the steering valve with the ball – as it is visible the ball fits well to the section, which has a huge influence on good fuel injection work.

Table 1 shows injection and return dosage values researched in the injector and work parameters during a test. The test was made for variable injection times and pressures. Test 1 concerns tightness research of injector and discharge value at not working nozzle for the pressure 145 MPa. Time test was 60 seconds. Test 2 is a check of full load dosage. During this probe the researched parameters are injection dosage and discharge by 135 MPa pressure (maximum work pressure of these injector) and injection time 720 µs. Another test was research of neutral gear dosage by 30 MPa injection pressure and 420 µs injection time. The last test was pilot dosage. It is characteristic for this research that low pressure about 30 MPa and small injection time 250 µs were applied. If this dosage is dropping it means that the injector should be repair. This dosage accounts for detonation combustion on neutral gear.

Table 1. Results of researches on injection dosage and discharge using the testing machine

	MPa	µs	mm³/H		Injector 1
				Catalog no	0445110083
No	Injection pressure	Injection time	Range		
1	145	60 s	0,00 – 0,00	Dosage	0,0
			0,00 – 72,00	Discharge	34,1
2	135	780	34,71 – 49,69	Dosage	46,6
			16,00 – 58,00	Discharge	32,3
3	30	420	0,31 – 3,89	Dosage	1,9
			0,00 – 58,00	Discharge	7,1
4	80	260	0,31 – 4,09	Dosage	2,4
			0,00 – 58,00	Discharge	9,0
Test pass					Yes

Additional test is injector work characteristics made on STPiW 3 testing machine. It shows an outlay of all dosages

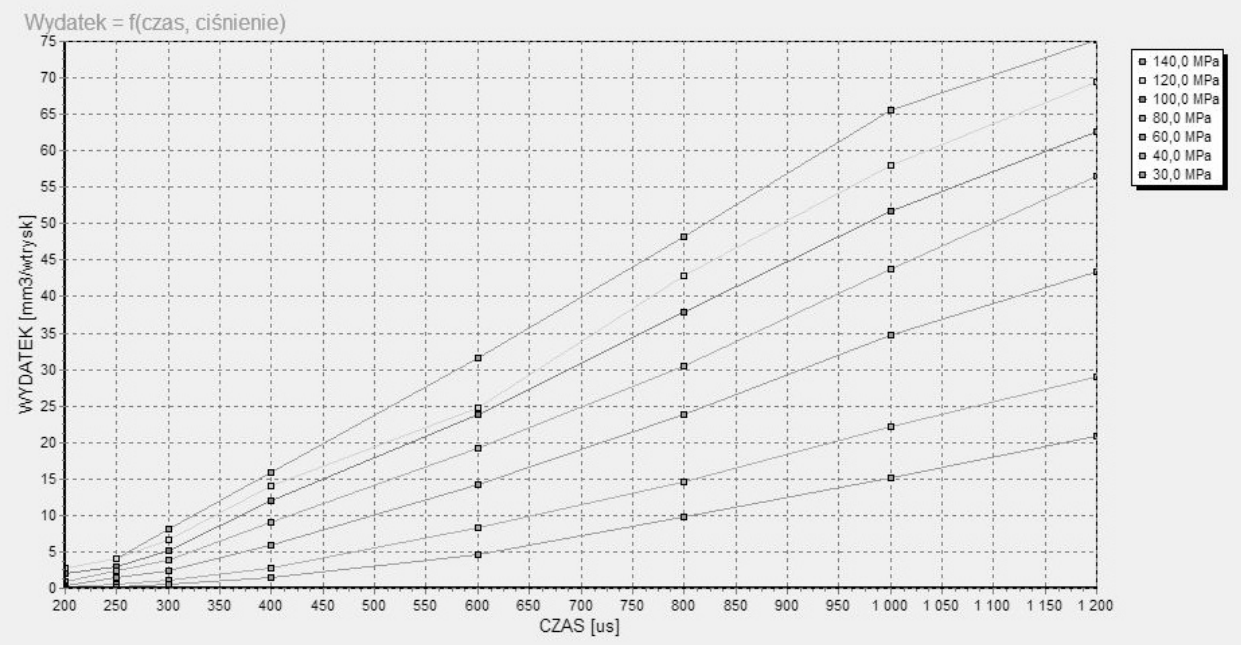

Fig. 7. Characteristic of the researched injector on testing machine

at various pressures and injection times. The characteristics is useful because it can be compared to all injectors in the engine in the whole range of work. Beginning from micro dosages and ending on full load with maximum injection times and pressures. Picture 7 presents full research on Bosch fuel injector characteristic with catalog number 0445110083.

CONCLUSION

The analysis of the carried out diagnose shows that researched fuel injector retained its own work parameters. The pictures made during microscope researches showed elements of steering valve and precision vapour after short use. Theoretically, these spare parts should be replaced with new ones, judging from the pictures. But tightness dosages and discharges tests showed that in spite of cavity wear of spare parts, the injector has all the working parameters correct. It means that it can be recognized as capable of good operation. Worrying is the fact of appearance of metal filings on valve surface steering in the injection work picture 5a. It means that the whole injection system should be disassembled, cleaned and dismantled and the height of pressure pump checked because metal filings come from it.

One reason of faster injectors damages are uses of high pressure pumps which soil the whole injection system with metal filings. Sometimes these filings are so small that they are not caught by fuel filter.

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DIAGNOZOWANIE WSPÓŁCZESNYCH WTRYSKIWACZY PALIWA W SILNIKACH Z ZAPŁONEM SAMOCZYNNYM

Streszczenie. Artykuł przedstawia sposoby diagnozowania współczesnych wtryskiwaczy paliwa silnika z zapłonem samoczynnym. Analiza została wykonana w specjalistycznym laboratorium zajmującym się badaniem i regeneracją układów wtryskowych silników spalinowych. Obiektem badawczym był wtryskiwacz elektromagnetyczny firmy Bosch o nr katalogowym 0445 110 083. Badany obiekt przeszedł całkowity proces diagnozy i weryfikacji. Wykonano dokumentację mikroskopową elementów narażonych na zużycie oraz wykonano testy poprawnego funkcjonowania na stołach probierczych.
Słowa kluczowe: silnik spalinowy, wtryskiwacz paliwa, układ Common Rail, regeneracja wtryskiwaczy paliwa, diagnozowanie układów Common Rail.