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ANALYSIS OF RESEARCH POSSIBILITIES OF FUEL UNIT INJECTORS

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Abstract

Article discusses issues concerning diagnosing and researching fuel unit injectors (UI). This fuel system has been taken off in automobiles but the problems with diagnosing and research is still actually. Motorized vehicles with fuel unit injector system were manufactured until 2010 but lorries are still producing. Only one automotive concern VW put in this system to motorized vehicles in Europe. The 1.9 TDI engines have PDE 1 (UI) and 1.4 TDI, 2.0 TDI engines have PDE 2 (UI). Unit injector is device which main tasks are spray and distribute fuel in combustion chamber of Diesel engine. Unit fuel injector is built with three sections: fuel injection nozzle complex, electromagnet unit and pump part. Injection nozzle complex is common mechanical one spring injector. That research is on check and eventually adjusts open pressure. Electromagnet units are non-dismantle and non-repair, but there is possibility dismantle and clean it. Electromagnet unit affects injection dosages and module BIP (being of injection period) unit fuel injection. The task of pump part is fuel damming until demanding values. The pump part makes up piston with and main body, spring and protect flat piece of metal. Theoretically, also this element is non-repair. Main unit fuel injector work parameters are injection dosages values and signal BIP. During fuel unit injectors research checks injection dosages with varies settings (rotation speed, injection time). These parameters are similar to engine work on idle speed (idle speed dosage), pilot dosage, middle and full load dosage.

Keywords: *unit injector, Diesel fuel, engine diagnosing, injector operating parameters*

1. Introduction

The main task of fuel unit injectors is to distribute and spray an adequate fuel dose in the combustion chamber of compression ignition engine. It is a system composed of three assemblies: spray nozzle section, solenoid section and fuel pumping element. The spray nozzle is a normal single-spring fuel injector. It is mounted on the casing with a clamping nut with pinholes that collect fuel. The solenoid section is an element controlling the operation of fuel unit injector and being responsible for the volume of fuel injection doses. It is composed of a solenoid core, spring, coil and valve needle with anchor. The task of fuel pumping element is to swell fuel to an appropriate value of the set working pressure. The casing of fuel unit injector is also a cylinder of high-pressure pump. The pumping section also consists of a plunger, spring and a spring pitch limiting plate. Fuel unit injector is driven by roller tappets from the camshaft. The advantage of fuel unit injector was the ability to generate an initial injection (pilot dose) which reduces exhaust gas toxicity and engine noise. In passengers' vehicles, electronically controlled fuel unit injectors have been implemented by Volkswagen automotive company. In 1.9 TDI engines, Bosch manufactured solenoid-controlled fuel unit injectors PDE 1 are used, while Bosch manufactured solenoid-controlled fuel unit injectors PDE 2 or Continental VDO Siemens manufactured piezoelectric fuel unit injectors in 1.4 TDI and 2.0 TDI engines. The Bosch manufactured solenoid-controlled fuel unit injectors (PDE 1 and PDE 2) are fully dismountable and it is possible to repair them completely, whereas the Continental VDO Siemens manufactured ones can be only cleaned internally and tested for the volumes of fuel injection doses [11]. Fig. 1 presents the Bosch manufactured solenoid-controlled fuel unit injectors of PDE 1 and PDE 2 generations.

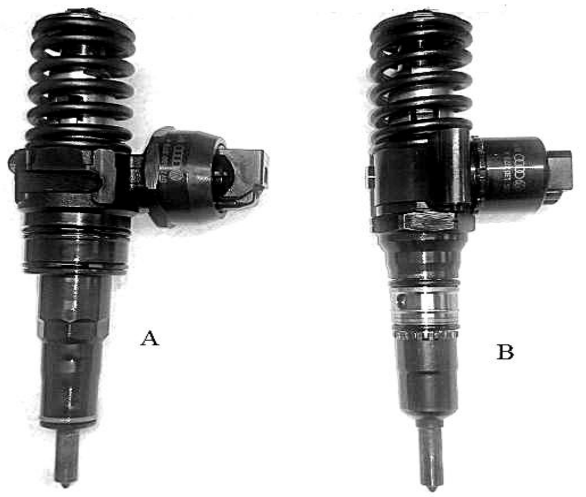

Fig. 1. Bosch manufactured solenoid-controlled fuel unit injectors: A) PDE 1, B) PDE 2

The diagnostic parameters of fuel unit injectors are as follows: injection dose at different conditions of operation, BIP (beginning of injection period) signal, opening pressure of spray nozzle, and coil induction value. Based on the values of these parameters, it is possible to conclude whether a fuel unit injector being tested is in working order or not.

2. Fuel unit injector construction and operation

A fuel unit injector is composed of three assemblies: nozzle, solenoid and fuel pumping element. Fig. 2 presents a fuel unit injector subdivided into these assemblies.

Fig. 2. PDE 2 fuel unit injector subdivided into its components: 1 – nozzle unit, 2 – solenoid section, 3 – fuel-pumping element

The most important element of fuel unit injector is its casing, which is also a pump cylinder. A recoil spring and a plunger, being fitted to the cylinder, are situated on it. These elements are responsible for generation of high pressure. There is also a high-pressure solenoid valve situated in the casing. Ducts inside the casing connect the chamber of fuel pumping section with a solenoid valve of low-pressure circuit and a spray nozzle. The task of solenoid valve is to control the beginning and the duration of fuel injection. It consists of an anchor, valve needle, valve spring and a solenoid. The task of the nozzle unit is to distribute and spray fuel in the combustion chamber of engine [1]. This element is composed of a spray nozzle with a needle, a screw cap, and some elements situated over the spray nozzle (spacers, spring and packing plates adjusting the opening pressure). Fig. 3 presents a fuel unit injector disassembled into its single component parts [5].

Fig. 3. Disassembled fuel unit injector subdivided into its particular assemblies: 1 – nozzle unit, 2 – solenoid section, 3 – fuel pumping element

During the operation of fuel unit injector, four phases are being distinguished: intake stroke, initial stroke, pumping stroke with fuel injection process, and residual stroke. During the intake stroke, the pump plunger moves upward, which is induced by the spring action. The over-pressurised fuel flows from the low-pressure circuit to the working space of solenoid valve through a supply duct. The control valve is open and fuel enters the high-pressure space. During the initial stroke, the drive cam presses the plunger, which starts to move downward. The solenoid valve is open. The swelled fuel enters the working space of low-pressure system through an overflow duct. During the pumping stroke, fuel is being injected into the combustion chamber of engine. The solenoid coil is energised; the solenoid needle is drawn in, and it closes a duct between the high-pressure chamber and the low-pressure circuit. This stage is being called the beginning of injection period (BIP). Closing the solenoid valve changes the coil current, which is identified by a controller (BIP identification) [2]. This way, the controller reads the real beginning of fuel pumping and takes it into account when calculating the next fuel injection process. The fuel pressure in the high-pressure chamber increases due to a downward movement of the plunger. The pressure in the spray nozzle mounts and when it is about 30 MPa the needle rises up and the real beginning of fuel injection to the combustion chamber starts. During the residual stroke, the coil current is being switched off, the solenoid valve opens and, after a short delay, a duct connecting the high-pressure space and the low-pressure circuit is being opened. In the transition stage between the pumping stroke and the residual stroke, a maximum fuel pressure is being obtained. Depending on the fuel unit injector, it varies between 180 and 205 MPa. When the pressure falls to a value being lower that the opening pressure, the spray nozzle closes and the injection process is being ended. The residual dose of fuel being pumped until the head point of drive cam has been reached flows away through an overflow duct to the low-pressure circuit [2].

It is possible to adjust the volume of injection doses in fuel unit injectors by changing the thickness of packing plate in the solenoid section (Fig. 4).

In the pumping section, a metal plate under the spring of fuel unit injector is very often damaged. Therefore, it should be remembered that the fuel unit injector head and gaskets should be adjusted and replaced approximately every 50 thousand kilometres during the operation of vehicles equipped with this type fuel supply. Fig. 5 presents a disassembled spring with the described element being damaged.

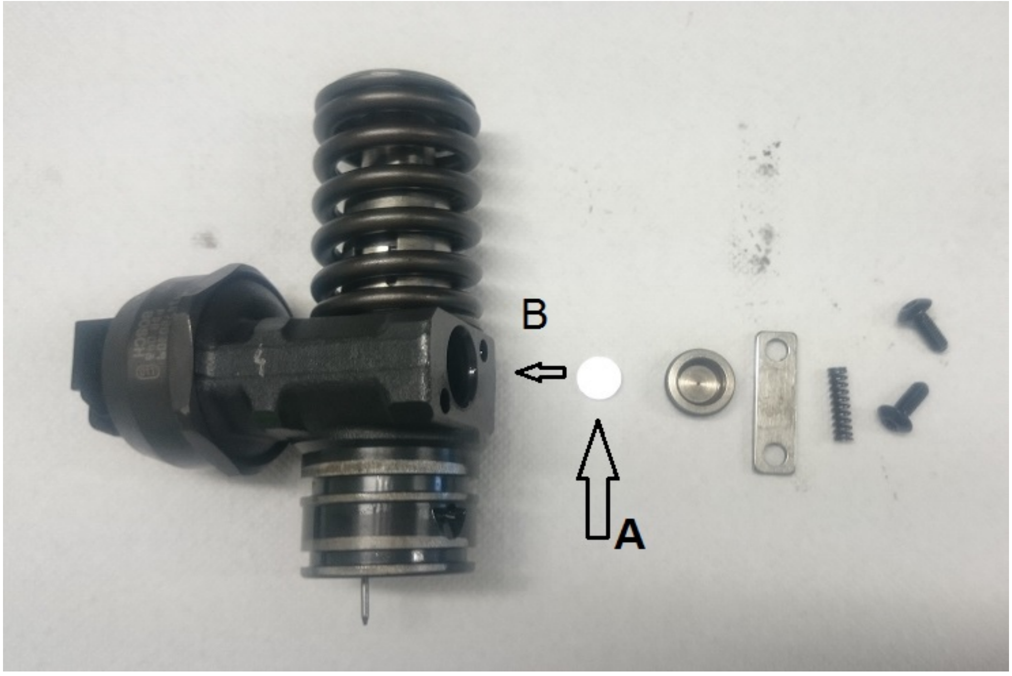

Fig. 4. Possibility to adjust fuel injection dose volume in fuel unit injectors by changing the thickness of packing plate (A) in the solenoid section (B))

(A) *(B)*

Fig. 5. Fuel unit injector element being very often damaged: A) a general view of the damaged fuel unit injector, B) a place where a metal plate under the spring chipped off

Figure 6 presents the main plunger situated in the casing of fuel unit injector. This element is responsible for swelling the fuel and constitutes, together with the casing, the barrel and plunger assembly. The figure shows impurities from the fuel filter, metal filings swarf, and various kinds of scale, which affect the element life. According to the manufacturer, the pumping section is non-dismountable and non-repairable but it is possible to replace the plates under the spring or the spring itself [3, 4]. Only the plunger and casing assembly is non-replaceable due to their fitting.

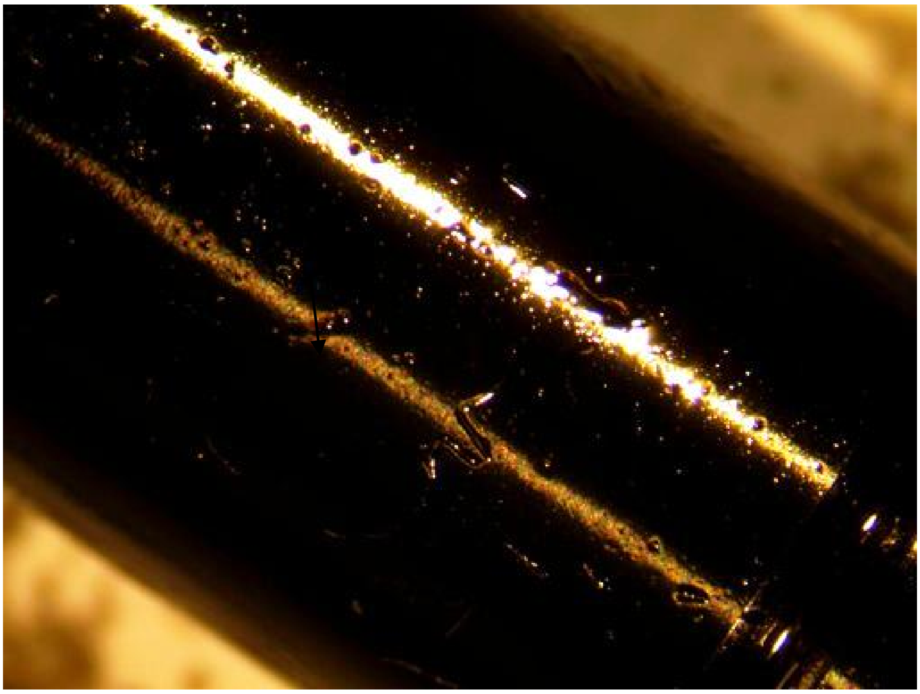

Fig. 6. Impurities on the main plunger of fuel unit injector

The next figure (Fig. 7) shows the pinholes supplying fuel to a fuel unit injector (A). It is very important that the pinholes are clean because it would stop working properly if they are clogged [8]. Various kind of scale often accumulates in the overflow duct (B).

(A) *(B)*

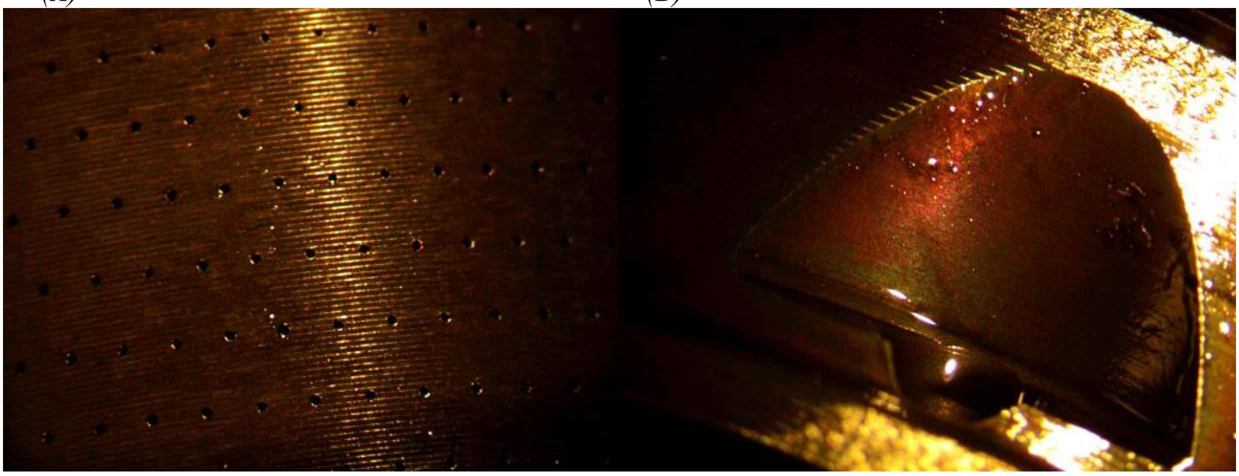

Fig. 7. Ducts supplying fuel-to-fuel unit injector (A) and an overflow duct (B)

3. Study objective and scope

The aim of this paper is to present the possibilities for testing and repairing fuel unit injectors. The fuel unit injector testing and repair process is carried out according to the scheme being presented in Fig. 8.

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 [9, 10]. Fig. 9 presents a test bench for testing the volume of fuel injection doses in fuel unit injectors STPiW 4 (Fuel Injection Pump and Fuel Injector Test Bench) with a Cambox attachment and an adapter for setting the opening pressure of fuel unit injector. 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 [6].

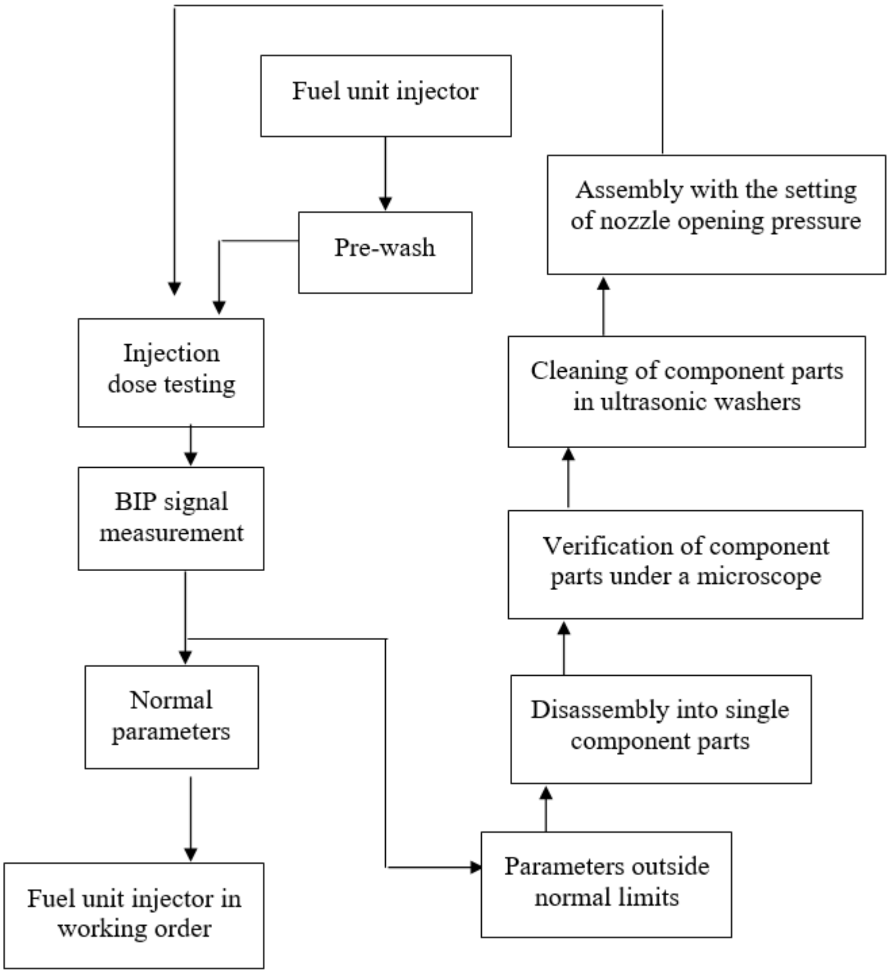

Fig. 8. Fuel unit injector testing and repair procedure

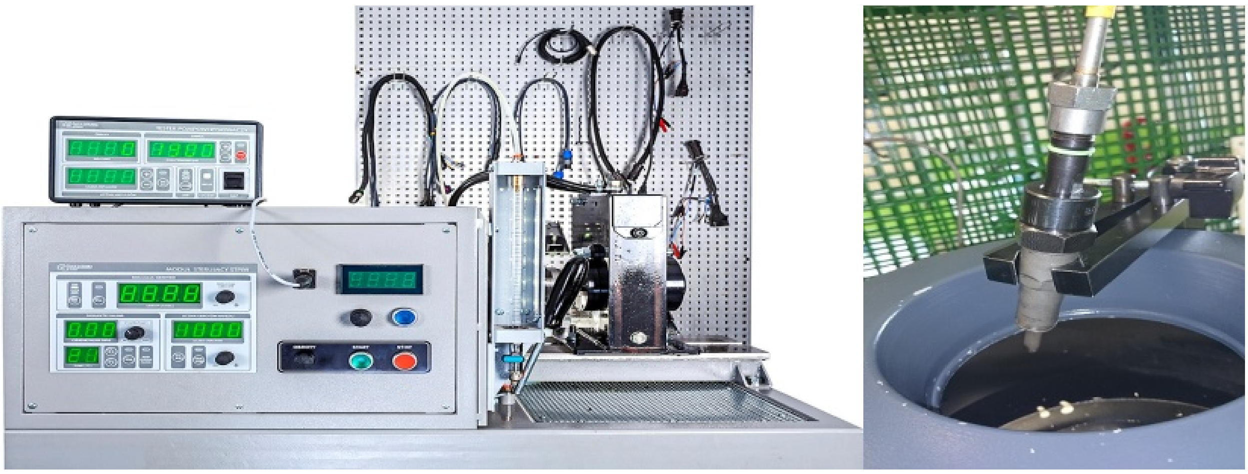

Fig. 9. Test bench for testing fuel unit injectors STPiW-4 with a Cambox attachment (left side), setting of the opening pressure in a special adapter on an EPS 100 tester (right side)

Figure 10 presents the Bosch manufactured solenoid-controlled fuel unit injector being tested, with a catalogue number 0414720313 [7].

Fig. 10. Fuel unit injector being tested, with a catalogue number 0414720313

5. Presentation of test results

The laboratory test involved testing the volume of fuel injection doses before disassembly, determining whether a fuel unit 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 unit injector being tested were too small. Measurements of the volumes of fuel injection doses were made at various rotational speeds of fuel unit injectors and at the fuel injection time of 1900 μs. The first measurement was made at a speed of 1500 rpm, the second at 1000 rpm, the third at 800 rpm, the fourth at 500 rpm and the fifth, the last one, at 400 rpm. A very important measurement is the test at a speed of 400 rpm because it reflects the engine idling. It is important that all volumes of fuel injection doses in fuel unit injectors at the same rotational speed vary by a maximum of 0.5 mm^3/H. If a fuel unit injector is dosing properly at maximum or average rotational speeds, while at low speeds the doses are too small, it means that the elements of the plunger and barrel assembly may be slightly seized or the fuel unit 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.

Figure 11 presents the volumes of fuel injection doses for a fuel unit injector before and after repair.

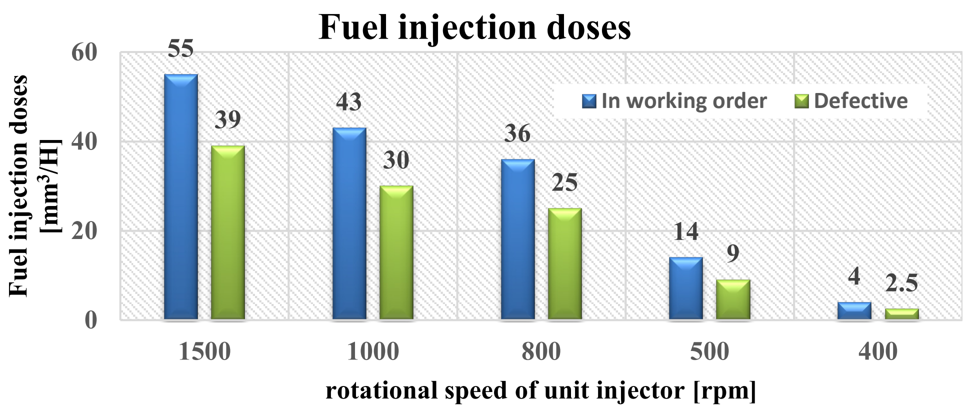

Fig. 11. Fuel injection dose volumes for the tested fuel unit injector before disassembly and regeneration (defective) and after repair (in working order)

6. Conclusion

The laboratory tests showed that it is possible to disassemble and clean fuel unit injectors, and possibly replace the faulty elements of their pumping section and solenoid. The main cause of the troubles of fuel unit injectors is impurities inside them, especially those on the elements of the plunger and barrel assemblies, wear of rubber gaskets, and impurities in the ducts that supply fuel. During the initial test, the volumes of fuel injection doses were too small. This was affected by many factors. After disassembly, numerous impurities inside the fuel unit injector were visible, the plunger controlling the solenoid section was corroded, the fuel unit injector packing was considerably worn and the nozzle opening pressure was too low. The fuel unit injector was thoroughly washed in an ultrasonic washer, and then dried. The nozzle opening pressure was adjusted from 16 MPa to 28 MPa. After assembly, the volumes of fuel injection doses were tested. The testing showed that the fuel unit injector regained its proper operating parameters.

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