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Research Article

DAMAGES TO INJECTORS IN DIESEL ENGINES

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ABSTRACT
The article describes damages to high pressure injectors used in common rail injection systems. The conducted analysis of their causes includes the diagnosis of injectors on a test bench and the results of microscopic research of damaged components. The tribological damages of high pressure injectors are local and cavitations pitting. The place of cavitations pitting are mainly check valves, where the reduction in the quantity of injected fuel is forming.

Key words: tribological damages, fuel injectors, common rail, compression ignition engine.

INTRODUCTION

The development of the modern diesel engines is now determined by the limits of toxic exhaust emissions. One of the limited toxic components is the particulate matter (PM). Reduced emission of particulates is promoted by very good fuel atomization and high temperature of combustion process. Obtaining the proper atomization of the fuel is only possible using small gaps (holes) in the ends of the injectors in conjunction with high-pressure injection. Currently used common rail injection systems are characterized by high injection pressures of up to 2200 bar. The amount of fuel per one cycle is usually divided into 3 to 5 or even 7 parts. Fragmentation of injected fuel dose allows for controlling the combustion process. Therefore, the components of such injectors perform more moves (opening – closing) than in classic injection systems with no fragmentation of injected fuel. This type of work is conducive to reduce wear and durability of the injectors. Currently durability of injectors is estimated at more than 60 million engine cycles [4, 5].

The injector is therefore a critical part of modern injection system, determining the correctness of its work. There are two types of injectors: solenoid injectors (Figure 1), which allow to divide the injected dose of fuel into 5 parts and piezoelectric injectors (Figure 2), in which the dose can be divided into up to 7 parts. Injectors controlled with solenoid valves have check valves and spring arrangement, which is the cause of some inertia in their work. Piezoelectric injectors can be made in versions without any springs and check valves. Reduction in the number and weight of moving parts (up to 75%) reduces the inertia of the injectors and allows for the increase in the accuracy and speed of fuel delivery [5].

RESEARCH OBJECT

For the research, electromagnetic and piezoelectric Bosch injectors were used. The injectors were installed in Mercedes-Benz Sprinter LCV. The construction of the surveyed injectors is shown in Figures 1 and 2.

The injectors have been removed from damaged engines, and then diagnosed. Table 1 summarizes the observed signs of damage and vehicle mileages for the given type of type injectors.

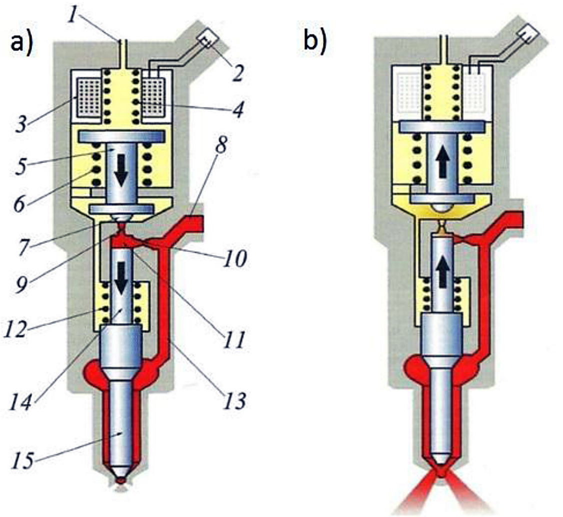


Fig. 1. Cross section of an electromagnetic Bosch injector used in common rail systems of I and II generation; a) injector closed, b) fuel injection into combustion chamber: 1 – drain channel of excess fuel, 2 – electrical connector, 3 – coil, 4 – upper plunger spring, 5 – piston, 6 – lower plunger spring, 7 – ball valve, 8 – high pressure fuel supply channel, 9 – drain gland, 10 – inlet gland, 11 – valve control chamber, 12 – spray nozzle spring, 13 – nozzle fuel supply channel, 14 – valve control plunger, 15 – nozzle needle [3]

Table 1. Investigated injectors and their failure symptoms

No.	Injector type	Mileage till damage	Failure symptom
1.	Electromagnetic	423 000 km	Inability to start the engine
2.	Piezoelectric	168 000 km	Engine hard to start
3.	Piezoelectric	224 000 km	Uneven engine work at idle

DIAGNOSTIC MEASUREMENTS

Diagnostic measurements of electromagnetic injectors was done on Bosch EP 200 tester. Diagnostic measurements included measurement of fuel doses. The obtained values should fall within the proper range for a given type of injector. In addition, the injectors were checked for leaks. The entire diagnostic process takes place automatically. Piezoelectric injectors were tested using Bosch EPS 945 tester. The diagnostic unit checks injector tightness, and then collects and uploads the dosing characteristics into the memory of injector (this is a new IMA code). It should be emphasized that piezo injectors are generally unrecoverable (there are no possibilities to exchange components). Only their regeneration is possible consisting of the above-mentioned recording of new dosage characteristics in the memory of the injector. Any leaks eliminate the possibility of further operation of the injector [1, 2, 5]. In cases where the injector diagnostic test indicated that no further use is possible, the injector was disassembled, and the components of precision pairs were subjected to microscopic observation.

MICROSCOPIC OBSERVATION

Microscopic examination was carried out with optical microscope Zeiss Neophot 2. The microscopic observations were done on the external surfaces of the pistons, needles, tips and check valves of the damaged injectors. Figure 3 shows a typical electromagnetic injector pistons damage.

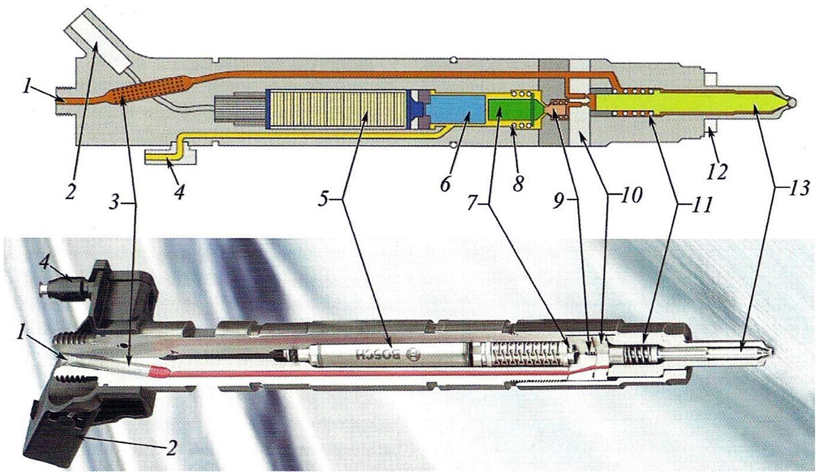


Fig. 2. Cross section of a piezoelectric Bosch injector used in common rail systems: 1 – fuel supply port, 2 – electrical connector, 3 – fuel filter, 4 – fuel return port, 5 – piezoelectric stack, 6 – intermediate piston, 7 – valve plunger, 8 – valve plunger spring, 9 – switching valve, 10 – throttling plate, 11 – nozzle needle, 12 – copper gasket in the housing of the injector head, 13 – needle [3]

That are usually small grooves and indents on the surface caused by the presence of mechanical impurities. As can be seen, that are local damages not covering the entire surface of the element. Damage to the piezoelectric injector needles also have a similar local character (see Figure 4). In the presented case these are minor scratches and pitting cavitation.

Another type of damage is characteristic for check and switching valves. In Figure 5 one can see distinctly the process of cavitation which started on the edge of valve opening in a piezoelectric injector. The consequence of this phenomenon is deterioration in the injector leak tightness, what with fuel at high pressure causes excessive flow through the overflow port of the

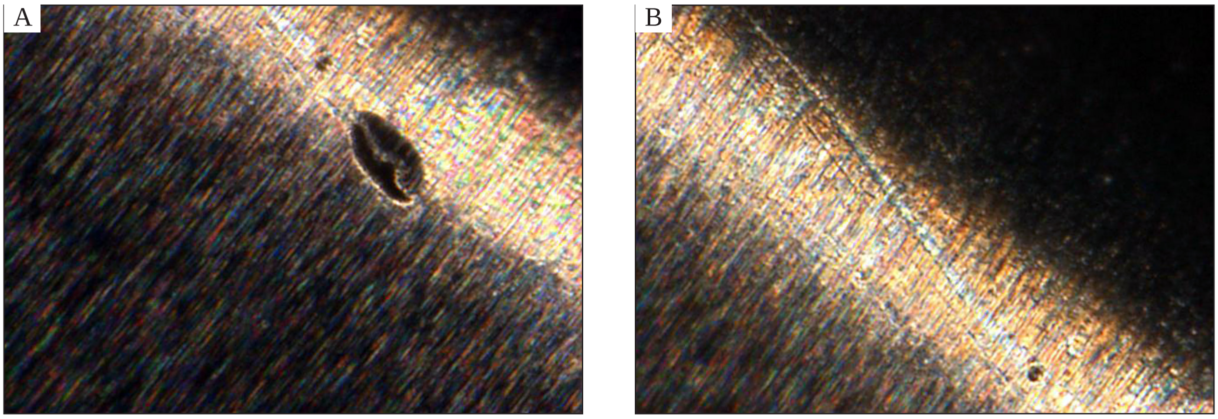


Fig. 3. Damages of the piezoelectric injector plunger: a) indentation, b) groove with a visible imprint of the contamination

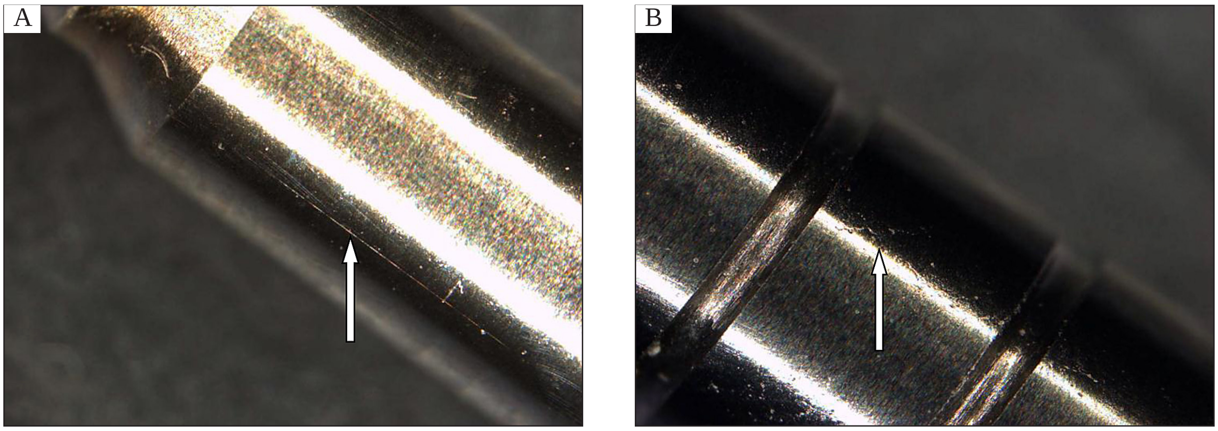


Fig. 4. Damages of the piezoelectric injector needle: a) longitudinal scratch, b) cavitation pitting

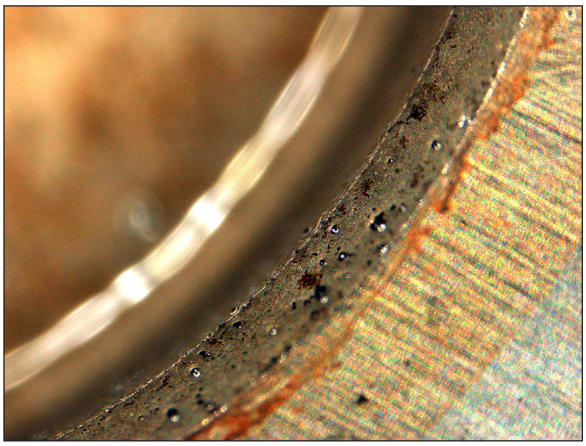


Fig. 5. Cavitation erosion on the edge of the pinhole overflow valve in a piezoelectric injector

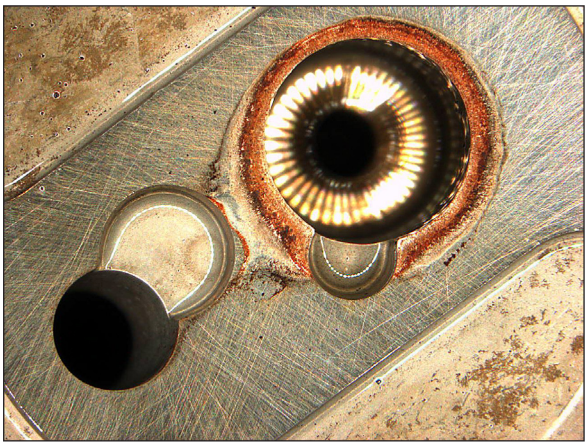


Fig. 6. Developed cavitation on the edges of the pinhole overflow valve in a solenoid injector

injector. Such types of damage result in difficult starting of the engine and uneven idling. Figure 6 shows cavitation damage of the pinhole overflow valve in a solenoid injector. Also in the case of this type of damage the injector is not able to give a sufficiently large amount of fuel, resulting in difficult start-up and a non-uniform work of the engine. Reduction of the dose of injected fuel results in lean fuel-air mixture. Increasing the amount of oxygen relative to the amount of fuel is accompanied by the increase in the speed and temperature of combustion. This is confirmed by the observations – some of the damaged injectors had clear signs of overheating. Figure 7 shows overheated tip of a piezoelectric injector. Figure 8 shows clearly visible thermal discoloration on the needle of the above injector.

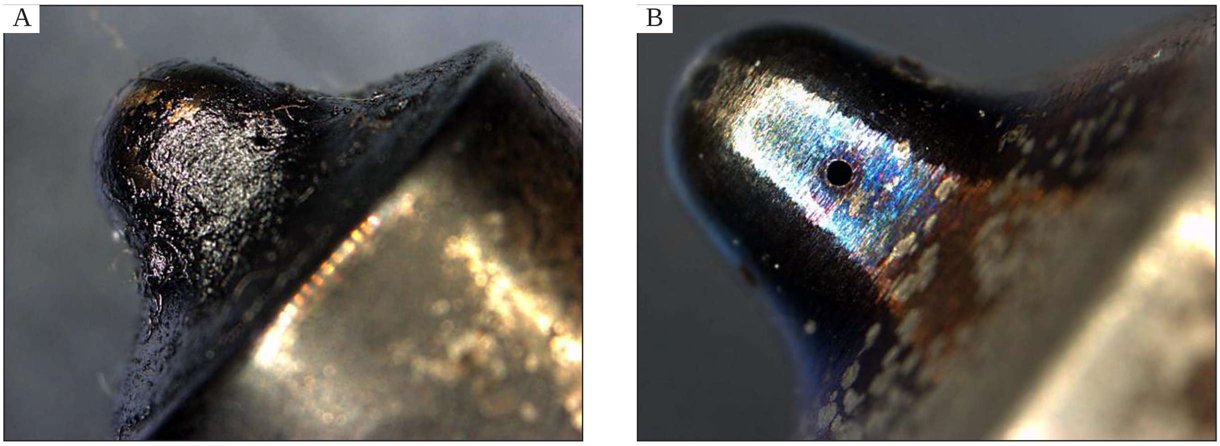
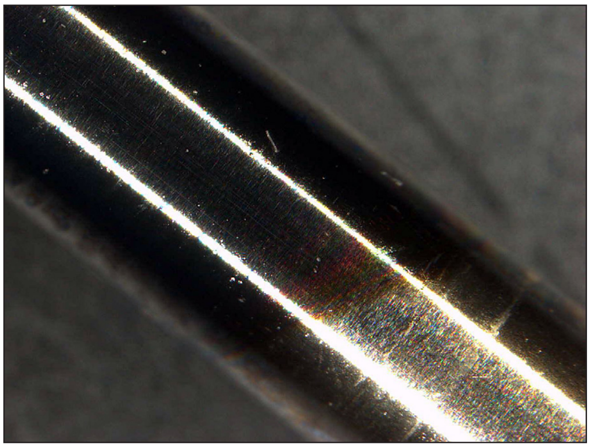


Fig. 7. Tip of the damaged piezoelectric injector: a) appearance after removing b) appearance after clearing – visible discoloration caused by the impact of high temperatures



Rys. 8. Thermal discoloration of the needle of the piezoelectric injector

CONCLUSIONS

- Typical damage symptoms of the injectors in common-rail injection systems are uneven idling and the difficulty in starting the engine.
- Damage to the injectors may be either: tribological wear, pitting, cavitation and thermal damage.
- The tribological damages to the common-rail injectors are local and can be caused even by a small amount of impurities.
- The place of cavitation pitting in the injectors are mainly check valves.
- Damage of the return valve causes a reduction in the quantity of fuel actually injected, resulting in a leaner air-fuel mixture. The combustion of lean mixtures causes overheating of injector tips.

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