Effect of unloader valve spring tension on hydraulic performance of CRI1 electromagnetic injector

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Abstract. The report reflects the results of an experimental study of the influence of the tension of the unloading valve spring on the hydraulic characteristics of electromagnetic nozzles. The research was done on a CMX6000X universal diesel fuel system test bench. An electromagnetic nozzle of the first-generation Common Rail - BOSCH CRI1 was chosen as the object of the study. It was found that with an increase in the tension of the spring of the unloading valve in all test modes, a decrease in the amount of fuel per cycle was observed. The rate of change of the amount of fuel per cycle for the individual test modes is different in the individual parts of the size range of the adjusting shim. The optimal thickness of the adjusting shim for the spring tension of the unloading valve for the tested nozzle is from 1.60 mm to 1.70 mm.

1 Introduction

Electromagnetic injectors in common rail diesel fuel injection systems are one of the elements whose technical condition has the greatest impact on diesel engine performance. Deteriorated technical characteristics of the injectors lead to reduced power and increased fuel consumption and toxic components in the exhaust gases. Therefore, it is necessary to periodically check the technical indicators of the injectors. This is done on specialized stands for testing diesel fuel equipment. The amount of fuel per cycle is measured at different set operating parameters. The quality of fuel atomization and fuel dripping from the nozzle is checked [1, 2].

Overall, the deterioration of technical characteristics in electromagnetic injectors used in Common Rail systems like the BOSCH CRI1 can have significant implications for vehicle performance, emissions, reliability, and maintenance costs. Inefficient fuel injection due to nozzle deterioration can lead to higher emissions of pollutants such as nitrogen oxides (NOx), carbon monoxide (CO), and particulate matter (PM). This contributes to environmental pollution and may lead to non-compliance with emissions regulations. Deteriorated electromagnetic injectors may cause intermittent or inconsistent fuel delivery, leading to unreliable engine operation. This can manifest as stalling, hesitation, or difficulty

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starting the engine. Regular inspection, maintenance, and replacement of worn nozzles are essential to ensure optimal engine operation and longevity. Engine performance issues caused by deteriorated injectors may be challenging to diagnose, as they can mimic symptoms of other problems. This can lead to prolonged troubleshooting and repair times. During the repair, many regulatory parameters are observed, depending on the design features of the injectors [3, 4].

2 Materials and methods

In this paper, the influence of unloader valve spring tension on the hydraulic performance of a first-generation common rail solenoid nozzle - CRI 1 is investigated. BOSCH nozzle 0445110021, which is installed in diesel engines of vehicles: Opel - Movano, Vivaro and Renault- Espace, Laguna, Master, Megane, Scenic, Trafic 1.9 DCI, was chosen as the object of the study. The experiments were conducted on a CMX6000X universal diesel fuel system test bench. The stand has a rich database of characteristics in factory test modes for different brands of CR pumps and injectors [5].

Figure 1 shows the general view of the CMX6000X universal diesel fuel system test bench [6, 7].

Fig. 1. Universal diesel fuel system test bench CMX6000X.

The BOSCH 0445110021 electromagnetic nozzle device is shown in Figure 2. In red are marked the elements that are used to achieve the regulation parameters, ensuring the set hydraulic characteristics of the amount of fuel per cycle. These control parameters are: relief valve stroke, relief valve spring tension, air gap between solenoid and valve armature, initial injection pressure, etc.

The principle of changing the spring tension of the unloading valve is shown in Figure. 3

By changing the thickness of the adjusting washer, the spring tension of the unloader valve is changed. When an electrical impulse is applied to the electromagnet, the unloading valve is moved, with which the pressure in the control chamber drops sharply and the injection process begins. The amount of fuel injected depends on the time the unloading valve is open. This time is determined by the duration of the electromagnetic pulse and the spring tension of the relief valve.

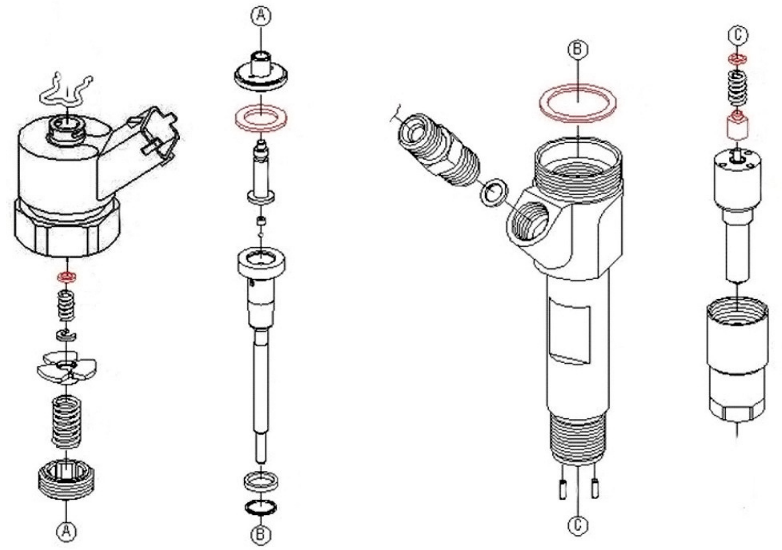

Fig. 2. The BOSCH 0445110021 electromagnetic nozzle device.

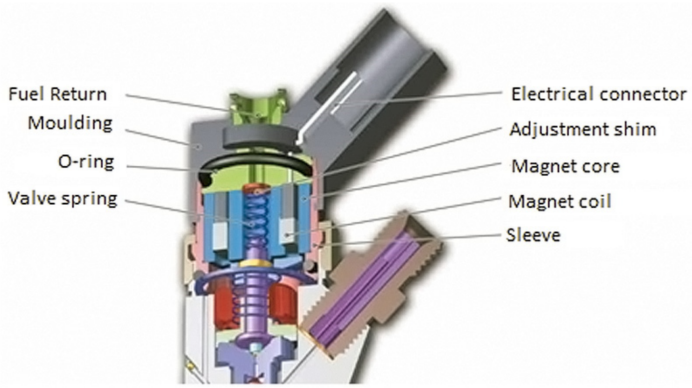

Fig. 3. Principle of changing the spring tension of the relief valve.

The tests were carried out with a change in the size of the adjusting washer from 1.20 mm to 1.80 mm. All control parameters have been previously checked and corrected within the permissible limit values according to the manufacturer's catalogue data.

3 Results and discussion

The amount of fuel per cycle Qc [mm^3/Hub] is measured at maximum load, average load, idling, pilot portions and excess (return) fuel at set parameters of the fuelling process: injection pressure P [MPa] and duration of the electrical pulse to the electromagnet t [μs].

The tests were carried out at fuel temperature T=400C and the following mode parameters:

Mode 1 - amount of fuel per cycle at maximum load - =135MPa and t=1300 µs;

Mode 2 - reverse (excess) amount of fuel at maximum load - =135MPa and t=1300 µs;

Mode 3 - amount of fuel per cycle at medium load - =80MPa and t=500 µs;

Mode 4 - amount of fuel per cycle at idle speed - =25MPa and t=600 µs;

Mode 5 - amount of fuel per cycle during pre-injection (pilot portion) at medium load - =80MPa and t=160 µs;

The obtained results are presented in Table 1.

Table 1. Experimental results for Bosch nozzle 0445110021.

Thickness of shim h [mm]	1.2	1.3	1.4	1.5	1.6	1.7	1.8
Mode 1 Qc [mm^3/Hub]	78	74	71.2	70	69.2	68.3	37.5
Mode 2 Return fuel Qc [mm^3/Hub]	155	84	40	32.2	31.1	30.4	30.1
Mode 3 Qc [mm^3/Hub]	24	21.3	18.8	18.8	17.5	16.9	16.3
Mode 4 Qc [mm^3/Hub]	6.2	5	4.8	4.6	4	3.6	3.2
Mode 5 Qc [mm^3/Hub]	9.6	8.2	6.3	4.6	3.2	1.9	1.6

Figure 4 graphically shows the change in the cycle amount of fuel and the excess (return) fuel in the maximum load mode. The amount of fuel per cycle is shown by the blue line red reverse (excess) amount of fuel with red line.

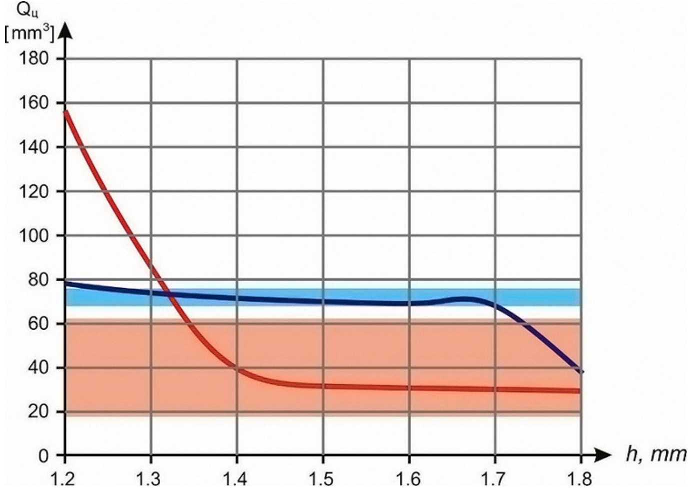

Fig. 4. Cycle amount of fuel and excess fuel at maximum load.

For the tested nozzle, the cyclic portion of fuel significantly decreases when the thickness of the regulating washer increases above 1.7 mm. The excess (return) amount of fuel increases dramatically when the thickness of the washer is less than 1.4 mm, and when it is 1.35 mm it exceeds the permissible norms. Figure 5 shows the amount of fuel per cycle in medium load mode.

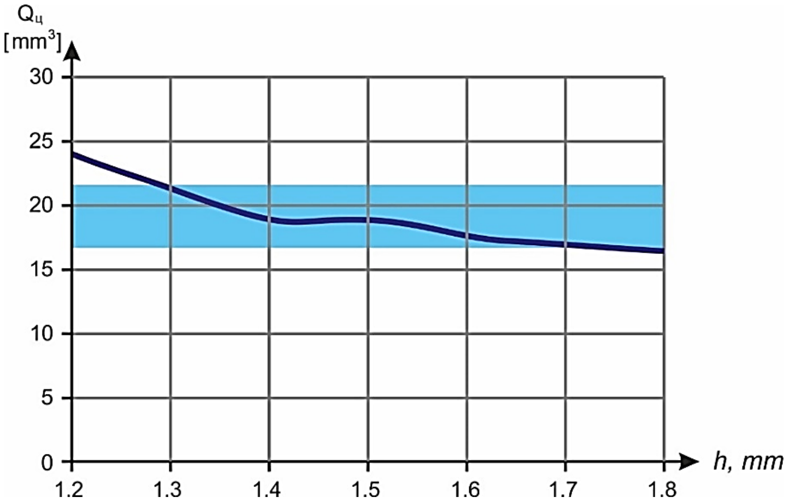

Fig. 5. Cycle amount of fuel in medium load mode.

At medium loads, with a decrease in the thickness of the adjusting shim, the cycle amount of fuel gradually increases. Figure 6 shows the amount of fuel per cycle in idle mode.

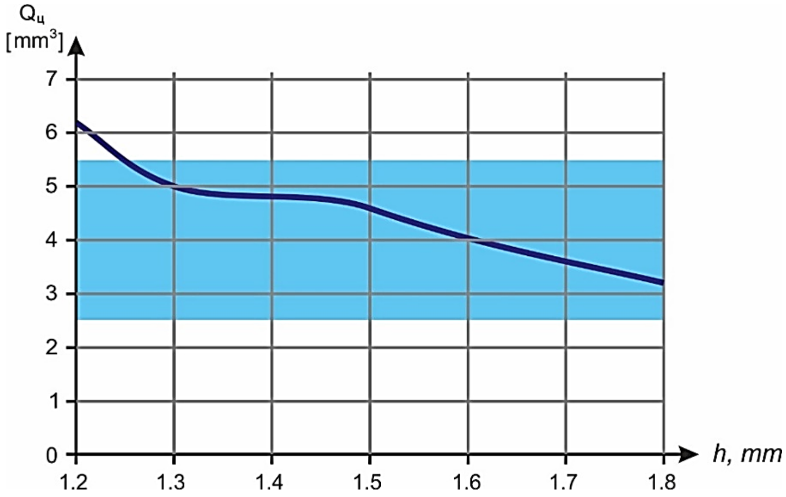

Fig. 6. Amount of fuel per cycle in idle mode.

In the studied size range, the cycle amount of fuel in the idle mode increases by 100% when the size of the adjusting shim is reduced. Figure 7 shows the pilot portion of fuel in medium load mode.

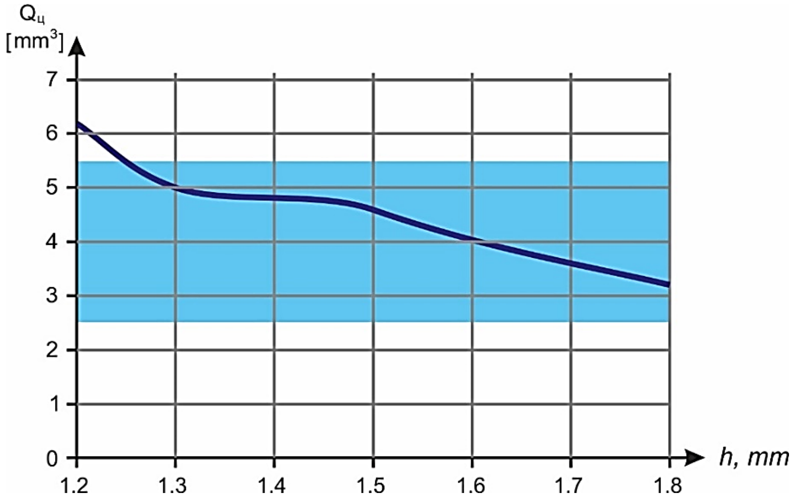

Fig. 7. Pilot portion of fuel in medium load mode.

In this test mode, the cyclic pilot fuel quantity increases fivefold as the size of the relief valve spring adjusting shim decreases.

4 Conclusion

The following conclusions can be drawn from the results of the experimental studies: The spring tension of the unloading valve is an important control parameter that has a significant impact on the hydraulic performance of CRI1 electromagnetic injectors. As the unloader valve spring tension increases on all test modes, we have a decrease in the cycle amount of fuel. In the studied size range, the cycle amount of fuel in maximum load and idling modes increases twice, and the excess (return) amount of fuel at maximum load and pilot portions at medium loads increases five times when reducing the size of the adjusting shim. The rate of change of the amount of fuel per cycle for the individual test modes is different in the individual parts of the size range of the adjusting shim. The optimal thickness of the adjusting shim for the spring tension of the unloading valve for the tested nozzle is from 1.60 mm to 1.70 mm.

References

1. Robert Bosch GmbH, Diesel-Engine management, 3rd ed., Professional Engineering Publishing Limited, pp. 308–311, (2004)
2. F. Palmieri, The Influence of Actual Layout and Off-Axis Needle Stroke on Diesel Nozzle Flow Under Ballistic Needle Displacement. J. Eng. Gas Turbines Power. **135**, 10, 101502, (2013), https://doi.org/10.1115/1.4024986
3. N. Yordanov, K. Hadjiev, E. Stankov, Experimental simulation of common rail electromagnetic injectors wearing, International scientific journal Machines technologies materials, **12**, 5, pp. 208-211, (2018)
4. J. Hammer, Einspritztechnik, Universitat Stuttgart, (2011)
5. T. Uzuntonev, S. Belchev, Changes in fuel supply parameters of Common Rail nozzle after major service intervals, IOP Conf. Ser.: Mater. Sci. Eng. **977**, 012027, (2020), doi:10.1088/1757-899X/977/1/012027

6. P. Ramon V. Maldonado, S. Devyanin, V. Markov, V. Neverov, A. Safin, A. Yakushev, Study of fuel injection and atomization processes of a diesel engine running on petroleum fuel and biofuel, E3S Web Conf., **471**, 05003, (2024), https://doi.org/10.1051/e3sconf/202447105003
7. S. Wang, H. Wei, X. Wang, X. Jing and C. Wu, Research on carbon deposition method and characterization of nozzle in direct injection gasoline engine, E3S Web Conf., **522**, 01004, (2024), https://doi.org/10.1051/e3sconf/202452201004