EXPERIMENTAL SIMULATION OF COMMON RAIL ELECTROMAGNETIC INJECTORS WEARING

ЕКСПЕРИМЕНТАЛНО СИМУЛИРАНЕ НА ИЗНОСВАНЕ ПРИ ЕЛЕКТРОХИДРАВЛИЧНИ ДЮЗИ ОТ СИСТЕМАТА COMMON RAIL

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Abstract:
At the time of exploitation, the geometrical position of the control valve changes as a result of wearing, which leads to a change of residual electromagnetic gap stroke and force of control valve spring. The following study measures the hydraulic characteristic changes, based only on common rail injector increased stroke of control valve and residual electromagnetic gap. The results show that the increasing of control valve stroke and residual electromagnetic gap increase the fuel flow rate and return fuel flow. Increased fuel flow rate and return fuel flow are presented with short injector signal time and lower levels of working pressure. The increasing is lower with longer injector signal time and high level of working pressure. The follow-up results are practically significant by common rail electromagnetic injector diagnosing and repairing.

KEY WORDS: SIMULATION, VALVE SEAT, WEARING, RESIDUAL ELECTROMAGNETIC GAP, HYDRAULIC CHARACTERISTICS

1. *Introduction*

Volumetric capacity of injection with electronic control depends on fuel pressure in the fuel accumulator and the duration of signal, energizing the electromagnetic coil of electromagnetic valve. The use of hydromechanics injector with electromagnetic control allows changing the start of injection and fuel flow rate of injection process.

Electromagnetic injectors used in first generation Bosch system, use fast switching electromagnetic ball control valve, controlling the fuel pressure of injector control piston chamber.

The movement speed of injector nozzle needle depends on the speed of pressure alteration in control piston chamber.

The dropping speed of control piston chamber pressure is a function of closing throttle cross section and control valve stroke.

In the process of continuous exploitation, the control valve stroke increases as a result of the impact load on the valve seat [1].

Passing through the control valve, fuel causes further erosion of the sealing surfaces of the saddle and the ball valve.

In the present study, the change in the hydraulic characteristic of the nozzle is taken into account only as a result of the increased control valve stroke and residual electromagnetic gap [7].

As a result of the change in the rate of these main control valve parameters, the fuel flow rate of both, the injected fuel and the fuel required to control the hydro-mechanical part of the injector is changed.

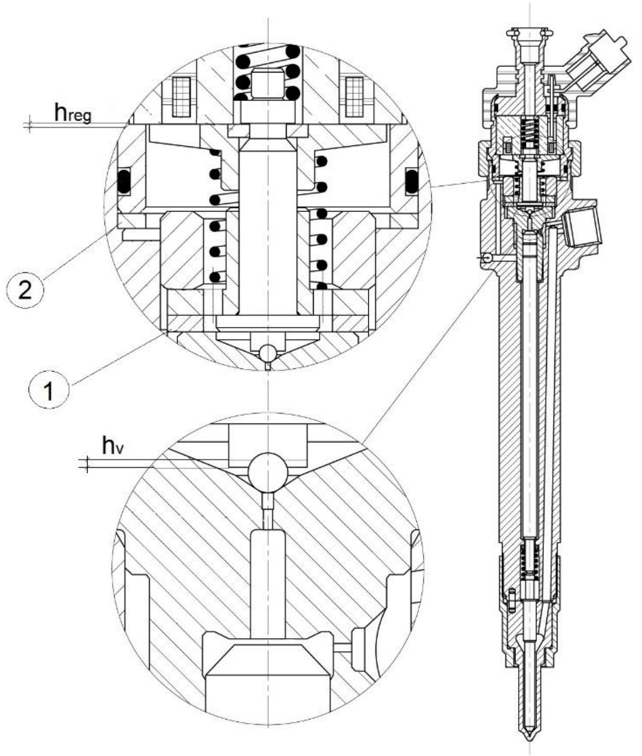


fig. 1 *Solenoid valve Bosch CRI1*

1 - Ball valve washer, 2 - Electromagnetic gap washer, h_{reg} - Electromagnetic gap, h_v - Ball valve stroke.

2. Discussion and results

With control valve stroke increasing, as a result of wearing, control valve goes down in the sealing surfaces of the saddle.

This alteration of control valve geometrical position leads to alteration in residual electromagnetic gap and the pressure force of control valve spring fig. 1.

Fuel flow rate, injected by electrohydraulic injector, depends not only on fuel pressure and signal duration, but also on geometrical position of elements.

By manufacturing of injector elements, the actual geometrical size differs from the specific size to the limit values.

There are differences in the geometrical position between its elements also as a result of assembling technologies including the tightening torque of the threaded connection.

These differences lead to alterations in registered fuel flow rates of injectors with constant fuel pressure and signal duration.

In order to maintain constant values of fuel flow rate of electronically managed electromagnetic hydromechanical injector it is necessary not only high precision of elements manufacturing, but also high accuracy of regulation parameters measuring.

In the experimental simulation of wearing influence of control valve are used calibrated regulating shims, that set control valve stroke h_v and residual electromagnetic gap h_{reg}.

Four experimental series were undertaken, first of which with a specific value according to the technical manual for the certain injector model.

An increase of the stroke h - 0.05 ÷ 0.08 ± 0.003 mm of the ball valve and the corresponding change of the residual electromagnetic gap was simulated due to the change of the geometric position of the elements in the baseline dimension.

The research was conducted in a laboratory at the Department of Engines & Automotive Engineering at the Faculty of Transport of the University of Ruse "Angel Kanchev".

A modified "Star 8" test bench was used, refitted with more powerfull motor and variable-frequency drive of the AC motor.

A high pressure pump, a common rail with pressure sensor and pressure regulator, fuel temperature controllers, injector controller were added. A two-channel oscilloscope for the injector control was used.

The testing of the hydraulic characteristics of the injector was carried out using fuel pressures throughout the system operating range of 30, 50, 80, 100 and 135 MPa and a duration of the control signals 150, 200, 250, 300, 400, 500, 600, 700 and 800 μS.

Graphics with results at typical manufacturing test pressures are presented, in which the injectors are functionally tested.

The temperature mode of the fuel in the test bench tank is maintained by a pipe cooler and the drive shaft rotation speed is maintained constant when performing all the tests.

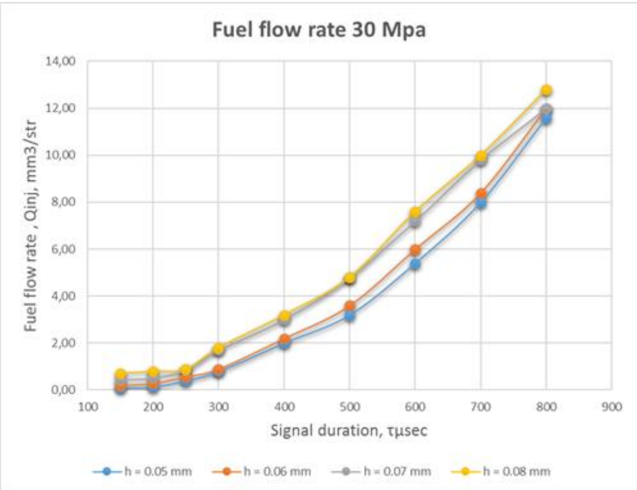


Fig. 2 *Alteration of the fuel flow rate, defined by the stroke of the control ball valve h_v = 0.05 ÷ 0.08 mm at 30 MPa*

The value of the fuel flow rate as a function of the control signal duration fig 2 at the various levels of wearing of the ball valve h_v and the corresponding variation of the residual electromagnetic gap h_{reg}.

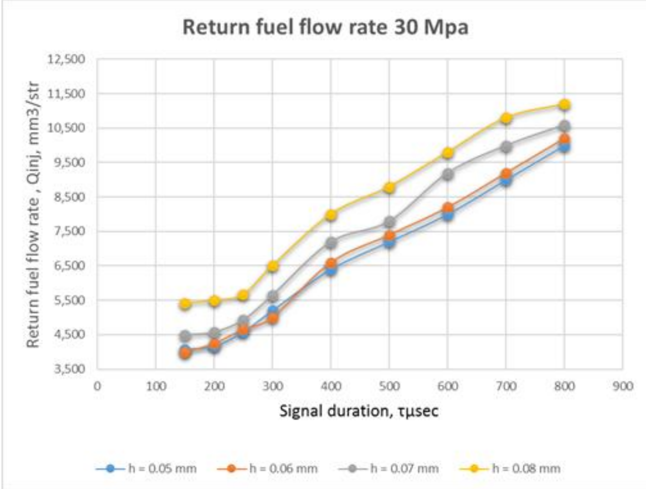


Fig. 3 *Alteration of the return fuel flow rate, defined by the stroke of the control ball valve h_v = 0.05 ÷ 0.08 mm at 30 MPa*

With an increase in wear, a corresponding increase in the fuel flow rate in each mode is observed. It is noteworthy that the greatest increase observed is the percentage of the short injections time that correspond to the preinjections.

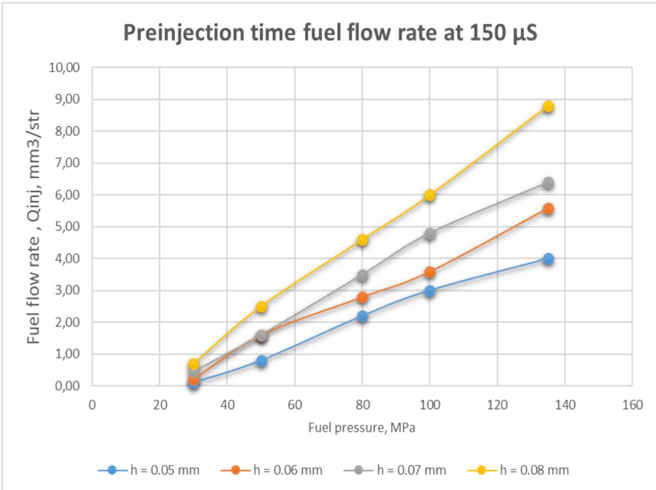


Fig. 4 *Alteration of the fuel flow rate at 150 μS, defined by the stroke of the control ball valve h_v = 0.05 ÷ 0.08 mm*

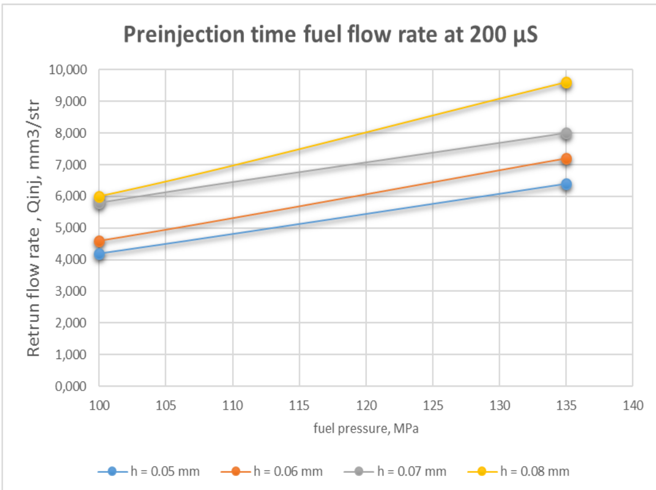


Fig . 5 *Alteration of the fuel flow rate at 200 μS, defined by the stroke of the control ball valve h_v = 0.05 ÷ 0.08 mm*

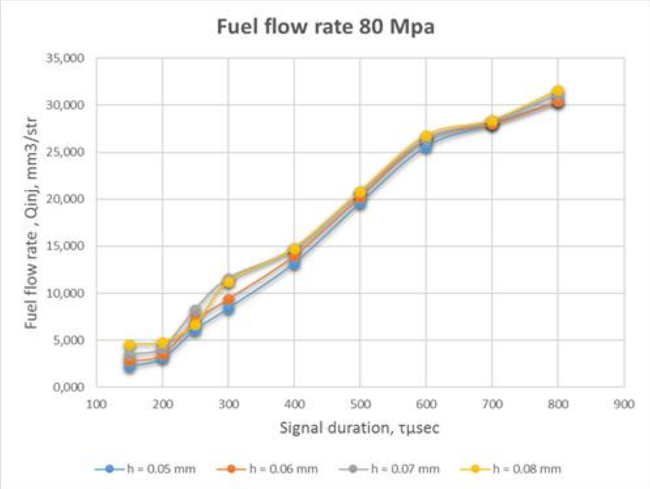


Fig. 6 *Alteration of the fuel flow rate, defined by the stroke of the control ball valve $h_v = 0.05 \div 0.08$ mm at 80 MPa*

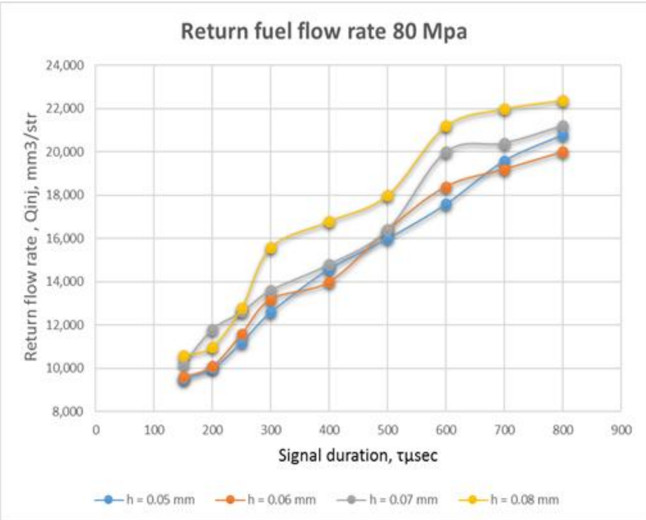


Fig. 7 *Alteration of the return fuel flow rate, defined by the stroke of the control ball valve $h_v = 0.05 \div 0.08$ mm at 80 MPa*

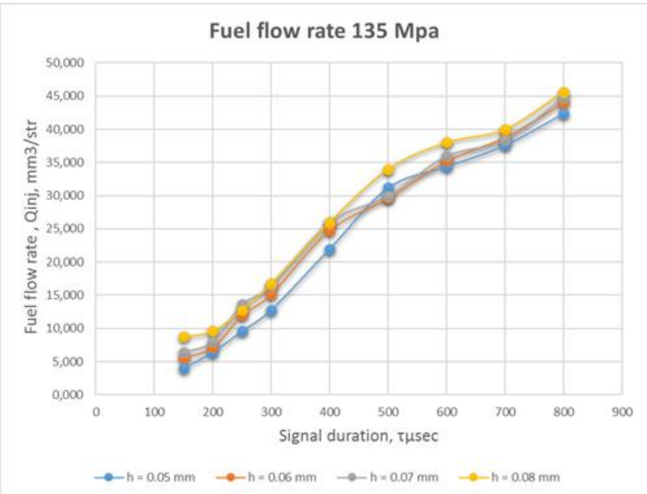


Fig. 8 *Alteration of the fuel flow rate, defined by the stroke of the control ball valve $h_v = 0.05 \div 0.08$ mm at 135 MPa*

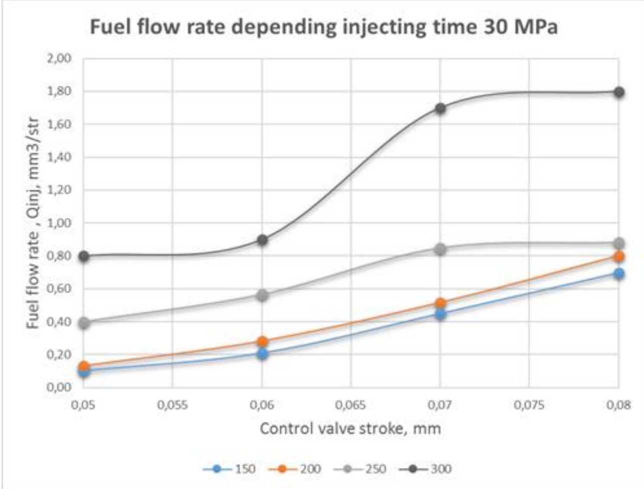


Fig. 9 *Alteration of the fuel flow rate, in range of preinjection time, defined by the signal duration at 30 MPa*

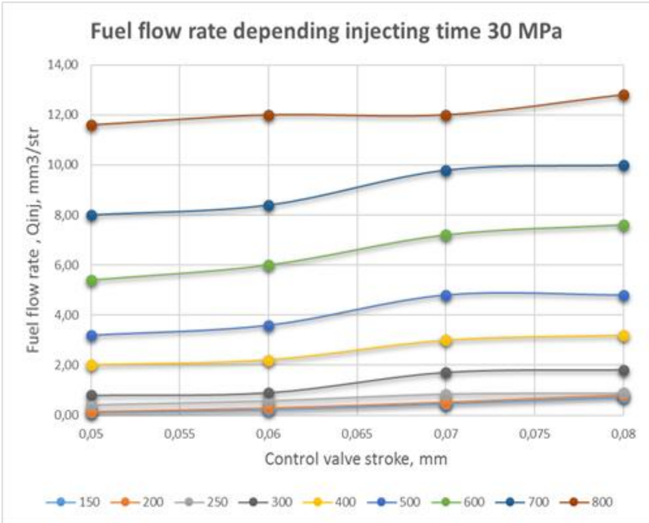


Fig. 10 *Alteration of the fuel flow rate, defined by the signal duration t = 150 ÷ 800 µS at 30 MPa*

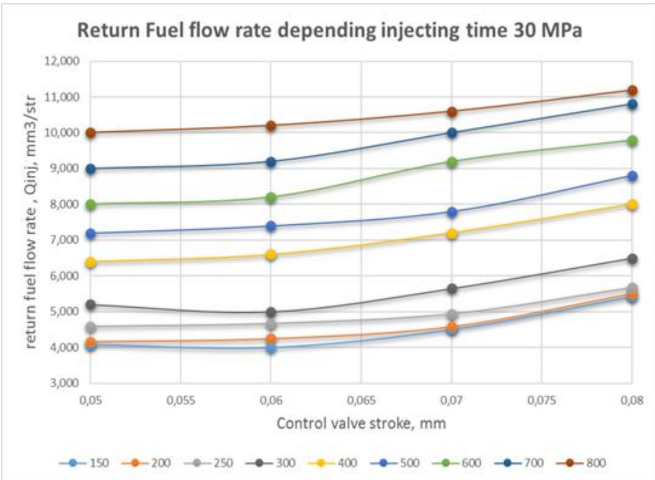
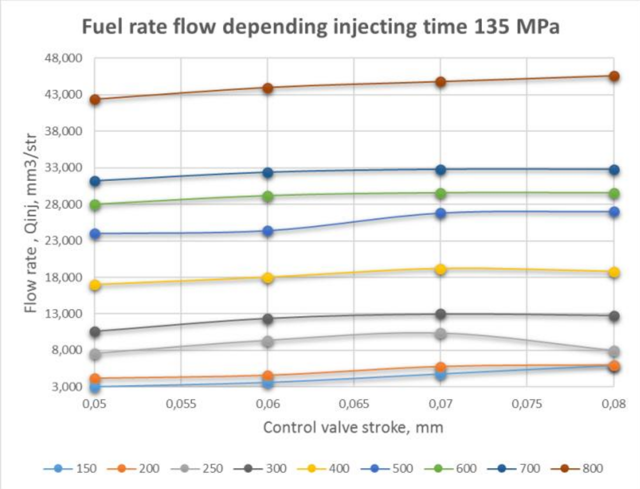


Fig. 11 *Alteration of the return fuel flow rate, defined by the signal duration t = 150 ÷ 800 µS at 30 MPa*



***Фиг. 12** Alteration of the fuel flow rate, defined by the signal duration t = 150 ÷ 800 µS at 135 MPa*

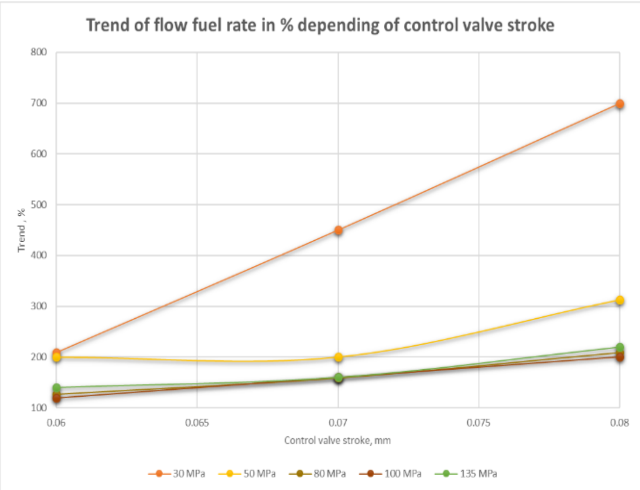


***Fig. 13** Trend of fuel flow rate in percent (%), depending of control valve stroke*

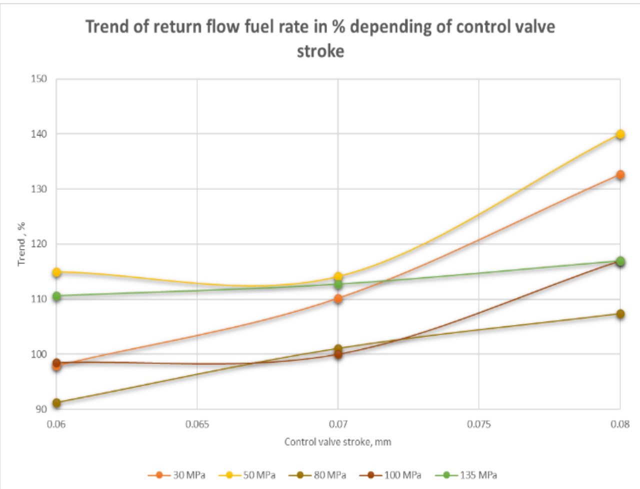


***Fig. 14** Trend of return fuel flow rate in percent (%), depending of control valve stroke*

3. *Conclusions*

Concerning the experiment, the following can be stated:

1. The study shows an increase in the fuel flow rate in all levels of simulated wearing.

2. With short duration of signals, corresponding to the preinjection rate, the percentage increase of the hydraulic characteristic is significant, and at 150 µS the fuel flow rate increase reaches 700%. With an increase in working pressure to 135 MPa this is up to 220%.

3. With the increase of the control signal duration, the trend of increasing in the percentage ratio decreases, having an increase of only 110% with 800 µS. With an increase in the working pressure to the maximum value for this system, 135 MPa, at the same signal duration, the impact of wearing on the fuel rate decreases to 107%.

4. Concerning the fuel flow rate, the increase in function of the signal duration at 150 µS is 133% and at 800 µS is 112%. As a function of the wearing, pressure at 30 MPa, the control portion increased to 117%, while at 135 MPa the increase was 124%.

5. With the return fuel rate as a function of the pressure, the alteration rate due to wear at 30 MPa increases to 117%, while at 135 MPa the increase is 124%.

6. By increasing fuel pressure the trend shows reduction of the impact of wear on the fuel rate, whereas for the return fuel rate this trend is reversed.

4. *References*

[1] Трифон Узунтонев, Сергей Киров, Сергей Белчев, Изменения в хидравличните характеристики на дюзите и якостните
качества на разпръскваচи от горивна уредба Common Rail при продължителна експлоатация, Научни трудове на Русенския университет - 2013, том 52, серия 4

[2] Белчев С., Узунтонев Тр. „Диагностични параметри за оценка състоянието на електромагнитни дюзи от системата Common Rail", Научни трудове на РУ „Ангел Кънчев" 2007, Сборник доклади стр. 204 - 208, ISSN 1311-3321

[3] Трифон Узунтонев, Горивни уредби на дизелови двигатели, Варна 2015

[4] Л.Илиев, В.Костов, Д.Пилев, Горивни уредби и автоматично регулиране на двигатели с вътрешно горене, Държавно издателство „Техника" 1985

[5] Атанас Митков, Теория на експеримента, „Дунав прес" Русе 2011

[6] Атанас Митков, Теория на експеримента, Русе 2010

[7] Сергей Белчев, Трифон Узунтонев „Исследование влияния конструктивных параметров на работу электромагнитной форсунки Common Rail", XII Международная научно-практическая конференция фундаментальные и прикладные проблемы совершенствования поршневых двигателей, Владимир 29-30 юни 2010 год.,

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The report has been reviewed.