A STUDY OF THE INFLUENCE OF CONTROL VALVE STROKE CHANGE ON THE CONSEQUENT WEAR ON FUEL FLOW RATE

Изследване влиянието на промяната на хода на управляващия клапан вследствие износване върху цикловата порция гориво

Dipl. eng. Yordanov N., Assoc. Prof. Kiril Hadjiev, PhD ,Assoc. Prof. Emiliyan Stankov, PhD

University of Ruse, Facilty of Transport, Department of Engines & Vehicles Technical, Ruse, Bulgaria

e-mail: nyordanov@uni-ruse.bg, khadjiev@uni-ruse.bg, emstankov@uni-ruse.bg

Abstract: *In the process of operation, there are changes in the injector with hydro-electromagnetic control of the nozzle needle. These changes are due to a wear on all components of the fuel system. Essential to the wear rate of the nozzle elements, excluding the clearing degree of the fuel and the extent of its cleaning prior to entering the high-pressure system of fuel system, are the operating pressure of the fuel, the number of sprays, the thermal load, the speed and the accelerations of the movable elements. The valve wear on the control valve changes the stroke of the ball valve. This variation results in an increase in the output flow from the control chamber, which increases the speed and the maximum stroke of the control piston and the flow fuel rate respectively. The ball valve stroke increasing respectively increases the distance between the core of the electromagnet and the coil. The increased distance between the coil and the core also has a significant effect on the hydraulic characteristics of the nozzle.*

KEY WORDS: VALVE SEAT, WEARING OUT, ELECTROMAGNETIC GAP, HYDRAULIC CHARACTERISTICS

1. *Introduction*

The fuel injection systems is a key sub-system for direct-injected internal combustion engines as its operation controls to a large extent both the mixture formation and the combustion processes. In particular, in compression ignition engines the fuel metering accuracy, the required injection rate time-profile and the uniform fuel spray spreading in the combustion chamber are strictly governed by the injection system behavior. The achievement of these complex tasks is mandatory in order to fulfill the current automotive market design targets in terms of fuel conversion efficiency, combustion noise control and pollutant emissions level.

The way to achieve all these requirements is to carry out a multiphase injection of the fuel.

The main disadvantage of the nozzles with hydro-mechanical control of the nozzle needle is that it is unable to change the characteristics and timing of the fuel supply, as well as to perform multi-phase fuel supply. This limits the fuel economy reducing opportunities and the toxic substances amount.

This disadvantage is corrected using hydroelectromagnetic control needle of nozzle.

This type of injector is able to accurately manage the fuel supply, but it considerably loads all elements of the injector design.

The way to achieve all these requirements is to carry out a multiphase injection of the fuel.

The main disadvantage of the nozzles with hydro-mechanical control of the nozzle needle is that it is unable to change the characteristics and timing of the fuel supply, as well as to perform multi-phase fuel supply. This limits the fuel economy reducing opportunities and the toxic substances amount.

This disadvantage is corrected using hydro-electromagnetic control needle of nozzle.

This type of injector is able to accurately manage the fuel supply, but it considerably loads all elements of the injector design.

(1) $S = \pi d h$, m^2 , where

(2) $d = 2R\cos\frac{a}{2}$

In which S is the area of the throttle bore, h - the stroke of the ball valve, d - the diameter of the ball valve, a - the angle of the inclination of the valve seat

When increasing the diameter, it is also necessary to increase the compressive force Fk of the ball valve.

This force causes a greater load in the control valve elements. Accordingly, reliability is reduced. [4]

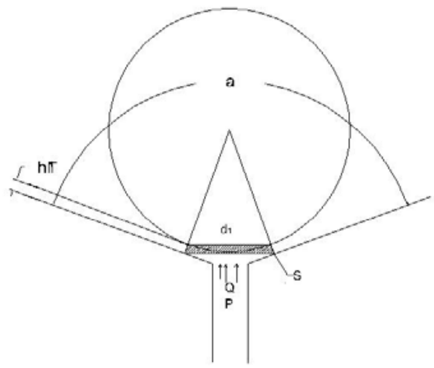

Fig. 1 Changing in speed defined by the diameter of the ball valve

This is the mechanism of the valve seat wearing out, as a major influencing factor are the modes in which there is a larger number and a long duration of the control pulses.

This wearing increases the stroke of the nozzle needle, thus multiplying the cross-section, increasing the actual fuel flow rate of fuel injected into the cylinder.

The change of the control valve stroke is followed by a change in the distance between the core and the electromagnetic coil.

When the valve seat is worn out, the control valve sinks down with it and the electromagnetic core, which increases the magnetic clearance h_k between the core and the coil (Fig.2). This change reduces the speed of core attraction, as well as the magnitude of the fuel flow rate, which, in turn, compensates the impact of the increased stroke of the control ball valve.

The purpose of this study is to determine the influence of the control valve wearing on the injection process.

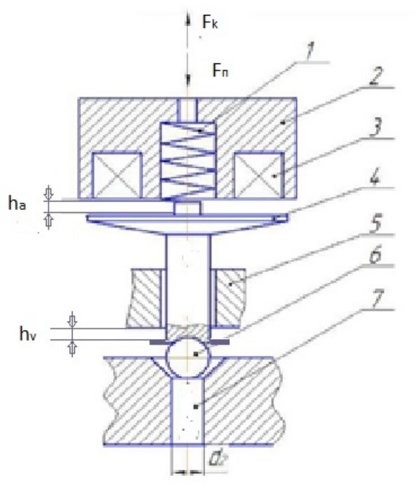

Fig. 2 General appearance of the solenoid:
1 - spring; 2 - core; 3 - coil; 4 - core; 5 - nut; 6 - ball valve; 7 - valve seat, h_a - electromagnetic gap, h_v - ball valve stroke

2. Discussion and results

The study of the effect of the control valve stroke magnitude on the hydraulic characteristics of the electromagnetic injector was carried out by an experimental installation for research purposes of common rail fuel systems in a laboratory in the Department of Engines and Automotive Engineering at the University of Rousse.

The subject of the study is a magnetic injector with ball control valve Bosch series 0445110.

The realization of the study is possible because the structure of the object allows changing the stroke of control ball valve and the magnitude of the electromagnetic gap between the coil and the armature of the solenoid. This enables making all the attempts on the same electromagnetic injector Bosch.

The standard magnitude of the electromagnetic gap must be a 0.08 mm, determining the fuel flow rate formation. By smaller electromagnetic gap values, the fuel flow rate increases. With greater gap, the fuel flow rate decreases, and the actual injection moment is displaced by the angle of rotation of the crankshaft.

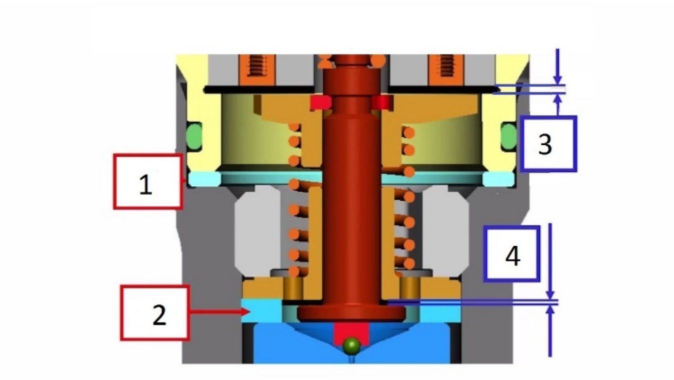

fig. 3 Diagram of the solenoid valve

1 - Electromagnetic gap washer, 2 - Ball valve washer, 3 - Electromagnetic gap, 4 - Ball valve stroke.

Implementation of the injection process occurs as a result of the following pressure difference in the fuel chamber under the nozzle needle and the control chamber. When the electromagnet coil is triggered, the ball valve is lifted. At this moment the pressure in the control chamber drops. After the trigger impulse stops, the ball valve closes quickly, causing wearing on the valve seat. With prolonged use, the ball valve stroke increases as a result of wearing on the valve seat. In this way the ball valve changes its stroke. This further disturbs the density of the ball valve to the valve seat. [2] These changes lead to an increase in the speed and the stroke of the control piston, respectively, of the nozzle needle, which starts wearing more intensely in its sealing surface to the nozzle.

The quantitative relationship between the magnitude of electromagnetic gap and the injection characteristics is examined by altering the thickness of the adjustable washer between the injector body and the electromagnet coil.

The values of the control pulses and the working pressure are experimentally selected according to the capabilities of the test equipment.

In fig. 4 and 5 show the results of the hydraulic characteristics according to the magnitude of the electromagnetic gap in the control valve.

Figures 6 ÷ 13 show the graphs of the results obtained in the modification of the hydraulic characteristics of the electromagnetic injector by modeling the wearing by the change in the control ball valve stroke,

These changes are observed when the stroke increases by 0.025 mm and 0.04 mm in comparison with the usual values of stroke, with a control impulse duration of 0.4 ÷ 0.8 ms and a fuel pressure of 30 ÷ 60 Mpa

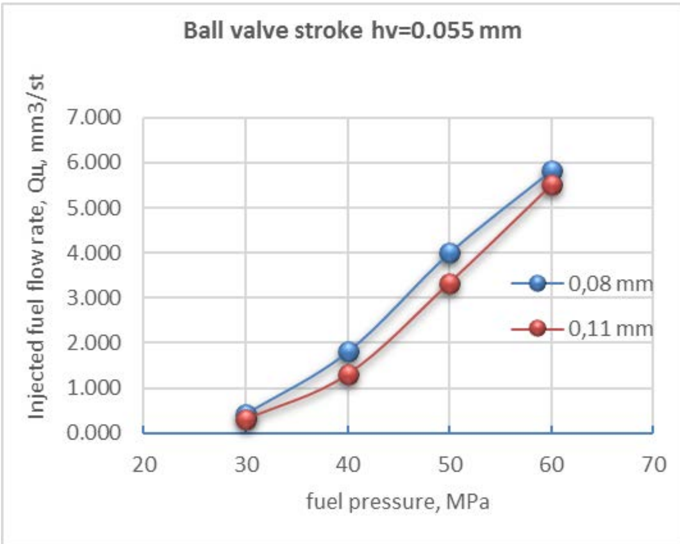

Fig. 4 Alteration of the fuel flow rate defined by magnitude of electromagnetic gap hcoil = 0.08 ÷ 0.11 in control valve at fuel pressure Pa = 30 ÷ 60 MPa.

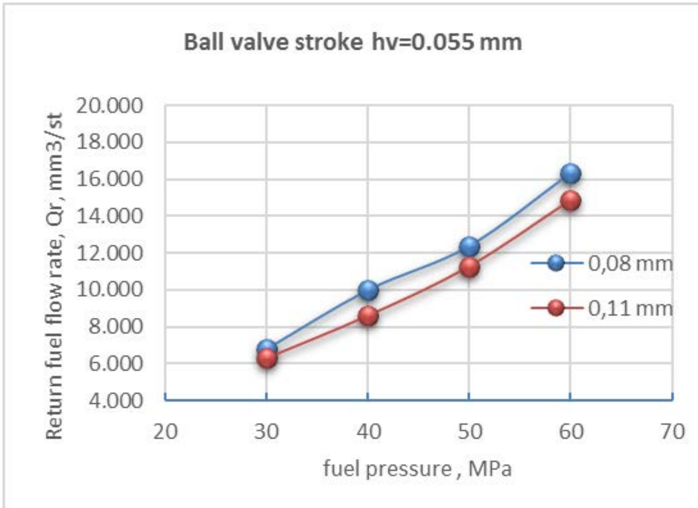

Fig. 5 Alteration of the return fuel flow rate defined by the magnitude of the electromagnetic gap hcoil = 0.08 ÷ 0.11 mm in the control valve and the fuel pressure Pa = 30 ÷ 60 MPa

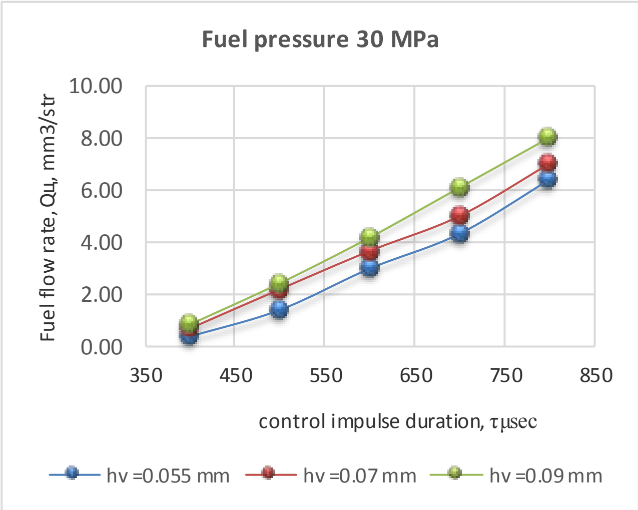

Fig. 6 Alteration of the fuel flow rate defined by the stroke of the control ball valve hv = 0.055 ÷ 0.09 mm

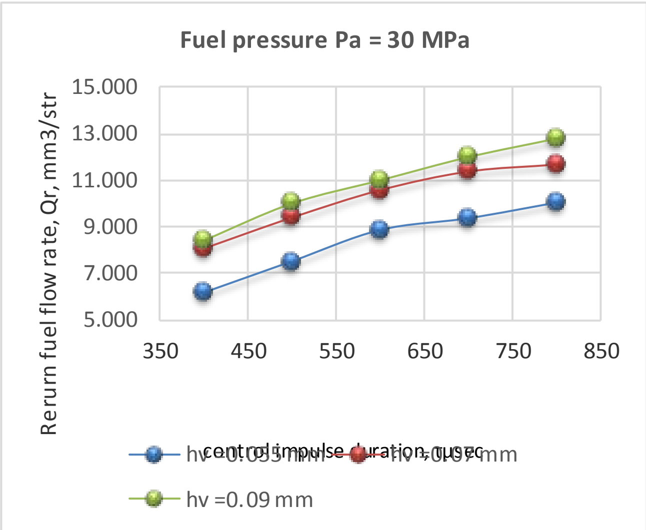

Fig. 7 Alteration of the returned fuel flow rate defined by the stroke of the control ball valve hv = 0.055 ÷ 0.09 mm

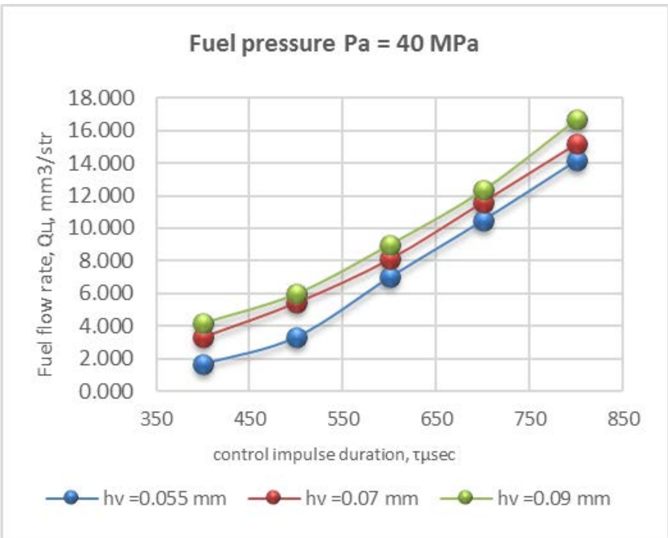

Fig. 8 Alteration of the fuel flow rate defined by the stroke of the control ball valve hv = 0.055 ÷ 0.09

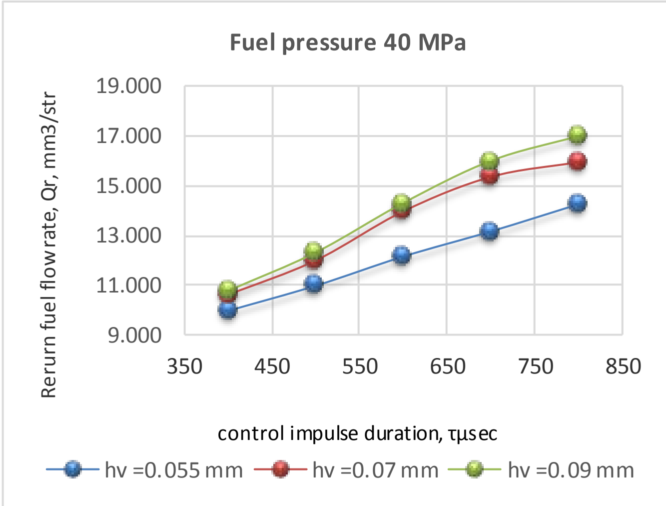

Fig. 9 Alteration of the returned fuel flow rate defined by the stroke of the control ball valve hv = 0.055 ÷ 0.09 mm

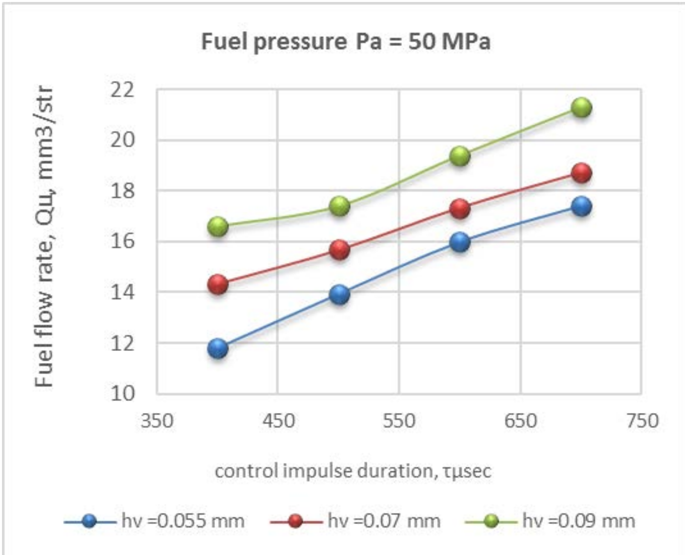

Fig. 10 Alteration of the fuel flow rate defined by the stroke of the control ball valve hv = 0.055 ÷ 0.09 mm

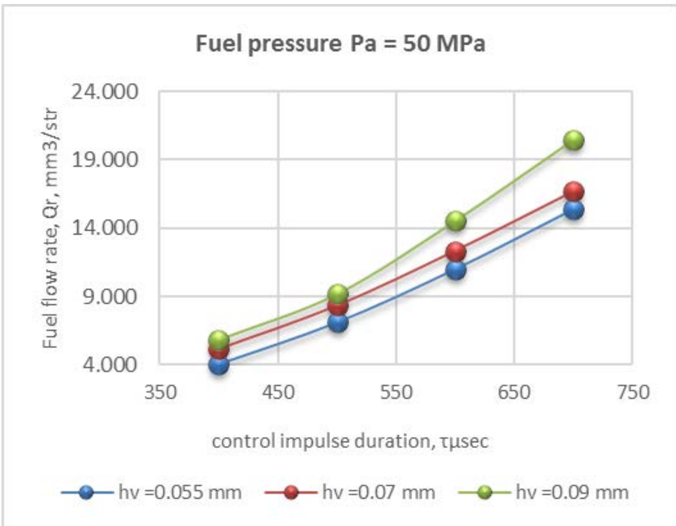

Fig. 11 Alteration of the returned fuel flow rate defined by the stroke of the control ball valve hv = 0.055 ÷ 0.09 mm

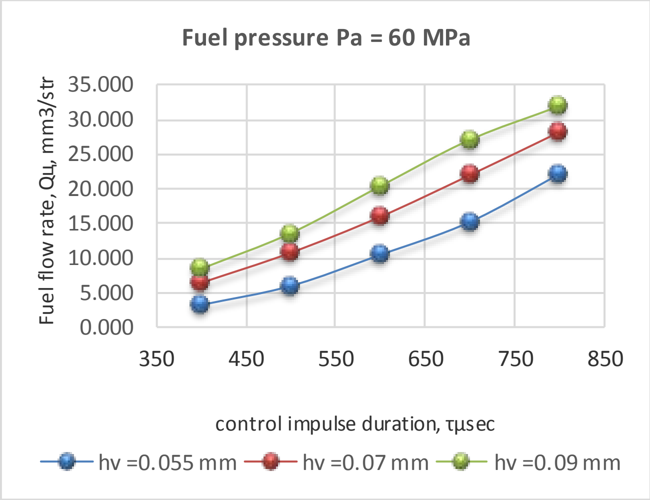

Fig. 12 Alteration of the fuel flow rate defined by the stroke of the control ball valve hv = 0.055 ÷ 0.09 mm

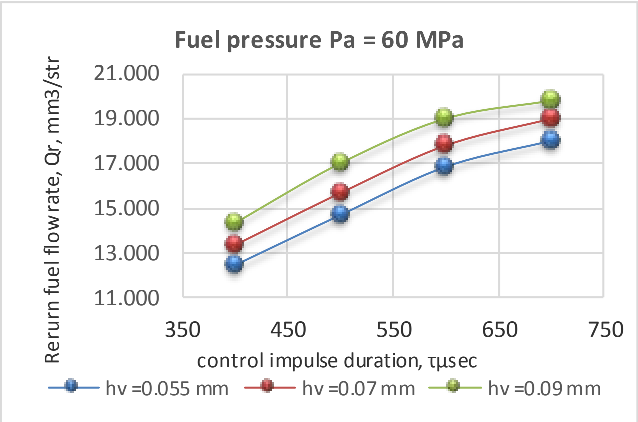

Fig. 13 Alteration of the returned fuel flow rate defined by the stroke of the control ball valve hv = 0.055 ÷ 0.09 mm

3. *Conclusions*

The following conclusions can be made from the experiment.

1. In the modeling of the change of the electromagnetic gap by 37% or the increase of the stroke by 0.025 mm a decrease in the fuel flow rate was found about 19%.

2. In the modeling of the change of control ball valve stroke by 27 % or 0.025 mm, an increase of the fuel flow rate was found about 19%, as the increase of return fuel flow rate was about 18%.

3. In the modeling of the ball valve stroke by 63% or 0.04 mm, an increase of the fuel flow rate was found about 21 %, as the increase of the return fuel flow rate was found about 17 %

4. As a result of wearing in the control ball valve, the fuel flow rate Qc, mm3 as well as the return fuel flow rate, mm3, is increased.

5. The measurement results obtained confirm the effect of the increased electromagnetic gap on the hydraulic characteristics of the injector.

6. Result of the increasing of the control ball valve stroke is the increasing of the electromagnetic gap between the core and the electromagnet coil.

4. *References*

[1] Трифон Узунтонев, Влияние на износването в клапанното легло на електромагнитна дюза от системата Common Rail върху нейните хидравлични характеристики, Науч3и трудове на Русенския Университет - 2015, том 54, серия 4

[2] Ю.П.Макушев, Л.Ю.Волков,Расчет электрогидравлического клапана управления ходом иглы форсунки и его диагностирование, стр. 74-77, УДК 621.436.038

[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] Г.Генов, Ц.Иванов, Д.Пилев, Изпитване на двигатели с вътрешно горене, държавно издателство „Техника“ 1985

[9] Б.Сакакушев и др. Измервателни инструменти и преобразуватели, Русе 2012

Dipl. eng. Yordanov N., Assoc. Prof. Kiril Hadjiev, PhD ,Assoc. Prof. Emiliyan Stankov, PhD

University of Ruse, Facilty of Transport, Department of Engines & Vehicles Technical, Ruse, Bulgaria

The report has been reviewed.