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THE USE OF DIGITAL HYDRAULIC TO THE POSITION CONTROL OF HYDRAULIC CYLINDER

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Abstract

The article presents the method of controlling the position of the hydraulic cylinder using hydraulic valves on/off with an appropriate strategy for digital control. Main elements of the hydraulic system under consideration include a group of electromagnetic hydraulic valves and hydraulic cylinder single acting. The control system was implemented in the environment of the real-time system based on MATLAB/Simulink. The digital control strategy is based on a fast enough on and off switching valves causing corresponding motion of the cylinder to the required position. This article presents the advantages and disadvantages of this type of control about the system with the proportional control system. The accuracy of this kind of control depends on the structure, properties of the valves or their static and dynamic characteristics. The results of analysis of the control system have the possibility of controlling the positioning hydraulic cylinder with a rather high accuracy, which can be used in place of proportional control systems. The use of digital control system allows, under certain conditions to obtain cost savings related to a reduction in energy consumption, to get a much better adaptation to variable control systems. This concept is an interesting alternative for the conventional control system and provides opportunities for application in systems, where conventional control is very expensive e.g. water hydraulics or to the clear systems where the use of hydraulic proportional technique is not necessarily, but depends on the user to the possibility of obtaining good quality control at a relatively low cost.

Keywords: *fluid power control system, hydrostatic transmission system, digital hydraulics*

1. Introduction

Current trends [8, 9] in the development of machines, continually strive to improve the production technology, save energy, increase energy efficiency as well as to improve the functionality of control systems. One aspect is the use of a suitable control algorithm and regulation that ensures the smallest error for positioning and will get the best quality results [1, 2]. An important role in hydraulic systems has the choice of an appropriate control strategy at the design stage, as a decisive influence on the selection of individual hydraulic components and above all the type of valves used. We can be distinguished two main control systems: analogue control based on proportional hydraulics, digital control, using valves on/off. In the initial stage of development, hydraulics based on the distribution valves on/off gained many users because of the low cost. Development of electronics, distribution valves were slowly being replaced by systems based on systems of proportional, since it allowed to obtain better results and greater flexibility especially in systems with complicated control. However, the continuous tendency of cost optimization causes an ongoing search for solutions to reduce costs but not lower the quality control. This solution was to use a valve on/off with digital control. The first approach was the use of several hydraulic valves (typically two-position, two-path) applied by the piston and by the rod way of different or the same sizes of volume flow rate (Fig. 1) [4].

The implementation of this a control system is performed by simultaneously switching the individual valves depending on the requirements, to enable to control the size of the volumetric flow rates and consequently control the speed and position of the hydraulic cylinder. This system

requires the appropriate strategy respective switching valves to achieve the expected value of the velocity. Another approach to digital control can be applied only one hydraulic valve on/off providing maximum volumetric flow rates. Projects of this type of control strategies may be made at the appropriate fast switching on and off valve, which can cause incomplete opening, or incomplete close valves. The same effect it is possible to obtain using similar control system operated the valve in proportion. The idea of such control is shown in Fig 2.

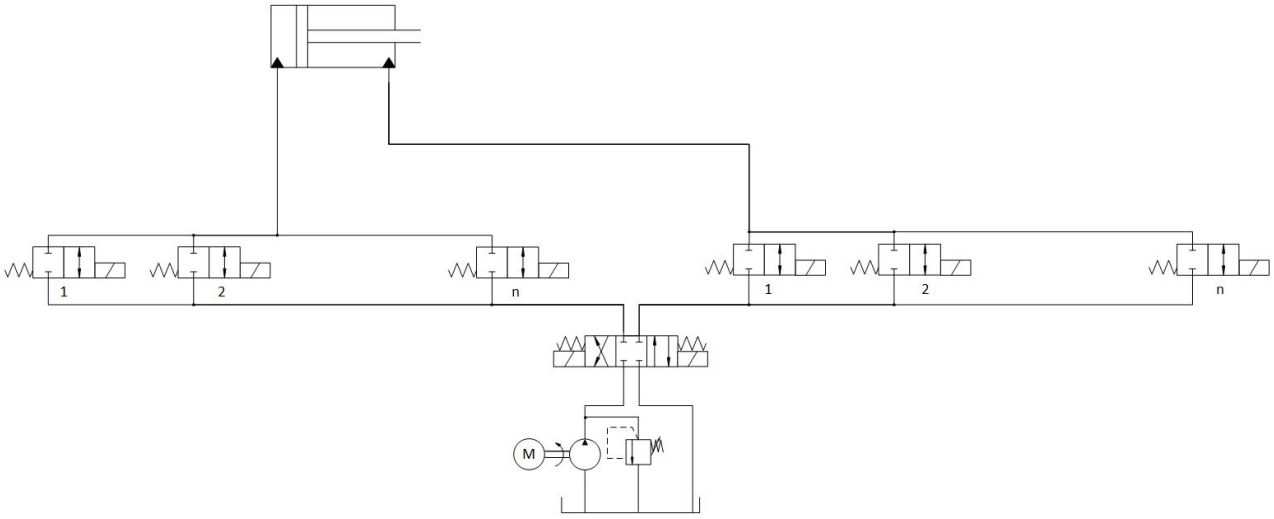

Fig. 1. Diagram a digital control system

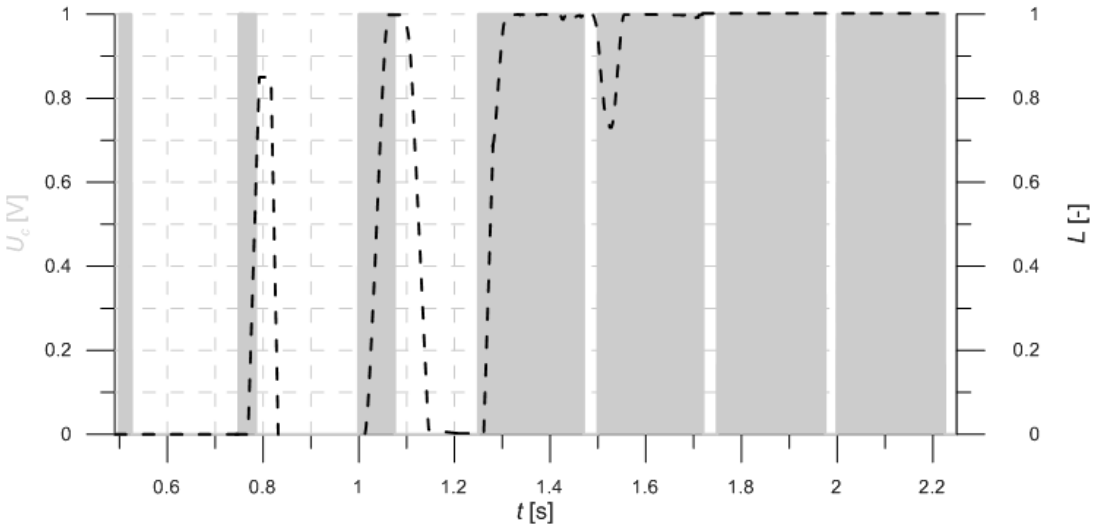

Fig. 2. Digital control strategy

Figure 2 shows the plots of the digital control signal (U_c – grey curve) and the standard displacement of the spool valves (L – black curve). The value of displacement of the spool one is at the full opening of the hydraulics valves, the value of displacement of the spool at zero completely closing the valve. Suitable modulation control signal allows the partial opening of the valve by an appropriately frequent change in signal from the high level (logic one) at a low level (logic zero), this gives the ability to set any velocity of devices.

2. The structure of the test stand

To determine the advantages and disadvantages and the quality and possibilities of the use of digital control of power in the oil hydraulic, built as a test stand (Fig. 3). This test stand consists

mainly of the double acting hydraulic cylinder (4), hydraulic four-way two-position distribution valve (3), the electric motor (1) connected with a fixed displacement hydraulic pump (2), the safety valve (5), and hydraulic tank (6) together with hydraulic lines.

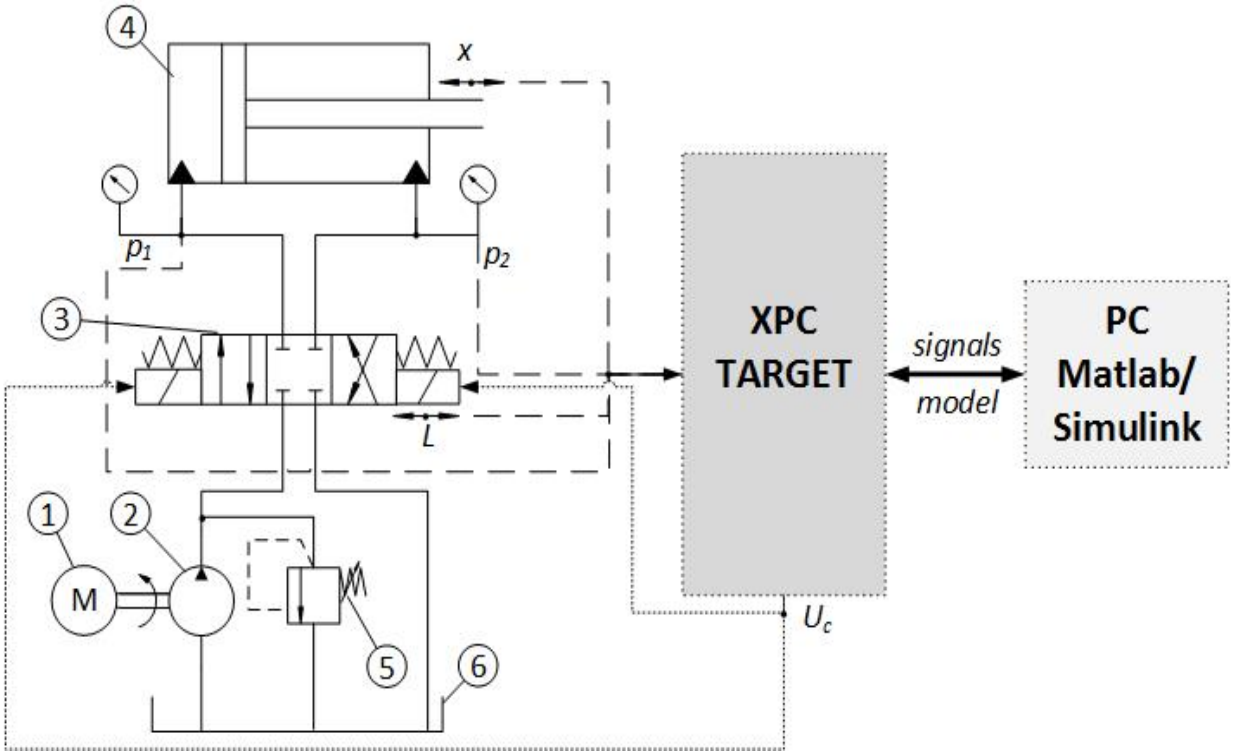

Fig. 3. Schema of the test stand

The test stand additionally equipped with a monitoring system of parameters. During the experimental test, measurements of following parameters were made: displacement of the piston rod (x), displacement of the distribution control valve (L), and the control signal (U_c) generated to the distribution control valve, the piston (p_1) and road pressure of the cylinder (p_2). The velocity of piston cylinder was calculated by making a differentiation of piston displacement. The measurement system was equipped with an analogue-digital card, the card relay, to manage, and recording information. To use MATLAB/Simulink with a special real-time system xPC Target dedicated to work with MATLAB/ Simulink. To control program was used MATLAB/Simulink with a special real-time system call xPC Target dedicated to working with MATLAB/Simulink. This system allows for rapid prototyping and adapts to different control algorithm based on hardware in the loop.

3. Experimental tests

Experimental studies are designed to answer the question of how the system behaves hydraulic cylinder using a digital control system. Experimental studies were performed on the test stand, where Matlab/Simulink has generated the digital signal, which have a fixed period of one sequence, while filling of control signal was changed. During the experimental studies carried out variation in the duration of the high state relative to the duration of the low state. They also tested the hydraulics cylinder without the load as well as the simulated load. Displacement of spool directional valve for greater clarity has been standardized and varied in the range [0.1], which means that achieving zero is equal the complete closure while achieving the value of one means the total opening of the directional valve. Examples of waveforms obtained during experimental tests for hydraulics cylinder without simulated load is shown in Fig. 4.

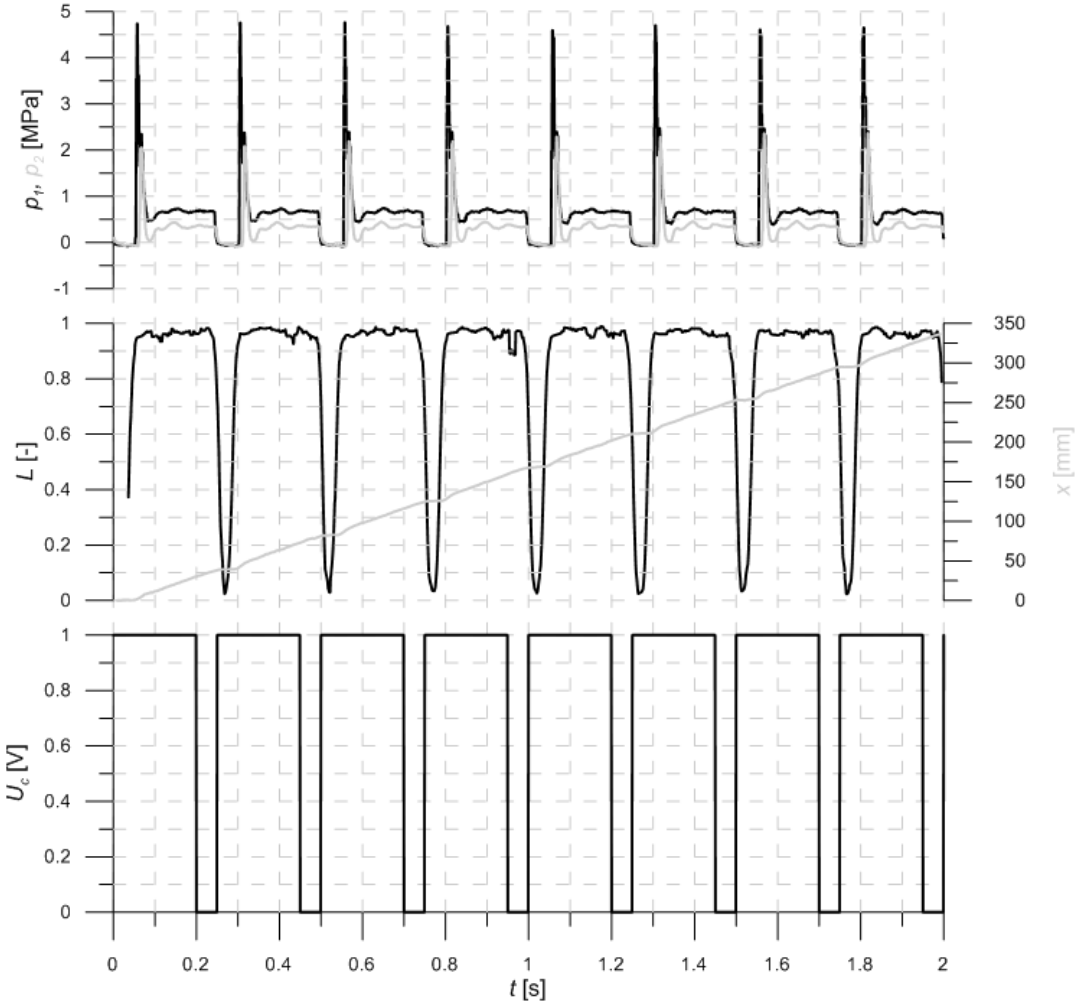

Fig. 4. Examples of plots parameters obtained during experimental tests

From these waveform parameters may be observed that, depending on the change of the control signal, a change velocity of the piston cylinder, and which also, an adequate selection of the degree of filling of the control signal, which allows achieving the desired velocity, as well as, when combined with the controller – to obtain the desired position.

Inappropriate selection of the control signal may cause discontinuous work of the hydraulic cylinder, which is appeared by pulsed operation of the displacement of the cylinder, which is shown in Fig. 5.

In Fig. 5, we can observe the appearance of two cycles: first – piston of hydraulic cylinder movement and second – piston of hydraulic cylinder stop. This is due to too long a time related with the state of the low-level control signal.

Example obtained at different velocity smooth operation of the hydraulics cylinder depending on the degree of filling of the control signal shown in Fig. 6.

In Fig. 5 it can be observed characteristic of cylinder displacement for the three exemplary degrees of filling of the control signal (70, 80, and 90 percent fill). Showing that depending on the degree of filling changing the velocity of the cylinder, in this case, the velocity of 150 mm/s to fill the 70 percent, up to 190 mm/s to fill the 90 percent. The major problem that has been observed during testing is associated with the appearance of the instantaneous phase of the cylinder stops. These phases appear at a smaller value of the degree of filling of the control signal (e.g. Fig. 5. continuous line). However, in the case of waveforms that appear in the stopping phase signals with the filling of more than 60 percent of the stop, they are not discernible to the observer only become apparent when analysing the results.

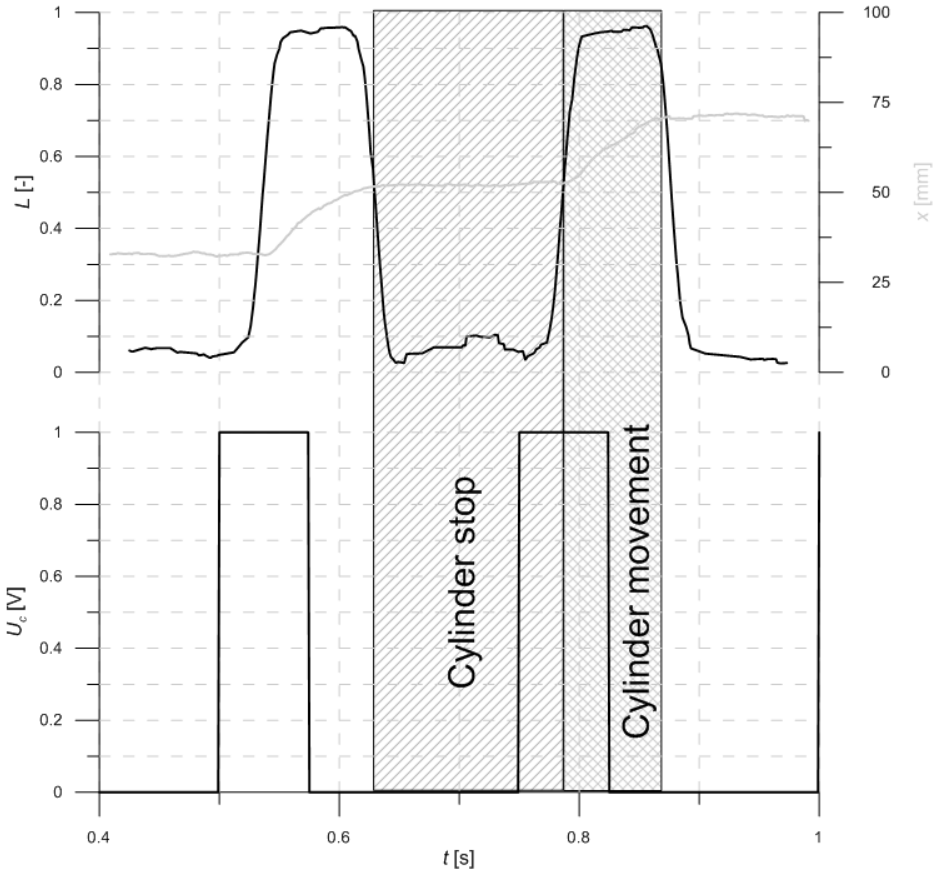

Fig. 5. Plots of system parameters for cylinder work in pulsation phase

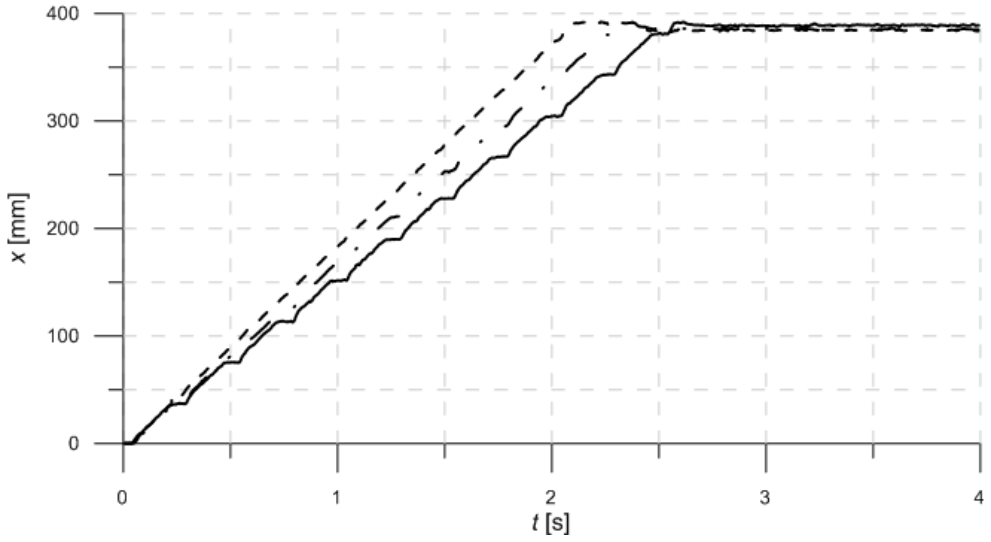

Fig. 6. Characteristic of cylinder displacement for different degrees of filling signal control (70% – continuous line, 80% – dot line, 90% – dashed line)

4. Summary

The concept of digital control of directional valve four-way three-position on/off type in the hydraulic systems seems to be a good alternative to the proportional control system. It allows us to get through a properly selected control signal to change the velocity of the workpiece (e.g., hydraulic cylinder), as well as using the controller to obtain the preset position. The main advantages of the utilization of this type of control are lower cost, higher efficiency, less energy,

the ability to adapt quickly to changes in the control strategy. There are also disadvantages that we should concentrate: extensive control equipment, individual control system depends on the type of components used, the occurrence of pressure pulsations, which may cause the acceleration of wear of hydraulic components. However, this concept is an interesting alternative for the conventional control system and provides opportunities for application in systems, where conventional control is very expensive e.g. water hydraulics or to the clear systems where the use of hydraulic proportional technique is not necessarily, but depends on the user to the possibility of obtaining good quality control at a relatively low cost.

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