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SYSTEM FOR ADJUSTING THE LINEAR DISPLACEMENT VELOCITY AND CONTROLLING AN ELECTROHYDRAULIC SERVO CYLINDER

Radu Iulian RĂDOI[1,*], Alexandru Polifron CHIRIȚĂ[1], Bogdan Alexandru TUDOR[1], Robert BLEJAN[1], Vlad BUZOIANU[2]

[1] National Institute of Research & Development for Optoelectronics / INOE 2000 – Subsidiary Hydraulics and Pneumatics Research Institute

[2] S.C. PROFLEX AUTOMOTIVE S.R.L.

*radoi.ihp@fluidas.ro

Abstract: *Certain industrial applications such as machinery, automated production lines or robots require a precise control of the movement speed of some mechanisms or tools. Hydraulic drives are suitable for applications where high power is required due to advantages such as high power-to-weight ratios, low speed torque, accurate control with servo proportional electro-hydraulic valves and compact design. For a precise control of applications with linear movement based on hydraulic cylinders, it is necessary to use closed loop systems. Closed loop systems involve the use of feedback transducers and servo controllers. The paper presents the results of the experiments of a velocity adjusting system for hydraulic servo cylinder, which uses a data acquisition board and a virtual instrument application made in the LabVIEW environment.*

Keywords: *Servo cylinder, servo valve, linear velocity, PID control*

1. Introduction

Hydraulic drives are widely used in large machinery and heavy industry applications due to possibility to scale the power and ability to change direction, torque and speed across a system very simple, without mechanical transmissions. Servo systems with closed loop control are used for positional adjustments, repeated movements with a certain adjustable stroke or a movement profile of some applications from machine tools. Closed loop control systems can use dedicated servo amplifiers, control cards or PLCs. These systems receive the setpoint variable as command input, the process variable at the feedback input, and the controller delivers a command signal to the execution element. The most widespread closed loop control system is made with PID controllers. Other authors have carried out research on the control performance of an electro-hydraulic actuator using AMESim [1] or the analysis of the speed control of a hydraulic actuator using digital hydraulics [2]. Another paper [3] proposes an electrohydraulic actuator where the speed variation is done with an EHU electrohydraulic unit equipped with an electric motor with variable speed. Also in [4] leakage compensation was studied for maintaining constant speed for a drive system with a hydraulic actuator, based on the control of a proportional directional valve and control of the input speed for pump.

In this work, a laboratory stand-type application was created with a servo cylinder and controller made with a data acquisition board and a software application developed in the LabVIEW environment. With the help of the application, a certain travel speed can be set and the evolution of the position, speed, pressures in the hydraulic cylinder chambers and the system error can be visualized on the diagrams.

2. Electrohydraulic system

The electrohydraulic system of the stand consists of a hydraulic servo cylinder with a Moog type D761 servo valve (Fig. 1) coupled with a hydraulic load cylinder and installed on a metal frame. The servo cylinder is fed from a pumping group with an axial piston pump. In the diagram in Fig. 2 one can see the load cylinder provided with two filling / venting valves (HT) and throttle valve (TV). The power supply of the servo cylinder is done through the F filter, a relief valve (RV) being connected in the derivation. The servo cylinder is equipped with two pressure transducers (PT) for the two chambers and a magnetostrictive stroke transducer (LT) for the cylinder rod. The scheme also includes the acquisition board (DAQ), a signal conditioner (SC) for the transducers with output signal 4 ÷ 20 mA and an amplifier for the control of the servo valve (VA). Signal conditioner and valve amplifier are supplied with voltage from a 24 Vdc source (PS). The valve amplifier is a modular type produced by Bosch Rexroth and has been calibrated for a maximum control signal of ±40 mA for the servovalve coils connected in parallel, the control input being a differential type with ±10 V.

Fig. 1. Hydraulic servo cylinder equipped with transducers

The characteristics of the hydraulic cylinder are:

- Piston diameter:	50 mm;
- Rod diameter:	20 mm;
- Stroke:	200 mm;

The characteristics of the servo valve are:

- Size:	04;
- Maximum supply pressure:	315 bar;
- Rated flow:	38 l/min;
- Signal for 100 % spool stroke:	±40 mA (coils connected in parallel).

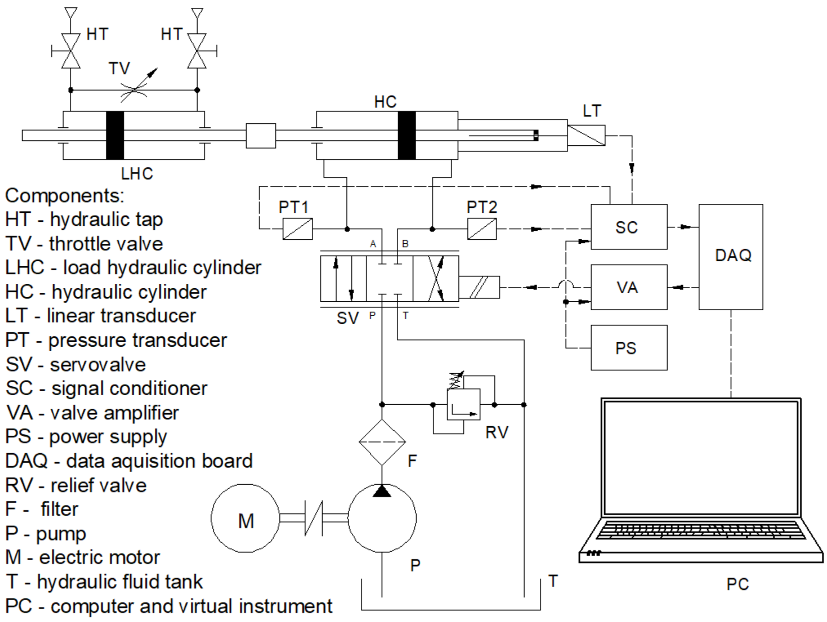

Fig. 2. Schematic of the speed adjusting system of the servo cylinder

3. Control system

A closed loop control system has the process variable as the controlled variable. The process variable is measured using a sensor. In the case of the application in this paper, the process variable is the speed and a position transducer is used to measure it, the speed being obtained by deriving the displacement according to (1).

$$v(t) = \frac{dx(t)}{dt} \quad (1)$$

The process variable enters the control system as feedback [5, 6]. The setpoint value is the desired command value for the process variable. At any moment, the process variable is compared with the setpoint value, and the difference between the two values is used by the controller to generate an output quantity to drive the system. If it is desired, at a given moment, to change the speed (setpoint) up or down, the controller commands the system (servovalve) to increase or decrease the flow rate supplied to the hydraulic cylinder chamber. Because the monitoring process of the process variable for the provision of feedback and the calculation of the order size to the system is a continuous one, the system is one in a closed loop.

The control system for adjusting the speed of a servo cylinder has been created with a LabVIEW virtual instrument, which uses an NI USB-6008 data acquisition board to transmit the setpoint command signal and to read the process variable from a displacement transducer of magnetostrictive type, incorporated in the servo cylinder (Fig. 3). To read the signals from the transducers, a DAQ Assistant block was used in which the analog channels were configured. Three analog inputs (AI0, AI1, AI2) were used, one for the displacement transducer and two for the pressure transducers connected to ports A and B of the hydraulic cylinder. The analog signal from the position transducer in the 1...5 V range is scaled in mm to display the displacement and after derivation the signal is scaled in m/s. Scaling was done by defining tables with interpolation points in Scaling and Mapping blocks. The Setpoint and Process Variable signals, which enter the PID block (Fig. 4) were scaled in the same range of variation, and the output signal that enters the valve amplifier type VT 11021 that controls the servo valve was scaled in the ±10 V range. To generate the command signal with the acquisition board, a DAQ Assistant block was used in which the analog output channel AO0 was configured. For the graphic display of the signals: setpoint, cylinder speed (process variable), pressure ports, cylinder movement and error, Waveform Chart blocks were used.

After several iterations regarding tuning the controller, the following values for PID Gains were established: proportional gain $K_p = 1$; integral gain $K_i = 0$; derivative gain $K_d = 0.1$.

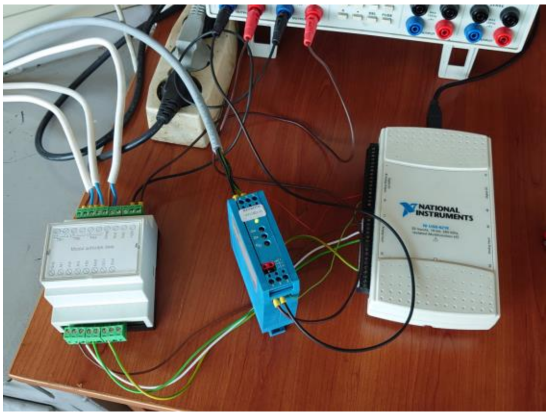

Fig. 3. Data acquisition system

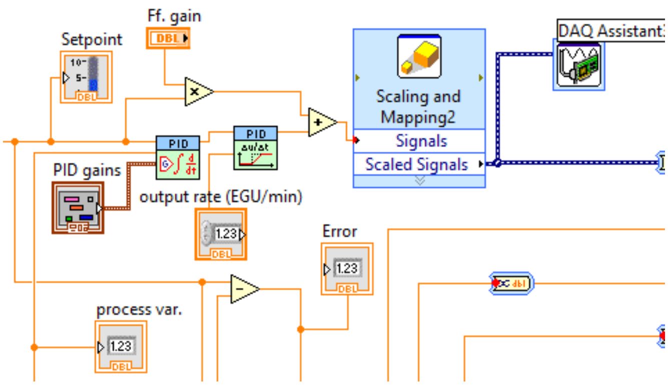

Fig. 4. LabVIEW controller network

PID tuning allows obtaining P, I, D parameters for optimizing control objectives such as disturbance rejection and setpoint tracking. The Kp parameter is used to increase the response speed, and if it increases too much it leads to oscillations. The Ki parameter is used to obtain steady-state response with the disadvantage that large oscillations can be obtained over a long period. The Kd parameter is used for damping purposes with the disadvantage that high frequency oscillations and sensitivity to noisy signals can be obtained.

4. Experimental results

After installing the actuation system with servo cylinder and tuning the PID controller, tests were done to obtain experimental data. A random signal was generated (Fig. 5) for the setpoint and the evolution of the response from the hydraulic cylinder was followed as precise as possible.

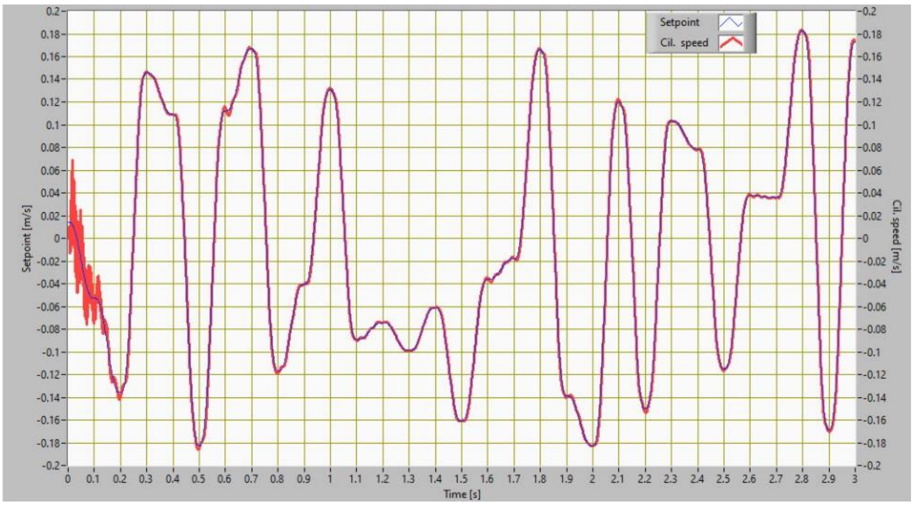

Fig. 5. Setpoint and process variable - cylinder speed

The pressure variation in the hydraulic cylinder chambers during the test can be seen in figure 6.

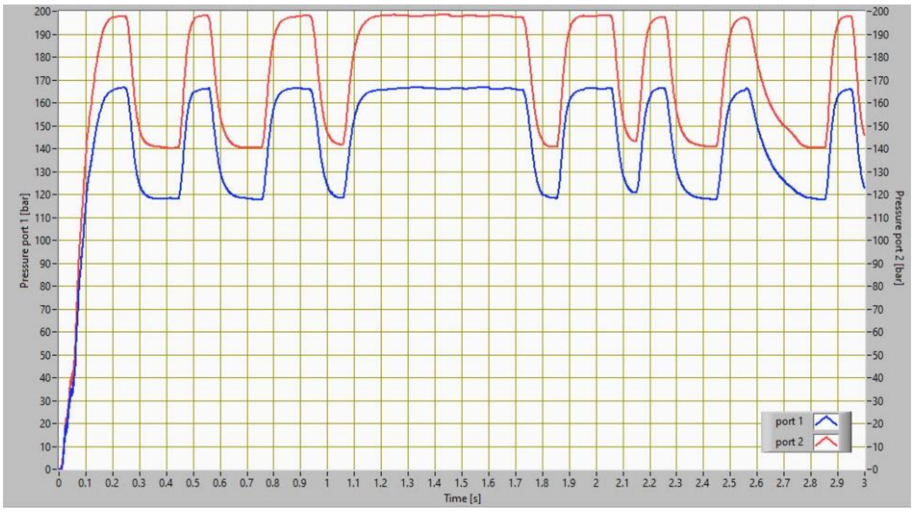

Fig. 6. Pressure at cylinder ports

The stroke profile of the hydraulic cylinder, during testing, can be found in figure 7. The maximum amplitude of the stroke was 70 mm.
The variation of the error of the speed control system during testing can be found in figure 8. When the system is put into operation, a slight oscillation is observed, which is dampened by the derivative gain set to the controller.

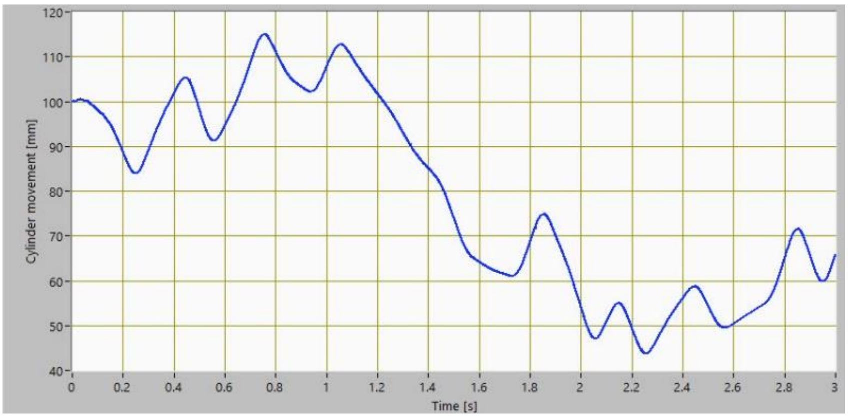

Fig. 7. Hydraulic cylinder movement

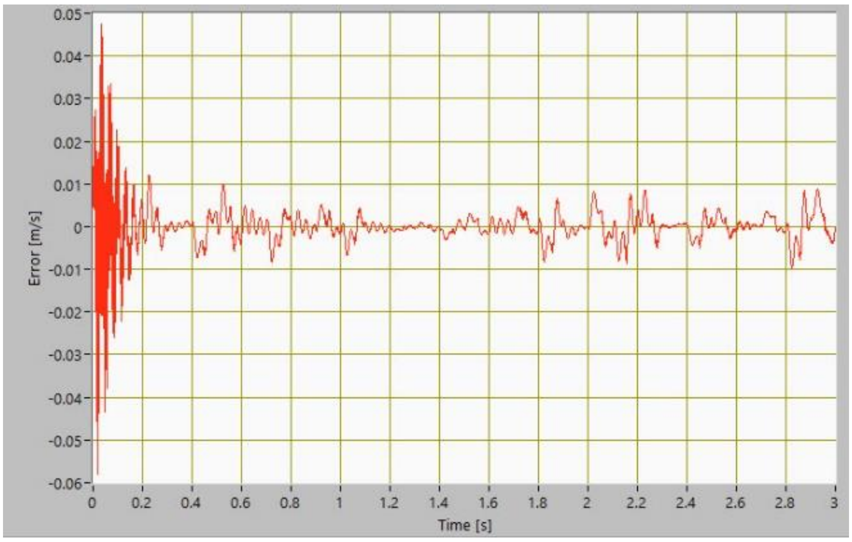

Fig. 8. System error variation

5. Conclusions

For laboratory applications that require closed-loop control, virtual instruments and data acquisition boards can be successfully used, without the use of controllers that can add additional costs.
The electrohydraulic system with speed regulation controller, made with a software application, can also be used for testing the dynamic performance of certain applications such as robotics, machinery drives, etc.
For industrial applications in the field of hydraulic actuations, numerical controllers implemented with the help of PLCs or industrial PID servo controllers can be used. The tuning of these controllers can be done by various methods such as Ziegler-Nichols, Cohen-Coon, etc. or with the help of PID tuning software.

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References

[1] Hu, Jing, Ming Liu, and Wei Li. “Position and Speed Double Closed Loop Control Performance of Electro-Hydraulic Actuator System Research Based on AMESim.“ *Applied Mechanics and Materials* 779 (July 2015): 220-225.

[2] Kalaiarasan, G., Giriraj Mannayee, Boopathi Marimuthu, S. Mayakoti, and K. Krishnamurthy. “Analysis of hydraulics actuator speed control using digital hydraulics.“ *International Journal of Mechanical Engineering and Technology (IJMET)* 8, no. 7 (July 2017): 213-224.

[3] Qu, Shaoyang, Federico Zappaterra, Andrea Vacca, Zifan Liu, and Enrique Busquets. “Design and Verification of An Open-Circuit Electro-Hydraulic Actuator System with An Integrated Electro-Hydraulic Unit.“ Paper presented at the The 13th International Fluid Power Conference 13. IFK, Aachen, Germany, March 21-23, 2022.

[4] Abou El-Azm Aly, A., M. Pascal, and R. Taher. “Experimental Study of Leakage Compensation for Actuator Speed Control in Electro-Hydraulic Systems.“ *International Journal of Engineering Research & Technology (IJERT)* 4, no. 12 (December 2015): 129-138.

[5] Rydberg, Karl-Erik. *Feedbacks in Hydraulic Servo Systems*. IEI / Fluid and Mechanical Engineering Systems, Linköpings Universitet, 2008.

[6] Hu, Dongming, Shoubao Ding, Huaiqiu Zhu, Bing Xu, and Huayong Yang. “Velocity-tracking Control of the Variable-speed Controlled Hydraulic System: Using Compound Algorithm of PD & Feedforward-feedback Control.“ Paper presented at the Third International Conference on Measuring Technology and Mechatronics Automation ICMTMA, Shanghai, China, January 6-7, 2011.