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NUMERICAL SIMULATION OF AN ELECTRO-HYDRAULIC SERVOMECHANISM

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Abstract: *The simulation of working mode of electro-hydraulic systems is an important aspect in their study. Mathematical models as well as getting closer to the physical phenomena that you want replicated or improved help us in making decisions on how to optimize them. Due to the complexity of the phenomena which ensures the proper functioning of their optimal solutions, designing them is done iteratively. Meet the required performance involves the use of mathematical modeling and numerical simulation of these systems. In this paper are presented the characteristics of static and dynamic operating regime of a servo-mechanism of electro-hydraulic control of a hydraulic pump.*

Keywords: electro-hydraulic servomechanism, modeling, simulation, position reaction, hydraulic cylinder.

INTRODUCTION

Recent trends in modeling and simulation of dynamic systems aimed at new concepts, such as co-simulation and real-time simulation. The concept of real-time simulation of dynamic systems allows the simultaneous existence of both a mathematical model parts, as well as parts of a physical model, canned thus a decrease of the degree of imprecision, due to certain phenomena, neglected in the mathematical model. Co-simulation require simultaneous use of multiple media resources modeling/simulation, allowing maximum benefit from the performance of each medium.

Numerical simulation of operation of electro-hydraulic systems or subsystems is an important aspect in their study. Mathematical models as well as getting closer to the physical phenomena that you want replicated or improved help us in making decisions on how to optimize them.

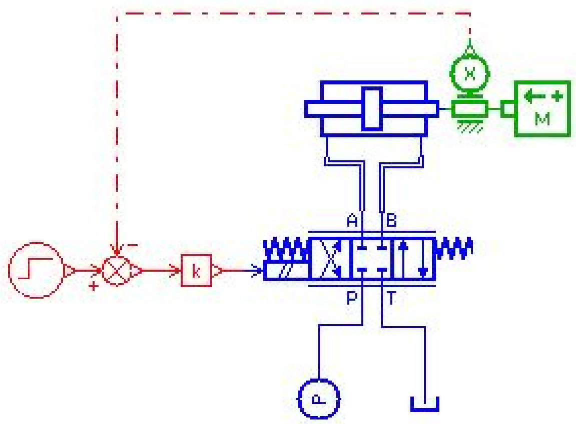

Figure 1. Electro-hydraulic servomechanism with position reaction

The electro-hydraulic servomechanisms are automatic systems for adjustment of the position, velocity, acceleration or force. The input parameter is an electric command signal and the output parameter can be position, velocity or acceleration of the linear hydraulic motor rod. Electro-hydraulic control systems are complex systems, and their operation is described both by phenomena associated with the volume hydraulic transmission and by specific phenomena as automatic adjustment processes. Due to the complexity of these phenomena determining optimal solutions in their design and implementation is iterative. Meet the required performance involves the use of mathematical modelling and numerical simulation of these systems. For the determination of the parameters should be resolved requires systems of differential equations that describe the dynamic behavior of systems. These systems are non-linear and the rule is the apelind numeric computer systems. Due to the differences between the real and simulated operation of these systems are needed for several iterations of setting their parameters.

The analyzed system, as shown in figure 1 is composed of: 4/3 proportional sleeding valve with closed center; group of oil supply; hydraulic tank; position transducer; compensator; linear hydraulic motor with inertial mass and viscous friction and signal generator.

The test stand used is an automatic control system composed of an electro-hydraulic servomechanism with position reaction. Self-adjusting control task is to bring a certain physical parameter to a prescribed value and to maintain this value. In an self-adjusting control process, the physical parameter is adjusted continuously, measured and compared with prescribed value. Once it finds a difference between these two values, a correction is made subject to appropriate adjustment in the installation, correction must agree to put the new adjusted value to the amount prescribed.

For the system analyzed, the prescribed value parameter, comparing it with the adjusted value and signal error correction is performed using the system data acquisition and processing.

MATHEMATICAL MODEL OF ELECTRO-HYDRAULIC SERVOMECHANISM

In figure 2 is presented a model of electro-hydraulic servomechanism with position reaction developed with AMESIM program.

The simulation network consists of: the group of oil supply constant pressure (constant speed electric motor, pump volume, normally closed valve); electrohydrauliuc directional control valve; double acting linear hydraulic motor with bilateral rod; inertial load; displacement transducer for directional control valve; displacement transducer for hydraulic cylinder rod; control software interface, analysis and interpretation of data, done in LabVIEW.

The linearized simulation model is shown in figure 3. A mathematical description of this model is presented in the equations below.

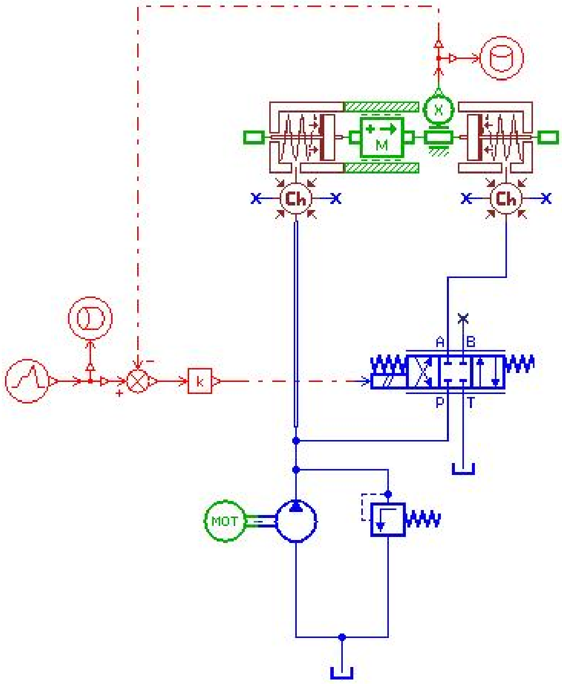

Figure 2. Simulating scheme of electro-hydraulic servomechanism with position reaction

The equation for position transducer is

$$\mathrm{U_T = K_T y} \tag{1}$$

where K_T - transducer constant $[V/m]$; y - hydraulic cylinder rod displacement.

The transducer position equation is

$$\varepsilon = U_0 - U_T \tag{2}$$

where ε is the control error, U_0 is the references signal and U_T is the signal from the position transducer.

The equation of the current generator of controller is

$$i = K_{ie}\varepsilon \tag{3}$$

where K_{ie} is the conversion factor $[A/V]$.

The motion equation of the slide valve

$$T_{SV}\frac{dx}{dt} + x = K_{xi}i(t) \tag{4}$$

where T_s is time constant of directional control valve.

The equation of directional control valve with 4 ways, 3 positions and the critical center closed is

$$Q_{SV}(x,p) = c_d A(x)\sqrt{\frac{p_S - signx \cdot P}{\rho}} = A_p\dot{y} + K_l P + \frac{A_p^2}{R_h}\dot{P} \tag{5}$$

where A_p is piston area; R_h is hydraulic rigidity of double acting hydraulic cylinder, K_l is leaks coefficient between hydraulic cylinder chambers.

The motion equation of hydraulic cylinder piston is

$$m_c\ddot{y} = F_p - F_a - F_e - F_f \tag{6}$$

where F_p is pressure force,

$$F_p = A_p P \tag{7}$$

F_a is damping force,

$$F_a = K_f \cdot v \tag{8}$$

F_e is elastic force,

$$F_e = 2(K_{e1} + K_{e2})(y + y_{0e}) = 2K_e(y + y_{0e}) \tag{9}$$

and F_f is friction force.

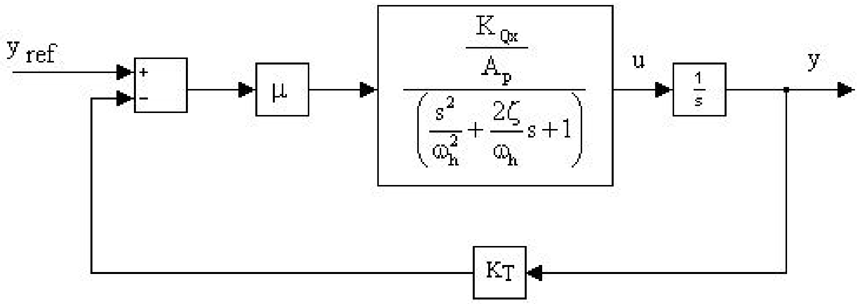

Figure 3. The linearized model of electro-hydraulic servomechanism.

Based on the following notations:
- natural hydraulic frequency

$$\omega_h = \sqrt{\frac{R_h}{m}} \tag{10}$$

- damping coefficient

$$\zeta = \frac{K_P}{2A_p^2}\sqrt{mR_h} \tag{11}$$

- speed amplification factor

$$K_v = \frac{\mu K_{Qx}}{A_p} \tag{12}$$

for the linearized model of electro-hydraulic servomechanism can be written the expression

$$\frac{z(s)}{\varepsilon(s)} = \frac{\mu \frac{K_{Qx}}{A_p}}{s\left(\frac{m}{R_h}s^2 + \frac{mK_P}{A_p^2}s + 1\right)} \tag{13}$$

The transfer function on direct path is

$$H(s) = \frac{z}{y - z} = \frac{K_v}{s\left(\frac{s^2}{\omega_h^2} + \frac{2\zeta}{\omega_h}s + 1\right)} \tag{14}$$

The transfer function of the servomechanism can be written as form

$$H_0(s) = \frac{z(s)}{y(s)} = \frac{K_v\omega_h^2}{s^3 + 2\zeta\omega_h^2 s^2 + \omega_h^2 s + K_v\omega_h^2} \tag{15}$$

RESULTS

To analyze the static and dynamic characteristics of servomechanism, was used graphical programming environment AMESIM-imagine. For plotting simulation models have been used standard symbols, specific elements of the hydraulic environment, existing in program libraries.
From the users point of view, the program is a graphical interface that displays the evolution of the whole system suggestive during the simulation process. By AMESim, schemes of technical systems are built by entering symbols or suggestive pictograms (usually ISO symbols parts used) taken from libraries in the active surface modeling. An important feature of the simulation program is the

automatic choice of the method of integration of systems of equations that can be adapted during the simulation depending on the characteristics equations.

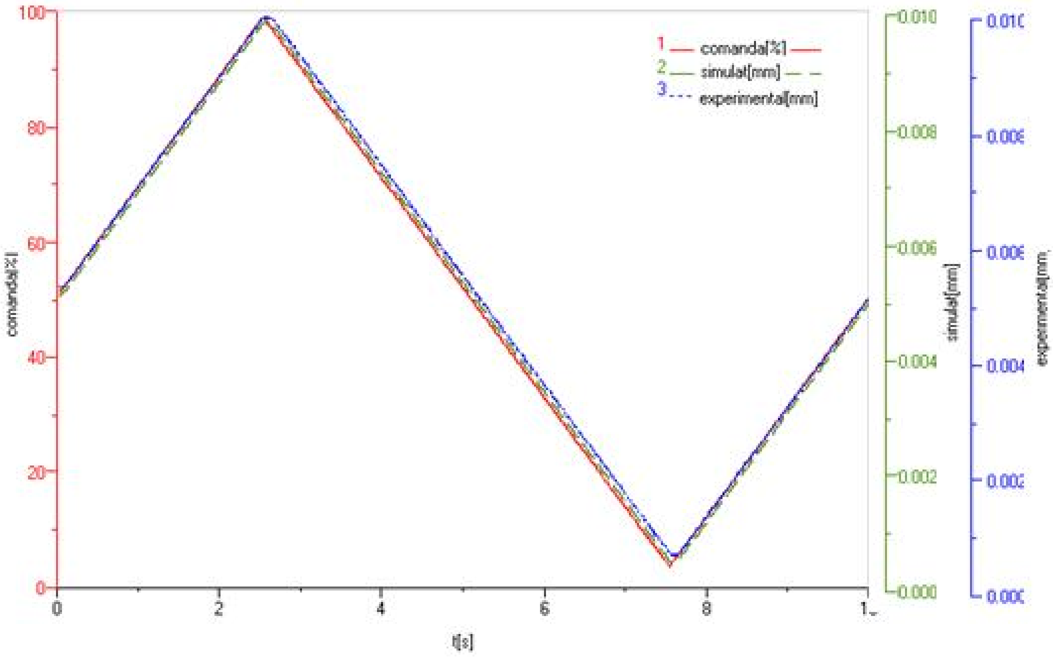

Figure 4. System response to ramp wave signal source (f = 0.1 Hz)

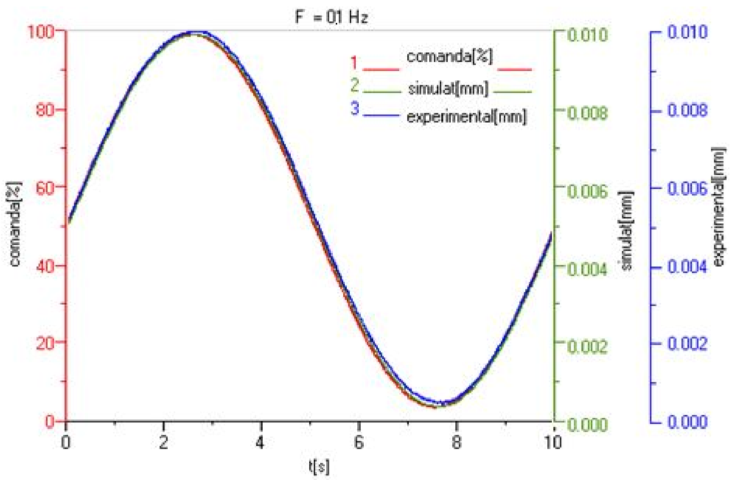

Figure 5. System response to sine wave signal source (f = 0.1 Hz)

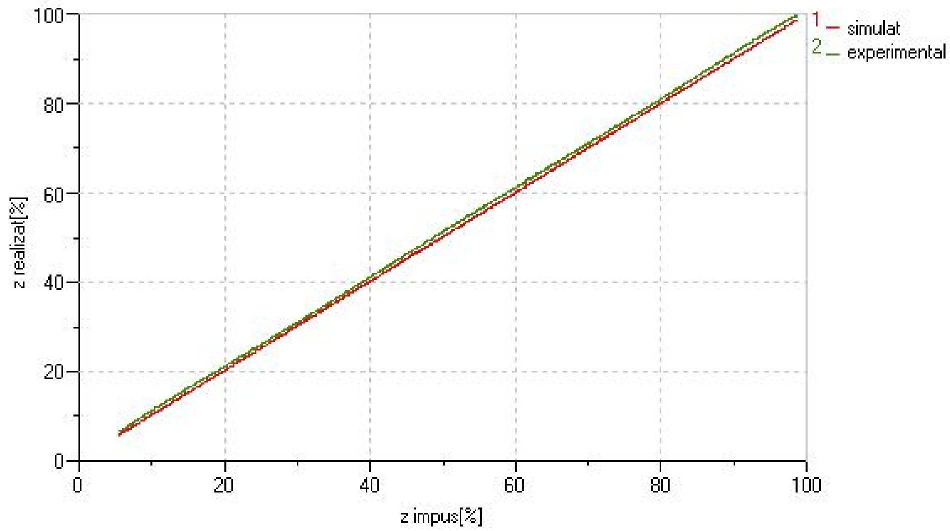

Figure 6. The moving of the hydraulic cylinder rod depending on the size of control parameter U. (f = 0.1 Hz)

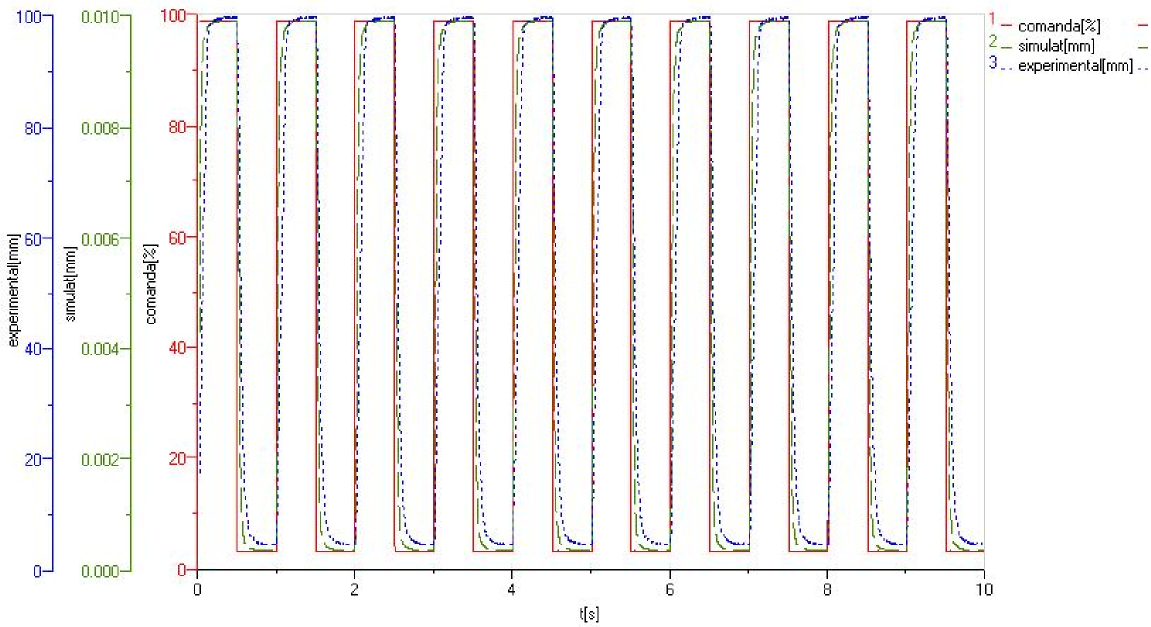

Figure 7. System response to square wave signal source (f = 1 Hz)

For determining the statics and dynamics regime characteristics, the system was excited with ramp, step and sine wave signals. Signal type frequency ramping has been chosen small enough to generate a cvasistatic regime. As a result of the simulation, were obtained the following characteristics: characteristics of stationary regime (figures 4, 5 and 6) and time response characteristics to square and ramp wave excitation signals (figures 7 and 8).

Calculations were performed for the following dates: load m = 100kg; supply pressure p = 160Bar; cylinder displacement = 300mm; cylinder diameter = 26mm; rod diameter = 12mm; rigid anchor = 2.1 · 107 N/m; damping = 4000Ns/m.

After drafting the simulation scheme, follows the following steps:

-to defining of parameters for all components;

-execution of numerical integration;

-interpretation of results that describe the behaviour of the system through the appropriate graphics.

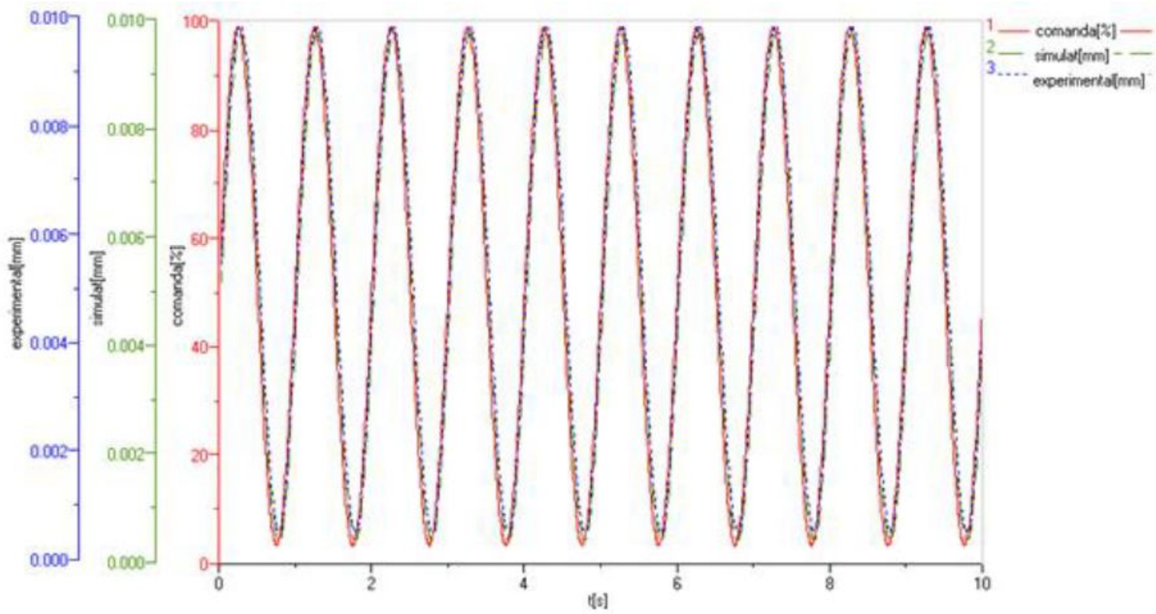

Figure 8. System response to square and ramp wave signal source (f = 1 Hz)

CONCLUSIONS

In this paper is presented an application of numerical simulation of an generic electro-hydraulic servomechanism with position reaction developed with AMESim program. The response characteristics to square, sine and ramp wave excitation signals obtained by numerical simulation for steady state regime were compared with the experimental results. The control model validation is confirmed by high similarity between the theoretical and experimental characteristics graphs obtained by coupling LabVIEW virtual interface / PXI to a physical model, developed in the laboratory, equivalent AMESim simulation model. It is found comparable dynamics, obtained by theoretical and experimental way, of the hydraulic transmission control system. Comparative analysis of the results looks like the numerical modeling is valid.

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