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REALIZATION OF SERVOMECHANISM WITH LINEAR MOTOR IN MATLAB – SIMULINK ENVIRONMENT

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Abstract: This paper describes a realization of a servomechanism with a linear motor. The paper is focused on identification of the parameters of a linear motor for the construction of its simulation model. Parameters for regulation loop of the servomechanism in the Real-Time Toolbox in Matlab/Simulink environment were calculated using the Modulus Optimum (MO) Method from those constants.

Keywords: servomechanism, linear motor, PID controller, Matlab, RealTime Toolbox

1 INTRODUCTION

The servomechanisms with a linear motor are modern and broadly alternative of a drives with rotary to linear translation. The linear servomechanism was constructed using the Matlab/Simulink environment and small linear motor as a demonstrative illustration for students.

The linear motor was taken from a chart recorder produced in ZPA Nová Paka (Figure 1). It is the linear electrodynamic motor. The stator is composed from two parallel block magnets. A rotor loop is threaded on one of magnets. It is lead by two circular beams. A motor is equipped with a potentiometric sensor, that converts actual position into voltage.

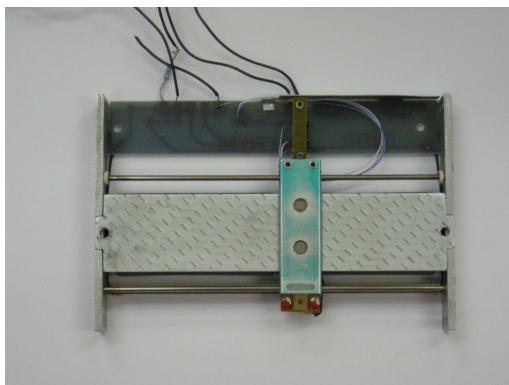


Figure 1. Linear motor

2 IDENTIFICATION OF LINEAR MOTOR

To tune control loop of the constructed servomechanism it was necessary to create a suitable mathematical model of linear motor and its constants. The inductance and resistance of motor's armature was measured on LCR Meter 4263HP. A total track of motor was measured as distance between ends positions of the motor. A weight of motor's armature was weighed on precision scale Leco EB 25. Other parameters which are motor constant c and speed were calculated from following equations:

$$v=s/t, \quad (1)$$

where v is speed, s is length and t is time which was subtracted from scope.

$$c\phi=U_i/v, \quad (2)$$

where $c\phi$ is constant of motor, U_i is generated voltage.

Generated voltage and time, during which motor pull through one's extreme position to the second was measured using oscilloscope Agilent 54622D. Obtained values are in Table 1.

Table 1: Parameters of linear motor

Frequency [Hz]	100
Voltage [mV]	500
Inductance [mH]	41
Resistance[Ω]	74
Length [cm]	10,5
Time [ms]	176
Voltage [V]	6,2
Motor constant [V/ms ⁻¹]	10
Speed [m/s]	0,6
Weight [g]	45

Furthermore, a simulation model was designed to determine the constants of the servo regulator. Mathematical model of the motor has been established on the basis of the following equations describing the electrical and physical dependency in the motor. We can say that the form is identical with the standard model of DC machine.

Voltage equation of the motor:

$$U_o = R \cdot i + L \cdot (di/dL) + U_i \quad (3)$$

where U_o is the voltage at the input, R is resistance, L is the inductance, U_i is the induced voltage, i is armature current.

Movement equation:

$$F_H = F_Z + m \cdot (dv/dt), \quad (4)$$

where F_H is the driving force, F_Z is loading force, m is total mass of armature and load. From the previous equations the model of motor has been established:

$$F_M(s) = v(s)/U_o(s) = (1/K_I) / ((s^2/\Omega_o^2) + (2\xi s/\Omega_o) + 1), \quad (5)$$

where v is speed, U_o is the voltage at the input, K_I is a motor constant, ξ is damping factor, Ω_o is own frequency. From the previous equation simulation schema of linear motor has been created (Figure 2).

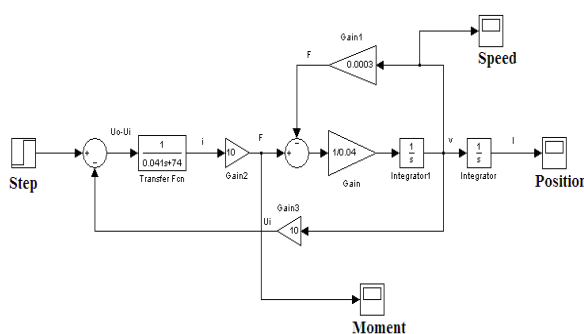


Figure 2. Simulation schema of linear motor

A cascading regulation scheme with position and speed regulator (Figure 3) was chosen for controlling the linear motor as a servomechanism. Current regulator was not used, because its speed was extremely limited by Matlab/Simulink environment.

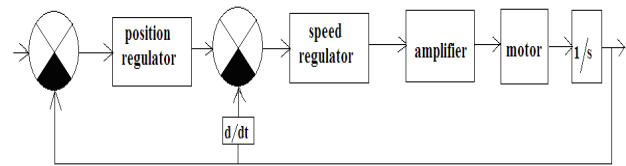


Figure 3. Regulation scheme of designed linear servomechanism

3 CONTROL LOOP TUNNING USING MODULUS OPTIMUM CRITERION

Regulator constants were determined using the method of Modulus Optimum Method from already known constants of motor's model. Regulator constants were determined using the following formulas:

$$\tau_M = mR/K^2 I = 0,03s, \quad (6)$$

where τ_M is the mechanical time constant, m is the mass of moving parts of motor, R is the resistance of armature, K_I is a constant motor.

$$\tau_E = L/R = 0,0005s, \quad (7)$$

where τ_E is the electrical time constant, L is inductance and R is the resistance of armature.

$$K_z = U_2/U_1 = 4,6, \quad (8)$$

where K_z is a gain of amplifier, U_2 is the voltage at the output amplifier, U_1 is the voltage at the output regulator.

$$K_s = K_z/c\phi = 0,46, \quad (9)$$

where K_s is the amplification system, K_z is the amplifier gain, $c\phi$ is a constant motor.

$$K_R = \tau_M/2T_z K_s = 2,17, \quad (10)$$

where K_R is a proportional gain controller, τ_M is the mechanical time constant, T_z is a delay caused by amplifier, K_s is the amplification of system.

4 IMPLEMENTATION OF SERVOMECHANISM

Control part of the servomechanism is comprised of a computer with multifunction card Advantech PCI-1711. The simulation scheme was realized in Matlab-Simulink, with the support of RealTime Toolbox. Analog output of the multifunction card was amplified by the amplifier circuit TDA 2030 and brought to the terminals of linear motor. Position of motor was sensed by potentiometric sensor, which is part of the motor.

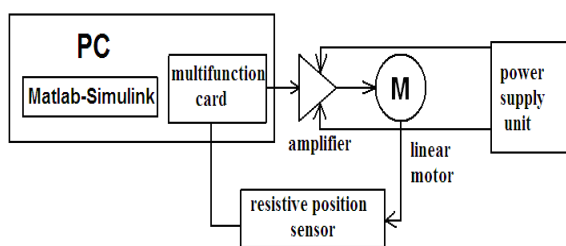


Figure 4. Experimental workplace

The final adjustment of speed and position regulators was done manually, because the constants obtained using the Modulus Optimum Method system led to almost unstable system. The reason is probably a fault in characterization of the entire control chain. Proportional component of position regulator was set to $P_p=1$. Proportional component of speed regulator was set to $P_r=1,7$. Integration components are left zero. The figure 5. shows a time record of the regulator output and position signal obtained from potentiometric sensors (Figure 5).

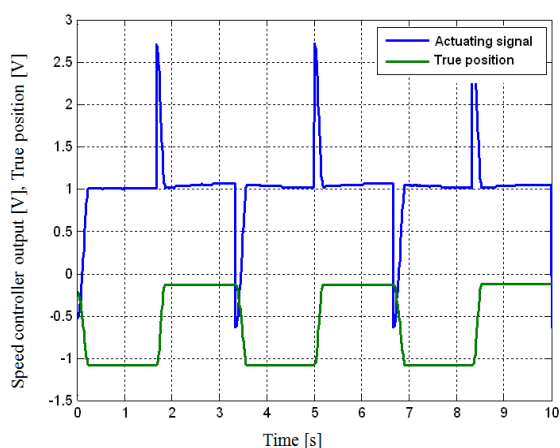


Figure 5. Time record of regulator output and position of servomechanism

5 CONCLUSION

Simple demonstration of servo-motor with linear motor was realized using old linear motor from chart recorder, RealTime Toolbox and the Matlab/Simulink environment. Although servo-motor was not successfully tuned using deterministic approach, it is a nice example for students, on which they can acquaint with problems of a real machines and systems.

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