STUDY OF MECATRONIC HYDRAULIC ROTATION AXES BEHAVIOR FOR INDUSTRIAL ROBOTS BY COMPUTER SIMULATION

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ABSTRACT

Based on the mathematical model, designed by the authors, regarding a servo-system commanded hydraulic rotation drive; there had been optimized position speed regulators by numerical simulation.

1. INTRODUCTION

To avoid the large test period during development of machine tools, industrial robots and other hydraulic industrial equipments, computer simulation is used to optimize position, speed and force control.

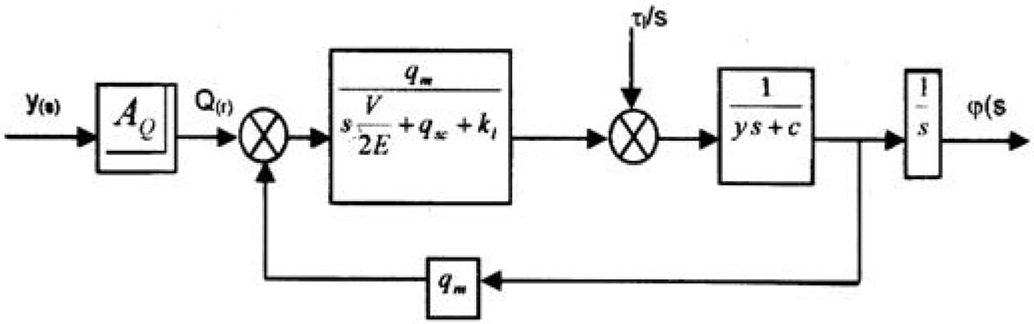


Fig. 1. Block diagram of rotational motor electro-hydraulic servo-system

In another papers the authors developed the mathematical model of a hydraulic rotation axis, where it had been established the transfer function of the electro-hydraulic servo-system presented in relation (1) and fig. 1.

$$H(s)=\frac{k_Q}{s\left\{\frac{JV}{2Eq_m}s^2+\left[\frac{cV}{2Eq_m}+(q_{sc}+k_l)\frac{J}{q_m}\right]s+\left[J+(q_{sc}+k_l)\frac{c}{q_m}\right]\right\}} \quad (1)$$

2. HYDRAULIC ROTATION AXIS SCHEME

The designed of the controlled axis is show in fig. 1 having the following elements: (1) Personal Computer; (2) Transducers reading head position (TIRO); (3) one sided hydraulic motors rotation; (4) Pressure transducer TP1; (5) Pressure transducer TP2; (6) Proportional distributor; (7) Hydraulic energy source; (8) Data acquisition card; (9) Position conversion circuit; (10) Pressure conversion circuit; (11) Control interface circuit.

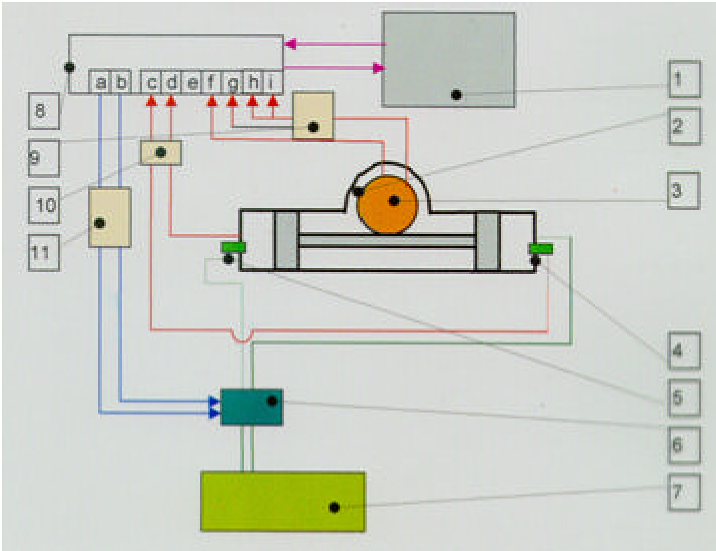


Fig. 2. Scheme of drive to axis hydraulic of rotation

3. ESTABLISHING THE AXIS SUBSYSTEM TRANSFER FUNCTION

To simulate the rotation axis presented in fig. 2:

– We will have to establish first the transfer functions for each subsystem.

– The block diagram of the axis is personated in fig. 3.

Position controller (RP) and speed controller (RV) having a P.I.D. structure made the control of axis.

– We will presented in future, the subsystems mathematical definition:

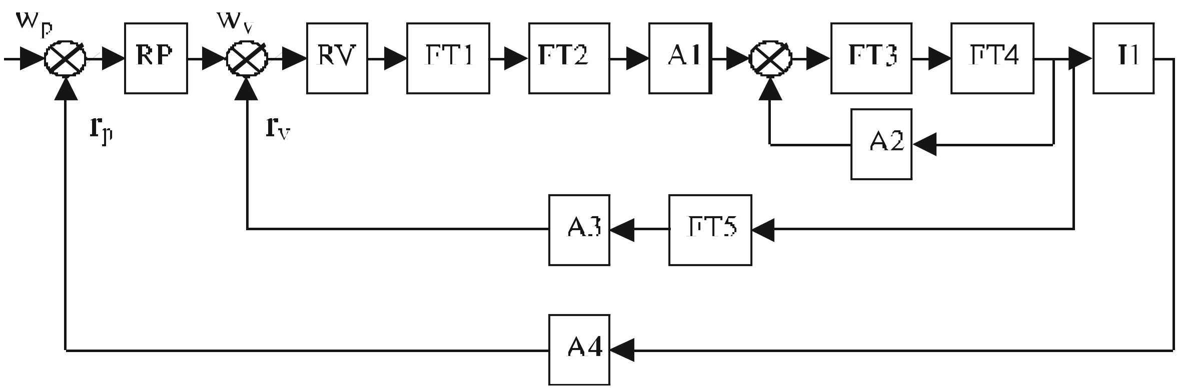


Fig. 3. Scheme block of the axis hydraulic of rotation

a) FT1 – command circuit interface voltage to current transform:

$$FT_1(s)=\frac{I(S)}{U(S)}=\frac{\frac{1}{R}}{T_c s+1} \qquad (2)$$

in where:

$$T_c=\frac{L}{R} \qquad (3)$$

for actual values:

$$FT_1(s)=\frac{0{,}1}{s+1} \qquad (4)$$

where: $I(s)$ – output current; $U(s)$ – input voltage; R – resister;

b) FT2 – transform of command current to proportional distributors command piston:

According to (1):

$$FT_2 = \frac{Y(s)}{I(s)} = \frac{A_{IY}}{T_{Y_2}^2 s^2 + T_{Y_1} s + 1} \qquad (5)$$

where: $Y(s)$ – output; $I(s)$ – input;

$$d = \frac{1}{2} \cdot \frac{T_{Y_1}}{T_{Y_2}} \qquad (6)$$

$$\omega_0 = \frac{1}{T_{Y_2}} \qquad (7)$$

$A_{IY} = 785{,}398$ – Amplification factor for the proportional distributor.

$\delta = 0{,}4$ – System damped factor

ω_0 – System frequency.

From (7) results:

$$T_{Y_2} = \frac{1}{\omega_0} \qquad (8)$$

where: T_{Y_2} – proportional distributors delay time;

The frequency can be considered: $f_0 = 10H$.

where: $\omega_0 = 2\pi f_0 = 2\pi 10\,[\text{rad/s}]$, resulting: $T_{Y_2} = \frac{1}{2\pi 10}[\text{s}]$

From (6) resulting: $T_{Y_1} = \frac{\delta}{10\pi}[\text{s}]$, delay time of the electrical signal.

From (5) we can write the FT_2 transform function:

$$FT_2 = \frac{785{,}398 \cdot 10 \cdot \pi}{0{,}25 s^2 + 0{,}4 s + 31{,}415} \qquad (9)$$

c) Elements A_1 and A_2 and transform functions FT_3 and FT_4 are characteristic for subsystem described in (1).

Replacing the actual values we will obtain $A_1 = 1{,}36$; $A_2 = 2{,}41 \cdot 10^{-3}$

$$FT_3 = \frac{0{,}00241}{7{,}85 \cdot 10^{-14} s + 162 \cdot 10^{-12}} \qquad (10)$$

$$FT_4 = \frac{1}{52{,}22 \cdot s + 800} \qquad (11)$$

d) I_1 – integrator

$$I_1 = \frac{1}{s} \qquad (12)$$

e) A_3, A_4 and FT_5 – measuring element $A_3 = 1$; $A_4 = 1$;

$$FT_5 = e^{-s\frac{T}{s}} \qquad (13)$$

where: $T = 0{,}01[\text{s}][\text{B15}]$

Exponential function can be simplified by Pade's method.

$$FT_5 = e^{-s\frac{10}{s}} = \frac{-200 s + 60.000}{s^2 + 400 s + 60.000} \qquad (14)$$

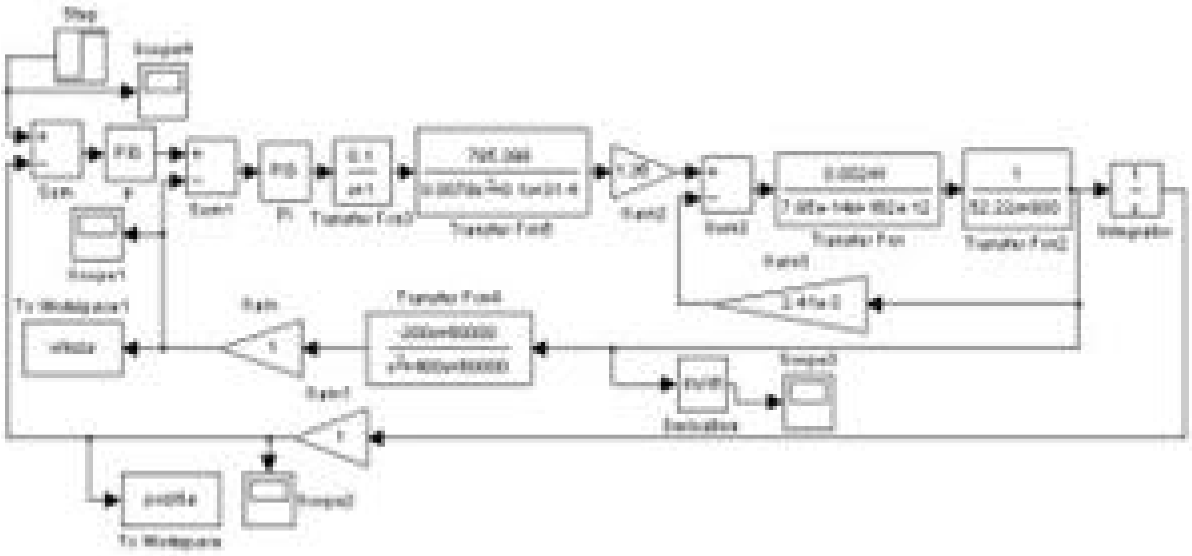


Fig. 4. The model axis of rotation hydraulic with regulator

4. SIMULATION MODELS OF ENTIRE SYSTEM

From the described subsystem, the model of the whole system was developed. Simulation model was made in SIMULINK (Matlab 5.1) language ode 4-5 integration method (derived from Runge-Kuta) had been used to integrate he differential equations.

The model is presented in fig. 4.

Combinations of various P.I.D. controllers were used in order to establish the optimal controller.

speed	position	speed	position
PI	P	P	P
PI	PD	PID	P
PI	PID	PI	PI

5. SIMULATION RESULTS

Running the simulation diagrams in fig. was obtained, using a step signal as input.

Studding the diagrams we can assume that the best results can be obtained for PI-P and PI-PD combination.

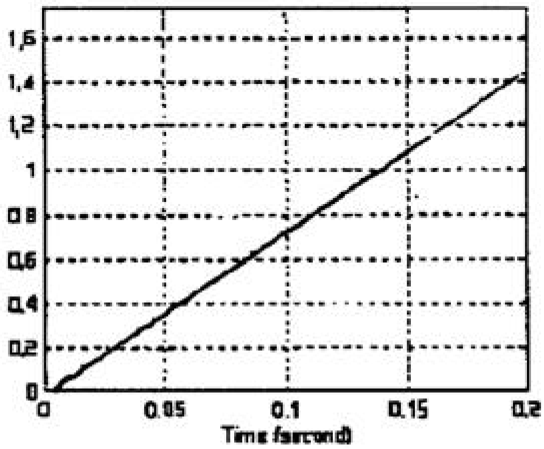
These combinations of controllers were used in the design of the acquisition and control program presented in paper [4].

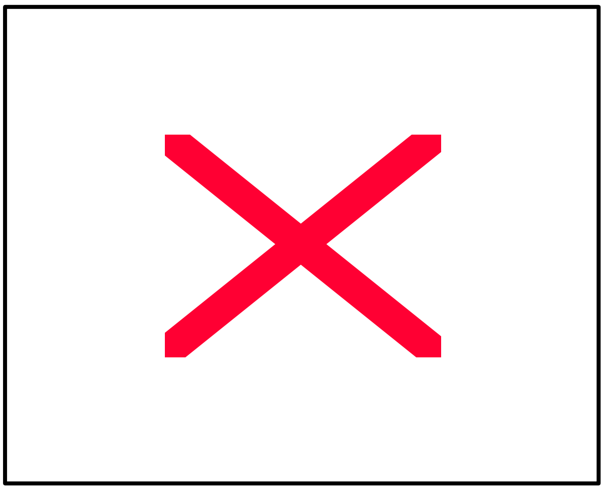
6. CONCLUSIONS

The simulation results had proven the models efficiency.

The simulation helped the authors to design and build up the RH10 industrial robots rotation horizontal axis.

Applying different parameters on the designed model can be extended to future applications.





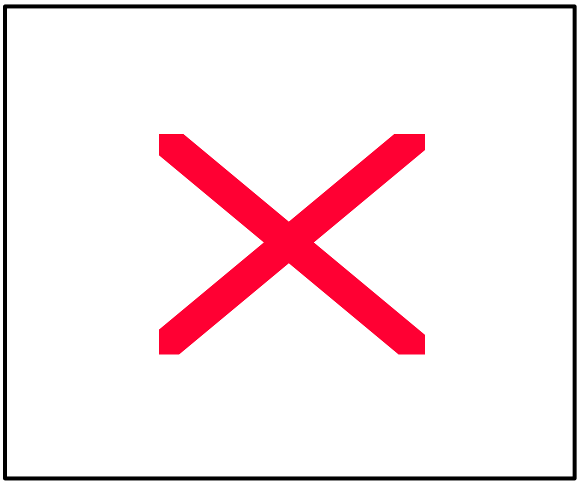


Fig. 5. Time dependencies of system speed and position with controller

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