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An Analysis Method of the Electro-hydraulic Rotational Module

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Abstract. The paper presents a dynamic research of a rotational module of structure to industrial robot MA 221, to establish the functional characteristics that recommend it for use in the structure of the robot. The mathematical model is both servo-system characteristic equations and dynamic equations of robot MA-221, obtained by solving the generalized equation for second case of Lagrange's. Actual research performed by two methods: BODE and UNIT STEP response of the established the construction parameters values of electro-hydraulic servo-system for stable operation

Keywords: servo-system ,electro-hydraulic, analysis, synthesis, frequencial methods

1. Industrial Robot MA-221

Very important in automatic control systems are stability characteristics and dynamic performances. The rigorous analysis and synthesis of an automatic system implies the most complex and correct mathematical modeling of all phenomenon produced during the process automatically controlled [3].

1.1. Electro-hydro-mechanical structure of the Robot

Industrial robot MA-221 (fig.1) is made of assembled rotation and translation modules (two rotation modules, position 2 and 4, and two translation modules, position 1 and 3 [1].

1.2. The rotation servo-system structure

The rotation servo-system structure, position 2 from figure 1 is presented in figure 2. The reaction of position and speed is realized from 5 through the gear Z_3/Z_4. The rotation angle φ of the worm M, made by engine 1 through the gear Z_1/Z_2 determines the movement of the worm on the worm-wheel RM. As a result of the axial movement of worm M and of the dispenser 4, with which is coupled, the hydraulic oscillate engine 3, 4 is moved.

Through the gear Z_3/Z_4 the reaction contact is determined, and the worm-wheel RM rotates with the movement of the worm until the dispenser reaches the neutral position and stops the movement of the system. The minimum increment of the angular movement can by determined for an angular pace of the engine. This leads to:

$$\theta_1 \cdot \frac{Z_1}{Z_2} = \varphi_M \cdot \frac{Z_3}{Z_4} \cdot \frac{Z_{RM}}{Z_M} \quad \text{or:} \quad \varphi_M = \frac{Z_1}{Z_2} \cdot \frac{Z_4}{Z_3} \cdot \frac{Z_M}{Z_{RM}} \cdot \theta_1 \qquad (1)$$

By analyzing relations (1) we conclude that the minimum increment of the angular movement is even lower when the relations Z_1/Z_2, Z_4/Z_3 and Z_M/Z_{RM} are lower.

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1.3. The mathematical model

The mathematical models results from both the servo-system and robot MA-221 dynamic equations, with the kinematic structure presented in figure 3, obtained by solving the generalized equation of Lagrange.

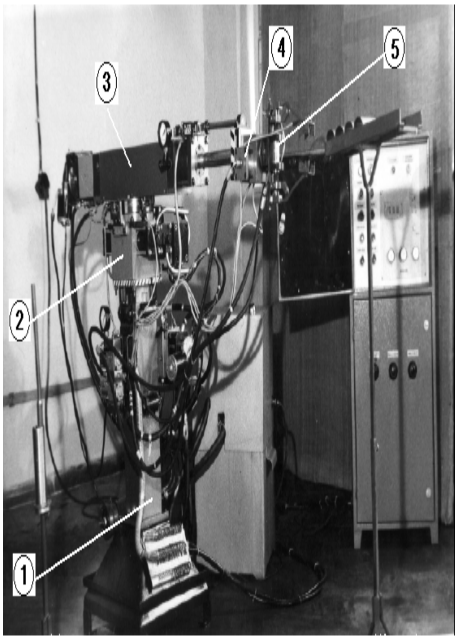

Fig. 1: The Industrial Robot MA-221

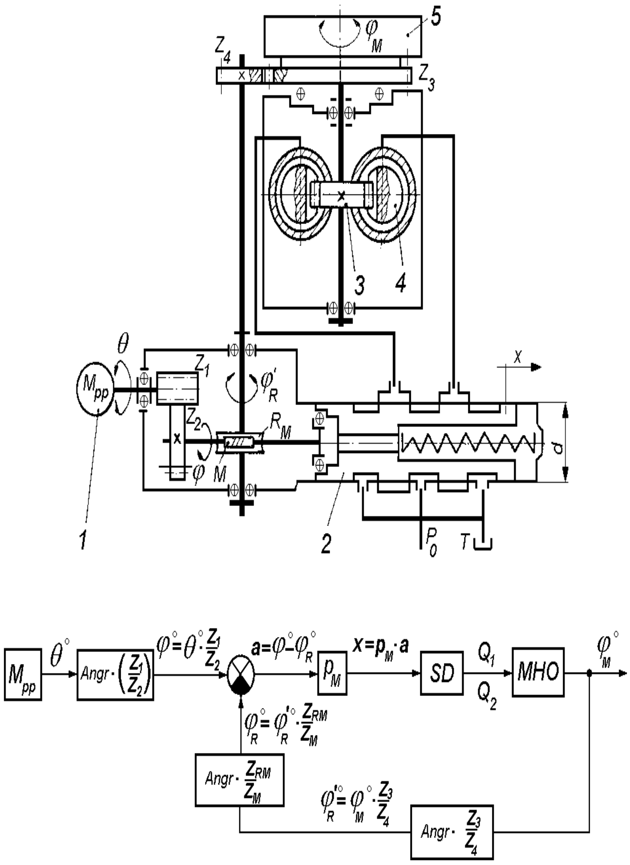

Fig. 2: The electro-hydro-mechanical structure

The mechanic constructive parameters of robot MA-210 are presented in table 1. Established systems of differential equations for the robot with four degrees of freedom, will be reflected in the functional equations of the electro-hydraulic servo-system used as constructive modules of the analyzed robot [1].

Table 1

M/P (kg/N)				Moments of inertia (kg m^2)				Construction measures (m)		
$\frac{m_1}{P_1}$	$\frac{m_2}{P_2}$	$\frac{m_3}{P_3}$	$\frac{m_{4+5}}{P_{4+5}}$	$J_{\Delta 1}^{(2)}$	$J_{\Delta 2}^{(4,5)}$	$J_{031}^{(3)}$	$J_{041}^{(4,5)}$	l_3	l_4	l_5
$\frac{50}{490}$	$\frac{20}{196}$	$\frac{5}{49}$	$\frac{10}{98}$	0.05	0.008	0.01	0.008	0.1	0.4	0.1

By knowing the fact that the rotation module is part of the kinematic structure TRTR presented in figure 3.

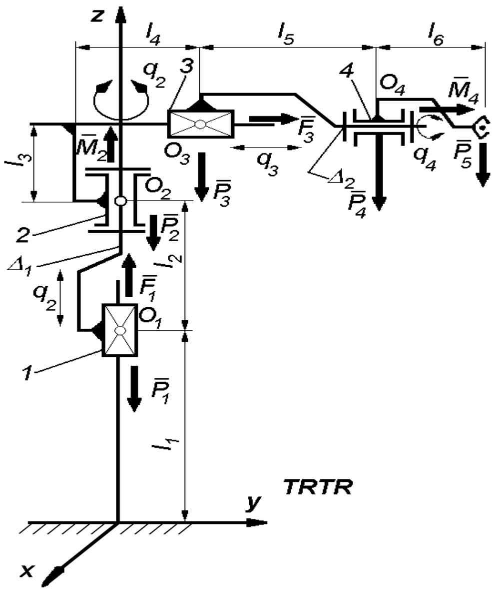

Fig. 3: Kinematic structure TRTR of the Robot MA-221

The reduced mass can be expressed as: $\frac{M_{red}}{2}\dot{z}^2 = \frac{J}{2}\cdot\dot{q}_2^2$, $\dot{z} = R_{p3}\cdot\dot{q}_2$ (2)

As in the above relations, the reduced mass is:

$$M_{red} = \frac{J_{\Delta 1}^{(2)} + J_{031}^{(3)} + J_{041}^{(4,5)} + m_3(l_4 + q_3)^2 + (m_4 + m_5)(l_4 + l_5 + q_3)^2}{R_{p3}^2} \tag{3}$$

The values of the physical parameters of the system are:

$$\frac{z_1}{z_2} = 1;\ \frac{z_3}{z_4} = 2;\ p_M = 0{,}31\,cm;\ A_Q = 10^4\,\frac{cm^2}{s};\ 2A = 38{,}49\,cm;\ \frac{4A\cdot L}{E_u} = 0{,}010\,\frac{cm^5}{daN};\ K_1 = 1{,}4\,\frac{cm^5}{daNs};$$

$$M_{red} = 0{,}78\,\frac{daNs^2}{cm};\ f = 0{,}7\frac{daNs}{cm};\ \frac{1}{R_{p3}} = 0{,}166\ \ cm^{-1};\ E_u = 15000\,\frac{daN}{cm^2};\ \rho = 0{,}86\cdot 10^{-6}\,\frac{daNs^2}{cm^4};$$

The transfer function of the open circuit in this case is:

$$T_D(s) = \frac{12609{,}06\cdot Z_{RM}}{0{,}0078s^3 + 2{,}347s^2 + 2965{,}06s} \tag{4}$$

With these values, the transfer function of the closed system becomes:

$$T_0(s) = \frac{51460}{0{,}0078s^3 + 2{,}347s^2 + 2965{,}06s + 12609{,}5\cdot Z_{RM}}$$

2. Stability analysis of electro-hydraulic servo-system

We will study the step response and the bode diagram of the closed and open system, using ZRM as a parameter. First, there was considered a variation range between ZRM = 26-71 teeth. The analysis results of the servo-system for this variation area (Z_{RM}=26-71 teeth) is presented in the figures 4 a, b, c, d, e, f, [2], [4].

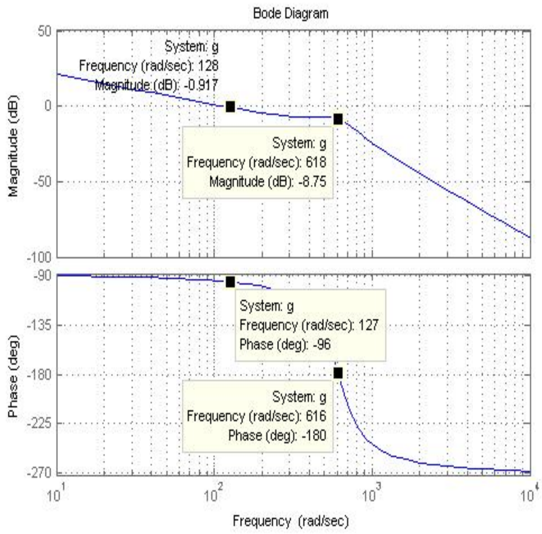

Fig. 4 a

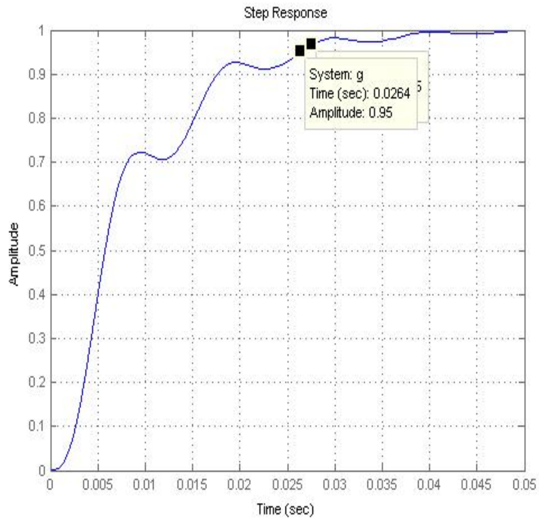

Fig. 4 b

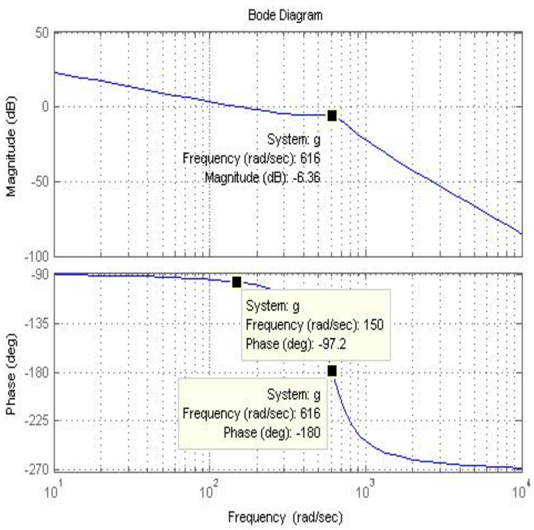

Fig. 4 c

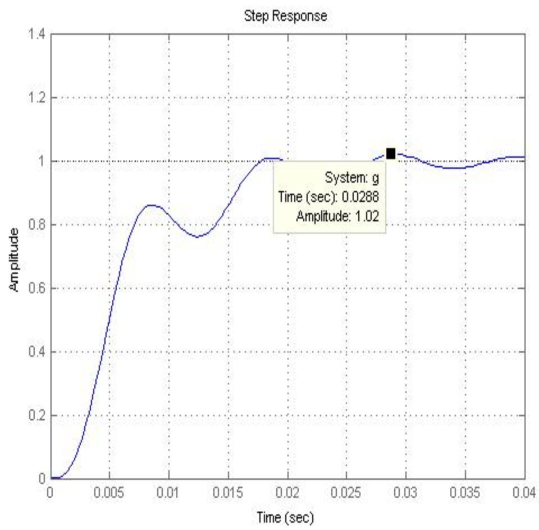

Fig. 4 d

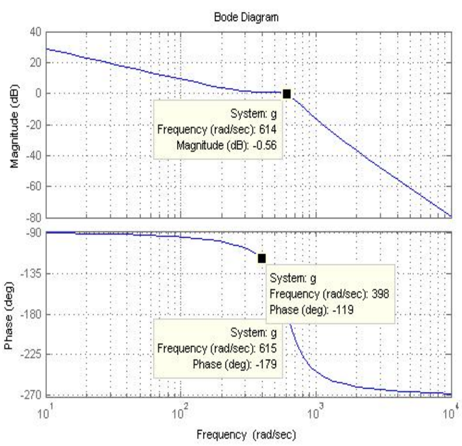

Fig. 4 e

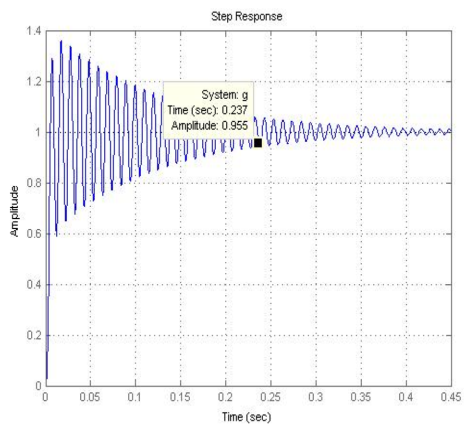

Fig. 4 f

3. Conclusion

The analysis of Figure 4 (a, b, c, d, e, f,) is found that, for this variation of ZRM = 6-71 teeth, the system has a good behavior up to 71 teeth. The more the numbers of teeth decreased to 26 teeth grow system behavior. The two analysis methods give us different information, such BODE diagram gives us information the winning side (MC) and the edge of the stage and step response provides information about the time of stabilization and override. As shown, only 71 teeth = ZRM system become unstable, but drops to 26 teeth how ZRM the servo-system becoming more efficient in terms of good dynamic. Performance are obtained for ZRM=26-66 teeth. For safety restrict the variation in ZRM =26-34 teeth. As we can see in figure 4, ZRM values situated near the lower limit of the studied area, correspond for using the rotation module in the construction of the industrial robots.

Further there was analyzed the response of the closed system for a more narrow area of variation (ZRM = 26-34 teeth) area in which there is no override response, or, the override has very small values. The simulated response for this area is shown in figure 6. We can notice in the figure that any value of ZRM from this area is the good. For very precise systems, where the override is forbidden, the optimum value of ZRM is 26 teeth, which represents the lower value from the area.

For applications in which certain value's of the override is permitted, the dynamic of the system is better, especially in terms of growth time. In this case the system is significantly faster.

The response of the system for Z_{RM} = 26 teeth is presented in figure 4.b. in which we cans notice that there is no override and the time of growth is nearly 28 ms. For confirming the stability of the system we will also study Bode diagram of the open circuit for the case Z_{RM} = 26 teeth. From the figure we can notice that also the mode book and the phase book are positive (8,7 dB and 52^0). This confirms the stability of the system for this value of the studied parameter.

4. References

[1] Bârsan, I., Researches Regarding the Use of Electro-Hydraulic Servo-Systems at Machine-Tools and Industrial Robots, *doctoral thesis*, „Politehnica" University of Bucureşti, 1993.

[2] Bârsan, I., Breaz, R.E., Researches Regarding the Synthesis of the Rotational Module from the MA-221 Robot Structure, *Proceedings of the Fifth International Conference on Hydraulic Machinery and Hydrodynamics,* ISSN 1224-6077, p. 17-24, Timişoara, 2000.

[3] Bârsan, I., Breaz, R. Automatic Hydraulic Systems Engineering, *Editura Universității „Lucian Blaga"*, Sibiu, 2003.

[4] Bârsan, I., Popp, I.O., Research regarding functional stabilisation of electro-hydraulic servo-systems, *Proceedings of International Conference on Manufacturing Systems, ICMAS*, Bucureşti, 2008.