International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 3 Issue 5, August 2019 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Control Synthesis of Electro-Hydraulic Drive Based on the Concept of Inverse Dynamics Problems

Soe Nay Lynn Aung[1], Akimenko D. A[2]

[1]Mandalay Technological University, Mandalay, Myanmar
[2]Bauman Moscow State Technical University, Kaluga Branch, Moscow, Russia

How to cite this paper: Soe Nay Lynn Aung | Akimenko D. A "Control Synthesis of Electro-Hydraulic Drive Based on the Concept of Inverse Dynamics Problems" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-3 | Issue-5, August 2019, pp.1768-1770, **https://doi.org/10.31142/ijtsrd27823**

IJTSRD27823

ABSTRACT

Electro-hydraulic drives are widely used in various branches of technology due to a number of its advantages, which include significant specific power (the ratio of power developed by the drive to its mass), high speed and the ability to position the output link with a sufficient degree of accuracy. However, hydraulic drives are non-linear objects, which makes it difficult to synthesize drive control, which provides the required dynamic characteristics. This paper presents an approach to solving the problem of constructing a control algorithm based on the concept of inverse problems of dynamics by an electro-hydraulic drive, consisting structurally of an electro-hydraulic amplifier and an executive hydraulic cylinder.

KEYWORDS: *Electro-hydraulic drive (EHD), mathematical model, dynamics, synthesis, closed-loop control, simulation*

I. INTRODUCTION

In various fields of technology, due to its advantages, electro-hydraulic drive (EHD), which refers to non-linear objects, is widely used [4]. Therefore, the actual task is to synthesize the control of such objects, providing the desired dynamic properties [5]. The solution of this problem based on the concept of inverse dynamics problems is considered below.

II. Mathematical Model

The mathematical model of the electro-hydraulic drive is represented by a system of equations

$$\begin{cases} x(t) = K_{eha}u(t); \\ |x(t)| \le x_{\max}; \\ \dot{p}(t) = \dfrac{2E}{V}\left[K_s x(t)\sqrt{\dfrac{1}{2}\left(p_d - p_{dr} - p(t)sign(x(t))\right)} - A_{hc}\dot{y}(t)\right]; \\ |p(t)| \le p_d - p_{dr}; \\ \ddot{y}(t) = \dfrac{1}{m_{hc}}\left[A_{hc}p(t) - F_l(t) - K_{hc}^{vf}\dot{y}(t) - C_{hc}y(t) - K_{hc}^{df}\,\mathrm{sign}(\dot{y}(t))\right]; \\ -l_0 + y_0 \le y(t) \le l_0 + y_0. \end{cases}$$

Here is $u(t)$ - voltage applied to EHD input; $x(t)$ - size of the opening of spool valve windows; $p(t)$ - differential pressure on the piston of the hydraulic cylinder; $y(t)$ - movement of the rod of the hydraulic cylinder; $F_l(t)$ - external load; K_{eha} - transmission coefficient of the electro-hydraulic amplifier; $x_{\max}$ - maximum opening of spool valve windows; E - modulus of elasticity of the working fluid; V - volume of hydraulic cylinder cavities including pipelines; K_s - coefficient of conductivity of spool valve; p_d - pressure of working fluid in the discharge line; p_{dr} - pressure in the drain line; A_{hc} - area of the working surface of the piston; m_{hc} - mass of the moving parts of the hydraulic cylinder; K_{hc}^{vf} - coefficient of viscous friction in the hydraulic cylinder; K_{hc}^{df} - coefficient of dry friction in the hydraulic cylinder; C_{hc} - stiffness ratio of the position load; l_0 - neutral piston position; y_0 - piston displacement from neutral position.

III. Problem

The problem is formulated as follows. It is necessary to synthesize a control that transfers the considered object from a certain initial state $y(0)$ to a given final state $y(\infty) = y^0 = \text{const}$, while the controlled process with the required accuracy must follow the reference process. The reference process is given by the differential equation

$$\frac{d^4}{dt^4}y_{ref}(t) + a_3\frac{d^3}{dt^3}y_{ref}(t) + a_2\frac{d^2}{dt^2}y_{ref}(t) + \\ + a_1\frac{d}{dt}y_{ref}(t) + a_0 y_{ref}(t) = a_0 y(t),$$

the numerical values of the parameters of which are determined from the condition of correspondence of the dynamics of the designed object to the requirements of the technical specifications.

To solve this problem, we use the concept of inverse problems of dynamics [1, 2, 3]. Assuming that dry friction is absent, there is no external load, and the drive operates under conditions under which the constraints are satisfied, the EHP model can be represented by the equation

$$\ddot{y}(t,U) = f(u,y,\dot{y},\ddot{y}),$$

Where

$$f(u,y,\dot{y},\ddot{y}) = \frac{1}{Vm_{hc}}\Big[-K_{hc}^{vf}V\ddot{y}(t) - \left(2A_{hc}^2E + C_{hc}V\right)\dot{y}(t) + 2A_{hc}EK_sK_{eha}u(t)\times$$

$$\times\sqrt{\frac{1}{2}\left(p_d - p_{dr} - \frac{1}{A_{hc}}\left\{m_{hc}\ddot{y}(t) + K_{hc}^{vf}\dot{y}(t) + C_{hc}y(t)\right\}\operatorname{sign}(u(t))\right)}\Big]$$

The degree of proximity of the EHD processes and the reference model is determined by the functional

$$J(u) = \frac{1}{2}\left[\ddot{y}_{ref}(t) - \ddot{y}(t,u)\right]^2.$$

Control is determined by the differential ratio:

$$\frac{d}{dt}u(t) = \lambda\frac{d}{du}J(u) = -\lambda\left(\ddot{y}_{ref}(t) - \ddot{y}(t,u)\right)\frac{\partial}{\partial u}f(u,y,\dot{y},\ddot{y}),$$

$\lambda = \text{const}$.

Denoted $K_u = -\lambda\left(\frac{\partial}{\partial u}f(u,y,\dot{y},\ddot{y})\right)_0$,

where $\left(\frac{\partial}{\partial u}f(u,y,\dot{y},\ddot{y})\right)_0$ corresponds to the state point y^0, and find the control law in differential form

$$\frac{d}{dt}u(t) = K_u\left(\ddot{y}_{ref}(t) - \ddot{y}(t)\right),$$

where the value $\ddot{y}_{ref}(t)$ is determined from the relation

$$\ddot{y}_{ref}(t) = a_0\int_0^t\left(y^0 - y(t)\right)dt - a_1y(t) - a_2\dot{y}(t) - a_3\ddot{y}(t).$$

Integrating, obtain in the final form the equations of the control algorithm

$$u(t) = K_u\left(\dot{y}_{ref}(t) - \dot{y}(t)\right),$$

$$\dot{y}_{ref}(t) = \int_0^t\left[a_0\int_0^t\left(y^0 - y(t)\right)dt - a_1y(t)\right]dt - a_2y(t) - a_3\dot{y}(t).$$

Figure1 shows the block diagram of the EHD control

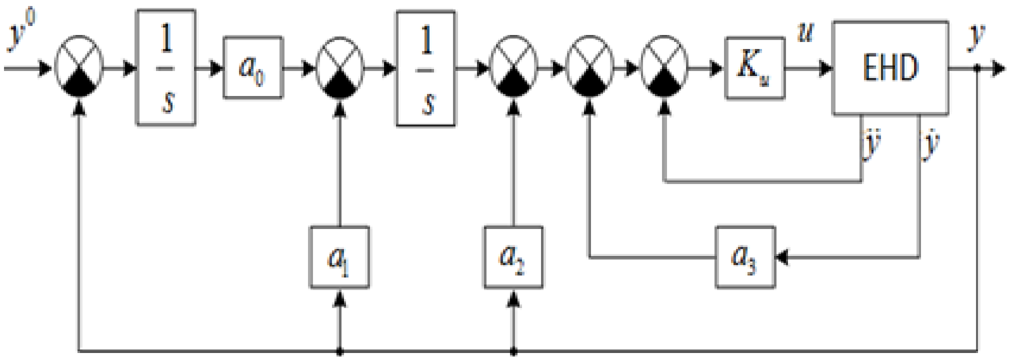
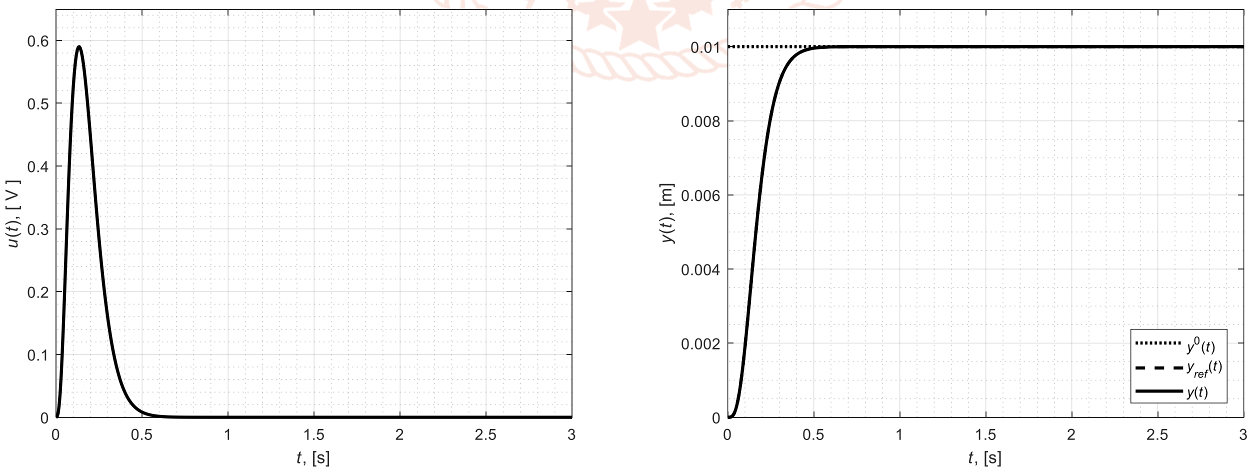


Figure1. Block diagram of a closed system

Figure 2 presents the simulation results for a constructed closed-loop control system for EHD.



(a) (b)

Figure2. The simulation results: (a) graph of the control voltage of the EHD; (b) graphs of the output signal

IV. Conclusion

Thus, the above approach to constructing the control of an electro-hydraulic drive, based on the concept of inverse problems of dynamics, allows to build a closed drive control system that provides dynamic characteristics of the drive, close to a given reference. Two approaches are considered in the construction of control algorithm. The first is based on minimizing the functional that determines the error between the real movement of the rod and the given reference, according to the gradient scheme of the first order. As a result, the control is constructed, for the formation of which information on the current position of the rod, its speed and acceleration are necessary, which causes some difficulties in the implementation of the obtained algorithm.

Acknowledgment
The author would like to thank all the teachers from the Department of Electronics, Informatics and Control Systems, Bauman Moscow State Technical University (Kaluga Branch) and the Department of Electronics Engineering, Mandalay Technological University (MTU). And I also would like to thank supervisor Akimenko D.A., my family and my friends who have helped me during this research.

REFERENCES

[1] Krutko P. D. Inverse problems of dynamics in the theory of automatic control. M.: Mechanical Engineering, 2004. - 576 p

[2] Krutko P. D. Inverse problems of the dynamics of controlled systems: linear models. M.: Science. The main edition of the physico-mathematical literature, 1987. - 304 p.

[3] Krutko P. D. Inverse problems of the dynamics of controlled systems: nonlinear models. M.: Science. Ch. ed. physical mat. lit., 1988. - 328 p.

[4] Krymov B. G., Rabinovich L. V., Stebletsov V. G. Actuators of aircraft control systems. M.: Mechanical Engineering, 1987. - 264 p.

[5] Popov D. N. Dynamics and regulation of hydraulic and pneumatic systems. M.: Mechanical Engineering, 1976. - 424 p.