UDC 621.22

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STABILITY OF THE HYDRAULIC DRIVE BASED ON A VARIABLE DISPLACEMENT PUMP WITH AN ELECTRO-HYDRAULIC REGULATOR

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Abstract
The simulation was carried out using the MATLAB software application in the Simulink environment. Based on the analysis of transient processes, the influence of system parameters on stability is investigated. The results make it possible to determine the conditions for ensuring stable and efficient operation of the hydraulic drive.
Keywords*:* hydraulic drive, system stability, MATLAB Simulink, modeling, transients.

Introduction

In modern logistics and industrial processes, special attention is paid to automating and optimizing operations related to the transportation and unloading of goods. One of the most important tools in this area is a truck unloader - a specialized equipment designed to quickly, safely and efficiently unload bulk materials or other products from vehicles. Its use can significantly reduce time and physical labor costs, increase productivity and ensure accurate dosing of unloaded materials [1].

Hydraulic drives of truck unloaders are equipped with unregulated pumps and have significant drawbacks, such as low energy efficiency due to the constant operation of the pump at maximum capacity and limited control capabilities due to the inability to smoothly adjust the speed of the actuators, which makes it difficult to accurately control the unloading process. Switching to adjustable hydraulic drives with proportional equipment can significantly reduce energy consumption, improve control accuracy and extend equipment life [2].

In the development and implementation of new types of hydraulic drives, a significant place is occupied by the study of hydraulic systems for stability, since the stability of a hydraulic system is a critical parameter that determines its ability to maintain performance under changing loads. Under dynamic operation, hydraulic drive equipment must provide stable and predictable operation without self-excitation, oscillations or loss of control [3, 4]. Thanks to modern modeling and analysis methods, it is possible to identify potentially unstable modes at the design stage, which significantly reduces risks and maintenance costs in the future [5, 6].

The purpose of the study is to determine the conditions of stability and operating characteristics of the hydraulic drive, taking into account the influence of various control and load parameters to ensure reliable, accurate and stable operation of the system.

Research results

An experimental stand has been created at Vinnytsia National Technical University to study the operation of hydraulic drives with modern hydraulic equipment and test it in various operating modes.

In this work, we studied the stability of the hydraulic drive by simulating a mathematical model [7] in the specialized MATLAB Simulink software environment. In the course of the study, the following parameters were changed in the appropriate ranges:

- area f_0 of the throttle f_0=4…6,4·10^{-6} m^2;
- area f_x of the throttle f_x=2…3,0·10^{-6} m^2;
- area f_e of the throttle f_e=0,7…1,0·10^{-6} m^2;
- gain k_x of the servo valve operating window k_x=3…7;

- gain k_z of the spool valve working window k_z=4…10;
- coefficient of viscous friction b_x of the servo valve b_x=10…15 kg/s;
- coefficient of viscous friction b_z of the spool valve b_z=1…5 kg/s;
- load value F_v, acting on the hydraulic cylinder F_v=1000…16000 N·m;
- area f_{th} of the throttle f_{th}=10…20·10^{-6} m^2.

As a result of the conducted research, the dependences of the pump flow rate Q_n on the pressure P_c were obtained, and the magnitude of the influence of each of the studied parameters on the stability of the hydraulic drive is given below in Table 1.

Table 1 - The magnitude of the influence of system parameters on the stability of the hydraulic drive

Parameter	Does not affect	Not significantly affected	Significant impact
f_0			+
f_x		+	
f_e			+
K_x	+		
K_z		+	
b_x	+		
b_z		+	

Conclusions

As a result of the study, the conditions of stability and the nature of the system's response to changes in the control signal and load were determined, and the following recommendations were formulated regarding the choice of hydraulic drive parameters and the magnitude of their impact on the system operation:

- area f_0 of the throttle and area f_e of the throttle have a significant impact on the stability of the hydraulic drive;
- area f_x of the throttle, gain k_z of the spool valve working window and coefficient of viscous friction b_z of the spool valve do not significantly affect the stability of the hydraulic drive;
- gain k_x of the servo valve operating window and coefficient of viscous friction b_x of the servo valve do not affect the stability of the hydraulic drive;
- when designing a hydraulic drive, the values of the parameters f_0 and f_e should be selected in the ranges f_0=4…4,5·10^{-6} m^2 and f_e=0,7…0,8·10^{-6} m^2 to ensure the highest stability index with optimal energy efficiency values during typical operating conditions.

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СТІЙКІСТЬ ГІДРОПРИВОДА НА ОСНОВІ НАСОСА ЗМІННОЇ ПРОДУКТИВНОСТІ З ЕЛЕКТРОГІДРАВЛІЧНИМ РЕГУЛЯТОРОМ

Анотація

Моделювання проводилося з використанням програмного пакету MATLAB у середовищі Simulink. На основі аналізу перехідних процесів досліджено вплив параметрів системи на стійкість. Отримані результати дають змогу визначити умови забезпечення стійкої та ефективної роботи гідропривода.

Ключові слова: гідропривід, стійкість системи, MATLAB Simulink, моделювання, перехідні процеси.

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