MECHATRONIC SYSTEM USED FOR FLOW CONTROLLING OF HYDRAULIC PUMPS WITH AXIAL PISTONS

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Lucrarea isi propune sa scoata in evidenta performantele tehnice importante ale sistemului mecatronic proiectat in scopul reglarii debitului la pompele hidraulice cu pistonase axiale. Metoda de reglare este continua si se refera in principal la un sistem de pozitionare in circuit inchis, de precizie ridicata. Prin rezolvarea modelului matematic al intregului sistem, in conditii dinamice, am obtinut o deplasare teoretica a pistonului, care se incadreaza in gama de valori acceptata. Aceasta poate fi o metoda de imbunatatire a randamentului pompei hidraulice cu pistonase axiale si a sistemului actionat in acelasi timp.

The paper aims to emphasize the main technical performances of the mechatronic system designed in order to control the flow of hydraulic pump with axial pistons. The control method is a continuous one and refers to a very accurate positioning system with mechanical feed-back. By solving the mathematical model of the entire system with dynamic conditions, we have concluded that the theoretical piston displacement is inside an acceptable range. This could be a method for improving the efficiency of the hydraulic pump and of the actuated system too.

Keywords: Control system design, Feed-back systems, Electro-hydraulic systems

1. Introduction

Since the development of control technique was pointed out, more applications for hydraulic systems were found, due to the possibilities of adding to them the accurate positioning. In such a way, the values of increasing actuation forces were considered nearby the main features regarding the kinematical parameters. Even more, they may provide the continue control of these parameters by using the adequate electronics and software.

Taking into account the theoretical equations for the hydraulic pump/motor flow, we assume that if the rotational speed of the electric motor is constant, a variable geometric volume will provide a variable flow. Variable flow

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2. Technical Approach

The main components of the technical solution of the proposed system are described in Fig. 1 and it could be applied for axial pistons hydraulic pumps. It includes the electric stepping motor 1, the hydraulic distributor 2 and the subassembly for mechanical feed-back 3 joined together with the piston of the hydraulic cylinder 4. The piston is fastened with the steel part 5, whose linear movement outside the cylinder brings about the oscillatory movement of the block with axial pistons of the pump, which is not shown in the picture.

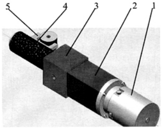

Fig. 1. The main components of the technical solution.

The cylinder piston CH (Fig. 2.) has an active surface on its left side and a very well known pressure value is acting on permanently.

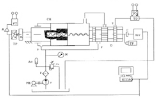

Fig. 2. The schematic of the proposed mechatronic system

In order to compute the pressure variation from the aspiration phase to repression we may use the following mathematical equation:

$$\frac{dp}{dt} = E \cdot \frac{v(t) \cdot A_p - \alpha_D \cdot A_r \cdot \sqrt{\frac{2}{\varphi} \cdot \Delta p} - Q_p}{V_0 + s(t) \cdot A_p} \tag{3}$$

where: E [N/m^2]-the elasticity modulus of the hydraulic oil; v(t) [m/s] and s(t) [m] are the speed and displacement of the piston as time function; A_p [m^2] the piston area; φ [kg/m^3] the oil density; Δp [N/m^2] the pressure variation; Q_p [l/s] the flow loss; V_o [m^3] is the initial volume inside the hydraulic cylinder of the block. This pressure variation will cause the pressure force as the main resistant force of the system.

The dynamic working process of the system is described by a mathematical model comprising seven first order differential equations grouped in a mathematical system, which may be solved with Runge-Kutta numerical method.

This mathematical model [3] is written below taking into account the mathematical model of the electrical stepping motor, the dynamic movement equation for the mobile subassembly (comprising the rod of the electric motor, the coupling subassembly and the screw as part of the feed-back system) and the equation describing the flow continuity (Spanu, 1999):

$$\begin{bmatrix} \frac{di_a}{dt} \\ \frac{di_b}{dt} \end{bmatrix} = \begin{bmatrix} L_{aa} & L_{ab} \\ L_{ab} & L_{bb} \end{bmatrix}^{-1} \cdot \begin{bmatrix} U_a - R \cdot I_a \\ U_b - R \cdot I_b \end{bmatrix} - \begin{bmatrix} L_{aa} & L_{ab} \\ L_{ab} & L_{bb} \end{bmatrix}^{-1} \cdot \begin{bmatrix} \frac{\partial L_{aa}}{\partial \theta_m} & \frac{\partial L_{ab}}{\partial \theta_m} \\ \frac{\partial L_{ab}}{\partial \theta_m} & \frac{\partial L_{bb}}{\partial \theta_m} \end{bmatrix} \cdot \begin{bmatrix} i_a \\ i_b \end{bmatrix} \cdot \frac{\partial \theta_m}{\partial t} \cdot \tag{4}$$

$$\frac{d\omega}{dt} = \frac{1}{2 \cdot J_r} \cdot (i_a{}^2 \cdot \frac{\partial L_{aa}}{\partial \theta_m} + i_b{}^2 \cdot \frac{\partial L_{bb}}{\partial \theta_m}) + i_a \cdot i_b \cdot \frac{\partial L_{ab}}{\partial \theta_m} \cdot \frac{1}{J_r} - - \frac{M_r}{J_r} - \frac{D_r}{J_r} \cdot \frac{d\theta_m}{dt} \tag{5}$$

$$\frac{d\theta_m}{dt} = \omega \tag{6}$$

$$\frac{dy}{dt} = v_p \tag{7}$$

motors and for other positioning systems with high accuracy too. It is a mechatronic solution for controlling the efficiency of hydraulic pumps, motors and systems.

In order to compute the dynamic mathematical model of this controller, the resistant pressure force is the main perturbation, which has to be very well completed. We have concluded its variation during the piston pump passing in front of the block distributor slit.

The dynamic mathematical model implying the electrical stepper motor, the distributor and the cylinder with its screw-nut mechanism reveals the technical parameters for the movement of the cylinder piston. Due to the very short period of time required for this displacement, the dynamic stability of the entire system has to be study as future work.

As future improvements, the brushless electric motor is the best way for accomplishing the functional requirements, because of its higher torque and command frequency, but the effective cost of the components is higher.

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