GENERAL ANALYSIS OF SCHEME FOR ELECTROHYDRAULIC POSITIONING ACTUATORS

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Abstract
Based on the analysis of known electrohydraulic positioning actuators, a generalized scheme for them is presented. The scheme includes the main parts of the control unit, the flow control module, the working fluid source and the executive mechanism. Depending on the operating principle of flow control module, the scheme has closed or open configuration. The main difference between electrohydraulic positioning actuators is the operating principle of flow control module. Each of the known flow control modules is proposed to be classified into one of the following four types: module based on value control of analog signals; module based on opening time control of discrete component; module based on direct control of the position of executive mechanism; module based on volume control of executive mechanism. The presented analysis can be used in the development of new schemes.

Keywords: electrohydraulic positioning actuator, generalized scheme, flow control module, positioning principle.

INTRODUCTION

Electrohydraulic positioning actuators are important components in the drive systems of modern machines. Different types of electrohydraulic positioning actuators are widely used in machines for various purposes, such as construction, road, agricultural machines etc.

In order to gain a comprehensive understanding of electrohydraulic positioning actuators and to provide useful assistance for its future development, a large number of known actuator schemes are analyzed. On this basis, a generalized scheme of electrohydraulic positioning actuators is presented, and the flow control module, which is the biggest difference between electrohydraulic positioning actuators, is specifically analyzed.

EXPOSITION

1 GENERALIZED SCHEME OF ELECTROHYDRAULIC POSITIONING ACTUATORS

Analysis of schemes of many known electrohydraulic positioning actuators showed that the generalized structure of electrohydraulic positioning actuators can be represented by the following scheme（**Fig. 1**）.

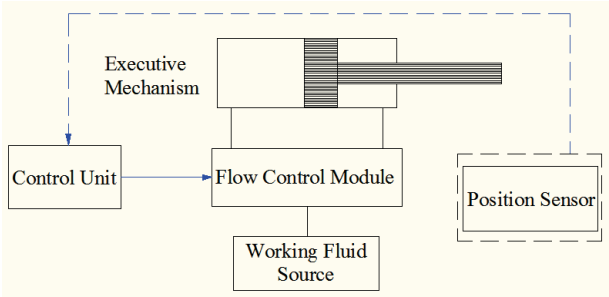

Fig. 1. *Generalized scheme of electrohydraulic positioning actuators*

According to the scheme (Fig. 1), the control unit sends signal to the flow control module based on the information of given position of the rod of executive mechanism. The flow control module determines the flow into the executive mechanism, and the flow determines the movement speed of the rod.

The displacement of the rod is controlled by position sensor. Information about the current position of the rod is transmitted to the control unit, which corrects the signal to the flow control module. When the rod reaches the given position, the flow control module pauses to provide flow to the executive mechanism. Eventually the rod stops at the given position.

The main difference between known electrohydraulic positioning actuators is the

principle of flow control. The necessity of the position sensor also depends on the applied flow control principle.

2 THE FLOW CONTROL MODULE TYPES

According to the analysis of the known flow control scheme in the indicated actuators, four basic control principles can be determined. Based on these basic control principles, four corresponding types of modules are constructed: value control of analog signals; opening time control of discrete component; direct control of the position of executive mechanism; volume control of executive mechanism.

2.1 Module based on value control of analog signals

In this type of flow control module, proportional or servo valve is usually required. Actuators [1],[2] are typical representatives of using this type of module. The scheme of such electrohydraulic positioning actuator (**Fig. 2**) consists of control unit, flow control module (proportional or servo valve), executive mechanism (hydraulic cylinder) and position sensor.

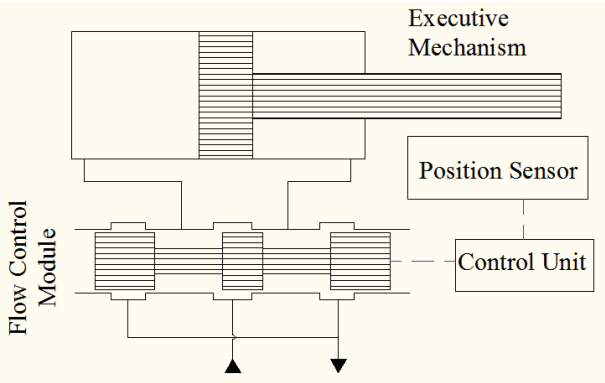

Fig. 2. *The scheme of positioning actuator based on value control of analog signals*

The working principle of the actuator is that the control unit controls the supply of working fluid by setting the value of the opening of the valve's working window, so that the cylinder's rod is driven to move. Meanwhile, the signals from the position sensor are returned to the control unit, where these signals are analyzed. When the rod reaches the desired position, decision signal made by the control unit is sent to close the working window, thus positioning function is implemented.

In order to ensure the positioning function, such actuators must have a closed-loop control system, so feedback is essential. Position sensors are normally used in such actuators.

2.2 Module based on opening time control of discrete component

This type of flow control module consists of discrete components. The scheme of actuator [3] shows this type of flow control module. The scheme of actuator (**Fig. 3**) consists of control unit, flow control module (discrete components), executive mechanism (hydraulic cylinder) and position sensor.

The working principle of the actuator is that the control unit uses the discrete signals to set the opening time of the same area window of the discrete components, thereby causing a certain amount of fluid to pass through to drive the cylinder's rod to move. Each tiny liquid part leads to a certain displacement of the rod, so the positioning function can be implemented.

Since the discrete components can work at relatively high frequencies, the rod can still achieve an appropriate speed even though the liquid part is very small.

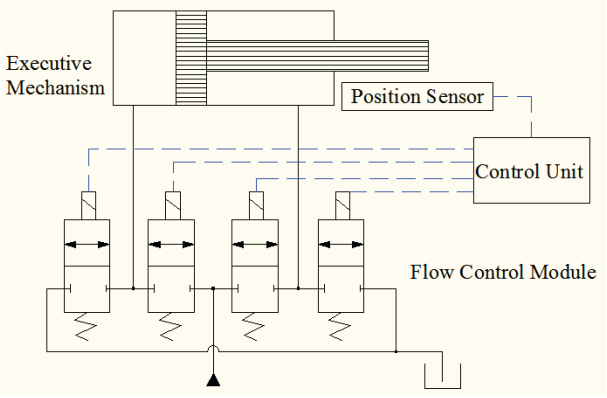

Fig. 3. *The scheme of positioning actuator based on opening time control of discrete component*

Under stable condition the displacement of the rod with given discreteness allows precise control and the position sensor is sometimes not required. But under unstable condition the close-loop control system with feedback is necessary.

2.3 Module based on direct control of the position of executive mechanism

This type of flow control module requires the coordinated cooperation of switching valves and throttles that are made up of the windows in

executive mechanism and the piston's edges. In actuators [4], [5] this type of flow control module are used. The scheme (**Fig. 4**) of such actuator consists of control unit, flow control module (switching valves) and executive mechanism with windows.

The working principle of the actuator is that the signal from the control unit controls the corresponding switching valve according to the required movement direction of the rod. The switching valve is opened and connected to the chamber of executive mechanism with tank. As a consequence, the rod with piston moves to the position corresponding to the window in the executive mechanism. The switching valve cooperates with the window to disconnect the flow through this window, and this causes the rod to stop in the planned position. Therefore, the positioning function is achieved directly by switching valves that cooperate with windows of executive mechanism.

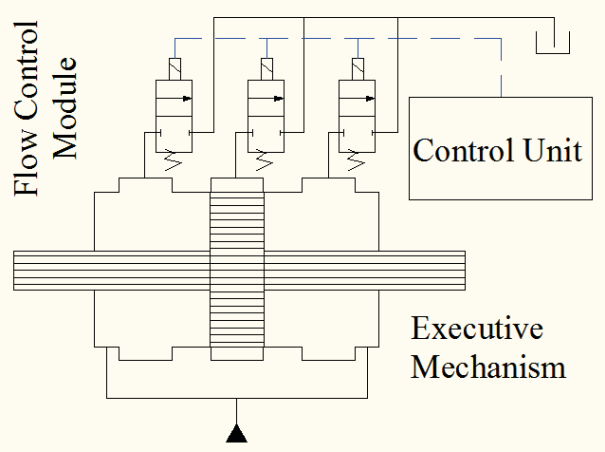

Fig. 4. *The scheme of positioning actuator based on direct control of the position of executive mechanism*

This type of actuator does not require position sensor, but the number of possible positions is limited.

2.4 Module based on volume control of executive mechanism

This type of flow control module requires the coordinated cooperation of valves and executive mechanism with multiple chambers. The executive mechanism of actuator with such flow control module have different configurations: multi-chamber built into cylinder (**Fig. 5**.a) [6], or a set of external chambers with different volumes (**Fig. 5**.b) [7]. The scheme consists of control unit, flow control module (valves, chambers with different volumes) and executive mechanism.

The working principle of the actuator (**Fig. 5**. a,b) is that the signal from the control unit controls the valve, which supplies fluid to the corresponding chamber with a certain volume. This drive rod moves to the stopper, which limits the volume of the chamber (**Fig. 5**.a), or drive rod moves to the position corresponding to the volume of the attached chamber (**Fig. 5**.b). The positioning function is achieved by supplying fluid to one or several chambers simultaneously. This causes the rod to move to a given position determined by the volume of a single chamber or combination of several chambers.

The actuator with such module type does not require closed-loop control system, but it has a limited number of positions.

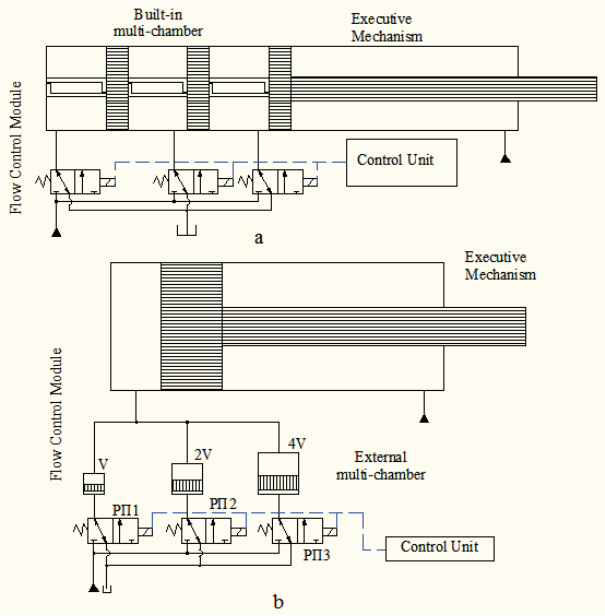

Fig. 5. *The scheme of positioning actuator based on volume control of executive mechanism. a—Built-in multi-chamber configuration; b—External multi-chamber configuration*

Therefore, the analysis of the known scheme of electrohydraulic positioning actuator allowed to generalize the idea of this type of actuator, and to determine the basic principles of flow control and the type of modules based on these principles. This can be very useful in the development of new promising schemes.

CONCLUSIONS

1. Analysis of the schemes of known electrohydraulic positioning actuators allowed to

build a generalized scheme of such actuators. And the generalized scheme can be divided into these parts: the control unit, the flow control module, the working fluid source and the executive mechanism. Depending on the working principle of the flow control module, the scheme has closed or open configuration.

2. It has been found out that the main difference in schemes of electrohydraulic positioning actuators is principles of flow control module, which can be classified into four types: module based on value control of analog signals; module based on opening time control of discrete component; module based on direct control of the position of executive mechanism; module based on volume control of executive mechanism.

REFERENCE

[1] Detiček, E., & Župerl, U. (2011).An Intelligent Electro-Hydraulic Servo Drive Positioning. Strojniški vestnik - *Journal of Mechanical Engineering*, 57(5), 394-404. doi: http://dx.doi.org/10.5545/sv-jme.2010.081

[2] Dindorf, R., & Wos, P. (2019, May). Force and position control of the integrated electro-hydraulic servo-drive. In *2019 20th International Carpathian Control Conference (ICCC)* (pp. 1-6). IEEE.

[3] Šimic, I. M., & Herakovič, I. N. (2016). High-response hydraulic linear drive with integrated motion sensor and digital valve control.

[4] Dindorf, R., & Woś, P. (2018). Sensorless step positioning of hydraulic linear actuator. *Czasopismo Techniczne*, 2018(Volume 11), 169-174.

[5] Yaqin, Z. (2011, August). Study on a new adjustable hydraulic positioning system. In 2011 International Conference on Mechatronic Science, Electric Engineering and Computer (MEC) (pp. 519-523). IEEE.

[6] Patent of Ukraine № 90383 IPC F15B7 / 00. Multi-position drive. / Novik MA, Kucheruk Yu. M., Dorogan VV, applicant and patent owner of NTUU "KPI" № a20081063 - application. 04.08.2008; publ. 10.02.2010 - Bull. № 8.

[7] Patent of Ukraine № 63275 IPC (2011.01) F15B7 / 00. Multi-position drive. / Novik MA, Didovets VE, applicant and patent owner Novik MA, Didovets VE № U201100846 - application. 25.01.2011; publ. 10.10.2011 - Bull. № 19.