RESEARCH IN INCREASING PERFORMANCE OF HIGH HYDRAULIC POWER SYSTEMS

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Abstract. The purpose of the work – to find out the features of throttle adjustment of the speed of movement of the piston of the hydraulic system of big capacity. The experimental research has been carried out with the above described device. In the hydraulic cylinder design changes have been executed, the sizes and throttle place by means of the theoretical throttle characteristic $A_{DR} = f(h)$ are changed. For reduction of the turn time of the working platform it was necessary to increase pressure in the hydraulic systems from 60 to 70 bar. Pressure increase has allowed the piston to increase the speed of movement. The time of turn of the working platform has decreased till 1.31 seconds. The piston pressure in the braking chamber is equal in the last phase of work to 48 bar, it tells about prevention of blowing the piston about the hydraulic cylinder.

Keywords: hydraulic system, hydraulic motor, pump, operating liquid.

Introduction

One of the most important regulative parameters of hydraulic actuating devices is their speed. As the theory of hydraulic gears states, the speed of hydraulic motors depends on the supplied flow when the working capacity of the motor is stable. The speed of the hydraulic cylinder plunger is directly proportional to the flow and inversely proportional to the area: $v=Q/A$. This shows that in all cases the speed of the actuating device may be controlled by changing the supplied liquid flow Q [4]. When a hydraulic system is composed of hydraulic machines of stable working capacity, the speed of the hydraulic actuating device may be regulated by directing a part of liquid to the tank through the pressure valve. Since during the regulation of the throttle speed significant power losses emerge (coefficient of efficiency is less than 0.30), throttle speed regulating should only be used for low-power hydraulic systems [1; 2]. However, some exceptions are possible when significant power losses are allowed because of the simplified control of the hydraulic system and lower price of the device.

The purpose of the research is to analyse the possibilities of throttle speed regulation of the high-power hydraulic system cylinder plunger in order to reduce the workbench turn duration and increase the performance of the device. The working cycle of the analysed device, which takes 13.20 s, includes the workbench turn and technological process when the workbench is in a fixed position. During the optimisation of speed regulation characteristics of the hydraulic cylinder, the possibilities of increasing the device performance should be assessed. The paper analyses an exceptional case: the use of a high-power device with a hydraulic gear when the speed of the actuating device is throttle-controlled.

Research tasks

1. To develop research methodology.
2. To develop the throttle characteristic $A_{DR} = f(h)$, which would enable reducing the duration of the workbench turn by maintaining its smooth stopping.
3. To perform the tests of the hydraulic system by regulating the speed of the hydraulic cylinder plunger following the throttle characteristic $A_{DR} = f(h)$.

Materials and methods

The kinematical scheme of the workbench turn mechanism of the device is given in Fig. 1. A 5000 kg weight workbench is turned by a hydraulic cylinder with its handle connected to the workbench coulisse. During a single working cycle, the workbench is turned at 60º angle and fixed; then the technological process is performed (relevant technological operations are carried out). During the technological process, the hydraulic cylinder plunger is returned to its initial position so that later another working cycle could be performed. This paper analyses the possibility of increasing the performance only by reducing the duration of the workbench turn (work process) which takes 1.60 s. This may be achieved by increasing the pressure of the pump, but the principal problem to be solved is smooth stopping of the workbench (without a hit in the final position). Solving this task involved determining the workbench stopping characteristic $A_{DR}=f(h)$, i.e., determining the variation dependence of the cross area A_{DR} of the throttle on the process of the hydraulic cylinder plunger h.

The scheme of the device turn system is presented in Fig. 1.

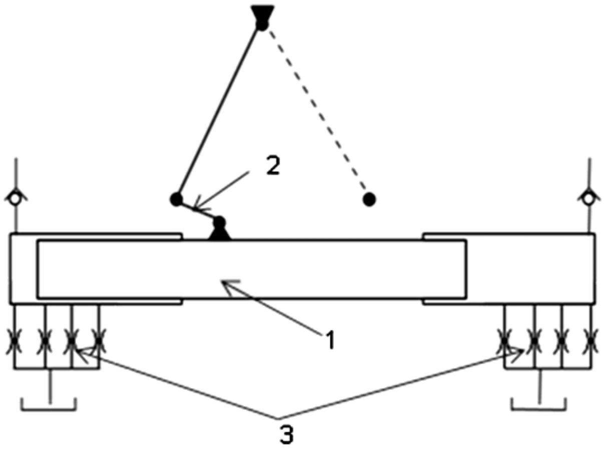

Fig. 1. **Kinematical scheme of workbench turn mechanism:**
1 – hydraulic cylinder; 2 – coulisse; 3 – speed regulation system

The hydraulic system of the workbench gear is presented in Fig. 2.

The hydraulic cylinder controlled by mass kinetic energy is equal to [5]:

$$W_K = \frac{m v^2}{2}, \tag{1}$$

where m – mass in motion;
v – speed of movement.

The kinetic energy change is converted into thermal energy and is equal to:

$$\Delta W_K = \Delta P_{DR} \cdot t, \tag{2}$$

where ΔP_{DR} – power throttling losses.

The power throttling losses are calculated in the following way:

$$\Delta P_{DR} = \frac{\Delta W_K}{t}. \tag{3}$$

Since $\Delta P_{DR} = p_{DR} \cdot Q_{DR}$, that

$$p_{DR} \cdot Q_{DR} = \frac{\Delta W_K}{t}, \tag{4}$$

where p_{DR} – pressure before throttle;
Q_{DR} – oil flow through throttle.

The pressure before the throttle is equal to:

$$p_{DR} = \frac{\Delta W_K}{Q_{DR} \cdot t}, \tag{5}$$

Since $Q_{DR} = A \cdot v$, that

$$F_{ST} = \frac{\Delta P_{DR}}{v}, \tag{6}$$

where A – plunger area.

Because $Q_{DR} = \mu \cdot A_{DR} \cdot \sqrt{\frac{2}{\rho} p_{DR}}$ [3], that

$$A_{DR} = \frac{F_{ST} \cdot h}{\mu \cdot t \cdot \sqrt{\frac{2}{\rho} p_{DR}^3}}. \quad (7)$$

The experimental research was performed using the above-described device with constructional changes introduced into its hydraulic cylinder, i.e., the sizes of throttles and their arrangement were modified according to the theoretically determined throttle characteristic $A_{DR} = f(h)$.

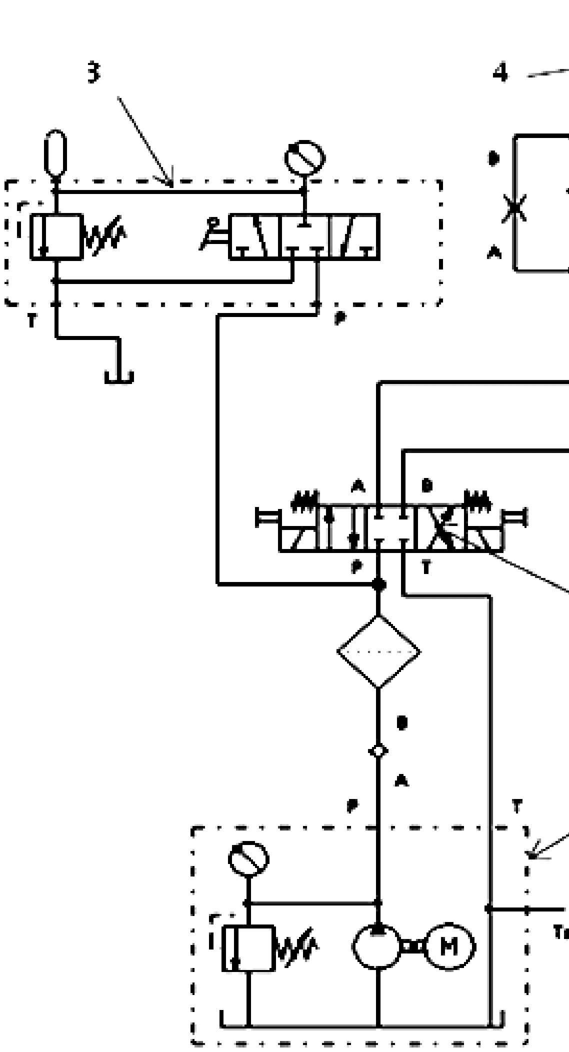

Fig. 2. **Hydraulic system of workbench gear:**
1 – pump; 2 – distributor; 3 – hydraulic accumulator; 4 - hydraulic cylinder; 5 – regulated throttle

Research results

In order to reduce the duration of the workbench turn, the pressure in the hydraulic system had to be increased from 60 bar to 70 bar. When the pressure is increased, the speed of the hydraulic cylinder plunger also increases; however, a more complicated problem arises, namely smooth stopping of the workbench. Since the workbench is hydraulically stopped, i.e., creating a counter-pressure to the plunger movement using throttles, the danger of very high pressure emerges. Moreover, when the speed of the workbench turn grows, dynamic loads of mechanical elements of the turn gear also increase; therefore, due to this danger, a modest pressure increase (up to 70 bar) was selected in the hydraulic system. The results, obtained during the experimental research, are given in Fig 3. The pressure in the stopping chamber of the plunger increased up to 224 bar (scale: 1 V = 16 bar). The workbench turn duration decreased to 1.31 s. At the end of the plunger work process, the pressure in the stopping chamber made up to 48 bar, which shows that the hit of the plunger into the cover of the hydraulic cylinder was avoided.

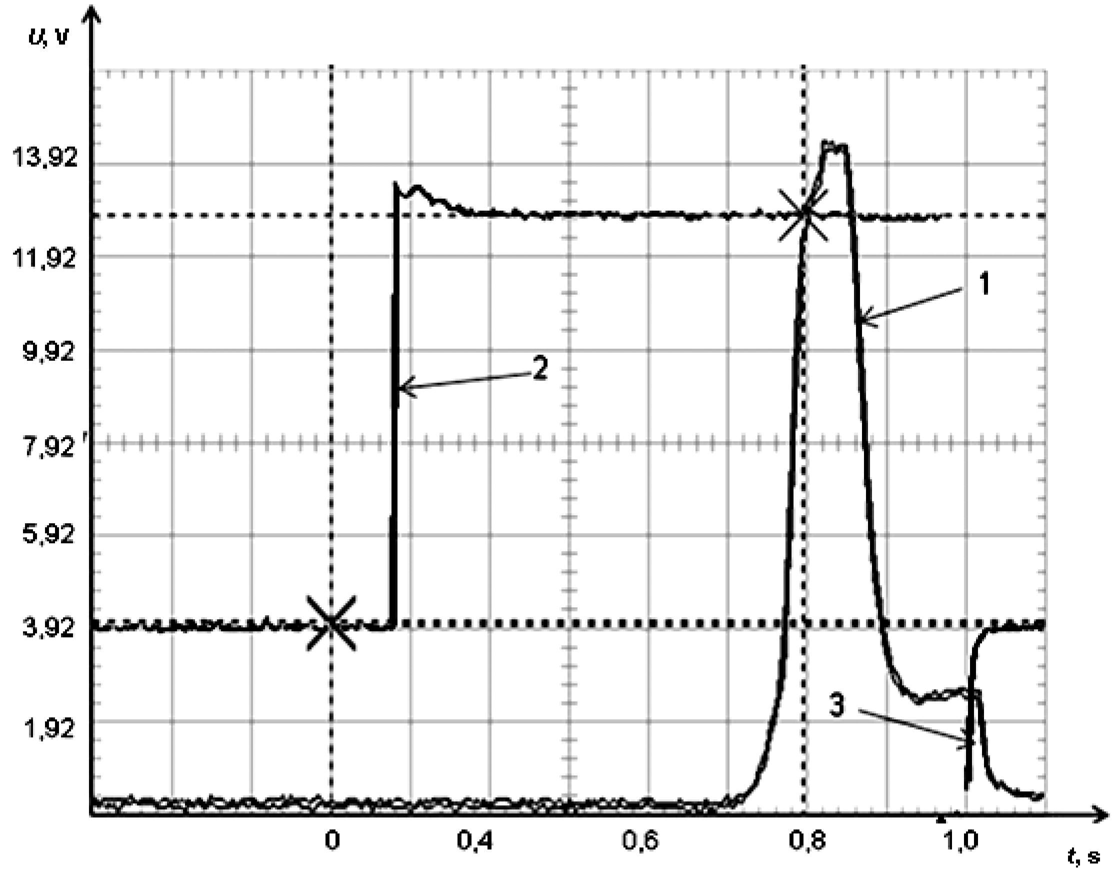

Fig. 3. **Characteristic of workbench stopping pressure:**
1 – pressure variation in stopping chamber; 2 – regulatory signal of distributor; 3 – end of process

Conclusions

4. The throttle characteristic $A_{DR} = f(h)$, obtained during the theoretical research, was used for changes in the throttle arrangement and sizes.
5. When the pressure in the hydraulic system was increased from 60 to 70 bar, the workbench turn duration decreased to 1.31 s.
6. Performance of the device (during one cycle) increased by 2.3 %.
7. The largest value of pressure in the stopping chamber reaches 224 bar, but does not exceed the maximum allowable load limit.
8. The pump pressure may be further increased and workbench turn duration reduced by carrying out dynamic test calculations of the device.

References

1. Попов Д.Н. Динамика и регулирование гидро- и пневмосистем. – Москва: Машиностроение, 1987, 464 с. (In Russian).
2. Башта Т.М., Руднев С.С. Некрасов Б.Б. И др. Гидравлика, гидромашины и гидроприводы. – Москва: Машиностроение, 1982, 423 с. (In Russian).
3. Проектирование и сооружение гидроустановок. – Лор на Майне: Маннесманн Рексрот, 1988. 376 с. (In Russian).
4. Башта Т.М. Гидропривод и гидропневмоавтоматика. – Москва, 1972, 320 с. (In Russian).
5. Hydraulik in Theory und Praxis. – Ditzingen: OMEGA Fachliteratur, 1997, 291 s. (In German).