Analysis of the design of the high-speed hydraulic drive of the reciprocating motion of the perforating press hammer

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Abstract. The article discusses the control system of a hydraulic power source of constant pressure, which is a pump-storage power source, equipped with the original design of the automatic unloading of the hydraulic pump, which provides relay switching of its operation mode. The results showed that due to changes in various design parameters of the unloading machine, you can not only change the upper (maximum) and lower (minimum) values of the battery charging pressure, but also adjust their difference depending on the requirements for the power source.

1. Introduction

Typically, in hydraulic systems, the oil temperature does not exceed 55 °C and only in the simplest hydraulic drives, the stability of which is not high, can reach 70 °C. Maintaining the thermal regime of the hydraulic drive, in which there is significant power loss due to oil throttling, is a very difficult technical problem, requiring a significant increase in tank volume or the use of an effective artificial cooling system. In the latter case, we first waste power in the hydraulic drive, and then we spend additional power on the operation of the cooling system. Energy throttle control is similar to regulating the speed of a car with a brake when the gas pedal is fully depressed.

Given that at \( p = \text{const} \), the power \( N \) is proportional to \( Q \) (or the speed of movement of the working body), which characterizes the ratio between the useful and lost power in the hydraulic drive described above. If with a quick supply (\( Q_{bp} \)) the power losses are relatively small, then with a working feed (\( Q_{rp} \)) almost all of the consumed power \( N \) is lost. The maximum losses, and therefore the maximum heating of the oil, occur when there is no payload on the hydraulic motor, and with increasing load, the losses decrease and cooling conditions are facilitated, that is, the heating of the machine decreases with increasing load (in mechanical systems, vice versa). Hydraulic drive (hydraulic drive) - a set of devices designed to drive machines and mechanisms through hydraulic energy. Mandatory elements of a hydraulic drive are a pump and a hydraulic motor [1-10].

The hydraulic drive is a kind of “hydraulic insertion” between the drive motor and the load (machine or mechanism) and performs the same functions as a mechanical transmission (gearbox, belt drive, crank mechanism, etc.).

The main purpose of the hydraulic drive, as well as mechanical transmission, is the conversion of the mechanical characteristics of the drive motor in accordance with the requirements of the load (conversion of the type of movement of the output link of the engine, its parameters, as well as...
regulation, protection against overloads, etc.).

In general terms, the energy transfer in a hydraulic drive is as follows:

- The drive motor transmits torque to the pump shaft, which reports the energy of the working fluid.
- The hydraulic fluid through the hydraulic lines through the control apparatus enters the hydraulic motor, where hydraulic energy is converted into mechanical energy.
- After that, the hydraulic fluid returns either to the tank or directly to the pump via hydraulic lines.

Types of hydraulic drives

- Hydraulic actuators can be of two types: hydrodynamic and volumetric:
  - In hydrodynamic drives, the kinetic energy of the fluid flow is mainly used.
  - Volumetric hydraulic drives use the potential energy of the pressure of the working fluid.
  - Volumetric is a hydraulic machine, the working process of which is based on alternately filling the working chamber with liquid and forcing it out of the working chamber. Volumetric machines include, for example, piston pumps, axial piston, radial piston, gear hydraulic machines, etc.

  One of the features that distinguishes a volumetric hydraulic drive from a hydrodynamic one is high pressures in hydraulic systems. So, the nominal pressure in the hydraulic systems of excavators can reach 32 MPa, and in some cases the working pressure can be more than 300 MPa.

- Volumetric hydraulic drive is used in mining and construction-road machines, in machine tools, etc.

Depending on the design and type of elements included in the hydraulic transmission, volumetric hydraulic drives can be classified according to several criteria.

- By the nature of the movement of the output link of the hydraulic motor
  - Hydraulic drive: when a hydraulic motor is used as a hydraulic motor, in which the driven link (shaft or housing) makes unlimited rotational motion;
  - Hydraulic drive of progress in which a hydraulic cylinder is used as a hydraulic motor - an engine with the reciprocating movement of the driven link (piston rod, plunger or housing);
  - Swivel hydraulic drive when a rotary hydraulic motor is used as a hydraulic motor, in which the driven link (shaft or housing) makes a reciprocating motion at an angle less than 360°.

- If possible regulation
  - If the speed of the output link (hydraulic cylinder, hydraulic motor) is regulated by changing the speed of the engine that drives the pump, then the hydraulic drive is considered unregulated.
  - Adjustable hydraulic drive in which during its operation the speed of the output link of the hydraulic motor can be changed according to the required law. In turn, regulation can be: * throttle, volumetric, volumetric-throttle.

  Regulation can be: manual or automatic.

- Depending on the control tasks, the hydraulic drive can be: stabilized, programmatic, watching
  - Self-adjusting hydraulic drive automatically changes the fluid supply according to the actual needs of the hydraulic system in real time (without phase shift).

  According to the scheme of circulation of the working fluid
  - Closed circuit hydraulic actuator in which the working fluid from the hydraulic motor is returned to the suction pump hydraulic line.

  The hydraulic drive with closed circulation of the working fluid is compact, has a small mass and allows a high rotational speed of the pump rotor without the risk of cavitation, since in such a system the pressure in the suction line always exceeds atmospheric. The disadvantages include poor conditions for cooling the working fluid, as well as the need to lower the working fluid from the hydraulic system when replacing or repairing hydraulic equipment;

  - Hydraulic systems with a closed circuit for the circulation of the working fluid (on the right) and with an open circuit (on the left). In the diagram on the left, the suction and drain hydraulic lines communicate with the tank (open circuit); in the diagram on the right, the tank is used only for auxiliary hydraulic systems (make-up systems). H and H1 are pumps; M - hydraulic motor; P - hydrodistributor; B - a hydraulic tank; H1 - make-up pump; K1, K2, - Safety valves; KO1 and KO2 -
check valves. Safety valves K (in the diagram on the left), K1 and K2 (in the diagram on the right) are triggered at a time when the load on the motor shaft is too high and the pressure in the hydraulic system exceeds the permissible value. Check valves KO1 and KO2 trigger.

Hydraulic power sources used in modern technological equipment and mobile machines are usually of two types - power sources for constant flow of working fluid and power sources for constant pressure. Among the constant pressure power sources, the most widely used are pump accumulator hydraulic power sources, operating as follows. The working fluid from the flow source (pump) is supplied to the consumer, at the inlet of which a hydraulic accumulator is installed. When the consumer is operating, its power is supplied from the battery, in which the pump compensates for the loss of liquid and, thus, at the inlet to the consumer, the pressure is always maintained at the same level - equal to the pressure in the battery.

The disadvantage of such power sources is that when the consumer is not working, the battery is recharged and the safety valve opens, on which all the energy transmitted by the pump fluid is lost. In order to prevent the safety valve from tripping, the so-called relief valves are used, which automatically open when the pressure at the pump outlet reaches the specified maximum (upper) value, ensuring idle operation. The consumer at this time works due to the energy stored in the battery. If the pressure in the accumulator drops below a predetermined minimum (lower) value, the discharge valve closes, putting the pump into operation.

Most of the currently known relief valves have significant dimensions and weight, are complex in design, but most importantly, as operating experience shows, they tend to freeze - stop the shut-off element in the intermediate position when the pressure in the hydraulic system and the pressure drop on the closing or opening shut-off valve are the same. In this case, throttling occurs on the shut-off element of the overflow valve, which leads to significant energy losses and heating of the working fluid.

![Figure 1. Hydraulic systems.](image)

Analysis of the design of the high-speed hydraulic drive of the reciprocating motion of the perforating press hammer. The disadvantages of all types of hydraulic drives described above can be attributed to the fact that their speed can be increased by increasing the volume of the hydraulic pump, and a significant decrease in efficiency. In, a scheme of a hydraulic drive of a reciprocating motion of increased speed with combined hydromechanical limiters of the output link stroke using two independent battery power sources is proposed, the schematic diagram.

2. Methods
The work of the high-speed hydraulic drive of the reciprocating motion is as follows [11-15].

To start the high-speed hydraulic drive of the reciprocating motion, made according to the proposed scheme, the electric motor is turned on, which rotates the shaft of the hydraulic pump. Then power is supplied to the electromagnet of the hydraulic distributor, which closes, stopping the
unloading of the hydraulic pump and, thereby, transfers the hydraulic system of the drive to the working state. In this case, the accumulators are charged and the moving parts of the hydraulic drive are lifted to the upper position.

When the pressure of the working fluid at the inlet of the accumulator reaches the minimum permissible value, the control microprocessor gives a command to close the valve (power is supplied to the electromagnet), which interrupts the supply of the working fluid from the hydraulic pump to the inlet of the accumulator and into the rod cavities of the hydraulic cylinders. The accumulator is charged up to the maximum permissible operating pressure of the hydraulic drive (before the safety valve is triggered). Then the power is removed from all solenoids of the hydraulic valves - the hydraulic drive is brought into working condition, the hydraulic pump is unloaded.

To complete the working stroke of the hydraulic drive of the reciprocating motion, the microprocessor sends a control signal to turn on the electromagnets: of the hydraulic valve; of hydraulic valve and of hydraulic valve. In this case, the hydraulic distributor closes the passage of the working fluid from the outlet of the check valve to the inputs of the accumulator, the safety valve and the rod cavities of the hydraulic cylinders. Hydraulic distributor connects the outlet of the accumulator with the piston cavities of the hydraulic cylinders, causing the moving parts of the hydraulic drive (for example, the movement of the punch of the press drive) downward. In this case, the working fluid supplied to the hydraulic system by pump through the check valves and enters the inlet of the hydraulic distributor, where it mixes with the working fluid coming there from the hydraulic accumulator and the combined flow through the hydraulic distributor and the check valve of the hydraulic drive is directed to the piston cavities of the hydraulic cylinders of the, carrying out a quick supply of the moving parts of the hydraulic drive to the workpiece being processed. When the moving parts of the hydraulic drive move down, the stop comes off the pusher of the hydraulic distributor, making it open. The working fluid displaced from the rod cavities of the hydraulic cylinders of the through the open hydraulic valve enters the inlet of the accumulator, carrying out its additional charging.

When the tool (moving parts of the hydraulic drive) hits the workpiece, the speed of its movement slows down a little, but because the charging pressure of the accumulator is high enough, it remains significant due to the combined flow of the working fluid from the hydraulic pump, the accumulator and the inertia of the moving masses (slider, pistons of hydraulic cylinders, etc.).

After the punch leaves the workpiece being pierced, the stop covers the hydraulic valve of the hydraulic drive, braking the moving parts, which, having reached the lower stop, completely stop. At this moment, a command is given to remove power from the electromagnet of the hydraulic valve of the hydraulic drive, which leads to the connection of the piston cavities of the hydraulic cylinders of the with the drain line, at the same time the working fluid under the pressure of the charged accumulator through the check valve is supplied to the rod cavities of the hydraulic cylinders of the, forcing them the rods together with the slider move to the top. The working fluid displaced from the piston cavities of the hydraulic cylinders, through the open hydraulic valve and the hydraulic valve enters the hydraulic tank. When the punch leaves the workpiece, the stop covers the hydraulic valve of the hydraulic drive, braking the moving parts, which, having reached the upper stop, completely stop. Note that as the moving parts of the hydraulic drive move to the top, the stop comes off the pusher of the hydraulic valve, making it open.

When the punch leaves the workpiece being processed and stops it, a command is given to reposition the workpiece - the cycle of the hydraulic drive has ended.

After rearranging the workpiece to a new working position, power is supplied to the electromagnet of the hydraulic valve - the working cycle of the hydraulic drive is repeated.

3. Results
It should be noted that in the considered scheme of the hydraulic drive of the reciprocating motion of increased speed, the accumulator operates with a constant volume of the working fluid, and the accumulator is recharged both during the permutation of the workpiece and during the reverse
movement of the moving parts, which significantly reduces the losses of the working fluid, liquid and allows to increase the speed of the hydraulic drive of the reciprocating motion when using a hydraulic pump with a smaller working volume.

The disadvantage of a high-speed drive (Figure 1.) is that its speed directly depends on the pump performance.

4. Discussion
The disadvantages of hydraulic drives include the fact that during the working movements of the executive body, most of the energy of the hydraulic pump is spent on throttling, and therefore on heating the working fluid, which leads to a decrease in the efficiency of the hydraulic drive.

References
[1] Lyashenko Yu M 2017 Application of the laws of mechanics of granulated solids in studies to loader bucket interaction with bulk material stack Proc. Int. Conf. on Industrial Engineering, Procedia Engineering pp 1388-1394
[2] Kobzev, K. 2020 Studies related to the calculation of the noise. the study of pumping hydraulic systems and the study of the use of an unloading valve in a hydraulic system E3S Web of Conferences 175,05037
[3] Popikov, P 2020 Reducing Amplitude of Load Swinging During Operation of Hydraulic Manipulators of Forest Transport Machines Lecture Notes in Mechanical Engineering c. 595-608
[4] Chetverikova, I.,2019 Saving hydraulic drive of the grapple slewing gear in timber transport machines and improvement of its work processes IOP Conference Series: Earth and Environmental Science 392(1),012067
[5] Kobzev, K. 2020 Learning the basics of a battery pack control system E3S Web of Conferences 164,13006
[6] Kobzev, K. 2020 The process of increasing the stable operation of the working body in crank presses E3S Web of Conferences 164,03017
[7] Staseva, E. 2020 Theoretical studies on the calculation of the noise of impact equipment in blacksmith shops E3S Web of Conferences 164,01030
[8] Stuzhenko, N.2020 Means and methods of noise protection to reduce the risk of cardiovascular disease in workers E3S Web of Conferences 164,01029
[9] Staseva, E 2020 The effect of noise on the human body, in particular, on cardiovascular diseases E3S Web of Conferences 164,01028
[10] Il’Ev, A. 2020 Vibration safety to reduce the risk of cardiovascular disease in workers E3S Web of Conferences 164,01025
[11] Rybak, A 2020 Simulation of the pump-battery power supply control system based on the unloading machine E3S Web of Conferences 164,01004
[12] Rybak, A.T.2019 Simulation of the stand drive system for testing plunger hydrocylinders, AIP Conference Proceedings 2188,050042
[13] Ivanovskaya, A.V. 2018 Simulation of drive of mechanisms, working in specific conditions, Journal of Physics: Conference Series 1015(3),032054
[14] Demyanov, A. 2019 Skid adjuster for humps E3S Web of Conferences135,02020
[15] Gnusov, M 2020 Improving the efficiency of forest fire prevention and suppression with of forest fire machine IOP Conference Series: Materials Science and Engineering 919(3),032025