The composition of the hydraulic drive on the example of the power head of high-speed equipment

K Kobzev¹*, A Rybak¹, I Zolotuhina¹, I Zanina¹, A Il'ev¹, N Kobzeva¹²

¹Don State Technical University, Rostov-on-Don, Russia
²Rostov State Medical University, Rostov-on-Don, Russia

*e-mail: 5976765@mail.ru

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. A mathematical model is proposed, obtained using a modeling technique based on the application of the theory of volumetric rigidity of hydraulic systems and their elements. The main property of a power source with an automatic unloading device of the proposed design, confirmed as a result of a numerical experiment, is that the automatic unloading device provides a clear relay switching of the pump operation mode from unloading to operating mode and vice versa. The revealed properties make it very promising to use a pump-accumulator power source in the hydraulic systems of mobile machines and technological equipment.

1. Introduction

This article contains the most common symbols of elements on hydraulic circuits of metal-cutting machines. The images of elements of various hydraulic circuits and their description are given.

In the drawings of the hydraulic circuits, the normalized equipment and working bodies are depicted by symbols, the mains - by lines. Special devices are depicted semi-structurally. The practice of operating the hydraulic systems of metal-cutting machine tools has established the most rational procedure for analyzing and finding faults in hydraulic drives. The hydraulic system can be imagined as consisting of separate circuits (control and drive), which are connected in parallel between the discharge and drain lines. In accordance with the working cycle of the machine, only a part of the contours or one contour is running at the same time. Thus, according to the violation of the normal functioning of any mechanism or group of machine mechanisms, it is easy to identify the contour in which the malfunction is concluded.

The so-called "functional diagrams", in which the states of each device of the circuit are recorded when the specified elements of the machine cycle are executed, can be of great help in finding the faulty circuit and malfunctions in the control circuits. The method of functional cyclograms is especially convenient in the presence of semi-structural hydraulic circuits, on which it is possible to represent one or another position of the moving elements of the hydraulic devices, indicated in the cyclogram, and evaluate the effect associated with each change in the state of the hydraulic device.

No less convenient in troubleshooting the "flow patterns" also displaying the property of hydraulic devices, but in a different record.
2. Methods

In its most general form, a hydraulic drive consists of a source of hydraulic energy - a pump, a hydraulic motor and a connecting line (pipeline).

In the hydraulic diagram fig. 1. Semi-structural and schematic shows a simple hydraulic drive, in which pump 2, driven by an electric motor 11, sucks the working fluid from the tank 1 and through the filter 4 supplies it to the hydraulic system, and the maximum pressure is limited by the adjustable spring force of the safety valve 3 (controlled by the pressure gauge 10). To avoid accelerated wear or breakage, the setting pressure of the safety valve must not exceed the rated pressure of the pump [1-10].

Depending on the position of the distributor handle 5, the working fluid through pipelines (hydraulic lines) 6 enters one of the chambers (piston or rod) of the cylinder 7, forcing its piston to move together with the rod and the working member 8 at a speed v, and the liquid from the opposite chamber through the distributor 5 and an adjustable resistance (choke) 9 is displaced into the tank.

With a fully open throttle and an insignificant load on the working body, all the working fluid supplied by the pump enters the cylinder, the speed is maximum, and the value of the working pressure depends on the losses in the filter 4, devices 5 and 9, cylinder 7 and hydraulic lines 6. Covering the throttle 9, the speed can be reduced until the working body comes to a complete stop. In this case (as well as when the piston rests on the cylinder cover or an excessive increase in the load on the working element), the pressure in the hydraulic system rises, the ball of the safety valve 3, compressing the spring, leaves the seat and the working fluid supplied by the pump (pump flow) is partially or completely bypassed through safety valve into the tank at maximum working pressure.

During long-term operation in bypass mode, due to large power losses, the working fluid in the tank heats up quickly.

The hydraulic diagram shows in the form of designations:
• source of hydraulic energy - pump 2;
• hydraulic motor - cylinder 7;
• guide hydraulic equipment - distributor 5;
• regulating hydraulic equipment - valve 3 and throttle 9;
• control devices - pressure gauge 10;
• reservoir for working fluid - tank 1;
• working environment conditioner - filter 4;
• pipelines - 6.
Hydraulic drives of stationary machines are classified according to pressure, regulation method, circulation type, control and monitoring methods. Functional diagrams and flow diagrams can be used separately or together. Due to their clarity, the flow patterns make it much easier to find faults in the hydraulic system and are available for medium-skilled personnel.

For more successful work on troubleshooting the hydraulic systems of machine tools, it is recommended to draw up instruction cards containing structural sweeps of the hydraulic system and a passport of possible malfunctions.

When finding faults in a hydraulic drive, it is always necessary to remember that electrohydraulic control is widely used in the schemes of metal-cutting machines, and a failure in the operation of a hydraulic drive may be due to a failure of an electrical apparatus.

Therefore, before proceeding with the repair of any element of the hydraulic system that did not work in accordance with the machine cycle, you must make sure that the electrical control circuits and the corresponding command devices of the electrical circuit are in good order.

The method of recording flow patterns by itself determines the hydraulic devices, the abnormal operation of which can cause a malfunction. Thus, any malfunction is noticed when the machine mechanisms perform a certain element of the work cycle, for which the path of the working fluid is recorded, and the position of the devices is indicated when this cycle element is executed. In case of malfunctions associated with the failure to fulfill a certain element of the machine cycle, it is enough to check the correspondence of the working positions of these devices on the machine, during the execution of this cycle, to their position according to the flow diagram.

It is those devices, the position of which does not correspond to the flow pattern, are the cause of the malfunction. To determine the causes of malfunctions caused by devices that do not change the position of their working bodies (hydraulic throttles, filters, etc.), it is required to disassemble and check parts for wear, scuffing, clogging, etc. [11-15].

The adjustment of hydraulic systems should begin with a study of the technical documentation. The instructions attached to the hydraulic machine contain a description of the structure of the machine mechanisms and their adjustments, a detailed description of the operation of the hydraulic system. The hydraulic diagram depicts the communications of the hydraulic system, the device and the location of the working mechanisms.

With complex hydraulic systems, this documentation is not always satisfactory for successful commissioning and operation, it is difficult to understand and not available to all categories of workers involved in commissioning. Thus, rational adjustment and operation of hydraulic systems of machine tools are associated with the rationalization of technical documentation. It is recommended, in addition to the instructional material, to attach a passport of typical malfunctions and ways to eliminate them, and all data obtained during commissioning should be entered into the adjustment passport. It is recommended to divide the hydraulic system diagram into structural sweeps in the form of a complex of main circuits of a typical structure, drawn up according to the elements of the working cycle. Each main circuit provides the performance of only certain functions, therefore the commissioning carried out on this system becomes more specific, and all problems are eliminated by sequentially checking the operation of the hydraulic units of each main circuit. Trunk loops are determined by flow patterns.

The general procedure for identifying trunk circuits and flow patterns is as follows:
1. reveal the working cycle of the machine;
2. for each working cycle, designations are given of the hydraulic devices participating in the operation of the cycle, and hydraulic motors;
3. according to the hydraulic scheme, channels are searched for, and with a semi-structural scheme, the belts of the hydraulic valves, which are involved in the work when performing this cycle;
4. identify the supply and discharge lines of the working fluid;
5. the entire reamer is placed between the pressure line of the pump and the return line.

Before starting the machine, it is necessary to fill the hydraulic tank with clean oil, fill the pipelines with oil and remove air from the system; in this case, the springs of the pressure hydraulic valves of the pumps must be completely loosened so that the hydraulic system is filled at the lowest pressure in order
to avoid the dissolution of air in the working fluid. The taps or air release plugs installed at the highest points of the pipelines are opened, the union nuts at the ends of the main pipes are loosened. Then turn on the pump motors. After clean oil comes out of the taps and from under the nuts, the pump motors are turned off, the taps are closed, the nuts are tightened, and the pressure hydraulic valves of the pumps are adjusted to the operating pressures specified in the instructions. Adjust the dividing panel hydraulic valves.

It is also necessary to release air from the hydraulic cylinders, for which special taps or plugs are slightly opened, and the pistons of the hydraulic cylinders are moved several times at high speeds from one extreme position to another. After the hydraulic system is completely filled with oil, it is necessary to add oil to the hydraulic tank up to the upper level of the oil indicator.

The composition of the hydraulic drive on the example of the power head of the modular machine.

![Figure 2. Powerhead hydraulic system of powerhead machine](image-url)

Depending on the method of depicting mechanisms and equipment on schematic diagrams, they can be semi-constructive, full and transverse.

The hydraulic system of any variant has at least two main lines - pressure and drain. Targeted routes are connected to them, which connect hydraulic motors of one action or another with the highways. Distinguish between routes: initial, free movement, precise movement, unregulated movement, control and blocking.

In fig. 2 shows a semi-structural, complete and transverse diagrams of the power head of a modular machine tool, which performs three transitions per cycle of work: fast approach, working stroke and fast retraction. On the semi-structural diagram (Fig. 2), during the transition “Fast feed”, both spools are displaced by pushing electromagnets: the main spool 1 to the right, and the spool 2 of rapid moves to the left. In this position, oil from the pump through the first left neck of the spool 1 enters the external
cavity of the cylinder 5, and from the opposite cavity of the same cylinder through the neck of the spool 2 and the second neck of the spool 1 is sent to the tank.

At the transition "Working stroke", the spool electromagnet 2 is turned off, which forces the oil from the rod end of the cylinder 3 to drain through the speed regulator 4 and then through the third neck of the spool 1 into the tank.

During the transition "Fast retraction", the spool 1 electromagnet is turned off, and the spool 2 electromagnet is turned on again, and this changes the direction of oil flow: from the pump through the second spool neck 1 to the rod cavity of the cylinder, and from the opposite cavity through the first spool neck 1 to the tank. In the Stop position, both electromagnets are disconnected, the spools become in the position shown in the diagram, and the pressure line from the pump through the second spool neck 1, the spool neck 2 and the annular groove around the rightmost drum of the spool 1 is connected to the tank.

In the complete schematic diagram (Fig. 2), all elements of the hydraulic system have designations similar to those of the semi-structural diagram, therefore, the above description of the operation of the hydraulic drive can be used in this case as well. Comparing the diagrams, you can see that the design of the second diagram is simpler, and, in addition, it clearly shows the function of the spools at their different positions.

The transverse diagrams (Fig. 2) show the same elements, and, in addition, the signs "+" and "-" and arrows of different lengths make it possible to clarify the actions of the electromagnets and the power cylinder. In fact, from the consideration of scheme 1, it follows that both electromagnets are connected, and oil from the pressure line NM through one neck of spool 1 enters the external cavity of cylinder 3, and from the opposite cavity it strips off through the necks of spool 2 and 1. The piston moves in the direction " Stem forward "quickly (long arrow).

From scheme II it follows that in this transition, only spool 1 works, which remains in the same position, and turning off the spool 2 of rapid moves connects the speed controller 4, consisting of a pressure reducing valve and a throttle. The piston at this transition moves in the same direction, but at a working speed (short arrow). Diagram III shows that spool 2 is turned on again, and spool 1 is turned off, but it takes part in this transition. With this switching of the spools, oil from the NM line through the necks of both spools enters the rod cavity of the cylinder, and from the opposite cavity it is drained through the second neck of the spool 1. The piston changes its speed and direction. From scheme IV it follows that both spools are off, and the pressure line is connected to the tank through their necks, and therefore, in this position, even when the pump is running, the hydraulic drive is turned off.

3. Results

From scheme II it follows that in this transition, only spool 1 works, which remains in the same position, and turning off the spool 2 of rapid moves connects the speed controller 4, consisting of a pressure reducing valve and a throttle. The piston at this transition moves in the same direction, but at a working speed (short arrow). Diagram III shows that spool 2 is turned on again, and spool 1 is turned off, but it takes part in this transition. With this switching of the spools, oil from the NM line through the necks of both spools enters the rod cavity of the cylinder, and from the opposite cavity it is drained through the second neck of the spool 1. The piston changes its speed and direction. From scheme IV it follows that both spools are off, and the pressure line is connected to the tank through their necks, and therefore, in this position, even when the pump is running, the hydraulic drive is turned off.

4. Discussion

The practice of operating the hydraulic systems of metal-cutting machine tools has established the most rational procedure for analyzing and finding faults in hydraulic drives. The hydraulic system can be imagined as consisting of separate circuits (control and drive), which are connected in parallel between the discharge and drain lines. In accordance with the working cycle of the machine, only a part of the contours or one contour is running at the same time. Thus, according to the violation of the normal functioning of any mechanism or group of machine mechanisms, it is easy to identify the contour in which the malfunction is concluded.
References

[1] Sedov, A. V. Adaptive-spectral method of monitoring and diagnostic observability of static stresses of elements of mechanical constructions / A. V. Sedov, V. V. Kalinchuk, O. V. Bocharova // IOP Conference Series: Earth and Environmental Science. - 2017. - 87(8). - P. 082043.

[2] Esipov, Y. V. Criteria for identification of stress state of periodic rod construction based on ferroelectric sensors of deformation / Y. V. Esipov, V. M. Mukhortov, I. I. Pojda // Piezoelectrics and Related Materials: Investigations and Applications. - 2012. - P. 283–291.

[3] Krasnoshchekov, A. A. Identification of crack-like defects in elastic structural elements on the basis of evolution algorithms / A. A. Krasnoshchekov, B. V. Sobol, A. N. Solov'ev [et al.] // Russian Journal of Nondestructive Testing. - 2011. - 47(6). - 412–419.

[4] Soloviev, A. Identification of crack-like defect and investigation of stress concentration in coated bar / A. Soloviev, B. Sobol, P. Vasiliev // In: Springer Proceedings in Physics. - 2019. - Iss. 4. - P. 165–174.

[5] Method and description of dynamic vibration reduction in cabins of gantry cranes / Kirill O. Kobzev, Sergey A. Shamshura, Alexander N. Chukarin, Vitaliy P. Bogdanovich and Valeriy E. Kasyanov // MATEC Web of Conferences, 226,01022 (2018)

[6] Substantiation of the parameters of vibration systems in the cab of the gantry crane at the workplace of crane operators /Kirill O. Kobzev, Sergey A. Shamshura, Alexander N. Chukarin, Alexey I. Buryanov and Valeriy E. Kasyanov // MATEC Web of Conferences, 226,01023 (2018)

[7] Principles of improving the smoothness of the working mechanism in forging and stamping machines / Kobzev K., Chukarin, A. // IOP Conference Series: Earth and Environmental Science, 403,012145 (2019)

[8] Theoretical foundations of the use of single-circuit negative feedback in safety friction clutches with differentiated friction pairs installed in forging equipment/ Kobzev, K.O., Bozhko, E.S., Mozgovoi, A.V., Molev, M.D., Stuzhenko, N.I. // IOP Conference Series: Materials Science and Engineering, 680,012014 (2019)

[9] The study of the use of multi-disc safety friction clutches in the working bodies of crank presses/ Kobzev, K.O., Bozhko, E.S., Mozgovoi, A.V., Kostromina, E.I., Babenko, L.G. // IOP Conference Series: Materials Science and Engineering, 680,012013 (2019)

[10] Pozharskii, D.A. Periodic crack system in a layered elastic wedge / D.A. Pozharskii, V.N. Sobol', P.V. Vasil’ev // Mechanics of Advanced Materials and Structures. - 2020. - Vol. 27(4). - P. 318–324.

[11] Cherpakov, A.V. The Study of Stratification of Multilayer Structures Based on Finite Element Modeling and Neural Network Technologies / A. V. Cherpakov, P. V. Vasiliev, A. N. Soloviev [et al.] // Advanced Materials. Proc. Int. Conf. on Physics and Mechanics of New Materials and Their Applications, PHENMA 2019. - 2020. - P. 439–447. https://doi.org/10.1007/978-3-030-45120-2

[12] Cherpakov, A.V. Simulation of wave processes in the multilayer structure surface layer properties identification by the finite element method / A. V. Cherpakov, O. V. Shilyaeva, M. N. Grigoryan [et al.] // IOP Conf. Ser.: Mater. Sci. Eng. - 2019. - Vol.698. - P. 066021.

[13] Lyashenko, Yu. M. Application of the laws of mechanics of granulated solids in studies to loader bucket interaction with bulk material stack / Yu. M. Lyashenko, D. N. Shurygin, E. A. Revyakina // Proc. Int. Conf. on Industrial Engineering. In: Procedia Engineering.— 2017. — P. 1388-1394.

[14] Kingma, D. P. Adam: A Method for Stochastic Optimization / D. P. Kingma, J. Ba // Proc. 3rd International Conference for Learning Representation, San Diego. 2015.

[15] Skid adjuster for humps / Demyanov, A., Demyanov, A., Rybak, A. // E3S Web of Conferences 135,02020 (2019).