Method for determining malfunctions of hydraulic drives of high-speed equipment

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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. 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 results of a numerical experiment carried out by numerically solving the equations that make up the mathematical model of a power source are also presented. As a result of a numerical experiment, the main technical capabilities of the considered power source and the influence of its main structural parameters and functional features of the system on operational properties are revealed.

1. Introduction
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
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.

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 start-up and debugging of the hydraulic systems of metal-cutting machines should be carried out in accordance with the cyclograms of the operation of the machines in the commissioning cycles. At the same time, the lengths of strokes are adjusted and the speeds of movement of the machine mechanisms are adjusted by hydraulic throttles, the cams pressing on the track control devices are adjusted and adjusted, the pressure switch is adjusted. The pressure switch should operate at pressures 5 kgf / cm2 more than the pressure required to move the machine mechanisms, and 5 kgf / cm2 less than the setting pressure of the corresponding pressure or pressure reducing valves.

After finishing the debugging of the hydraulic system in the adjustment mode, automatic machines are checked for operation in an automatic cycle. In this case, the accuracy and reliability of the operation of the electric control system of the sequence of switching on of electrohydraulic devices and the reliability of the interlocks are additionally checked.

The time of each transition and the cycle time of the machine tool are finally adjusted and specified.

The trouble-free operation of hydraulic drives of metal-cutting machines is largely determined by the observance by the service personnel of the basic operating rules, due to some of the features characteristic of any volumetric hydraulic drive. These features include:

1. uneven movement of actuators caused by fluctuations in operating temperature;
2. abrupt movement of mechanisms when air enters the working fluid or when gases are released in it;
3. the presence of internal fluid leaks through the working clearances of hydraulic machines and devices (to reduce leaks, the working clearances are very small, depending on the purpose of the hydraulic unit);
4. presence of external leaks through the seals.

The specified features of the volumetric hydraulic drive are associated with the most common causes of malfunctions in the hydraulic systems of metal-cutting machines that arise during operation. These reasons are the increased heating of the oil in the system, the ingress of air, dirt and dust into the hydraulic system, external leaks of the working fluid.

The cooling surface of hydraulic units and hydraulic drive elements is selected so that the maximum temperature of the working fluid does not exceed 65-80 °C (in order to avoid significant leaks, the recommended working fluid temperature is 50 °C). Thus, when operating machines in accordance with their technical characteristics, the oil temperature and its viscosity must be within acceptable limits. Increased heating of the oil can be caused by: 1) the use of an oil of high viscosity (not corresponding to the passport of the machine); 2) a change in the speed and nature of fluid flow in pipelines; 3) increased losses in local resistance (knees, rounding, sudden narrowing, etc.); 4) increased oil pressure in the hydraulic system, exceeding the required pressure for the normal operation of the machine, therefore, it is necessary to use the oils specified in the passports in the machines. When repairing and replacing pipelines, their flow cross-sections should not be reduced, and when installing pumps with increased flow, a verification calculation of the hydraulic system for oil heating should be performed [3].
When upgrading hydraulic equipment, it should be remembered that the permissible flow rate of the working fluid is 4-6 m/s in the discharge lines and up to 2 m/s in the suction lines. Bends and dents of pipelines should not be allowed, they must be protected from possible damage. Bending radii of pipes must be at least three diameters.

To prevent air from entering the hydraulic system, it is necessary to maintain the tightness of the entire system, especially in the suction and drain lines, monitor the oil level in the hydraulic tank and fill it up in a timely manner. The ends of the pipelines connected to the hydraulic tank must be below the line of the minimum oil level in the hydraulic tank by at least three times the diameter of the pipes. The reliability and durability of the hydraulic drive depends significantly on the degree of oil purification in the hydraulic system. Pollution consists of solid particles entering the system from the outside, for example, with atmospheric dust, and particles formed as a result of wear and oxidation of hydraulic drive elements, as well as oxidation products of the fluid itself. Contamination can also get into the hydraulic system as a result of poor flushing of parts during the repair of hydraulic units, poor-quality cleaning of the hydraulic tank, and the use of contaminated pipelines.

It should also be remembered that the mineral oil as delivered may already be contaminated. Only clean oil should be used in hydraulic drives; it should be poured into the hydraulic tank only through means that provide primary cleaning, for example, strainers. It is necessary to maintain high cleanliness during the repair and installation of hydraulic equipment and pipelines. The inner surface of newly used pipes must be thoroughly cleaned from rust and scale (pickled). Filters for continuous oil cleaning must be kept in good condition, periodically completely change the oil in the hydraulic tank, cleaning and washing it. However, it is not allowed to use the ends for cleaning. During operation, the hydraulic tank must be securely closed.

External leaks can occur due to damage to the seals of hydraulic units and hydraulic lines and can lead to failure of the hydraulic drive due to an impermissible drop in the oil level in the hydraulic tank. External leaks, if any, must be repaired immediately.

The listed rules for the operation of the hydraulic drive are simple, and they can be easily performed by workers involved in the operation and repair of hydraulic machines. Compliance with these rules and systematic monitoring of the condition of the hydraulic drive elements ensure the trouble-free operation of the machines for a long time.

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.
3. Results

Common causes of faults in hydraulic systems and how to fix them: The pump does not deliver liquid. Wrong direction of rotation of the pump shaft - Change the direction of rotation. Insufficient oil level in hydraulic tank - Top up oil in hydraulic tank. Suction pipe clogged - Inspect and clean the pipe. Air is sucked in in the suction pipe - Check the connection between the pipe and the pump. Lower the pipe into the hydraulic tank to the required level. Restore tightness. Excessively high fluid viscosity - Select fluid with appropriate viscosity. Reduced pressure in the hydraulic system. Pump worn out - Check pump flow. Replace pump if necessary. Increased pump leakage - Change seals. Fluid leaks through cavities and pores of the pump casing - Change the pump casing. Excessive leaks from hydraulic connections - Check for leaks in the pump. The pressure in the system should rise with a plugged pipeline or pressure hydraulic valve. If the leaks in the pump do not exceed the norm, then it is necessary to check the pipelines and their connections. Increased leaks in the hydraulic power cylinders - Check the hydraulic cylinders. If the seals are worn out (cuffs or piston rings, rod seals), replace them with new ones. Free drainage of the oil through the hydraulic pressure valve - Dismantle the valve and fix it.

- the hole is clogged; valve core stuck open
- the ball valve is clogged (dirt under the ball);
- clogging of the guides under the ball;
- weakening of the spring of the ball valve;
- leakage of oil from the backpressure cavity of the ball valve

Pressure hydraulic valve is set for reduced pressure - The valve must be adjusted to a pressure exceeding the working pressure by 5-10 kgf/cm². Incorrect operation of the hydraulic overflow valve - Replace the hydraulic valve spring. Violation of switching of the hydraulic valve on a cycle - Check the operation of solenoids and cams. Noise during operation of the hydraulic system. Suction pipe or filter clogged - Check and clean filter and suction pipe. Insufficient filter capacity - Change filter. Air leaks in the suction pipe or along the pump shaft - Tighten the stuffing box. Suction of oil with air bubbles - Change the oil in the hydraulic tank; fill the hydraulic tank to the required level. Clogged breather in the tank - Inspect and clean the breather. Noise from a running pump - Ensure that the pump is securely fastened, that the motor and pump shafts are aligned; check clearances in the pump drive. Noise during operation of valves (pressure or overflow) - Replace the direct acting hydraulic valve on the hydraulic unit with a ball valve; reduce pump flow and reduce the amount of discharged oil. Noise from pipelines - Secure pipes with staples. The movement of working fluid in some areas of the hydraulic system with shocks and eddies - Increase the diameter of the pipelines and the radius of pipe bends. Uneven movement of executive bodies. Air in the hydraulic system - Eliminate the causes of air entering the system: bleed the air from the hydraulic cylinders (at idle speed), eliminate the...
causes of oil foaming. Guides tightly tightened - Adjust guides. Stem packing overtightened - Adjust the packing. Seizure marks on the guides - Remove the seizure marks. Polish the working surface of the stem. Skewed stem in relation to the guides - Check or replace stem. Operation at a pressure close to the pressure to which the hydraulic valve is adjusted - Adjust the hydraulic valve springs. Uneven oil supply by the pump (broken or jammed blades) - Disassemble the pump and replace the blades. Insufficient resistance in the drain cavity of the cylinder - Tighten the spring of the hydraulic valve in the drain hose. Insufficient oil level in hydraulic tank - Top up oil in hydraulic tank. Reduced working feed. The filter in front of the hydraulic throttle is clogged - Inspect the filter, clean or replace it. The throttle of the flow regulator is clogged - Dismantle and clean the throttle. The spring of one of the hydraulic valves of the flow regulator has weakened - Change the spring and adjust it to a differential pressure of 1.5-3.5 kgf/cm². Interruption of the working flow - Eliminate the stuck open pressure or bypass valve, stuck pressure reducing valve in the flow control system. Reduction of feed under load. Reduced sensitivity of the pressure reducing valve in the flow regulator system - Flush the hydraulic valve and install a less rigid spring. Increased leaks in the hydraulic system (in the main supply circuit) - Check for leaks from the working fluid pump; wash and grind the cores of the hydraulic valves. Oil contamination - Change oil, flush the system with kerosene. Clogged filters - Check and clean or replace filters. Clogged slots in hydraulic valves and hydraulic chokes - Check the operation of hydraulic valves and hydraulic chokes. Decrease in oil viscosity when heated - Select a suitable oil or eliminate the cause of excessive heating. Increased pressure at idle. Clogged filters in the supply circuit - Clean the filters. Clogged piping and channels - Disassemble the piping, check and clean it. The overflow valve is set to a pressure higher than normal - Adjust the overflow valve. Increased local resistance in case of pipe damage and improper selection of equipment in terms of performance - Straighten pipes, change equipment. Guides too tight, jamming without lubrication - Adjust wedges and strips. Excessive heating of the oil in the system. The springs of the hydraulic valves in the hydraulic drain line are tightly tightened - Adjust the hydraulic valve to a normal drop of 0.5-2 kgf/cm². Pump overflow - Change pump. The overflow valve does not work properly during unloading - Adjust the hydraulic valve for normal unloading; clear the feedback channel to increase sensitivity. Incorrect operation of the oil cooler - Adjust the thermostat (thermostat) and check the cooling water circulation. The system runs on oil with a higher viscosity - Change the oil to another with a lower viscosity. No fast moves. Stuck hydraulic pressure valve open - Check the function of the pressure hydraulic valve and flush it. Broken oil line - Change pipe. Oil leaks in the connections - Retighten or replace the valve. The directional valve switches incorrectly - Check the operation of the cams or solenoids. Violations of the correct alternation of cycle elements. Stuck hydraulic valve - Eliminate the cause of the jam. Cams and stops are incorrectly set - Check the setting of the cams according to the sequence diagram. The lock of the hydraulic distributor does not work properly (in particular, the spring is broken) - Eliminate the cause of the incorrect release of the lock. Contacts of microswitches are burnt - Clean contacts. Violation of the correct operation of the control valves - Check the operation of the hydraulic valves along the main circuits and cycle elements. Other hydraulic system problems. Violation of the cycle of work - Check the correct installation of the cams and stops, check the springs of the retainers, and also eliminate malfunctions that cause incorrect alternation of the elements of the cycle. The equipment cannot be adjusted - It is necessary to change the oil and flush the system. Violation of the stability of the hydraulic system (hydraulic shocks and uneven travel) - Dynamic instability can be eliminated by connecting an additional capacity (buffer) or changing the operating mode of the machine. Vibrations (self-oscillations) - Eliminated by the same methods as in case of violations of dynamic instability. Generally dirty hydraulic system - Thoroughly flush the entire system.

4. Discussion
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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] 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 с. 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 Conferences 135,02020
[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