Research stand for studying the hydraulic drive of adaptive drilling machines

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Abstract. The work relates to mining, in particular to machines used in mining. The article is devoted to the improvement of rotary type drilling machines and methods for investigating the effectiveness of drilling machines. The research complex is described in detail - a stationary stand for the study of rotary drilling, for the study of hydraulic-driven drilling machines. The research complex is made on the basis of a commercially available drilling machine "UBG.00" and allows you to carry out studies of rotary-type drilling machines used in geological exploration, mining, drilling technological wells and experimental drilling machines with adaptation properties. The stand allows, within the limits of regulation, to change drilling modes, to investigate the effect on the process of adaptation of the strength of the drilled rock, blunting of the cutting tool, to investigate power and dynamic characteristics. Adaptation is performed by redistributing the supplied power between the torque and the feed force. The description of the stand design is given, the technical characteristics of a hydraulic-driven drilling machine are given. The limitations adopted during experimental studies, taking into account the characteristics of the hydraulic drive, are formulated. It is shown that in an experimental adaptive drilling machine, the throttle elements of the hydraulic drive have external control and are programmatically controlled to change drilling modes and control methods. External control is performed by a programmable controller and allows drilling in various modes: "free feed", "forced feed", "drilling at constant speed", "adaptive drilling" and others.

1. Introduction

One of the most common processes in mining, including mining, is the drilling process. Drilling machines are used in geological exploration, in tunneling, and in many other technological processes. The most common of the drilling machines are rotary type drilling machines. With the development of technologies in mining, drilling machines are constantly being improved, and drilling process control systems are also being improved.

The concept of adaptive mining machines is known, the executive body of which performs two interconnected working movements [1-3]. These machines use a two-differential drive, which is relatively well studied by Professors Vodyanik G. M. and Drovnikov A. N. and their students [4-6].

There are also known studies of other scientists in the field of adaptive drilling machines [7-9]. Such a drive has the ability to automatically adjust the speed characteristics of the feed and rotation, depending on the torque loads on the hydraulic motors. To give the mining machine adaptive qualities, variants with the use of a birotative engine [1], mechanical and hydro-mechanical differentials [5-6] were studied. Studies have shown high operational qualities of mining machines with adaptive drive
[10]. At the same time, experimental studies are the classical basis of research [11]. Stationary research stands are often used when performing experiments, and in recent years, more and more often the stands are performed in the form of robotic research systems [12].

Such machines with two working movements of the executive body include rotary drilling machines. There are known stands for the study of dynamic processes during drilling with such machines [13]. Automatic operation control of the drilling machine is achieved by changing the structure of the hydraulic drive, by forming two hydraulic differentials.

The drilling process of these machines has not yet been fully studied. Therefore, the task of improving the adaptive process of rotational drilling is urgent.

The article describes the design of the developed research stand for the study of automated hydraulic drive. The drive of a typical drilling machine is converted into an adaptive drive due to the special connection of the feed hydraulic motor and the rotation hydraulic motor.

A drilling machine with such a drive has a number of advantages: low cost and the ability to relatively easily upgrade existing drilling machines with hydraulic motors for rotation and feeding, giving these machines adaptive qualities. The analysis of methods for optimizing the drilling process showed that, within certain limitations, the optimization goals can be achieved by using just such machines without traditional automation tools. From the point of view of automatic control, the differential drive has an internal feedback through the kinematic links, while the negative feedback is carried out simultaneously through two channels - the torque (torque) and the feed force, that is, it has a more flexible control of the operating mode. The disadvantages of a two-differential drive (relatively high control losses) can be leveled by accurately describing the limitations of the control area, and the control capabilities are expanded by introducing additional, non-torque feedbacks. The adaptive qualities of such machines consist in their self-tuning to operating modes that are close to optimal. Along with the automatic adjustment of the operating mode of such a drilling machine, depending on the drilling conditions, in a certain range of external influences, these machines implement the principle of protection against sudden overloads and protection of the mechanisms of the drilling machine from breakdowns. These qualities are provided by the structure of the drive of an adaptive drilling machine and essentially do not have the means of electronic automated control systems (including sensors, regulators, etc.).

2. Materials and methods

Stationary research stands are known for studying the drive of drilling machines. For example, there is a well-known stand for the study of force-moment loads of an adaptive drive [13], which, to a greater extent, provides for the study of kinematic issues of the drive of drilling machines. We have improved this stand. Figure 1 shows a diagram of this stand.

A method has been developed that allows us to study the impact of the working conditions of the drilling machine on the drilling performance. On this stand, it is more possible to explore the possibilities of setting the drives to modes that are close to optimal.

The technical characteristics of the drilling machine are given in table 1. The stand consists of a frame in the upper part of which a sample of the drilled material is fixed. The drilling machine under study is fixed in the base of the frame. At the same time, it is possible to perform, for comparison, drilling with a standard drilling machine "UBG.00.000" of the Ludinovskiy aggregate plant.

The drilling process was carried out mainly with a single cutter of the "RP42M1" type, but it is possible to use other drilling tools. The stand allows drilling with standard and experimental crowns under identical conditions.

Fixing the rock sample is carried out as follows. The sample (its dimensions are 84 × 55 × 55 mm) is mounted on a steel sheet with a hole for feeding the rod with a cutter, the corners are clamped to the side faces of the block, which are bolted together.

The stand allows you to change samples of the drilled material: sandstone, granite, coal, and sand-cement blocks, specially prepared for research. Figure 2 shows the general stand in the conditions of the experiments.
Figure 1. Diagram of the stand for the study of the adaptive drilling process: 1-telescopic hydraulic cylinder, 2-rotary hydraulic motor, 3-rods chuck, 4-drilling material, 5-stand frame, 6-hydraulic hoses, 7-control panel, 8-drilling rod.

Table 1. Technical characteristics of the UBG 1A drilling rig.

| Parameter name                                      | Data                        |
|-----------------------------------------------------|----------------------------|
| Type of drive                                       | Hydraulic                   |
| Operating mode                                      | Rotational                  |
| Hole diameter, mm                                   | 28…45                      |
| MIa/ Working pressure (max), MPa                    | 8.0                         |
| Torque on the spindle at the oil pressure drop on the hydraulic motor, Nm | 154                         |
| Spindle speed control, min⁻¹                         | 100…575                    |
| Maximum flow rate, l/min                            | 50                          |
| Maximum feed stroke, mm not less than, mm           | 1360                        |
| Maximum feed force, N                               | 5000                        |
| Overall dimensions, not more than, mm:              | 1280, 700, 890             |
| Weight, kg, not more than                           | 80                          |
| 80% full life, hour                                 | 1000                        |

The stand is equipped with measuring sensors. The moment of resistance to rotation, the speed of rotation of the drill rod, the feed force, the flow rates of the hydraulic cylinder and the hydraulic motor, the pressure before the engines and after the engines, on the adjustable chokes are measured. The stand is connected to an autonomous oil station with a constant flow rate.
The adjustment chokes are externally controlled and programmatically controlled to change drilling modes and control methods. External control is performed by a programmable controller and allows you to perform drilling in various modes: "free feed", "forced feed", "drilling at a constant speed", "adaptive drilling" and others.

When making measurements, the following assumptions are made:

- The speed of the oil station drive motor, and the hydraulic pump are constant, and the power of the drive motor is infinite.
- The hydraulic motor and the hydraulic cylinder are connected to the load by a transmission without backlash.
- Leaks are proportional to the pressure drop.
- The flow rate of the liquid is proportional to the volume of the liquid in the pressure line, the rate of pressure change, and inversely proportional to the modulus of its elasticity.
- Wave processes in hydraulic lines due to their short length do not affect the dynamics of the hydraulic drive.

3. Results and Discussion

Preliminary results were obtained. In particular, the adjustment of the degree of adaptation was studied, the dependence of the characteristics of the hydraulic drive on the settings of the hydraulic circuit throttles was investigated.

Detailed studies on this stand will allow us to verify the adequacy of the results of modeling the operating modes of the studied adaptive drive to full-scale experiments.

Feedback in such machines is carried out through the kinematic links of the machine, which has a certain circuit of the drive elements. To develop a design methodology for such machines, it is advisable to perform a number of studies on the study of force-moment connections in their drive on a specialized stationary stand.

Here are some measurement results on the developed stand.

The following studies were carried out:

- The influence of the fortress are drilling rocks on the testimony of the drilling process
- The influence of the settings of the chokes on the performance of the actuator and the indicators of the drilling process. Figure 3 shows the resulting dependencies. The influence of...
the contact strength (Rk) of the drilled material on the specific feed (S), torque (M). The specific feed (S) at a constant speed determines the drilling performance.

As can be seen in the above graphs, with an increase in the strength of the drilling material with an adaptive drive scheme of the drilling machine, the moment of resistance to rotation increases, and the power consumption increases. It is obvious that with a higher axial force (F), the torque of rotation is higher and the intensity of its growth increases. Obviously, the power of the rotation engine should provide this increase.

At the same time, the specific drilling feed (C), and hence the productivity, decreases in a hyperbolic relationship. By adjusting the throttle settings, you can reduce the intensity of the decrease in the specific feed, but then the intensity of the increase in the torque resistance to rotation will increase. There is a certain balance between the performance and the load on the rotation motor of the drilling machine, which can be adjusted from the maximum maximum performance, to the minimum rational power of the rotation motor. Figure 4 shows the dependence of the influence of the degree of bluntness of the cutter (Fbl) on the moment of resistance to rotation (M) for different strength (Pk) of the drilled material.

The given dependencies are linear. With an increase in the strength of the drilled material, the moment of resistance to rotation increases significantly. With an increase in the bluntness of the cutter for soft drill rocks, the rotation moment increases slightly. Obviously, when drilling strong materials, it is necessary to replace the cutting tool more often in order to reduce the moment of resistance to rotation and avoid breakage of the cutting tool, in the case when the power of the rotation motor is sufficient.

4. Conclusions
The conclusions were drawn from this paper:

- The design of the stand allows you to perform extensive studies of the rotary drilling process both with a standard drilling machine and with an adaptive one, the hydraulic motors of which are included in a two-differential scheme.
- On the stand, it is possible to study various designs of cutting heads, to study drilling modes, and the impact of machine operating conditions on drilling performance.
- External control of the adjustment chokes allows you to programatically change the operating and kinematic parameters of the hydraulic drive, optimize these modes for different drilling materials and the degree of bluntness of the cutting tool.
Figure 4. Torque dependence (M) from the blunt area of the cutter (Fbl) at different strength of the drilled material (1) Pk1 = 1188 MPa, (2) Pk2 = 250 MPa, (3) Pk3 = 44 MPa.

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