Study of adaptive hydraulic drive of rotary drilling machine

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Abstract. The article deals with drilling machines in which the ratio of the load between the power to rotate and the power to feed is carried out automatically due to the structure of the adaptive machine, with the provision of self-regulation for drilling modes close to optimal. Changing drilling conditions automatically results in a change in the ratio of speed to feed force, providing maximum performance while protecting against sudden overloads, for example, when encountering solid inclusions in the drill rock, or when shading a well. The ratio of frequency of rotation and feed rate determines the specific depth of cut (specific feed) and determines the performance of the working process of the drilling machine. A typical example of such a machine is a drilling machine rotary type with hydraulic rotation and feed.
The cutting theory determines the rational drilling conditions, known rational specific feed, rational speed, minimum and maximum feed force, depending on the strength of the material being drilled and the degree of blunting of the cutting tool.
The block diagram of such a drilling machine is considered and the analysis of the influence of parameters and characteristics of individual hydraulic elements on the drive setting on the rational mode of operation is given. The research stand and its structure are given, some results of experimental researches are given. It is established that the chokes of the drive settings can adjust the degree of adaptation, change its sensitivity to external influences and change the range of operating conditions for the rational functioning of adaptive drilling.

1. Introduction
Known drilling machines in which the drilling process is carried out by automatically maintaining the ratio of two connected movements. These are the two main movements of the Executive body-the drill rod: forward movement in the direction of drilling and rotational movement.
Classic drilling machines designed for mining or construction work; represent an extensive class of machines, with a variety of power and performance. These machines are designed for specific conditions of their application. But for all these machines there is a rational relationship between the two working movements.
The mining and construction drilling machines are adjacent to Metalworking machines, in which the drilling process is provided by at least two interconnected movements. Moreover, in most cases, their ratio determines the performance of Metalworking, especially the specific energy consumption of cutting and productivity, as well as the temperature conditions of cutting and the purity of the surface. The resource of the cutting tool depends on how close the considered ratio is to the rational value. The current level of development of the cutting theory regulates the optimal conditions of Metalworking for different materials and conditions of the machine.
2. **Topicality**

Obviously, it is important to automatically maintain a rational ratio of the two working movements of the Executive body of the drilling machine in the conditions of variability of strength, viscosity and other characteristics of the drilling material. In this regard, the concept of drilling process control without the involvement of automation and computer technology is known [1]. This method is known, it was developed by a number of researchers and tested in industry [2,3]. Let's take a closer look at some of the known studies.

3. **Practical relevance**

The peculiarity of the control of the working process of machines with an Executive body performing two working movements is the account of random and systematic external influences to which the control system must respond to an adequate (adaptive) change in the operating mode, one or both control channels. In this case, the control criterion can be both a rational ratio of working movements and their parameters, and the transition of the drive to a special, for example, emergency (protective) mode.

For this purpose, it is advisable to use the methods of hydraulic automation, and in particular to use an automated hydraulic drive, which uses hydraulic differentials [4]. Thus a feature of such schemes is the implementation of feedback via silo-instantaneous kinematic links [5]. Experience in the development, research and application of this type of drives has shown the ability to provide high performance and stability of these machines [6,7].

An example is a device that is designed for roughing parts of a complex profile by milling (Fig.1). This device automatically provides stabilization of the thickness of the removed layer during machining of curved surfaces [8].

![Figure 1](image)

**Figure 1.** Schematic diagram of the device to stabilize the thickness of the removed layer when machining curved surfaces. (SU A. S. No. 483224): 1-motor, 2-throttle feedback, 3 -actuator, 4 - mill, 5 - surface processing, 6 - reversible feed drive, 7-feeder; 8,9 - throttles setup

Next (Figure 2) the block diagram of this device is shown.
Figure 2. Block diagram of the device to stabilize the thickness of the removed layer in the machining of curved surfaces

For figure 3 shows the hydraulic scheme of the adaptive drilling machine [9], the drive structure of which contains two hydraulic differentials. The first differential is formed by the hydraulic hose from the exit of the hydraulic pump, a hydraulic hose connected to the choke DR1 and the hydraulic hose going to the hydraulic motor HM. The second differential is a hydraulic cylinder.

Figure 3. Hydro scheme adaptive drill machine "UBG-1A»

Figure 4. Structural scheme of adaptive hydraulic drill machine "UBG-1A»
As can be seen from the comparison of the above schemes, the drive of the adaptive drill, machine and drilling machine can be represented by the bridge inclusion of a hydraulic motor or hydraulic cylinder in the diagonal of the bridge.

Obviously, depending on the ratio of the shoulders of the bridge, the direction of flow in the diagonal can be direct or reverse. The principle of operation of the adaptive drilling machine "UBG-1A" is given in the article [10].

During the research was used as a standard drill machine rotary type "UBG-01-000" Lyudinovo aggregate plant and the adaptive drill machine "UBG-1A", the drive which was re-made from gidrobiontov model of the drilling machine. The drive scheme of a typical drilling machine is shown in figure 5.

![Figure 5. Hydraulic scheme of drilling machine "UBG.01-000" where HP- hydraulic pump; YM - hydraulic motor; throttle1, throttle2 - throttles settings; HC-hydraulic cylinder](image)

As can be seen in the above diagram, the speed of the drill rod of a typical drill machine is not regulated, and the feed control is performed by the reverse spool and the throttles throttle1, throttle2. The experiments used the real characteristics of the hydraulic cylinder, hydraulic motor and switching equipment of a typical machine "UBG.01-000".

The feature of drill machines that have adaptive drive, is their ability to automatically maintain a rational ratio of the speeds of these movements without additional automatic.

To solve the problems of establishing the degree of adaptation to changing drilling conditions and determining the rational conditions of regulation, a research stand was developed, the scheme of which is shown in figure 6. The General view of the stand is shown in Fig. 7.

![Figure 6. Hydraulic scheme of the research stand on the basis of the drilling rig "UBG.01": GP – hydraulic pump; HM – hydraulic motor of rotation; HC – cylinder flow; throttles1,2,3 – throttles settings for operating modes, throttle 4 – control external feedback](image)
Figure 7. General view of the stand for the study of adaptive drilling control systems

The developed stand made it possible to supplement and clarify the known research in the field of adaptive rotary drilling machines, to outline ways of their improvement. Table 1 provides information on the research drilling rig used. The table shows the nominal operating parameters and modes. The stand is a control system for the hydraulic cylinder feed and hydraulic motor rotation of the drill rod at different throttle settings, which allows you to adjust the ratio of flow between the rotation and feed drives at different settings, which corresponds to different drilling modes. By adjusting the throttles, it is possible to achieve redistribution of flows in hydraulic circuits, which will bring the measurement conditions closer to the modeling conditions of this system [11].

Table 1. Technical characteristics of the stand «UBG-1».

| Installation parameters                  | Parameter value                      |
|-----------------------------------------|--------------------------------------|
| Torque on spindle, NM at a differential oil pressure, MPA | 154 / 14-20                          |
| Spindle speed, vol./min / at oil consumption, l/min | 345-805 / 30-70                      |
| Feed stroke, mm                         | 1360                                 |
| Maximum feed force, N                   | 5000                                 |
| Dimensions (H*H*L), mm                  | 1280*700*890                         |
| Weight, kg                              | 80                                   |
| Working fluid                           | min. oil viscosity                   |
|                                         | 200-330 SST                          |
| Bore diameter, mm                       | 28-45                                |
The studies obtained data to determine the adequacy of the previously developed model of adaptive drilling machines, studied the factors affecting the accuracy of adaptation and the degree of approximation of the automatic control process to the rational conditions of drilling. The following studies were carried out:

1. The influence of the fortress is drilling rocks on the testimony of the drilling process
2. The influence of the settings of the chokes on the performance of the actuator and the indicators of the drilling process.

The influence of the degree of contact strength on the performance and performance of the drilling process on the specific feed \( S \), torque \( M_{rot} \) shown in figure 8.

**Figure 8.** Dependence of torque (M) and specific feed (S) on rock strength (Rk), at feed force: 400H (1) and 800H(2)

The influence of the degree of wear of the cutting edge on the performance and performance of the drilling process at different rock strength are shown in figure 9.

**Figure 9.** The Dependence of torque from the area of bluntness of the cutter at the castle rocks (1) Rk₁ =1188 MPa, (2) Rk₂ =250 MPa, (3) Rk₃ = 44 MPa

The possibility of setting the throttles to regulate the threshold value of the feed force and automatic transition to the reverse movement of the feed cylinder rod in the case of jamming of the
Drill rod was experimentally investigated. The influence on the control characteristics of one of the most important in the scheme of the throttle "DR1" – which is the "shoulder" of the first hydraulic differential. The value of the flow section of the throttle determines the degree of sensitivity of the adaptation scheme.

For Figure 10, 11 examples of dependence of flows on the moment of resistance to rotation at different values of resistance of the throttle "DR1" (degree of opening) are given.

![Figure 10. Dependence of flows in the hydraulic lines from the moment of resistance to rotation, when the degree of closing throttle Dr1: 4%](image1)

As can be seen in the graphs at a relatively low hydraulic resistance of the throttle DR1 (figure 10), the reverse automatically occurs when the torque resistance to rotation increases at about 180 Nm. And with a high degree of throttle closure (figure 11) the reverse is not performed up to 570 Nm. This mode for the operating range is performed without reverse. Adjustment of the throttle DR1 provides adjustment of the degree of adaptation.

4. Conclusions
1. Feature of the above inclusion of elements of the hydraulic circuit is the solution of automatic control circuit. By increasing the torque on the hydraulic motor rotation, the feed force will automatically decrease, up to the reverse movement. What is necessary, for example, when jamming the rod during drilling.
2. Increasing the strength of the drill rock, would reduce the specific feed and reduce the torque, but in this control scheme, reducing the torque will increase the feed force and stabilize the drilling speed.
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