Adaptive drive and adaptive mechanisms of technological machines

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Abstract. Examples of the development and application of mechanisms and machines endowed with the properties of self-adjustment (adaptation) to changing operating conditions, in particular machines for mining operations, are presented. It is shown that adaptive mechanisms and machines have a number of advantages in variable operating conditions. At the same time, the area of knowledge on the creation and use of adaptive machines and mechanisms to date, remains poorly understood. The purpose of the work is to present the concept of adaptation of mechanisms and machines to operating conditions, the Executive bodies of which work with variable loads. The results of the paper can be useful for machines and mechanisms design with self-adjusting and self-regulating characteristics. Adaptive mining tunneling, drilling machines and adaptive cutting tools reveal the concept of adaptive machines and mechanisms characteristics to changing operating conditions. The principle of operation of an adaptive drilling machine designed for drilling operations is described. It is shown that the feedback between the torque of the resistance to rotation on the drill rod and the force of the rod feeding on the face is carried out through the force-torque connections with the optional use of electronic automation tools.

1. Introduction

In a large group of technological machines, the workflow is ensured by the ratio of two related movements. For example, it can be noticed in rotary drilling machines. This ratio often determines rational modes of operation and affects the performance and resource of machine functioning. In this case, the drive of such machines can be organized by using one engine or two engines. In the first variant, the engine power is divided into two movements, and each of the associated movements is controlled through transmission. In the variant of using two engines, their work is synchronized to perform the necessary ratio of each of the working movements. To perform construction, mining and geological explorations, drilling machines of various capacities with different productivity are used at different drilling conditions.

Two operating movements are usually performed by mining and tunnelling, loading and other mining machines.

2. Relevance

In the practice of controlling the drive of machines with two coupled movements, automatic control systems are often used. But the machines in which the automatic maintenance of rational balance of working movements is provided without involving automation and computer control are of special interest. This method is well known, as it was developed by a number of researchers at Novocherkassk
Polytechnic University [1, 2, 3]. This paper presents some results of the development of previous studies.

Consider the adaptive drive on the example of a loading machine (figure 1). The drive of such loading machine includes hydraulic and mechanical differentials. The first is formed by means of parallel inclusion of the hydraulic motors $HM_1$ and $HM_2$. The second differential is formed by a planetary adder. Due to the sequential activation of $HM_2$ and $HM_3$ hydraulic motors, the automatic adjustment of the speed of the machine body to the loading material is provided from the moment of resistance on the loading body. At the moment when the resistance on the shaft of the motor $HM_3$ is less than the set one, the machine speed moving forward increases. At critical rotation on the shaft of this hydraulic motor, the machine stops, and when the rotation exceeds the critical indicators, the machine reverses the movement and drives away from the loading materials.

Details of the machine are given in the description of the copyright certificate [3].

![Diagram of hydraulic drive of the loading machine](image1)

**Figure 1.** Hydraulic drive of the loading machine according to A.S. USSR № 420793; 1-plantetary gear, 2-track supports.

Figure 2 shows a diagram of a hydraulic loading machine with two hydraulic differentials [4]. The first differential is formed by dividing the flow rate of the hydraulic pump 3 into two arms: the hydraulic motor 4 and the hydraulic motor 6. It is obvious that the expenses through the shoulders of this hydraulic differential can be redistributed. On the drain line of the hydraulic motor 4, a reversible hydraulic motor 5 is included, which is the drive of the mechanism for moving the machine towards downloadable material.

The hydro motor 5 forms the second hydraulic differential. Indeed, the drain line of the motor is connected to its drain line of the hydro motor. Both the direction of rotation and the frequency of rotation of the hydraulic motor 5 depend both on the loading of the loading mechanism and on overloading of the conveyor and on the resistance to the advancement of the machine behind the loaded material.

Consider another example. Figure 3 shows a basic hydraulic diagram of an adaptive drilling machine and a block diagram of its drive [5].

From the above stated scheme, it is obvious that the rotation on the hydraulic motor of rod rotation 2 determines or (regulates) the feed force of the hydraulic cylinder. At a certain operating moment the resistance of the considered motor to rotation and the feed pressure is automatically reduced, that leads to stabilization of the resistance moment to rotation of the hydraulic motor rotating shaft. The description of the design of adaptive machines and the results of studies of the adaptive drive are given in [6-11].

Consider some typical examples of adaptive devices designed for rock cutting. The unit of fastening of the cutting tool is developed (figure 4). The cutter uses a mechanical trigger. At the time of dynamic impact, at the maximum cutting force, there is a micro-pressing and rotation of the cutter. This ensures the wear of the cutter on the cone generatrix. The resource of such a cutter, reinforced with a hard alloy, is increased by about 8 times. Adaptation to the cutter wear process is manifested in its self-sharpening properties.
Figure 2. The Hydro-mechanical scheme of adaptive loading machine: 1- hydraulic pump, 2- motor loading, 3- machine movement motor ,4- loading conveyor motor.

Figure 3. Driving diagrams of the boring machine “UBG-la”: (a) - hydraulic circuit, (b) –structural diagram: 1- hydraulic cylinder, 2 - hydraulic motor of rod rotation, 3, 4.5 - throttles; 6- hydraulic pump, 7- control equipment, 8 - hydraulic lines to the pump.

We have developed cutters for mining machines with automatically updated cutting edge. The variant of such cutter for coal cutting is given [12].

A variant of the design of such a cutter is shown in figure 5. Cutter for the destruction of the coal includes a holder 1, a toothed wheel 2, the movable working element with cutting part 3. The toothed discs 2 mounted on holder 1 from the bottom.

The movement mechanism of the working element is made in the form of a worm pair, the gear wheel of which is mounted on the guide screw 5 and connected to the working element, and the worm 4 is connected to the gear wheel 2. The guide screw 6 is provided with a nut 7, and the working element is closed by a protective casing 7.
Figure 4. The device of a rotary self-sharpening cutter. 1-cone cutter with shank, 2-mechanical trigger parts, 3 - support axle.

Figure 5. Self-Sharpening cutter: 1-holder a, 2-gears, 3-movable cutting part, 4-worm gear, 5-guide screw, 6-movable nut, 7-cutting plate cover, (a) side view, (b) section view.

The destruction of durable rock cutting tool takes high impact loads. We have developed a method of fastening the cutting tool [13,14], which significantly reduces the breakage of the reinforced part of the tool and its holder (figure 6).

Adaptation of the cutter to shock loads is ensured by its flexibility and fastening elasticity of the holder. In critical operating conditions, in cases when there are a lot of coal inclusions or very strong rocks, the time of operation can be automatically increased, while the peak values of the efforts can be reduced. These loads and shocks when cutting hard rocks or rocks alternating in hardness with coal inclusion do not lead to a sudden breakage of the cutting part, as it is reinforced with a hard alloy. Cutter adapts to shock loads.
Figure 6. The design of the elastic attachment of the tool in the tool holder: 1-cutting part, 2-shank, 3-holder, 4-outer holder, 5-shock absorber, 6–internal holder.

3. Conclusion

The following conclusions may be read:

1. Conceptually, adaptative characteristics can increase the reliability and performance of machines and mechanisms.
2. Examples of adaptive mining machines having been tested show the necessity to consider this approach as the way of machines and mechanisms improvement.
3. Particularly high effect of adaptive drive and adaptive mechanisms is manifested in critical operating conditions.

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