Improvement of shock system of hydraulic drill to increase drilling intensification

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Abstract. The article deals with features of drilling and blasting operations with the use of hydraulic drills prevailing in the amount of use as drilling heads on drilling (mining) equipment. The device and the operating principle of hydraulic drills are discussed. In order to increase the intensification of drilling, the modernization of hydraulic drills is proposed by using the "shock-worker –striker - shank" shock system, which is characterized by an increase in the transfer coefficient of the shock pulse through the striker, performing high-frequency oscillations («rattling» striker) between the shock-worker and the shank. A graph of the dependences of the parameters of the modernized shock system is given and the conditions for the existence of the «rattling» phenomenon of the striker due to which the drilling productivity is expected to be increased are indicated.

1. Introduction.

When considering ways to increase the productivity of mining operations, two directions can be distinguished [1-3]:

- extensification of mining operations, consisting in increasing the quantitative components of existing production facilities and equipment on them (increase in the number of mines, horizons, units of equipment);
- intensification of mining operations, which consists in increasing the quality components of existing production facilities and equipment, by improving and modernizing existing production facilities.

It is worth noting that the extensification of mining operations requires large capital expenditures and, in a certain period of time, it is impossible to realize. And with the intensification of mining operations, it is possible to significantly increase the production characteristics of enterprises and equipment on them without wasting time and money.

Thus, the use of high-performance self-propelled drilling equipment was the main way to intensify mining in the development of ore deposits by drilling and blasting, which resulted in a constant increase in loads on drilling equipment.

The most effective way of using this technique in the development of particularly powerful ore bodies is to fan the ore with deep wells, in which the drilling and blasting complex includes drilling, charging, ventilating, securing, cleaning and delivery to the ore of the mined ore [4, 5].

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Since the drilling of blasting holes is the most laborious from the whole cycle, using the principle of intensification in relation to drilling machines and the equipment used on them, it can be noted that one of the promising areas is the improvement of the shock system of hydraulic drills, which today occupy the major share used rock-cutting equipment.

2. Principle of operation of hydraulic drills.

The work of all hydraulic drills consists in the perforation and rotation of the drilling tool, which can be either a single rod with a crown or a composite drilling rig consisting of several screwed rods with a crown on the latter.

By the principle of the rotation of the drilling tool, all the drills are divided into two types [3]:

- with dependent rotation of the drilling tool (impact-rotary);
- with independent rotation of the drilling tool (impact-rotational).

A large amount of transmitted energy and a hight intensity of the impact in hydraulic drills can be realized only with the use of a separate drive for independent rotation of the drilling tool, which will allow the most rapid destruction of the rock and form a round form of the will. Therefore, in the drills in question, the most important aspect for modernization will be the process of impacting the tool on the rock.

Drilling tools in classical hydraulic drills (Figures 1) are impacted by collision of the piston 1 with the shank 2, the threaded end 3 of which is screwed with a drilling tool (rod with a crown) at a speed of 10-11 m/s [4].

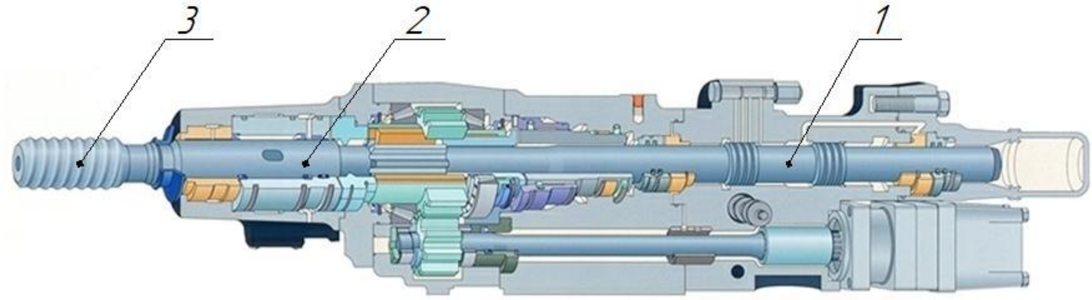

Figure 1. The device of the standard hydraulic drill COP 4050MUX.

The mass of the piston in the hydraulic drills of the middle class is within 5 kg, for heavy models of hydraulic drills it can reach up to 13 kg. To achieve the required speed of the piston, the hydraulic fluid that acts on it is working surface, on the shape of which the shape of the shock pulse depends. The normal operating pressure in the circuits of hydraulic systems reaches values in the range of 120-230 bar.

Thus, it can be assumed that the main directions of modernization of hydraulic drills are [3]:

- increasing the working pressure in the contour of the impact mechanism;
- increase in the length of the working stroke of the piston;
- increase in the dimensions of the working surfaces of the piston.

However, the above-mentioned directions for the modernization of hydraulic drills assemblies are extremely time-consuming, since they lead to the need to design a new machine, so the creation of such prototypes is possible only in the factory with the involvement of considerable resources of the manufacturer.

3. Modernization of the shock system of hydraulic drills.

The solution of the problem related to the impossibility of further modernization of hydraulic drills without significant costs can be the use of a three-mass shock system (Figure 2). The essence of system of three-mass shock system is the placement between the shank and the piston - the element of a relatively small mass - the striker [6, 7, 8] so that the frequency of impacts of the piston remain unchanged. Such technological solution does not require significant constructive changes and the phenomenon resulting from the use of this system, called the «chatter» of the striker [6, 7], can significantly increase drilling productivity and expand the range of application of existing hydraulic drills.

The process of «chatter» striker is the vibration of the striker between the approaching piston and the shank, expressed by a series of repeated impacts of the striker on the surfaces of the shank and piston. It ultimately leads to the «sticking together» of all three elements of the system and the release of the energy of the elastic deformation of the striker due to «quasi-plastic» impact [6].

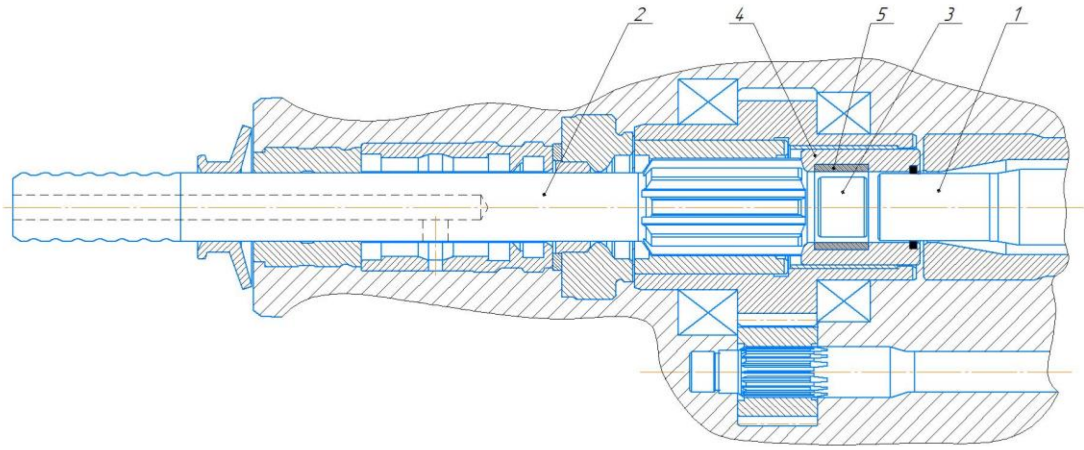

Figure 2. The device of the modernized hydraulic drill.

Piston 1 reports the shock pulse shank 2 through the striker 3 (Figure 2). During the working stroke in the cavity of the brush 4, the striker «chatter», which ends with the collision of all three bodies, that is, with a «quasi-plastic» impact (Figure 3.6) [7, 12] and the entire impact energy, is transmitted to slaughter through the drilling rig (rod set) screwed onto the threaded end of the shank.

The three-mass shock system implemented in the PP-63 pneumatic drill constructions proved the advantages of using the striker's «chatter» process in such shock systems, exceeding the drilling speed with drills with this shock system relative to standard drills is at least 30%. This is proved by many years of research of modernized pneumatic drills in the conditions of «Apatite» organization, confirmed by protocols and test certificates, video matrials [6].

For hydraulic drills, a three-mass shock system should facilitate:

- increased productivity of drilling, with constant frequency of impact of the piston;
- increase in the resource of the working face of the shank;
- reducing the load on the hydropneumatic accumulators due to the reduction of noise and vibration.

During the operation of the hydraulic drill with the proposed shock system, it becomes necessary to hold the striker in the position corresponding to the beginning of the working stroke of the piston (Figure 3.1) and return the striker to this position at the end of the working stroke. In Figure 2 holding the striker and returning it to its original position is accomplished by using a permanent magnet 5 installed in the brush 4. This requires the execution of a striker made of the material of the ferromagnet.

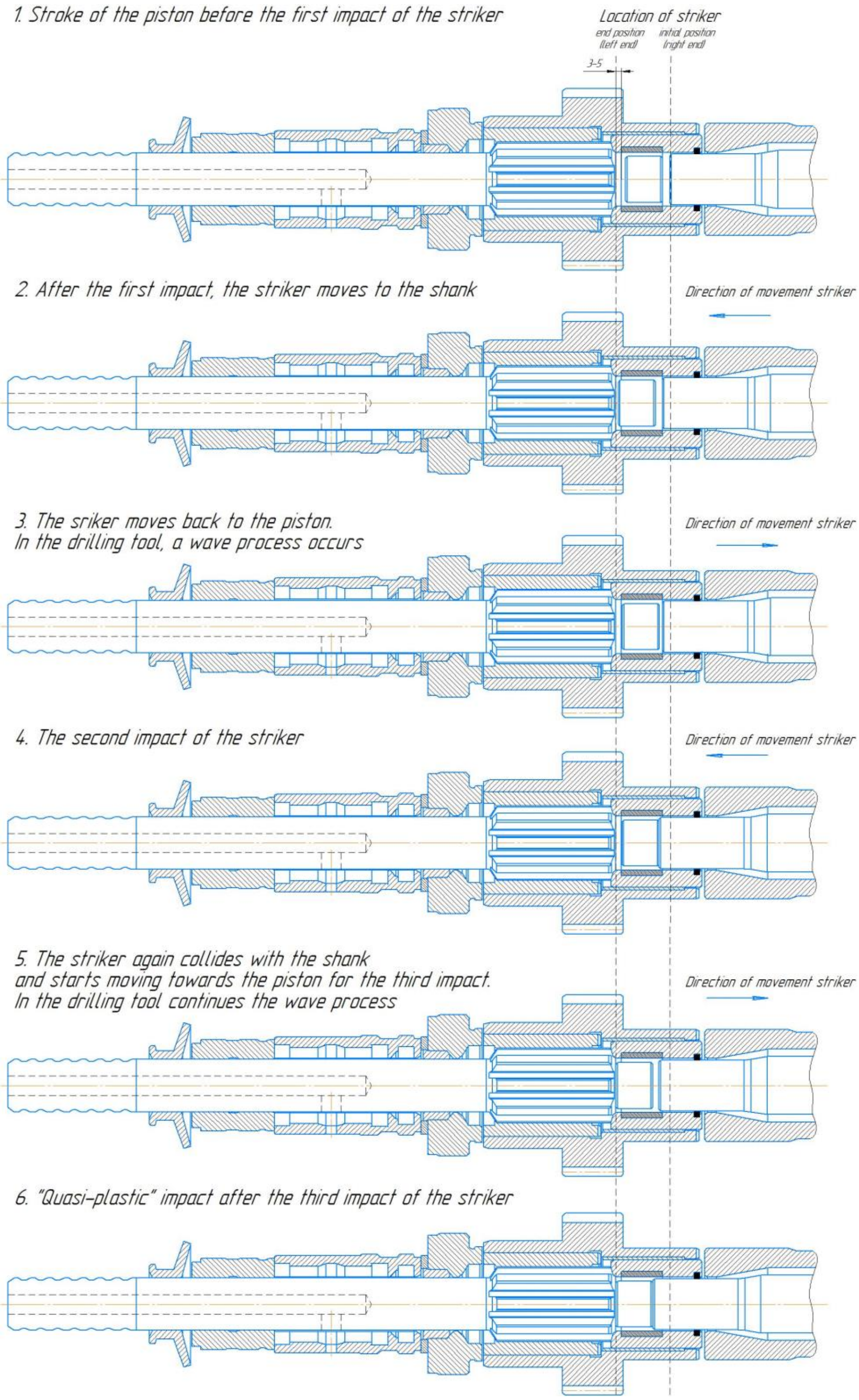

Figure 3. «Chatter» striker process in the proposed shock system.

4. Calculation of the parameters of the modernized shock system.

For selection of the parameters of the new shock system, namely the necessary mass of the striker and the mass of the piston (with the fixed weight of the drilling rig), it is required to use the calculations proposed in the works: Yungmeister D A, Pivnev V A [7, 8].

The first condition for the existence of the «chatter» of the striker [7, 8]:

$$\frac{4R}{(1+R)^2} < \frac{1-\mu}{1+\mu\nu}, \tag{1}$$

where μ - coefficient characterizing the ratio of the mass of the striker to the sum of the masses of the piston and striker (the mass of the twin striker m_2); ν - coefficient characterizing the ratio of the mass of the twin striker m_2 to the mass of the drilling rig m_1; R – coefficient of recovery of the velocity.

Having inserted in the condition known parameters of the elements of the shock system used on drilling machines:
- weight of the drilling rig, which can be in the range of 60.9 ... 409.3 kg;
- the mass of the piston averages 12 kg, and together with the striker - 13 kg.

Let us calculate the coefficients for different lengths of the drilling rig. Thus we obtain the dependence of the parameters of the elements of the shock system (Figures 4).

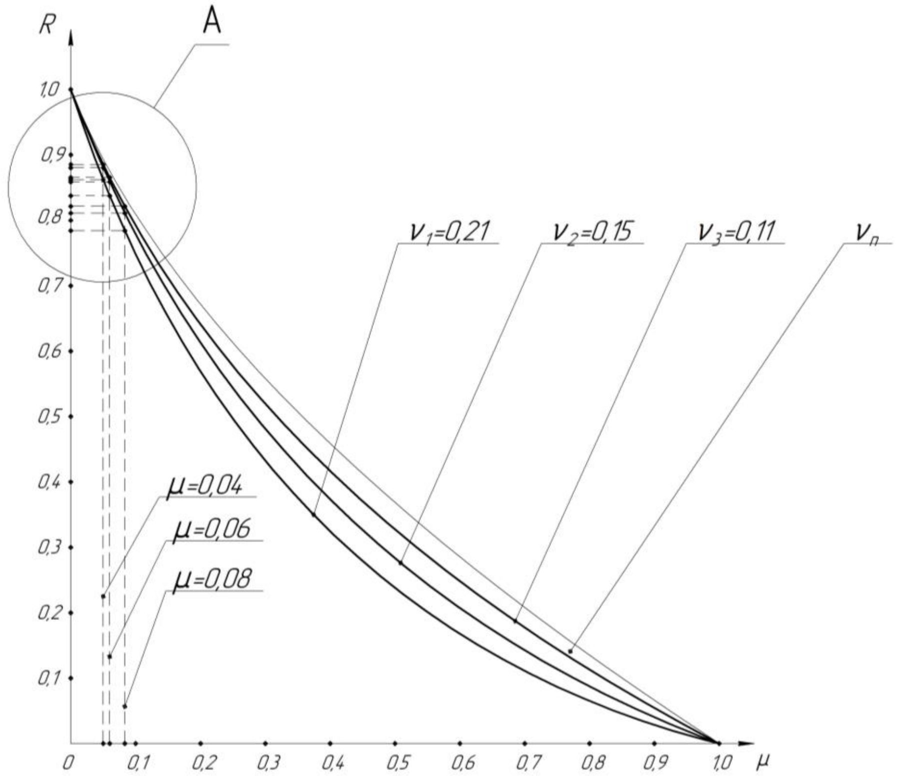

Figure 4. The graph of the dependence of the velocity recovery coefficient on the parameters of the mass of the elements of the shock system (ν_1 – mass ratio for drilling with one boom, ν_n – mass ratio for drilling with nth boom)

Preliminary calculations and studies allow us to state [9] that the phenomenon of «chatter» of the striker when using a three-mass shock system is an intensification of the drilling process, since the passage time of the shock wave and its return as a reaction from the face may coincide with the time of the next impact of the striker to the end of the shank , because of which the rate of recovery of the velocity of the elements of the shock system can exceed the tabulated values [10]. As a result of this increase in the speed recovery factor, the impact energy is increased and more effectively transferred to the drilling tool and the face, thereby increasing drilling productivity by 15-20%.

One of the main conditions for ensuring a stable process of «chatter» is the excess of the actual value of the coefficient of recovery of speed R above the table one, equal to 0.78 (Fig. 4, Zone A).

As shown in Figure 4, with increasing depth of drilling, the coefficient ν decreases, so it is possible to allow R above the tabulated value, while remaining in the zone (limited by the axes and curve ν) of the stable «chatter» process, by exposing the striker of reflected and re-reflected waves compression in the stove, piston and striker. At the same time, use the maximum light weight from the condition of its strength. The increased values of the coefficient of recovery of the striker's speed will make it possible to achieve an increase in the amplitude of the impact pulses transmitted in the rods, in comparison with the single interaction in the two-mass «piston-shank» model. This feature is confirmed in theoretical studies of the three-mass shock [11].

An additional condition for increasing the stability of the «chatter» process is the following relation:

$$T_{wave} < T_{rat}\,, \tag{2}$$

where T_{wawe} – duration of the wave process in the drilling rig (compressional wave propagation along the drilling rig), sec; T_{rat} – the estimated duration of the «chatter» without regard to the impact on the striker of reflected waves after the departure of the shock-worker during idling, sec;

The results of calculations of the passage time of the reflected wave along the drilling rig and the time for «rattling» for the depth of drilling with one rod and 28 rods are summarized in Table 1.

Table 1. Comparison table.

Drilling depth, m	Time of passage of the reflected wave along the drilling rig, sec	The duration of the striker «chatter» process, sec
1.83	0.000485	0.0102
51.24	0.00095	

Based on the results obtained from calculations of the propagation time of waves and the process of «chatter», it can be concluded that the reflected waves from the face will come earlier than the end of the «rattling» period of the striker.

5. Conclusion

The possibility of implementing the «chatter» process of the striker in the design of the drills is confirmed by theoretical and experimental studies on pneumatic drills. But using a three-mass shock system («piston-striker-shank») and obtaining a stable process of «chatter» are difficult due to the uneven air pressure in the mine network. However, for ideal conditions, the upgraded pneumatic drill PP-63 showed a 1.5 - 1.8 time excess of drilling speed.

In hydraulic drills in the impact zone of the striker (between the shank and the piston), there is no high pressure of the medium, which should not interfere with the stable process of the «chatter» striker.

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