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Mechanism of discrete rotation of hydraulic perforator tool

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Mechanism of discrete rotation of hydraulic perforator tool

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Abstract. The background for engineering a hydraulic rotary–percussive hydroperforator is discussed. The structural layouts of the drilling tool and hydroperforator rotary mechanism are presented. In the rotary mechanism, percussion and rotation assemblies are powered by the same source. The distinctive feature of the drilling method implemented in the developed perforator is shown.

1. Introduction

Hand-held dills are widely used in mining, construction and roading. By mode of functioning, these tools are grouped into hammer drill and rotary hammer drills [1]. In hammer drills, drill rod is rotated during forward or backward stroke of piston by helical pair and crickwork. In rotary hammer drill, drill rod is rotated independently from piston motion by a special device.

The existing drills are mainly driven hydraulically and need large compressors. Deficiency of such set is low efficiency, pollution with oil fog formed in return air exhaust and limited blow energy. According to [1], rotary hammer drills possess low torque, and the capacity spent to rotation of the tool is less than 15% of its percussion capacity.

Jackhammer drills meant for destruction of hard coatings also have drawbacks. For this reason, they are replaced recently by hydraulically driven hammers supplied by small hydro stations. The latter set of equipment has at the least three times as high efficiency as the set of a pneumatic hammer and a compressor station. Hydraulic hammers are lighter in weight, more convenient in operation and ecologically friendly.

It was mentioned in [2] that "…hydroperforators for rotary–percussion drilling machines, at the same size and weight as air-drills, transfer 2–3 times as much power to the drilling tool and increase drilling efficiency by 2–3 times." At the same time, due to no exhaust, hydroperforator produce noise 5–15 dB lower than air drills. Furthermore, as shown in [3], hydroperforators have more rational design of a striking piston, which, at the same blow velocity, creates smaller stress in drill rod as against pistons of air-drills. As a consequence, durability of drill rigs is increased.

Finally, air-drills are low-efficient in highland conditions. By the data from [5], energy and process performance of air-drills depends considerably on elevation of a working site. For example, in operation at the elevation of 4–4.5 thousand meters, performance of air-drills can decrease by 2.4–4.4 times, while the energy requirement of the process will grow by 1.3–2.4 times.

In this regard, it can be stated that one of the promising ways of improvement of hand drills is their transition to hydraulic energy. This trend is already implemented abroad. For instance, Atlas Copco (Sweden) has produced a hand-held hydraulic rotary hammer drill of small weight. Judging from literature sources, no hydraulic hammer drill yet exists. At least, it is unannounced. In this connection, the present research aims to develop design and concept flow chart of hydraulically driven hammer drill.

2. Rotation mechanism of hydraulic perforator tool

It is necessary that drilling tool rotates after blow, which in air-drills is executed by helical pair representing a screw mechanism with high angle of inclination and large lead of screw. These mechanisms are of modest reliability and, moreover, have the transfer torque constraints.

Application of air-drill design solutions in hydraulic hammer drills is not always possible. This is connected with low reliability of helical mechanism and, also, with difficult generation of high torque using the helical pair.

Thus, design of a hydraulic hammer drill needs both a hydraulic drive and a drill rod rotator more reliable than the helical mechanism. In the known design of hydroperforators, drilling tool is rotated using a special drive. At the same time, some designs of hydroperforators connect rotation of drilling tool with the percussion mechanism [5, 6].

One of the scenarios of the drilling rod rotation provides using a rotary hydraulic motor (Figure 1). It consists of a housing *1,* swivel nut *2* and a stator *3* arranged in the central opening of the housing *1*. The stator is immovable relative to the housing, and the nut can turn around its axis by a present angle. In the nut *2* a rotor *4* with rollers *6* is placed. The internal surface of the rotor is made as a hexagonal opening, where a drilling rod *5* is inserted and rotates together with the rotor. Along the outer diameter of the rotor, in parallel to its rotation axis, grooves are made to accommodate the rollers.

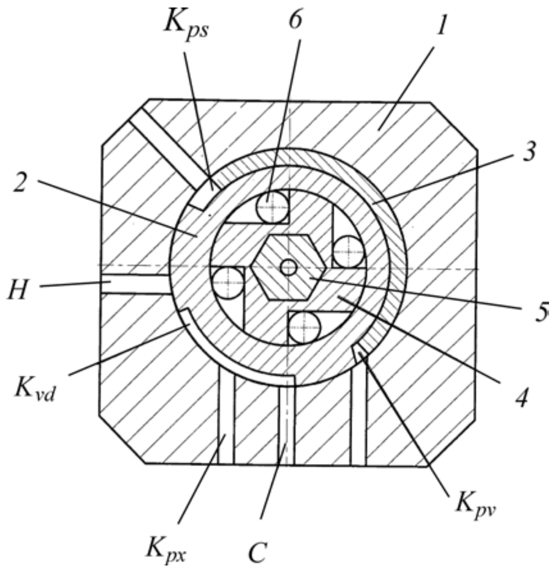

Figure 1. Layout of the hydroperforator motor: *1*—housing; *2*—rotation nut; *3*—stator; *4*—rotor; *5*—drilling rod; *6*—roller.

In this configuration of the rotor grooves, during clockwise rotation of the nut *2*, rollers roll to the wider part of the groove and transfer no torque from the nut to the rotor *4*. In the counterclowise rotation of the nut, the rollers are jammed between the nut and rotor in the narrow part of the groove, ad the nut turns counterclockwise with the rotor. In this fashion, the rotation nut with the rotor and rollers represents a free wheel unit which transfers torque in one direction, clockwise in this case.

Operation of a hydroperforator means synchronous functioning of the impact mechanism and rotary hydraulic motor. In between the surfaces of the rotation nut and the stator, the working chambers K_{ps} and K_{pv} are made (Figure 1). In order that the nut makes backward–rotational motion, the chambers connect in turn with the head and discharge lines. Switching of fluid flows in these chambers is ensured via switching channels connecting the chambers with the percussive mechanism.

This allows control over motion of the hydraulic motor rotation nut depending on position of the piston of the percussive mechanism.

Between the hydraulic motor housing and the rotation nut surface, there is the percussion mechanism control chamber *Kvd*. This chamber connects in turn with the head *H* and discharge *C* channels, in-between which there is a channel connecting the control chamber *Kvd* with the controlled chamber *Kpx* of the percussive mechanism.

It should be mentioned that in the air-drills, rotation of the drilling tool by the helical mechanism occurs when the drilling tool as a result of recoil from rock mass experiences no rotation resistance. The role of the rotation mechanism only reduces to repositioning of the drill bit from one place to another.

Rotation of the drilling tool by the rotary hydraulic motor happens at the moment of change in direction of the forces acting on the piston. In hydraulic percussive mechanisms, switching of the forces takes place twice within a single working cycle, at the end of the idle and power strokes [7]. Accordingly, the rotation nut of the hydraulic motor makes two turns within the working cycle.

The torque transfer from the rotation nut to the drilling tool only takes place on one direction dependent on the direction of the grooves of the free wheel unit. In the scenario in Figure 1, the torque transfer to the drilling tool is possible in clockwise rotation of the nut. This is ensured when the chamber *Kpv* connects with the head line and the chamber *Kps* connects with the discharge line.

Figure 1 shows position of the rotation nut *2* after completion of the drilling rod turn. The chamber *Kps* is connected with the head line, and the chamber *Kpv*—with the discharge line. For this reason, the nut under the action of fluid pressure in the chamber *Kps* is held in this position unit this chamber connects with the discharge line and the chamber *Kpv*—with the head line.

When the chamber *Kpv* connects with the head line and the chamber *Kps* connects with the discharge line, the rotation nut turns clockwise. The rollers of the free wheel unit are jammed between the internal surface of the rotation nut and the rotor grooves. Because of that, its further rotation goes with the rotor and the drilling rod. This is the way of the torque transfer from the rotation nut to the rotor. The rotor and the drilling rod connected with it turns at a set angle. In this case, the turn of the drilling rod can take place when the cutting edge contact rocks mass. Thus, rotation of the drill rod is accompanied by the rock cutting.

For comparison of working processes in the air-drill and hydroperforator, Figure 2 gives the plots of the velocity *U* and displacement *Y* of the piston, angular velocity ω_{rod} and turn angle φ_{rod} of the drilling rod for the hydroperforator (Figure 2a) and air-drill (Figure 2b). At the bottom of Figure 2, there are the plots of the change in the angular velocity ω_{nut} and turn angle φ_{nut} of the rotation nut of the hydraulic motor and the helical nut of the air-drill. The plots in the figure depict the variabt wgeb tgedrilling tool rotates after blow, i.e., at the end of the power stroke.

It is seen in Figure 2a that when the piston starts moving off the collision plant ($Y = 0$), the rotation nut *2* (Figure 1) is immovable. At the time t_{nut} (Figure 2a), the rotation signal is sent, and the nut turns in the time Δt_{nut} by the angle φ_{nut}. The piston is at the distance Y_c from the collision plane in this case. At the time t_1 a signal is sent to switch the direction of the force acting on the piston. Under the action of this force, the piston velocity drops to zero, then it displaces toward the drilling rod and hammers on its rear end; then the rotation signal is sent, and the drilling rod turns by the angle a поршень. Под действием этой силы скорость движения поршня-ударника снижается до нуля φ_{rod}. At the same time, the other side rotation signal is sent to the nut, and the nut turns together with the rod in the time Δt_{rod} by the angle φ_{nut}. When the rod rotation is completed, the signal is sent to switch the force acting on the piston and the piston moves toward the collision plane. The drilling rod remains immobile and is held in this passion by the free wheel unit. Then, the cycle is repeated.

In the air-drill (Figure 2), the idle stroke of the piston is accompanied by the rotation of the drilling rod until stop of the piston at the coordinate Y_0. In the power stroke of the piston, the helical screw with the drilling rod are held immobile by the clickwork. The helical pair screw, which is the piston stock, turns backward by the angle φ_{screw}.

The vital difference of the hydroperforator with the rotation mechanisms consists in the face that after blow on the drilling rod end, the piston remains immobile within the time t_{rod} as it is influence by the power stroke force which presses the piston to the drilling rod. As a result, during rotation of the drilling rod, rock cutting takes place.

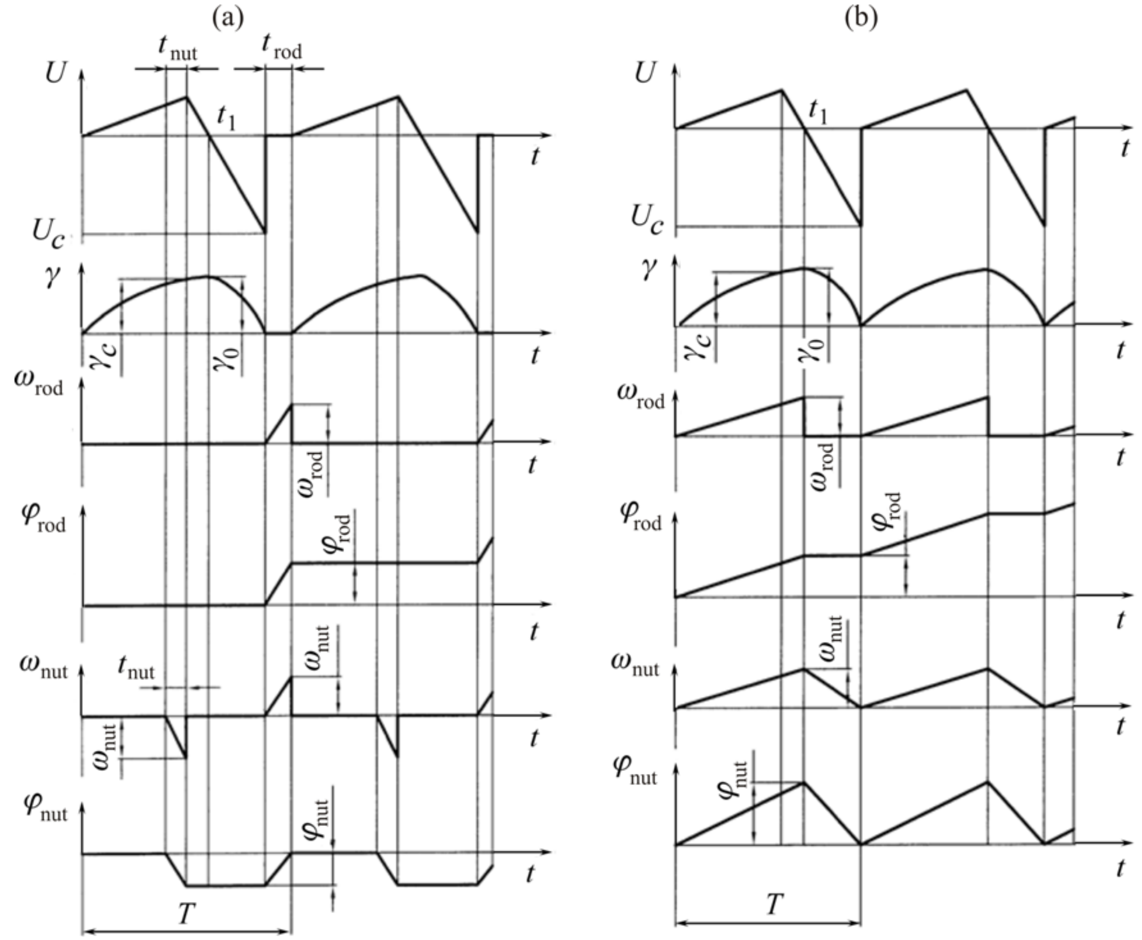

Figure 2. Working process of (a) hydroperforator and (b) air-drill: U_c—piston collision velocity; Y_0—piston travel; Y_c—switch coordinate of forces acting on piston; T—one cycle time; t_1—switch time of forces acting on piston; t_{nut}—turn time of rotation nut; Δt_{nut}, Δt_{rod}—respectively, turn durations of rotation nut and drilling rod.

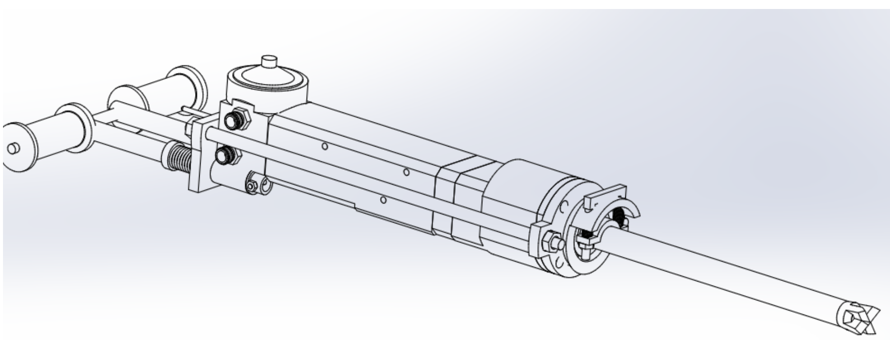

Figure 3. Experimental prototype of hydroperforator.

Based on the discussed scheme, the experimental prototype of the hydroperforator is developed (Figure 3). Its weight is 42 kg at the estimated impact capacity of 2.1 kW, torque of 108 N·m and the head line pressure of 10 MPa. The hydraulic motor capacity calculated based on the fluid pressure and flow rate is 1.49 kW, which is 70% of the impact capacity of the perforator. For comparison, the air-drill PT63 of the same weight develops the torque of 32.2 N·m and ensures percussive capacity of 1.8 kW.

Benchmark tests of the experimental prototype of the hydroperforator in drilling using a four-edge bit with a diameter of 43 mm show that the proposed variant of the perforator is efficient and can be used to continue design projects of industrial machines.

3. Conclusions

Thus, the research results prove exploitability of the proposed design of the hydraulic hammer drill.

Rotation of the drilling rod by the hydraulic rotary motor allows, at the same weight of the hydroperforator and air-drill, higher torque transfer to the drilling tool by 3 times at the concurrent increase in the impact capacity by 16–17%. Upgrading of the experimental prototype can improve its performance.

It is also advisable to trial the proposed design in more powerful perforator arranged on drilling machines.

References

[1] Vasiliev VM 1989 *Peforators: Reference Book* Moscow: Nedra (in Russian)
[2] Ivanov KI, Latyshev VA and Andreev VD 1987 *Drilling Equipment in Mineral Mining* Moscow: Nedra (in Russian)
[3] Alimov OD, Manzhosov VK and Eremyants VE 1985 *Blow. Propagation of Deformation Waves in Percussive Systems* Moscow: Nauka (in Russian)
[4] Eremyants VE 2017 Variation in energy and production data of pneumatic percussiuon machines in the uplands Journal of Mining Science Vol 53 No 4 pp 694–701
[5] Uraimov M 2015 Patent No 1726 Kyrgyz Republic: C1 E21B 6/06. Hydraulic Puncher *Byull. Izobret.* No 4
[6] Uraimov M 2016 Patent No 1958 Kyrgyz Republic: C1 E21B 6/06. Hydraulic Puncher *Byull. Izobret.* No 5
[7] Grishin IA, Knyazbaev JS 2015 The Basic directions of perfection of agent modes in flotation of coal *Successes of modern natural science* No 12 pp 87–90
[8] Uraimov M and Sultanaliev BS 2003 *Hydraulic Hammers. Elements of Design. Generalization of Production and Operation of Hydraulic Hammers Impulse* Bishkek: Ilim (in Russian)