Technological possibility of cinematic impulse rotators

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Abstract. The effectiveness of dynamic destruction by drilling rock, concrete and minerals depends on the direction of a single force pulse. The structures of the torsional vibration exciters provide the direction of the force pulse towards the cleavage of the fracture surface, thus achieving a significant reduction in the energy intensity of the fracture process and changing the method of cleaning the well from the shovel. The optimal value of the contact time of the working tool with the material being processed determines the amount of destruction and maximum use of the energy supplied for useful work.

1. Introduction

The process of mechanical destruction of materials, in particular rocks of medium and more than medium strength, involves dynamic loads use [1]. Drilling wells and holes in concretes and minerals with imposition of shock loads is carried out by roller bits, pneumatic hammers, mechanical vibrators. Optimum exposure modes are determined by the regularity of single pulses change [3, 4]. The direction of impact in the majority of existing devices facilitates compression perpendicular to the surface of the material being processed. At the same time, the impact cleavage significantly reduces energy expenditures on destruction. The new principle of creating a periodic load allows you to change the direction, the time of operation and the pattern of oscillations perturbation. Integration of uniform rotation and periodic loading is achieved in systems with two or more degrees of rotation drives freedom. Dynamic and kinematic excitation of torsional vibrations is used. The kinematic excitation guarantees a given amplitude-frequency characteristic, the loading rate, the regularity of the trajectory of dynamic motion [2]. Adjusting the dynamic parameters of the tool's interaction with the material being processed, regardless of the uniform rotation and the feeding force, broadens the possibilities for determining the optimum operating modes.

2. Purpose of research

The purpose of the present research is determination of kinematic and design features of torsional vibration exciters to ensure optimum work performance.

3. Materials, methods, constructions

The patterns of changes in force impulse of the driven shaft part are determined by the combination of movements of two cam mechanisms. Two pairs of contact surfaces make it possible to obtain the optimal interaction of the tool with the material being processed in a wide range. An experimental

determination of the effectiveness of dynamic effect was carried out for various design solutions of the device for disturbing oscillations during drilling marble and granite. The rotation speed and feeding force were constant during the experiment. Fixed in static and dynamic modes were as follows: the depth of drilling for a certain period of time; consumed current; fractional composition of destruction products. The current consumption was measured with a digital multimeter MU-62, and the time – with a stopwatch. Fractions of destruction products were weighed on electronic scales.
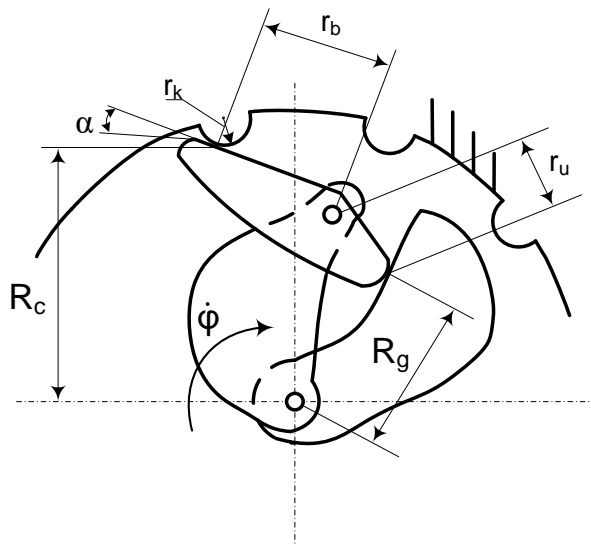
Figure 1. The exciter of torsional vibrations.

Figure 1 shows the basic device by the method of excitation of torsional vibrations [8]. The cam follower is mounted on the driving part of the actuator shaft. The distance from the rotation axis of the cam follower to the point of contact with the stationary cams of the body is denoted by: r- the leading radius; from the axis of rotation to the point of contact of the driven part of the shaft; r is the radius of the pulse. The cam on the body of radius r with the rotation of the working member shaft turns the cam-pusher and transfers the force impulse of the driven part of the shaft. The totality of the rotator and the exciter of vibrations is usually called the impulse rotator. The amplitude-frequency characteristic of the driven part of the shaft is determined by the structural kinematic circuit. The amplitude of vibrations of the point on the working tool is proportional to the radius of rotation. On the driving part of the drive shaft of the working element, there is a cam follower.

For the contact point of the cam follower with the surface of the driven part of the shaft, the amplitude is:

$$A = \frac{r_k \cdot sin(\alpha) \cdot r_u}{r_b},$$

where α is the angle between the surface of the cam follower and the tangent to the body cam.

The maximum value of the displacement of the point R with the radius r determines the size of the cam. At sin α = 90°, the displacement is r.

Frequency of oscillations per second with a fixed body in one turn of the working element is:

$$f = \frac{n \cdot k}{60},$$

where n is the uniform rotation (revolution per minute);

k is the number of collisions per revolution.

The need for the material to be processed in the regularity of loading by a single impulse is

determined by the geometric dimensions of the body cam, the arms of the cam follower and the profile of the mating surfaces in the kinematic pairs. The pulse repetition frequency, when matching the speed of the leading part of the shaft, can bring the working tool to an optimal distance for the subsequent unit force impulse, which increases the efficiency of dynamic fracture

The oscillation frequency is determined by the adjustable number of impacts of the cam follower with fixed cams of the body and the independent rotation of the body. Studies of roller-bit drilling have shown that the destruction will be voluminous by the condition:

$$t_k \geq A \cdot e^{-dkp},$$

where t_k is the contact time of the dynamic loading roller tooth with rock;

k is the coefficient of the bit design;

P is the axial load;

A $u\alpha$ are coefficients that determine the properties of the rock;

e is the base of the natural logarithm.

The efficiency of destruction with changing drilling conditions is achieved by new design solutions The spasmodic process of rock destruction at the first stage for some time creates a stressed state by the amount necessary for the beginning of brittle fracture:

$$\tau = \frac{P_1 \cdot \left(1 + \frac{\varsigma}{c}\right)}{v_0 \cdot \varsigma} \; ; \; \varsigma = k \cdot f,$$

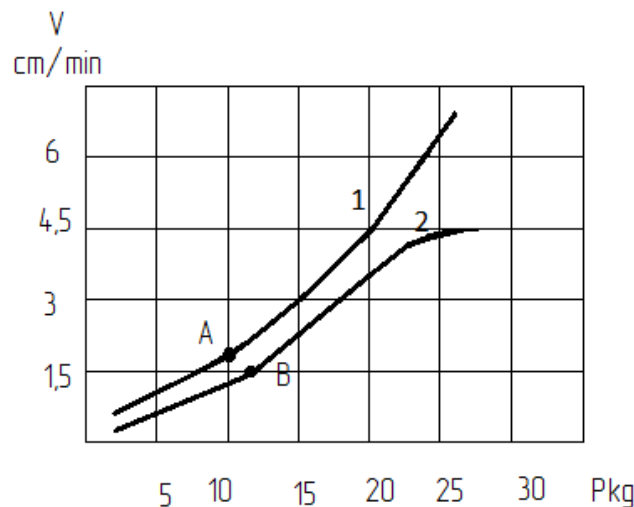where P_1 - destructive force of the first shock;

f - contact area of the cutting part;

ς - coefficient of interaction with the rock;

c - rigidity of the system;

v_0 - the speed of force application.

The need for the processed material under optimal loading conditions is most fully ensured by the design of impulse rotators. The most important factor in reducing the energy intensity of material destruction by a single impulse is the direction in which the force acts on the rock cleavage. The cleavage fracture force is several times less than the compression force. The change in the direction of force action, its magnitude, application speed and action time are established without the need to change the rotation modes of drillstring and feeding force. In addition, the design of the working body allows the transportation of the shovel by a screw conveyor, eliminating the pneumatic or hydraulic cleaning of blast holes. To maximize the use of single impulse energy, the kinematic chain of uniform mobile movement of the working tool can create the necessary preliminary voltage in the initial period of impulse force. In addition, the design of the working body allows the transportation of the shovel by a screw conveyor, eliminating the pneumatic or hydraulic cleaning of blast holes. Impulse action time in the exciters of torsional vibrations, perturbation force and the speed of action on the rock are determined by the size of the links and the profile of kinematic pairs. The radius of the body cam r_k (see Figure 1) deflects the cam follower arm r_b by a predetermined amount; the ratio of the arms r_v/r_u and the contact point of the cam follower with the surface of the shaft driven part determine an angle and rotation time of the working tool by a single impulse. The dependence was determined by applying torsional vibrations to a drill of 8 mm in diameter (Chrome-Vanadium steel 40 Cr with a carbide tip) over the stone.

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Figure 2. Dependence of the mechanical drilling speed *V* of the Keilgin marble on the feeding force *P*.

Rotation speed did not change during the experiment (Figure 2). When creating a force impulse, two cam followers were used with modified kinematic pair profiles. In the authors' opinion, change in the dependence form $v=f(P)$ is caused by a change in the loading pattern. Points A and B indicate the beginning of effective volumetric fracture.

4. Conclusion
- Directions of force impulse to rock cleavage increased the possibility of maximum use of supplied energy for the destruction of the material being processed.
- Adjustment of the amplitude-frequency characteristic of force impulse independent of other parameters made it possible to match the modes of torsional vibrations excitation with the optimum demand of the material being processed in dynamic loading.
- Research on the impact on technical and economic parameters of drilling, a loading pattern and analysis of design features of the disturbance oscillations drive was carried out.

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