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Exploration and determination of the principles of rotary-percussive underground slimhole drilling

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ABSTRACT

A possibility of the efficient use of rotary percussive drilling to provide drilling smaller diameter holes (40–70 mm) both in mining and prospecting is disclosed herein. A new construction designed for the nipple thread connection is described. The relative amplitude variation, change of power pulse time and energy in their propagation throughout the drilling tool are determined. A possibility of the efficient power pulse transfer along the drill string to the rock destruction tools with new nipple connections which allow automating the make-up and breakout system of drill pipe was supported by experiments.

1. Introduction

To intensify the rotary drilling in medium–hard and harder rocks rotary-percussive drilling is used for underground holes of different purposes, depths and diameters, especially small ones.

The advantages of small diameter borehole (40–70 cm) are as follows: significantly low energy costs of rock disintegration; a maximum mechanical drilling speed due to the breast reduction and the corresponding volume of disintegrated rock; smaller metal content of such units as bore bits, drill strings (bars); smaller rate of circulation; dust lowering in drilling.

Presently, hard drilling is, mainly, carried out by means of downhole hammers. Experience has shown that it is practically impossible to fabricate a highly efficient and reliable hammer with diameter lesser than 75 mm because of difficult engineering problems.

Slimholes in medium hard and harder rocks can be drilled with highly efficient rotary top hammers with powerful percussive mechanisms located outside the borehole.

Drilling machines of this kind are used in solid-minerals mining but, unfortunately, they are not widely used in domestic exploratory drilling. However, their advantage over the existing drilling technique is obvious in operational exploring of base and precious metal deposits, and also prospective uranium deposits in full-hole drilling or underground drilling with formation sampling.

Traditionally, a core sample is more preferable by geologists in analyzing information about the presence of minerals and precious metals in rocks. Therefore, the geological exploration technology based on the drilling method of reverse circulation (RC) and performed by a downhole hammer (or roller bits) with double-wall pipes and a simultaneous washover of chip so as to conduct its geological analysis, is of limited application in Russia.

RC is used as a more economical and a faster way of reaching the ore body (‘precollaring’) and is widespread in the USA, Australia, and South-East Asia in addition to conventional core drilling [1].

Drilling method which suggests the use of top hammers placed outside the borehole provides the effective slimhole drilling. Similar to RC drilling, formation sampling is proposed and, on the whole, it corresponds to the efficient use of resources and increases the drilling process productivity.

As it is known, the rotary-percussive rock disintegration is a combination of two principal mechanical methods, namely percussive and rotary. At this, rock cutting tools penetrate into the rock under the feed force, torque, and impacts provided by special mechanisms with a definite frequency. At the same time, the processes of shearing, crushing, deformation, cutting, and attrition of rocks occur.

While hammering the shank of the drill string a strain wave (stress wave, power pulse) is forming in the latter, which changes

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its form, transforms, and its energy is partially dissipates when passing through thread connections [2–6]. In addition, transverse waves formed in the drilling tool restrain the bit from longitudinal penetration necessary for rock disintegration. Moreover, in the course of the strain wave propagation throughout connections, their heating and even destruction is possible [7,8].

As a whole, the problem of improvement of the underground slimhole drilling technique includes a range of independent issues connected with wave formation with rational properties (pulse energy, force amplitude, time), percussive energy transfer to elastic wave guides what the drill string corresponds to, efficiency improvement of energy transfer to rock [5,6,9–13].

This paper presents research findings of dynamic processes in a drill string at rotary percussive drilling of smaller diameter holes.

Power pulses generated by percussion hammers of rock-drilling machines last merely for some hundreds of microseconds (Δt 200–600 ms) while the magnitude of force increases up to dozens of tons during the short period of time Δt and improves the efficiency of disintegrating medium hard and harder rocks.

Drill strings are the more important part of the drilling tool. Thus, for example, it has been statistically stated that some 60% of all breakdowns occur owing to the drill string failure. Therefore, it is extremely important to maximally use all the life extension potentials that will reduce the overall cost of exploration drilling and reserve development. Thus, it is necessary to create such connection which will allow improving the drill string efficiency and increasing the working efficiency in borehole drilling.

The experience of prospecting underground slimhole hard drilling with the expedient use of impact shows, that the application of rotary-percussive method is restrained due to the unsound opinion on the inefficient percussive energy transfer through the drill string to a drilling tool, and also insufficient durability of connections and their destruction. The problem can be solved by means of a conceptually new construction of the drill string with nipple connections which are completely hidden inside the tube.

2. Research methodology

2.1. Experimental research method of power pulse propagation in a drill string

The original method procedure for experiments has allowed estimating the efficiency of pulse energy transfer all over the drill string with new nipple connections in underground slimhole drilling [14].

Investigation of relative change of pulse energy, force amplitude, and power pulse time while their propagation within the nipple-connection drill string during the impact loading was conducted on a test bench consisting of a support which locates concrete blocks having through holes with diameter of 42 mm which simulated an artificial borehole having depth up to 39 m (Fig. 1). A drill string of 33.5 mm diameter has nipple connections which are completely hidden inside the tube.

A pendulum impact machine with cylindrical hammers hanging on it was used for a drill string shank having parameters listed in Table 1. Measurements were conducted under the same conditions: the same sensors were used; a drill pipe with strain-gauges stuck on it was placed by turns in five equally-spaced positions of the drill string. The result of amplitude variation of power pulse, pulse energy, and pulse time propagation along the drill string was presented dimensionless, i.e. it demonstrated how the value of the given parameter was changed in the given section as compared to its value in the beginning of the drill string.

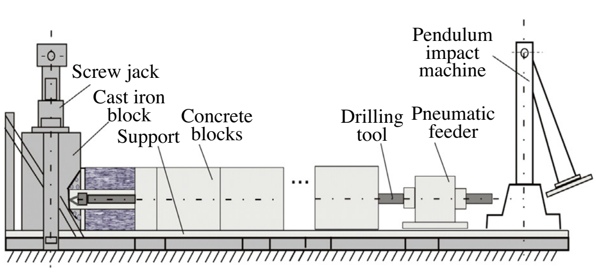

Fig. 1. Test bench for power pulse propagation along the drill string.

2.2. Experimental research method of stresses in thread pipe connection

To measure the bending stress, wire strain gauges with 10 mm nominal length and 100 Ohm resistance were stuck in the middle of the nipple. A drill string of circular pipes was connected with nipples.

Investigations were conducted in the artificial borehole comprising separate concrete blocks. Axial force was generated by a piston compressed-air feeder within the range of 3.4–11.3 kN. Hammer-piston pre-impact velocity varied due to the change of compressed air pressure supplied to the rotary-percussion mechanism of a drill head. The drill string torque was generated by a loaded lever in the range of 49–245 N·m.

3. Basic design of the drill string having new nipple connections

To effectively transfer power pulses through thread pipe connections formed in the drill string by the top hammer of rock-drilling machine, it is necessary to provide a tight contact of the joined pipe ends while the cross-section of the threaded pipe section should be the same as of its threadless connection, i.e. identical throughout the entire drill string. Moreover, the construction of thread connection should not induce a strain wave reflection or minimize it when propagating from the top hammer to the rock destruction tool of the drill string. Otherwise, a significant and, sometimes the extreme part of pulse energy transferred to the drill string will be consumed by destruction of connecting elements of the drill string while mere its smaller part will reach the rock destruction tool.

Designed was such a construction of thread connection which locates a nipple completely inside the pipes joined (Fig. 1), the latter are butted.

When hammering the shank butt, a power pulse forms a strain wave in a drill string in end-on and radial directions, threaded pipe

Table 1
Hammer parameters accepted by the experiment.

Parameter	Hammer					
	1	2	3	4	5	6
Diameter (mm)	34	34	48	Hammer-piston of drilling machine BY-70Y: 59-piston rod; 130-piston	74	75
Length (mm)	330	700	450	309	255	450
Mass (kg)	2.4	5.0	6.4	7.4	8.15	15.45