The analysis of reasons of harmful vibrational loads of roller-bit drilling rig operating equipment

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Abstract
The problem of the high dynamic loads on the mechanical and electromechanical equipment of roller-bit drilling rigs, which are used when ore deposits open mining, was considered. It was found that their reason was drilling flight extreme vibrations causing basic machine units violent vibrations. Some existing theories explaining the mechanism of this process were analyzed. A new definition of the phenomenon was suggested, namely the mode of resonant vibratory-percussion scraping of drilling device on the borehole wall. The methods of this phenomenon controlling were considered, and their advantages and disadvantages were annualized. We came to conclusion that there is the need of development of effective methods and means of roller-bit drilling rigs drilling flight longitudinal and transverse vibrations reducing in order to prevent the mode of resonant vibratory-percussion scraping of drilling device on the borehole wall.
Key words: BLASTHOLE ROLLER-BIT DRILLING RIGS, DRILLING FLIGHT VIBRATIONS, DYNAMIC LOADS ON THE DRILLING RIGS OPERATING EQUIPMENT

The widespread use of roller-bit drilling rigs when ore deposits open mining requires careful attention to the problems arising during their operation. In particular, the extreme elastic vibrations often occur when drilling by rotational-feed mechanism spinel scheme rigs. These vibrations lead to the mast metal structures permanent deformations, which cause violent vibrations of machine frame and cab [1]. These phenomena result in increased wear, failure of mechanical and electromechanical rigs equipment, degradation

of sanitary-hygienic labor conditions of operating personnel. In this regard, the task of the roller-bit drilling rigs dynamic loads reducing is quite important.

Some authors explain this phenomenon as drilling flight buckling failure [1, 2], but after carrying out of researches, we found that the extreme dynamic loads are not always related to drilling flight flexural stability and are determined by other factors. In particular, the paper [3] shows that drilling flights consisting of heavy drill rods of Ø219(215)×51.5 mm and Ø203×50 mm and 8–24 m in thickness are completely stable with classical bend. Furthermore, the joint action of the critical load and centrifugal force, when bent flights rotating, provides their stability in the standard drilling modes [4]. However, the experiment found that there is a quite violent vibration of the flight and the entire machine when drilling by flight of 24 m in thickness and rotation frequency 28–32 min^{-1} [5]. Considering the data of paper [4], it is quite obvious that this phenomenon is not related to flexural stability of drilling flight bent by centrifugal forces.

Investigations of this phenomenon allowed its defining more concisely and accurately, namely resonant vibratory-percussion scraping mode (RVPSM) of drilling device on the borehole wall [3, 6]. The real causes of drilling device RVPSM were found by using of modern innovative methods of computer modeling.

In paper [3] it has been found that RVPSM occurs if the drilling flight rotation frequency coincides with natural frequency of its vibrations. At that, there is the phenomenon of resonance and the flight transverse vibrations amplitude is more than 3 times higher than the gap width between the borehole wall and the rod. The latter begins to scrape the wall violently in vibratory-percussion mode, with the flight rotation frequency, the vibration and dynamic loads on the mast and the entire machine are sharply increased.

In consequence of drilling device RVPSM occurring, there are intensive impact loads on supporting node relative to guide channel beams of more than 300 kN in size. These channel beams cause overvoltage exceeding 192 MPa in the stiffening elements latticed interlacing near the guide channel beams [6]. For the steel of grade st.3, of which the mast is made, the allowable stress is $[\sigma]$ = 187 MPa, therefore the stiffening elements of mast frame are deformed and destroyed, and the rotation head sometimes falls out of the guide. Furthermore, there are significant resonance vibrations in the rotation head on the polyspast stays of its thrust and lifting mechanisms. Such vibrations cause the heavy wear of supporting node carriage slide block insert of the rotation heads and channel beams (rotation head guides) and also the high dynamic loads in the polyspast system ropes. At that, the ropes are broken causing the emergency situation. The rig violent vibration excited by RVPSM of drilling device has a negative impact on the operating personnel health leading to vibration disease of workers.

RVPSM of drilling device occurs suddenly (unpredictably for operators) and in order to liquidate it, they have to reduce the drilling device rotation operating frequency several times, and in some cases, the value of the axial feed force of tool to the bottomhole. Then, the attempts of returning of drilling mode parameters to the previous frames are made until RVPSM occurs again. This method of dealing with RVPSM results in a significant reduction in drilling rate forcing the operators to move constantly the control elements and control rig drilling modes, which becomes the cause of their emotional and physical fatigue during the work shift. Therefore, the wash liquid flow in the borehole is reduced by drilling rigs operators in order to reduce the dynamic loads, whereby the borehole is filled by drill cutting waste forming the thick abrasive slurry. The borehole filling by the drill cutting waste damps the longitudinal and transverse vibrations of the drilling flight, and the rig vibration is significantly reduced. However, the drill rod and bit wear off intensively, the drilling rate is reduced, the drilling flight rotation resistance is increased, in consequence of which the energy costs for borehole drilling and operational costs for drilling operations are increased significantly.

Thus, there is a significant need for development of effective methods and means of roller-bit drilling rigs drilling flight longitudinal and transverse vibrations reducing in order to prevent the mode of resonant vibratory-percussion scraping of drilling device on the borehole wall.

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