Investigation of influence of operating regime on the productivity and energy costs of roller-bit drilling mills of RBDM-250

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Abstract
In the paper, the experimental researches results of dependences of vibrational loads on the working equipment of roller-bit drilling mills of RBDM-250 type on the drilling practices of blast hole in the conditions of Kryvyi Rih basin openpits are explained. The technique and technological tools of researches are described. The computer model of a drilling rig flight consisting of two drill rods of 8 m long either is offered. It is established that in resonant operation mode, the vibration amplitude of a flight is higher than the gap width between bore hole walls and the rod, in consequence of which, we can observe the phenomenon of vibratory-percussion scraping of the rod on a bore hole wall; it causes extreme dynamic loads on the mill equipment.
Key words: BLAST HOLES ROLLER-BIT DRILLING MILLS OF RBDM-250, INFLUENCE OF DRILLING REGIMES ON THE PRODUCTIVITY AND ENERGY COSTS

As it is known that operation of roller-bit drilling mills is followed by the equipment increased vibration, which affects negatively its longevity and deterioration of working conditions of the operating personnel [1, 2]. During the researches of dependence of drilling mills of RBDM-250 vibration on the blast holes drilling modes conducted at Kryvyi Rih National University, modeling of vibration amplitude of a drilling flight and comparison of their values with a gap between a wall of a bore hole and rods surface were carried out.

Process of modeling was carried out by Solid Works Simulation Premium by means of the FFEPlus application for a drilling flight of l = 16 m length, consisting of two eight-meter rods Ø215×51.5 mm (taking into account their wear). The Fig. 2 shows the constructive scheme of a drilling flight for its computer model building.

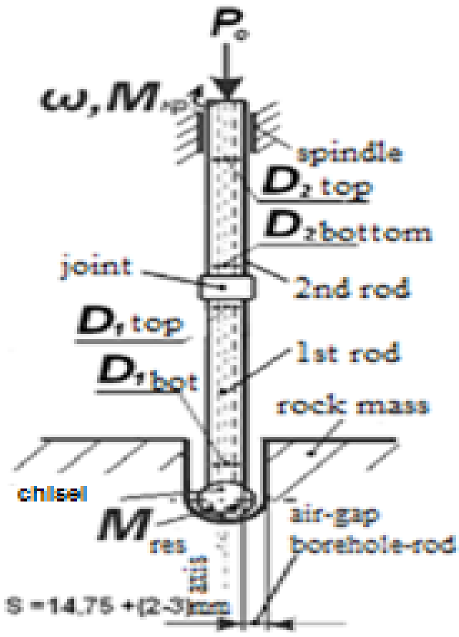
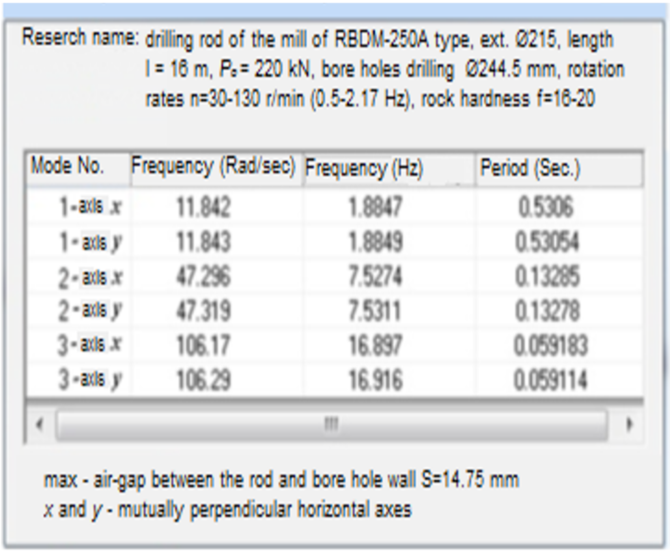


Figure 1. The constructive scheme for computer model building of a drilling mill considering its wear

When drilling, the surface of drilling flight is worn out nonuniformly along the length. Near the drilling bit, deterioration level is higher; in the rod top part it is less ($D_{1bot} < D_{1top}$), at that, the first rod is worn out more intensively than the second and third one; therefore, while in operation, the rods rotation is carried out (their positions are interchanged). In this regard, the measurement of rods diameters along the flight length was performed before modeling. In the left part of Fig. 2, the list of the rotation modes of a drilling flight from two rods of the mill of RBDM-250A type on mutual perpendicular horizontal axes x and y on each mode is shown. And in the right part, the distribution diagram of rotation linear dynamics of a drilling flight on an axis z of 16 m long in a bore hole of Ø244.5 mm is given.

Calculations showed that at a resonant frequency of the first mode (in round figures, 1.885 Hz on axes x and y) rotations of a drilling flight with number of turns n = 113 min^{-1}, vibration amplitude a_1 had to reach 171 mm in the center of a drilling flight (Fig. 2a). However, due to restriction of vibrations resonant amplitude by bore hole walls, the rod of drilling flight starts scraping on the bore hole wall by the external surface in the vibratory-percussion mode, and not only on the first mode, but also on the second one with a frequency of 7.5 Hz and amplitude of 21.7 mm (Fig. 2b) that also exceeds the available gap S = 14.75 mm between a bore hole wall and rod. Such mode causes extreme dynamic loads on the rig equipment.

The evaluation of energy consumption when drilling is conducted on the RBDM -250MNA-32 rig (Ore Mining and Processing Industrial Complex "Ukr-mekhanobr", Kryvyi Rih) in three modes: subresonance, at drilling flight resonance when bore hole gumming (Table 1). The feeding pressure, drilling flight rotation number, values of voltage and rotator flow were fixed from the display in the operator cab. From the Table, it is seen that in the resonance mode, the energy consumption increased from 23.3 to 31.2 kW, i.e. by 34% in comparison with the subresonance mode. In order to reduce the vibration of the drilling rig, the bore hole was gummed (it is filled with a dense abrasive slurry). In this case, energy consumption increased from 31.2 to 35.5 kW, which is by 18% more in comparison with the resonance mode.



Reserch name: drilling rod of the mill of RBDM-250A type, ext. Ø215, length l = 16 m, P_o = 220 kN, bore holes drilling Ø244.5 mm, rotation rates n=30-130 r/min (0.5-2.17 Hz), rock hardness f=16-20

Mode No.	Frequency (Rad/sec)	Frequency (Hz)	Period (Sec.)
1-axis x	11.842	1.8847	0.5306
1-axis y	11.843	1.8849	0.53054
2-axis x	47.296	7.5274	0.13285
2-axis y	47.319	7.5311	0.13278
3-axis x	106.17	16.897	0.059183
3-axis y	106.29	16.916	0.059114

max - air-gap between the rod and bore hole wall S=14.75 mm
x and y - mutually perpendicular horizontal axes

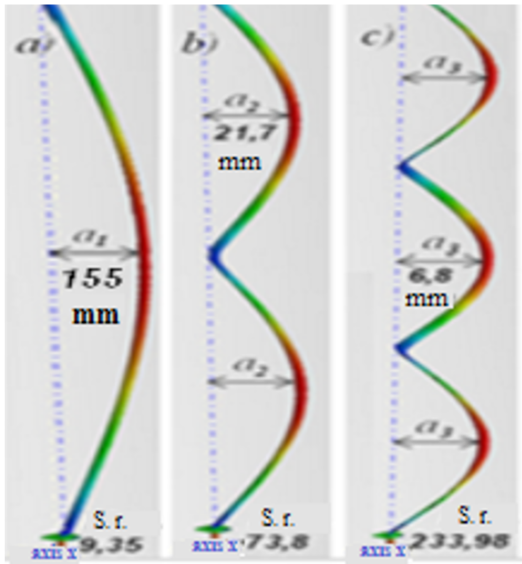


Figure 2. List of the regimes (at the left) and distribution diagram of rotation linear dynamics (on the right) of a drilling flight on an axis z of 16 m long in a bore hole of Ø244.5 mm: a) at a frequency of the first mode; b) at a frequency of the second mode; c) at a frequency of the third mode; S. r. - scale range

Table 1. Evaluation of energy consumption when drilling in the subresonance, mode, at drilling flight resonance when bore hole gumming.

No	Drilling mode	Rotation number, n, min^{-1}	Current consumed by rotator I, A	Voltage of the rotator, U, B	Power consumed by rotator, W, kW
1	Normal	99	100	233	23,3
2	Resonance*	113	133	235	31,2
3	When bore hole gumming	95	151	235	35,5

*Note: mode of vibration stability loss of a drilling flight.

The investigation of drilling rate and energy consumption at various drilling regimes was conducted also in the conditions of Ingulets GOK on the RBDM-250A mill No 87 (drilling by two heavy rods of Ø215×51.5 mm in the rock with a strength of 16-18 according to M. M. Protodyakonov scale with drilling flight feeding pressure of 220 kN). Previously, considering wear and actual rods sizes, modeling of natural vibrations and amplitude of resonant vibrations was carried out, therefore the following numbers of rotations are determined: *a)* subresonance mode $n_{subr.}$= 100 min^{-1}; *b)* resonance mode – loss of vibration resistance n_{res}= 115 min^{-1}; *в*) superresonance - nominal detuning from the resonance mode n_{superr}= 130 min^{-1}. At drilling rate determination, depending on the drilling modes, this parameter was registered after the second rod adding in order to avoid the errors because of the bottom hole top layer, which is partially destroyed after the previous blast. Drilling time along the length of the second bar of 8 m was determined, and then, the drilling rate and specific energy consumption were calculated. Dependences of drilling speed and power consumption on operating mode of RBDM-250A mill are given in Fig. 3. From these dependences, it is seen that the energy consumption increases in the resonance mode by 20.5%, and the drilling rate decreases by 4% in comparison with the usual drilling mode.

The energy consumption decreases by 7% in comparison with the resonance mode on a frequency of detuning by increase in rotations number. Thus, the drilling rate increases by 15.5%. Specific energy consumption and drilling rates of the rig are given in Table 2 depending on the drilling modes.

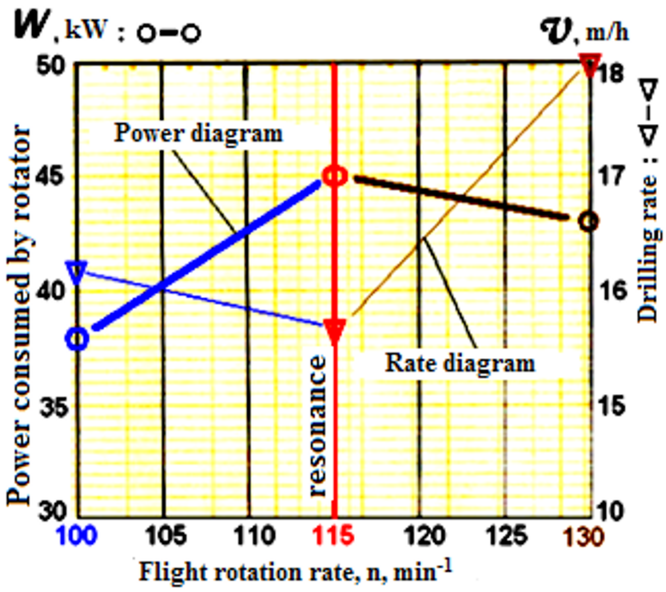


Figure 3. Dependences of drilling rate at various operating modes of RBDM -250MNA-32 mill

Table 2. Drilling rates and energy consumption at different drilling modes

No	Drilling mode / *n*, min^{-1}	Current consumed by rotator, *I*, A	Voltage of the rotator, *U*, B	Power consumed by rotator, *W*, *kW*	Drilling rate, V_d, m/h	Specific energy consumptin, kW·h/ l. m. of bore hole
1	Subresonance/100	101	380	38,4	16,2	2,4
2	Resonance/115	113	410	46,3	15,6	3,0
3	Superresonance /130	102	425	43,4	18	2,4

From the Table, it is seen that specific energy consumption increases considerably (by 25%) in the resonant mode (from 2.4 to 3 kW·h/l. m. of bore hole). Specific energy consumption in the superresonance drilling mode is reduced to the value of the superresonance mode. However, the superresonance drilling mode is more rational in comparison with subresonance one. In this mode, the drilling rate increases by 11% in comparison with subresonance mode.

Thus, the drilling modes by heavy rods of the flight length of L_{fl} = 16 m with number of turns *n* = 125–130 min^{-1} at standard axial feeding pressure of drilling flight P_o = 200–220 kN provide the minimum specific energy consumption of 2.4 kW·h/ l. m. of bore hole, maximum drilling rate v_d = 18 m/h and the absence of vibration rigidity loss of drilling flight, extreme loads on the equipment and operator workplace.

References

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