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Determination of Rational Geometrical Parameters of Drilling Tool of Iron Notch Opening Machines

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Abstract

The issues related to computation of contact stresses which occur in the contact patch of drilling tool and tap-hole mix when iron notch opening by means of rotative-percussive drilling method are considered. The recommendations regarding a rational choice of geometrical parameters of boring crowns for iron notch opening machines are presented.

Keywords: *iron notch opening machine, rotative-percussive drilling, contact stresses, boring crown, iron notch, cable system*

The experience of Ukrainian and foreign metallurgical works has shown that rotative-percussive drilling is the most widely used method of iron notch opening [1, 2]. So, enhancement of efficiency in rotative-percussive drilling is up-to-date.

The computation of contact stresses which originate in the surface of contact of drilled tap-hole mix and boring crown enables to analyze the efficiency of any drilling tool. In present work, the results obtained after investigation of contact interaction of boring crown of iron notch opening machine and tap-hole mix in order to determine the rational characteristics of iron notch opening machine tool are presented.

The boring crown of iron notch opening machine is presented in Figure 1 and is related to chisel-type boring tool. The contact patch length equals the boring crown tooth length l, and the width h equals the mean contact width of the boring crown tooth and solidified tap-hole mix (Figure 2).

According to [3], the mean width of contact patch is:

$$h = h_0 + \frac{2(Q_1 + Q_2)tg\gamma}{l}, \qquad \text{(Eq. 1)}$$

where h_0 - the initial width of contact patch, m; l - the contact patch length, m; γ - a half an angle of tapering of boring tool, deg (Figure 2).

Coefficients Q_1, Q_2 are mechanical characteristics of boring crown material and solidified tap-hole mix. They are determined as follows [3]:

$$Q_1 = \frac{1-\mu_1^2}{E_1}, \; Q_2 = \frac{1-\mu_2^2}{E_2}, \qquad \text{(Eq. 2)}$$

where μ_1, E_1 - Poisson's ratio and elasticity modulus of boring crown, μ_2, E_2 - Poisson's ratio and elasticity modulus of solidified tap-hole mix.

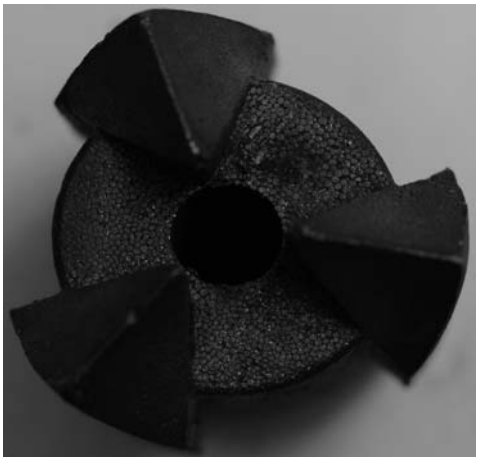

Figure 1. Working body of up-to-date boring crown made for iron notch opening machine

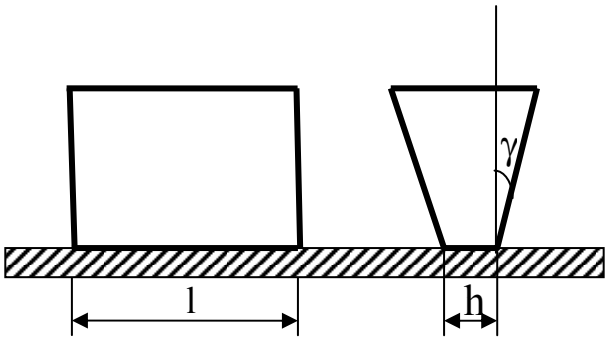

Figure 2. Chisel-type boring tool

In work [4], it is demonstrated that when investigating the processes occurring in the transmission elements of opening machine, the wave phenomena in a drill rod at the impact effect of boring unit's perforator hammer should not be neglected. If the cable system contains only elements of relatively small sizes, this system is called classical and the methods of theoretical mechanics are used for determination of impact characteristics. If the length of these elements is more than diameter, then such a system is called a wave system.

In work [4], each element of percussion system is checked by criterion of applicability of the wave theory of impact. Therefore, a method of joint solution of wave equations for cores with equations of a contact problem of elasticity theory for the end surface is applied for analytical research [5].

This method enabled to determine the maximum contact stresses in the area of boring crown and tap-hole mix interaction. According to the wave theory, the impact impulse, that has been formed earlier in the area of stress of perforator hammer and drill rod, comes to the boring crown. Then, the impulse is transferred at the sound speed through the drill rod with almost no distortions, since neither area of rod section nor material properties do not change along the length. As a result, when determining the maximum contact stresses, it is necessary to consider an acoustic stiffness of the drill rod material $\rho \cdot a$ (product of density by sound speed distribution in a material). The contact stresses occurring on the contact surface of destructive elements of boring crown and tap-hole mix reach their maximum at duration of impact impulse T, that depends, first of all, upon perforator hammer type tip. The maximum contact stresses are defined using Equation (3) [3].

$$\sigma_{\max} = \frac{2}{\left(\frac{1}{F_1} + \frac{1}{F_2}\right)} \cdot \frac{\rho a \cdot V_0}{h \cdot l} \cdot \left(1 - e^{\frac{-\pi \cdot l \cdot L_1}{F_2\left(\frac{E_1}{E_2}+1\right)\cdot \ln\frac{4}{h}}}\right) \qquad \text{(Eq. 3)}$$

where $\rho \cdot a$ - the acoustic stiffness of perforator hammer and drill rod; V_0 - the initial impact speed of boring crown and tap-hole mix; h - the mean width of contact patch; F_1, F_2 - the cross-section areas of perforator hammer and drill rod, respectively; l – the contact patch length, m; L_1 - the perforator hammer length, m.

The impact fracture will occur at the contact stresses of great size [6]

$$\sigma_k = \frac{18\sigma_p}{\left(1 - 2\mu\right)^2}, \qquad \text{(Eq. 4)}$$

where σ_p - the tensile strength of tap-hole mix at compression.

Equation (3) considers the impact pattern of slag-notch drilling. The experiments carried out have demonstrated that the tensile strength of tap-hole mix at compression σ_p reaches 28.93 MPa.

We will consider the example of computation of the contact patch width for the boring crown implemented in the iron notch opening machine at JSC "Iron & Steel Integrated Works "Azovstal". On the basis of technical features of machine specified, the initial data for computation are as follows: μ_1 = 0.3; $E_1 = 2 \cdot 10^{11}$ Pa; μ_2 = 0.22; $E_2 = 0.5 \cdot 10^{-11}$ Pa; $\rho \cdot a$ = 4; V_0 = 6 m/sec; $F_1 = 28.71 \cdot 10^{-4}$ m^2; $F_2 = 7.406 \cdot 10^{-4}$ m^2; l = 0.025 m; L_1 = 0.075m. According to Equation (2) $Q_1 = 0.45 \cdot 10^{-11}$.

According to Equation (4), the stresses are $\sigma_k = 1{,}66 \cdot 10^9$ Pa. The maximum stress curve depending on the mean contact patch width of iron notch opening machine boring crown (Figure 3) is drawn from Equation (3). The dotted line corresponds to σ_k pressure value. From Figure 3 it is possible to find out the maximum admissible value of contact patch width. This value

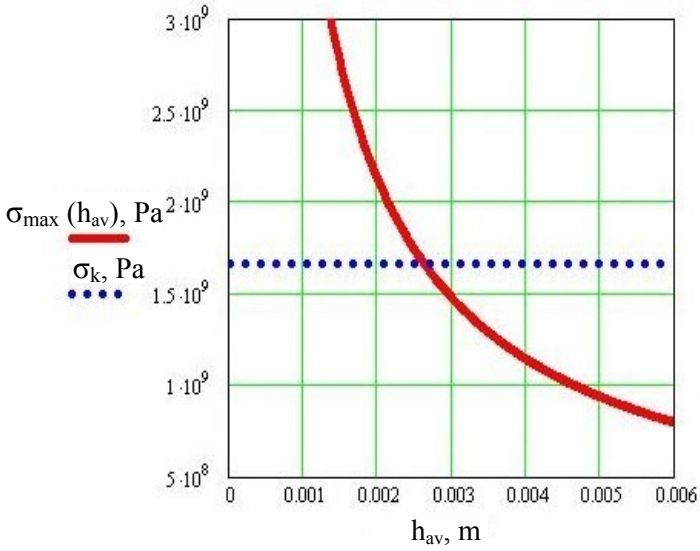

Figure 3. Interrellation between the maximum contact stresses and mean width of contact patch (curve), critical normal stresses for tap-hole mix solidified

corresponds to the point of intersection of maximum possible stress curve and stress dotted line (tap-hole mix is fractured at these stresses). From Equation (3) it is clear that the maximum possible stresses on the boring crown - tap-hole mix interface depend upon design parameters of boring tool (L_1, l, ρa) and drill (F_1, F_2).

From Figure 3 it is clear that the value of maximum contact stresses is inversely proportional to the mean width of contact patch, which increases during drilling since the boring crown becomes dull as a result of fray.

To determine the rational cross-section of drill rod according to conditions of maximum contact stresses achievement in the center of tap-hole mix destruction by boring tool, the private derivative $\frac{d}{dF_2}\sigma_{\max}$ of Equation (3) was set to zero by means of applied MathCAD programs. As the negative root of equation does not satisfy solution, the optimum value of drill rod's cross section is $9.5 \cdot 10^{-4}$ m^2 at drill diameter of 65 mm. Based on 9 mm-diameter of internal vent passage, the optimum external diameter of drill rod is determined as follows:

$$D_{opt} = \sqrt{\frac{4}{\pi}F_2 + d^2}, \qquad \text{(Eq. 5)}$$

where d - the diameter of drill rod's vent passage.

After substitution of number values, we obtain D_{opt} = 0.036 m.

Conclusions

1. There are found out the analytical dependences that enable to determine the values of maximum contact stresses in the area of tap-hole mix fracture at drilling. As a result, it is possible to choose the optimum geometrical sizes of boring crowns at the stage of their design.

2. It is established that as the mean width of contact patch of drill tooth increases up to 2.65 mm (Figure 3), cable drilling is extremely inefficient since the maximum stresses do not reach the value necessary for destruction.

3. The optimum cross-section area is $9.5 \cdot 10^{-4}$ m^2 at iron-notch diameter of 65 mm according to the conditions of maximum contact stresses achievement in the contact zone of boring tool and tap-hole mix. Thus, the optimum outside diameter of drill rod is 36 mm, if diameter of the rod cooling channel is 9 mm.

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Определение рациональных геометрических параметров бурового инструмента машины для вскрытия чугунных леток доменных печей

Селегей А.Н., Мушенков Ю.А.

Рассматриваются вопросы расчета контактных напряжений, которые возникают на площадке контакта бурового инструмента и леточной массы при вскрытии чугунной летки при ударно-вращательном способе бурения. Также представлены рекомендации по рациональному выбору геометрических параметров буровых коронок для машин вскрытия чугунных леток доменных печей.