ROCK BREAKING

EFFECTIVENESS OF THE USE OF HIGH IMPACT ENERGIES FOR BREAKING HARD LEDGE ROCKS

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It is now theoretically possible to use more than 10 different methods of rock breaking in the "heading" members of entry-driving machines, namely, by using cutters, roller bits, impacts, water jets, thermal and electrophysical methods, microexplosions of liquid explosives, etc.

The oldest and energetically most advantageous method of rock breaking is cutting. However, a serious disadvantage of this method is the rapid wear of the tool, even when it cuts moderately hard rock; thus whereas at a contact strength $P_c$ of the rock of only 20 kg/mm$^2$ and an abrasiveness ($a$) of 1 mg the degree of wear is 0.014 bits/m$^3$ of rock, at $P_c = 100$ kg/mm$^2$ and $a = 10$ mg, this figure increases to 10.1 bits/m$^3$, and at $P_c = 200$ kg/mm$^2$ and $a = 45$ mg to 519 bits/m$^3$ [1].

Despite the recent introduction of such devices (based on design or process modifications) as RK-8 rod bits, rotary bits, and so-called power cutting, one cannot expect a marked increase in the range of rock effectively handled by means of cutting tools.

Roller-bit drilling is assumed to be the most promising method for mechanical breaking of rocks above average hardness, but the character of the dependences of the tool life and the energy consumption on the rock hardness indicates the limited potentials of its use (Fig. 1).

As regards other methods of rock breaking, we can state that at present the results of investigations do not permit their use as the basis for designing entry-driving machines for rocks of above-average hardness.

The Karaganda Conference [2] examined the feasibility of using various different methods of rock breaking from the viewpoint of the development of entry-driving machines; it was emphasized that fracturing by impact had been investigated repeatedly, but that the aim pursued was the establishment of the laws governing fracturing by percussion drilling. Data on the percussion method have been obtained in greater or lesser detail for coals and frozen rocks. There are as yet no data justifying the use of percussive rock breaking as the basis for designing a cutter-loader for driving workings in rocks of above-average hardness.

An analysis of investigations on percussive breaking of rocks, performed in the Leningrad Mining Institute and by TsNIIS of Mintransstroi, together with the VNIIgidrougol' Institute, reveals that the tool life is quite inadequate. Thus hard-alloy tipped picks withstood only 1600 impacts in the case of rocks with a hardness coefficient of 10.

Experimental investigations by the TsNIIPodzemshakhstroi Institute showed that for fracturing rocks with a hardness of more than 6 the expenditure on tools in driving a roadway of 8-m$^2$ cross section was three times more than involved in drivage by drilling and blasting.
### Table 1. Theoretical and Actual Breaking Strength of Certain Crystals

<table>
<thead>
<tr>
<th>Crystal</th>
<th>Breaking strength, kg/m²</th>
<th>ratio of theoret. to actual value</th>
</tr>
</thead>
<tbody>
<tr>
<td>α-Iron</td>
<td>1350</td>
<td>0.30</td>
</tr>
<tr>
<td>Zinc</td>
<td>360</td>
<td>0.18</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>300</td>
<td>0.50</td>
</tr>
<tr>
<td>Quartz</td>
<td>1000</td>
<td>11.60</td>
</tr>
</tbody>
</table>

From investigation on low-energy impacts, Sevast'yanov [3] concluded that for rocks with a hardness of up to 7* the percussive method can compete successfully with the drilling and blasting method; for rocks with a hardness of more than 8 the use of the percussive method is undesirable owing to the high cost entailed by the low tool life.

Specialists engaged in rock breaking and the design of rock-tunneling machines agree that the development and practical application of highly efficient machines for tunneling in rocks of average and above-average hardness are being held back by the absence of a reliable and wear-resistant rock breaking tool.

However, theoretical investigations at the Institute of Hydrodynamics of the Siberian Branch of the Academy of Sciences of the USSR give grounds for expecting that with an increase in the impact energy to tens of thousands of kilogram-meters, the effect of tool geometry on the efficiency of rock fracturing greatly decreases; it is therefore possible to select parameters of the tool, for which its wear is economically permissible.

Let us deal with certain aspects of the physics of solids and rock mechanics. It is known that the theoretical strength of crystalline materials can be determined from quantum-mechanical theories on the interaction of electrons and atomic nuclei.

Thus, the breaking strength of a sodium chloride crystal subjected to the effect of external mechanical forces is

\[
P = fN = \frac{e^2}{r^4} = \frac{2.3 \times 10^{-20}}{8.1 \times 10^{-32}} \text{ dyn/cm}^2 = 3 \times 10^9 \text{ dyn/cm}^2 = 300 \text{ kg/mm}^2,
\]

where \( P \) is the breaking strength of the NaCl crystal, \( f \) is the attractive force of the ions, equal to \( e^2/r^2 \), \( N \) is the number of ions per unit area, equal to \( 1/r^2 \), \( r \) is the distance between the positive and nearest-neighbor negative ions in NaCl, equal to \( 2.8 \times 10^{-8} \text{ cm} \), and \( e \) is the charge value, equal to \( 4.8 \times 10^{-19} \text{ dyn} \).

The actual strength of individual crystals is much less than the calculated value (for example, 600 times less in the case of sodium chloride, as may be seen in Table 1).

The significance of fissures in strength reduction has been demonstrated by Ioffe [4] for rock salt and by Griffith [5] for glass, and confirmed by calculations of Grünberg [6], who determined the forces induced within a sphere as a result of sudden omnidirectional heating.

In contrast to single crystals, polycrystalline bodies, such as rocks, have a much greater number of defects: pores, pits, gas bubbles, and microfissures. Fissures play an important part in the deformation of bodies because, when an external load is applied to them, the stress is not distributed uniformly but concentrated at the boundaries of the weakened sites. If the lateral surface has a small but very pronounced fissure (with a small radius of curvature at the bottom of the fissure), the force at the edge of the fissure will be several hundred times greater than the mean force over the whole cross section of the stressed body. At internal defects acute overstress peaks are obtained around the fissures, cavities, and pits, as observed in the case of an elongated plate with a hole. Inglis [7] showed that in the case of a defect in the form of an elliptical hole with semiaxes \( a \) and \( b \) the maximum strength is greater than the average stress by a factor of

\[
\sigma_{\text{max}} = \sigma_{\text{av}} \left(1 + \frac{2a}{b}\right).
\]

Therefore the presence of defects in a body reduces its resistance to deformation. However, the strength of a body being broken will evidently depend more on the presence of dangerous defects responsible for its weakest sites than on the overall number of defects. Intense fissure formation begins specifically at such dangerous defects.

* The rock hardness is given on the Protodyakonov (senior) scale.