ON CERTAIN FEATURES OF THE MECHANICAL DESTRUCTION OF ROCKS UNDER THE ACTION OF STATIC, IMPACT, AND PULSATING LOADS

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Abstract

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ON CERTAIN FEATURES OF THE MECHANICAL DESTRUCTION OF ROCKS UNDER THE ACTION OF STATIC, IMPACT, AND PULSATING LOADS

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The destruction of rocks in crushing machines is carried out by crushing pieces of rock between two flat, cylindrical, or conical surfaces. Because the pieces entering the crusher have an irregular shape, the load is transmitted to the rock by the crushing surfaces over areas of fairly small dimensions.

In the zone of contact between the rock and the crushing surfaces, the material is destroyed to a powdery state, filling the volume of an irregular cone whose base is the contact area (Fig. 1). The destruction (crushing) of the entire piece of rock occurs mainly due to tensile stresses and deformations.

To study the features of the mechanical destruction of rocks under compression between two surfaces, experiments were carried out on the destruction of quartzite under the action of static, impact, and pulsating loads.

In outward appearance the rock is grayish-pink, dense, and finely fragmental. Under the microscope it is found that fragmental grains constitute 95% of the rock, while approximately 5% consists of sericitic pore cement. The fragments are represented mainly by quartz; their sizes range from 0.1 to 1.0 mm, with 0.2 to 0.3 mm predominating. The fragments are rounded in shape, predominantly oval; round grains are also present. Individual fragments are represented by siliceous rocks and fine-grained quartzites; the shape of these fragments is the same as that of the quartz grains. Accumulations of dust-like grains of an ore mineral, apparently hematite, are confined to the cement.

From the drilled quartzite core, cubes with a side of 15 mm were prepared, with two opposite faces ground.

In order that the destruction scheme in the tests would correspond to the crushing of irregularly shaped pieces of rock between two surfaces, destruction was produced by a ball (diameter 12.72 cm, ShKh-15 steel) placed at the center of the specimen. A static, impact, or pulsating load was applied to the ball.

The static load was applied on a press. The destructive force was 1000–1200 kg.

Fig. 1. Fracture of quartzite specimens under loads: a —static, 35×; b —impact, 75×; c —pulsating, 35×

Figure 1: Fig. 1. Fracture of quartzite specimens under loads: a —static, 35×; b —impact, 75×; c —pulsating, 35×

During impact destruction of the specimens, the impact energy and the magnitude of the destructive force were not recorded.

To obtain a pulsating load, a laboratory apparatus was constructed in which the specimen was loaded by a force varying from 0 to $P_{\max}$. Preliminary adjustment and recording of the force P were carried out by strain-gauge methods. With the selected $P_{\max} = 430$ kg and a frequency of 24 Hz, the time to destruction was from 1 to 5 min.

To study the nature of destruction under the action of various types of loads, the method of preparing polished sections, widely ···

known in petrography. The thickness of the thin sections of the rocks was $0.02 \div 0.03$ mm.

Microscopic studies of thin sections of fractured specimens made it possible to establish that a crack in rocks (in particular, in the quartzite described) does not follow intercrystalline zones, but directly cuts across the crystals, always propagating more or less rectilinearly. Along with the main crack, a number of secondary cracks may appear, which also pass through the crystals; parallel displacement of the main crack is possible when the secondary crack continues the main one at some distance, without joining it (Fig. 1b).

Fig. 1. Fracture of quartzite specimens under loads: *a* —static, 35×; *b* —impact, 75×; *c* —pulsating, 35×

In the fracture of specimens under a pulsating load, in contrast to static or impact fracture, one can sometimes observe the passage of the crack through intercrystalline regions, with its deviation at that point from rectilinearity.

To assess the comparative strength of crystals and intercrystalline bonds, experiments were carried out on the fracture of specimens under the action solely of tensile stresses. For this purpose, specimens were specially prepared in the form of thin sections (about 0.05 mm thick),

which were subjected to tensile loads until failure. In addition, for the same purposes, specimens with a cross section of 6 × 4 mm were prepared and tested under bending loads that caused tensile stresses in layers located below the neutral layer. In both cases, failure of the specimens occurred along intercrystalline bonds (Fig. 2). This provided grounds for considering the strength of the intercrystalline bonds to be less than the lowest tensile strength of the crystals.

To clarify the question of whether a volumetric stressed state is the cause of crack propagation through the crystals, experiments were carried out on the

Fig. 2

Figure 2: Fig. 2

Fig. 3. a—the contact zone of the specimen with the spherical surface, 35×; b and c—elements of the surface of the contact zone, 220×.

Figure 3: Fig. 3. a—the contact zone of the specimen with the spherical surface, 35×; b and c—elements of the surface of the contact zone, 220×.

failure of specimens under compression in a plane-stressed state. Specimens were subjected to failure under the action of loads transmitted through a cylindrical surface normal to the cylinder generatrix. In this case the crack also passes through the crystals.

Fig. 2. Failure of a quartzite specimen under the action only of tensile forces, 35×

Careful investigations of the contact zone of an undestroyed specimen with a spherical surface, to which a static or pulsating load was applied, showed that characteristic of all types of loading was the presence of small cracks extending from the surface of the indentation into the crystals (Fig. 3).

Thus, both in the case of a volumetric and of a plane stressed state, the development of a crack with an increase in the load or in the number of loadings takes place not along intercrystalline zones, but through the crystals. The crystals are under the action of both tensile and compressive loads; in this case the compressive stresses are directed along the acting force, and the tensile stresses perpendicular to it. The compressive load increases the strength of the cohesion of the crystals along intercrystalline bonds and weakens the strength of the crystals themselves. Confirmation of this is the destruction of crystals to a powder-like state in the contact zone of the rock with the crushing surface. The concentration of stresses at the end of an incipient crack promotes failure of the specimen through the crystals.

The experiments conducted make it possible to draw a very important conclusion: when assessing the strength of specimens of rocks (of the quartzite type) under crushing, one should take into account the mean integral strength of the constituent crystals (and not of the specimen as a whole) in tension, allowing for deformations and stress concentration at the end of the developing crack. This will make it possible to estimate the strength in crushing of any polycrystalline substance, if the tensile strength of the crystals composing it is known.

To obtain the integral strength of crystals, there is no need to conduct special experiments with single-crystal specimens. It is sufficient to test polycrystalline specimens in a plane-stressed state, when the destructive load is applied through a cylindrical surface perpendicular to its generatrix. Then, having the results of tests of specimens with different contents of crystals of the same

Fig. 3. *a*—the contact zone of the specimen with the spherical surface, 35×; *b* and *c*—elements of the surface of the contact zone, 220×.

or another substance, we will be able to obtain tables of the integral strength of crystals, the use of which will make it possible to determine, with sufficient accuracy, the crushing strength of polycrystalline specimens consisting of different components, at any content of them.

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Note: Figure translations are in progress. See original paper for figures.