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Vladimir .A. MANSUROV
Akademia Górnicza w Karagandzie, Kazachstan

CLASSIFICATION OF ROCK AND AREAS OF NATURAL RESOURCES DEPOSITS PREDISPOSITION TO ROCK BURSTS

Summary. In the laboratory experiments was determined the energy value of elastic waves relased when a crack of determined size (unit) was formed. This characteristic for different types of rocks that changes more than in ten times is phisically based parameter. Which values the energy of their failure process. We suggest the classification of measure of PRB of rock based on analisis of this characteristic. PRB value of rock massif parts is suggested to classify according to the parameter characterising the upper limit of elastic waves energy, relased during their failure. It is determined from dependence of magnitude versus number of seismic events (Gutenberg B., Richter C.F.) constructed on observation after microseismic activity of different parts of rock massif part, where AE/MA events are registered and used in calculations.

KLASYFIKACJA SKŁONNOŚCI GÓROTWORU I REJONÓW ZŁÓŻ SUROWCÓW MINERALNYCH DO TĄPAŃ

Streszczenie. W artykule zaproponowano, by rozpatrywać górną granicę energii fal sprężystych, powstających podczas tworzenia się pojedynczych spękań, jako skłonności górotworu do tąpań. Badając poziomy aktywności mikrosejsmicznej w marmurze i granicie, autor dowodzi o przewadze proponowanej metodyki nad tradycyjnymi metodami badań próbek skał w warunkach laboratoryjnych. Podczas badań próbek określano zależności pomiędzy wielkością gromadzonej energii w skale w fazie dokrytycznej a następującymi zjawiskami dynamicznymi, pomiędzy wydzieloną energią sprężystą a skłonnością górotworu do tąpań itd. Otrzymane wyniki badań pozwalają klasyfikować skały według ich aktywności mikrosejsmicznej oraz prognozować stany zagrożeń w górotworze.

КЛАССИФИКАЦИЯ СКЛОННОСТИ ГОРНОГО МАССИВА И РАЙОНОВ ЗАЛЕЖЕЙ МИНЕРАЛЬНОГО СЫРЬЯ К ГОРНЫМ УДАРАМ

Резюме. В работе предлагается рассматривать верхнюю границу энерхии упругих волн, возникающих во время образования единичных трещин, как склонность горного массива к горным ударам. Исследования уровня микросейсмической активности были проведены в марморе и граните. Автор доказывает, что такие исследования лучше традиционнх исследований образцов пород, проводимых в лабораторных условиях. Во время исследований определялась зависимость между количеством энергии, накапливающейся в породе в докритической фазе, и наступающими динамическими явлениями между выделеной упругой энергей и склонностью горного массива к горным ударам и т.д. Полученные результаты позваляют классифицировать породы по их микросейсмической активности, а также прогнозировать степень удароопасности.

1. INTRODUCTION

Rocks have a great number of physical-mechanical properties. This difference is shown also in the fracture laws including elastic energy release under their deformation. The tendency of rock to brittle failure or dynamic events is very interesting because of rock bursts problem. Laboratory tests of rock on stiff testing machine helped to find out the differences in their tendency to brittle failure according to the modulus of the fall, calculated as Young's modulus on post-failure part of "stress-strain" curve (see Petukhov and Linkov (1983)). Thus,in situ it isn't always possible to use this characteristic because the mechanical behaviour of the rock massifs is not equivalent to the behaviour of samples of small size, tested in laboratories. Moreover, the rock in rock massif is in complex stress states, which are not always known.

In this connection it is of great interest to find the method of evaluation the burst prone rocks according to their response to the applied stress. In this paper we tried to use for this purpose method of acoustic emission/microseismic activity AE/MA. This method is based on the phenomenon of elastic energy release under dynamic changes of structure in a loaded body. For rocks of brittle failure AE/MA is mostly connected with crack formation (Vinogradov (1964)) followed by elastic impulses caused by quick unloading micro areas around the crack (Kuksenko and Stanchits and Tomilin (1983)).

2. METHODS OF EXPERIMENT

Different rocks were studied. In this paper we give the detailed results for granite and marble. For the other rocks the results are qualitatively similar. The samples of cylindrical shape with ratio of height to diameter equal to 2, with diameter of 30 mm were tested. The experiments were held on 500 ton force testing machine of Armavir plants. Axial $\varepsilon_{\|}$ and radial $\varepsilon_{|}$ strains and compressive stress were measured. The volumetric strain e_V was determined from the known equation $\varepsilon_V = - \varepsilon_{\|} + 2\ \varepsilon_{|}$. AE was recorded by the system, which is described in details by Mansurov (1993). For the generated acoustic signals AS under sample loading the amplitude A and duration B were measured from the envelope and also the time of radiation. For the same samples N cons istin of 512 AS the average meanings A, B were evaluated and energies of the every impulse was calculated as $E_i = \alpha A_i^{\ 2}\ B_i$. Ratio α for the experiments was estimated in the specially held experiments and was equal to $\approx 5 \div 6$.

3. RESULTS OF EXPERIMENTS

A. As far as the released as elastic waves energy E is proportional in the first approximation to the volume of formed crack V (Stanchits and Tomilin C1983)), that is

$$\sigma, \text{MPa} \approx \beta\ V$$

it is quite natural to suppose that proportional ratio, β depends on the conditions of rock loading and its failure.

In figure 1 the dependances of volumetric strain ε_V both on stress (curve 1) and on combined released elastic energy as AS (curve 2) is shown. Their behaviour is very complicated but it can be explained under their simultaneous analysis. Curve 1 before loading $\approx 0,7$ from strength limit σ^* is in the area of negative values ε_V which is connected (Bieniavski, 1967) with the sample sealing. Then the curves turn sharply and go into the area of positive value ε_V. The reason is the effect of cracking. The forming cracks generate acoustic signals. They explain the course of the curve 2. In its left part the sample sealing competes with its loosening while crack formation. When curve 1 crosses the ordinate axis it means that sample sealing and loosening are equal.

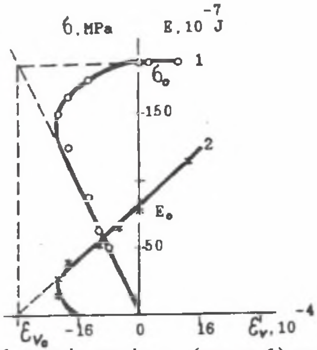

Fig. 1. Changing of volumetric strain ε_V (curve 1) and acoustic signals energy E during the increase of stress σ under uniaxial loading of granite sample.

Rys. 1. Zmiana odkształcenia objętościowego ε_V (krzywa 1) i energii sygnału akustycznego podczas wzrostu naprężenia σ przy jednoosiowym ściskaniu na przykładzie granitu

Consequently, the volume of the cracks V generated by the time equals to the sample, volume decrease due to the starting cracks and pores sealing. If we continue the straight portion of the curve 1 (the tangent to the curve) to intersection with line, which goes through the point σ_o of the cordinate axis we may easily evaluate ε_o. This value can be evaluated in the other way.

The right part of the curve 2 is practically straight and is due to dilatansy caused by new cracks formation. If we continue this straight line portion up to the axis e_V, we gain the value e_{V_0} too. The values gained by the two ways are close to each other. The straight line equation may be written as:

$$E = E_o + \beta\, \varepsilon_{V_0} V_s,$$

where: V_s - is the starting sample volume, and constant

$$\beta = E_o(\varepsilon_{V_0} V)$$

It must be marked that as a rule E is measured in relative units. However the absolute value of impulses can be evaluated if the preliminary (calibration) of the loading and AE recording system would be held (Kuksenko at all (1986)). The experiments with different types of rocks showed that this value changes from

$$\sim 1\ J/m^3 \text{ up to } 100\ J/m^3$$

B. Let's consider dependencies of energy release for the rocks under investigation on the value of the applied stress, which are shown in figure 2.

For the convenience of comparison they are constructed in normalized coordinates. On the abscissa axis the ratio of current stress to its failure value and on the ordinate axis are plotted - combined energy release at the different moments to its value on the point of strength limit. From the plots it is seen that for marble the energy release begins at small stresses, but in absolute value it is not large. For granite the noticeable elastic energy release begins when its limit value 07 - 08 is gained, but then it increases sharply and the combined energy value is therr units more that it is with marble. For marble AE generation is going on practically during all the loading, whereas for granite it is only at large stress. It reflects ability of granite to accumulate elastic energy without intensive cracks formation. And marble deformation is going on together with microfailure ond elastic energy relase from the very begining. In the measured range of the number of AS is not uniform by their energies (see figure 3).

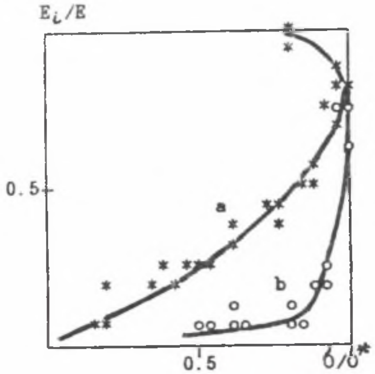

Fig. 2.AE - energy relase under loading (a - marble, b - granite)
Rys.2. Emisja akustyczna - wyzwolenie energii podczas obciążania (a - marmur, b - granit)

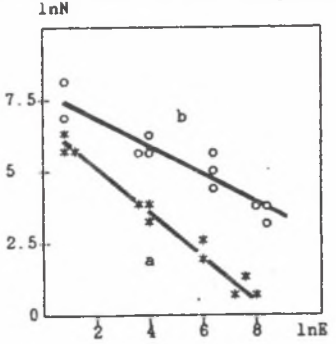

Fig. 3. Recurrent intervals for marble (a) and granite (b) samples
Rys.3.Zbieżność zmian dla marmuru (a) i granitu (b)

Small energies have the greatest number of AS. When energy increasesthe number of AS sharply decreases. Distribution is qualitatively similar to the recurrence intervals of earthquakes (Gutenberg and Richter (1954)). Extrapolation of dependencies before intersection with axis of energy E allows to evaluate the maximum values of energies, released in one impulse, which are characteristic to the potential burst-proneness of investigated rock. This values correlate well with the know characteristics of brittleness.

4.DISCUSSION OF THE RESULTS

The experimental results given above allow to make some conclusions about tendency of rocks to rock bursts (brittle, dynamic failure).

Firstly, the more energy the material can accumulate during deformation without microfailure, the more significant are the dynamic effects on the last stage of macrofailure.

Secondly, the more is the part of released elastic energy in large quantities portions, the more burst-prone is the rock.

Thirdly, the more energy is released during crack formation ofthe unit size in loaded volume, the more burst-prone is the rock.

According to the gained results the following questions arise:

1) How is determined the slope of the dependencies shown in figure 3;
2) Why does granite release much more elastic energy that marble?

The grained results don't give simple answer to these guestions and it is only possible to give some noncontradictory suppositions, which demand further model experiments for their confirmation. Thus, it can be noticed, that the structural heterogenity and brittleness of the material lead to localization of the failure process, which in its turn increases the part of large sized cracks in the total number of microcracks and the slope of dependencies (Mogi, 1962).

For answer on the second question it is necessary first of all to try to value the sizes of cracks corresponding to the recorded AS energies. Such instruct value may be done from the positions of concentration criterion of cracks enlarge. According to Petrov's (1984) work macrocracks and macrofailure occur when small cracks achieve the definite threshold concentrations, which leads to their clusterization.

This concentration $N^* = 1\ (K\ L_o)^3$, where $K \approx 3$, L - size of microcracks. If we adopt that the AS number is equal to the number of cracks N with the sizes not more that L, it is easy to evaluate $L \approx K\ N^{\bullet-1/3}$.

The smallest sizes of cracks, which are recordered with the given sensitivity of data acquisition system and correspond to one and the same values of energy $E_o = 10^{-12}$ J as we see, greatly differ. For granite $L_o \approx 0,1$ mm, for marble this fact doesn't mean that in marble there are no smaller cracks. They appear but the elastic energy, which releases is lower the threshold of sensitivity. If we adopt now that the released elastic energy while formation of the crack with size L is equal to $E = \beta\ L$, we may evaluate the constant β for the given materials, adopting that to maximum energy E corresponds the energy release from the whole volume of the sample, corresponding to the length of critical Griffith's crack. Since the sample volume in all cases was the same, $\beta = E_m$, that is they differ as essentially for the investigated rocks as the values of maximum energies. As far as ratio β means the energy released in unit volume while crack formation we may suppose why it is smaller for marble that for granite.

According to Hill and Stephens (19974), AS amplitude $A \approx \sigma^2\ L\ c^{-1}$, where σ - stress in thre plase of crack appearing, L - length of crack, c - sound speed in the material (it means local stress dependent on the material structure with the given level of applied average stresses). For marble it is difficult to expect increased local stresses, because the calcite grains, which constitute the rock and which have a developed systems of sliding do not provide circumstances for concentrations of stresses, which easily relax due to microshears. For heterogeneous granite, which is the unit of all quartz minerals concentration of stresses is easily achieved with small average stresses. The fracture in the overstressed areas is accompanied by AS generation of large amplitudeand energy.

5.CONCLUSIONS

1. Energy value, which releases in the loaded body with the increasing of cracks of unit size characterizes the tendency of the material to catastrophic failure and gives an opportunity to classify rocks on the degree of danger.

2. AE/MA recording in mines allows to evaluate the degree of danger of failing element of the underground constructions.

3. Current control of recurrence intervals of microseismic events and changes in their slope in mines allows to make a scale of degree of danger and evaluate the possible consequences and also approaching the dangerous event of a rock burst type.

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