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GEOPHYSICAL ASPECTS OF ROCK MATERIAL FRACTURING UNDER DIFFERENT VELOCITIES OF LOADING

Jan Maisler and Jan Frank

Institute of Geotechnics, CSAS, V Holešovičkách 41, 182 09 Prague 8, CSFR

Abstract

The chief task of our paper is to excite interest of the geophysical public in material loading in broad limits of by us achieved strain rates. The paper deals with different mechanisms of brittle fracturing, which are present during every way of loading. Possibilities of seismic and acoustic measures during individual experimental loadings are given in the end of this paper.

Introduction

Results of our previous researches [1,2] aimed to the way of rock material fracturing during high strain rates showed different ways of that in basic building units of rock material. Individual grains, respectively sub-grains of rock material are usually damaged in dependence on the velocity of the loading. This conclusion seems to be logical because of two basic aspects of dynamic loading. The first one is the distinct increase of loading stress amplitude which is related to increase of loading velocity and the second one is the velocity of relaxation response to the coming stress in the rock material. The second aspect is in good correlation to the well known phenomenon of strength limit growth with applied loading velocity in the rock materials, even in conditions of rheologic or quasistatic loadings. Our previous experiments have shown further on, that every structural unit of the rock material is able to present one or more mechanisms of brittle fracturing, application of which is dependent on the loading velocity. These mechanisms cover classical Griffith' s pattern of fracturing for very low loading velocities (rheological or quasistatic ones), mutually independent fra- cturing of mineral grains, which depends on crystallographic structure of the grains and their defects - for higher velocities, as well as failure of crystal lattice in mineral subgrain which can be account for a perfect crystal and its fracturing in full volume of the grain is often called planar effects. The last pattern of fracturing is distinctive for many minerals like quartz, olivine or some feldspars, and is a result of very fast pulse loading, respectively shock metamorphism caused either artificially (special blasting works, nuclear explosions in the underground, etc.), when stresses exceed 10 GPa, or naturally, as a result of impacts, i.e. impingement of big cosmical bodies on the Earth' s surface.

Mechanism of fracturing of mineral grain

According to our premise, there are a few basic mechanisms of deformation in every mineral grain, initiation of which is directly dependent on the achieved velocity of loading and induced dynamic stress. In this theory we also suppose the smaller structural unit causes the dynamic stress as relaxation, the faster is this relaxation to pass, but the higher value of trigger stress is needed.

As you can see on the Fig.1., in case of brittle failure of the sample after quasistatic loading, there are through fractures of Griffith' s pattern, which need relatively homogeneous field of elastic stress during very slow increase of loading and additionally, concentration of stress in full volume of the sample is needed.

In case of higher in order velocity of loading in experimental set of Hopkinson split pressure bar [HSPB], the stress is concentrated in area just limited by the front of the propagating stress wave and therefore inside of individual grains. Fracture pattern then has character of transcrystalline flaws which cover individual grains in the first step only and which are connected by a net of secondary intercrystalline failures on borders of adjacent grains later. The propagating fracture looses its Griffith' s character during this type of loading and gains signs of fracturing controlled by the crystal lattice, what is proved by identical angles of intersections of two basic failure systems in individual grains (see circle marks).

In case of loading on rock samples made from the same material using close explosion of chemical blasting agent, there are a few mechanisms of brittle fracturing working simultaneously (see Fig.3.). This phenomena is most likely caused by huge overplus of output of the loading medium which is able to develop both of the fracturing types - the primary one as well as the secondary one arising during the phase of primary stress relaxation like a classical Griffith' s strain flaw. This secondary mechanism causes the broadly open fractures which are so characteristical for this way of loading and which is therefore generally used for industrial application of blasting works aimed to disintegration of rock massif. Even in this case there is visible the crystallographic character of the fracture pattern, though it is slightly covered by the previously described secondary processes of sample disintegration.

When the rock sample is loaded using method which allows achievement of higher velocity than the velocity of longitudinal elastic wave propagation in the rock material (shaped charge, two steps light gas gun), there arise thick fracture nets of crystallographic character - when the velocity of loading is approximately equal to acoustic velocity (Fig.4.). But if the loading velocity is much higher than the longitudinal elastic wave velocity in the material, so called planar effects will arise inside individual grains, caused by disintegration of bonds in crystal lattice. Mineral grains damaged in this way can be found in nature in formations which were loaded in their geological history by impacts of great extraterrestrial bodies, velocities of which can achieve values between 15 and 73 $km.s^{-1}$, or in rocks loaded recently by close underground nuclear explosion. Nowadays, it happened to achieve similar velocities even in laboratory conditions, just thanks to the two steps light gas gun. Obtained patterns of mineral grains fracturing give an evidence of planar effects, which are present especially in quartz grains.

Conclusion

Application of some specific geophysical measuring methods, especially from the field of acoustic phenomena research and their frequency spectra in dependence on the way and achieved velocity of loading and therefore on character of final fracture pattern of individual experimental samples would be considered by the authors of this article as a contribution for both of their own work in the field of mechanics and dynamics of rock materials fracturing and of basic geophysical research in mechanics and dynamics of the seismic focus.

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