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EXPERIMENTAL STUDY AND NUMERICAL MODELLING OF FRACTURE PROCESS TRANSITION TO BLOW-UP MODE

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ABSTRACT

The statistical analysis of the data of the spatiotemporal evolution of the stress-strain state (SSS) before the catastrophic fracture for the rock mass during mining was carried out as well as of loaded rock specimens, based on the results of numerical calculations and experimental data. The revealed changes of the statistical parameters, which have common features in all the studies carried out, can be regarded as precursors of catastrophic fracture. In general, the process of deformation before fracture is correlated and corresponds to a state of dynamic chaos, and in some areas where the correlation coefficient was high, to a state of self-organized criticality.

Keywords: failure, precursor, nonlinear dynamics, stress evolution.

INTRODUCTION

The basis of the study is an analysis of time series, reflecting the evolution of the SSS of the loaded media up to fracture. In the case of experiments on the loading of rock specimens, the data on the change in the speed of the lateral surface obtained with the use of a laser Doppler vibrometer were analysed. In the case of numerical calculations, the time variation of the SSS parameters at the selected points of the calculation area was analysed.

RESULTS AND CONCLUSIONS

Statistical analysis was carried out by different methods. Cross-correlation analysis by the sliding window method showed that a high level of the correlation coefficient of the catastrophic fracture stage with the previous process of accumulation of damages is observed only in a very short time interval approximately equal to 8-10 times of the failure yield to the critical stage.

Spectral analysis based on the fast Fourier transform (FFT signal) and the 2D hodograph of the complex vector of the FFT signal revealed a fractal structure of the fracture process. The enlarged hodograph fragments vividly demonstrate the multiscale character of fracture, the increased hodograph pictures are qualitatively equivalent to the original picture. Moreover, a sharp change in the hodograph structure indicative of the increase in the fracture scale is observed only near the catastrophic event, so it can be regarded as a precursor of catastrophic fracture.

Wavelet analysis using a symmetric Daubechies wavelet well captures short signal emissions corresponding to local failures. Their growth as the fracture point is approached shows that a large-scale catastrophe is close.

The evolution of the graphs of the distribution function of fluctuations (PDF), the decrease in the slope of the amplitude-frequency characteristic (AFC) in logarithmic coordinates, the graphs of the frequency of seismic events as they approach catastrophic stage are also precursors of large-scale fracture.

All the revealed precursors of fracture and the peculiarities of the evolution of the SSS of the loaded medium are observed, in particular, in the analysis of the results of numerical modelling of the process of inelastic deformation and fracture of the rock mass at mining. These features of evolution in the mathematical model completely coincide with the evolution of real objects - the fractured rocks. These results are discussed partially in [Smolin *et al*., 2016]. The variant of numerical modelling of life span of specimens at three-point bending tests vs applied force is shown in Figure 1, in comparison with experimental data. The unstable development of deformation processes during fracture in experiments and in numerical modelling in the case of using the evolutionary approach occurs according to one scenario with the coincidence of all phases of the evolution of the SSS reflected in the AFC and PDF dependencies.

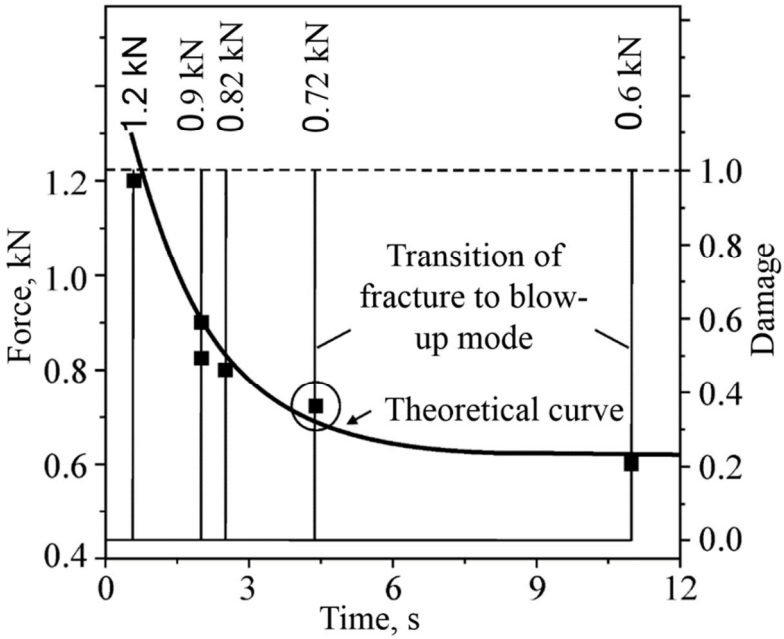

Fig. 1 - Comparison of theoretical curve (continuous) with experimental data (points) of loaded artificial marble. Thin lines at the graph are dependencies of life span (damage) of specimens at corresponding level of applied force (written above the lines).

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