Proceedings of the 7th International Conference on Mechanics and Materials in Design,
Albufeira/Portugal 11-15 June 2017. Editors J.F. Silva Gomes and S.A. Meguid.
Publ. INEGI/FEUP (2017)

PAPER REF: 6691

BLOW-UP MODES IN FRACTURE OF ROCK SAMPLES AND EARTH'S CRUST ELEMENTS

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ABSTRACT

It is well known that the final stage of macroscopic fracture develops as a catastrophe in a superfast blow-up mode. However, the specific features of this stage are well studied only on large scales of earthquakes. Of particular interest for fracture prediction are both the stage of superfast catastrophic fracture and the mechanical behavior of the medium in the state of self-organized criticality prior to transition of fracture to the blow-up mode in order to reveal precursors of fracture transition to the catastrophic stage. This paper studies experimentally and theoretically the mechanical behavior of the medium prior to the catastrophic stage and transition to the blow-up mode.

Keywords: blow-up modes, rocks, earth's crust elements, fracture.

INTRODUCTION

Evaluation of durability of objects and structures under loading and reliable prediction of the evolution stages of their deformation, including catastrophic fractures, are among the most important challenges of mechanics and physics of fracture. An essential feature of deformation evolution in loaded solids is the existence of a slow, quasi-stationary stage of accumulation of small-scale damage, hardly pronounced. Stress fluctuations in the vicinity of such micro-scale defects are extremely small and so is their range of action. As long as their concentration is comparatively low, they hardly interact with each other. When it becomes critically high (according to Zhurkov's concentration criterion of crack growth), the cracks begin to interact, bringing the loaded medium into a state of self-organized criticality (SOC), where all the damaging processes become correlated due to the information exchange via the stress microwaves generated by the growing cracks. The process of their coalescence and a transition of fracture to the macroscopic level develop as a superfast catastrophe. One of the main objectives of this work is to investigate this regime.

RESULTS AND CONCLUSIONS

The experiment on loading small-sized (marble and artificial marble) specimens was performed in a DVT GP D NN tensile compression testing machine (Devotrans, Inc.). The specimens measuring 15×15×15 mm were subjected to uniaxial compression at a constant load up to their macroscopic fracture. This allowed determining the specimen life span as a function of applied load with a concurrent registration of the surface velocities, including those during the superfast catastrophic stage. To do so, we used a laser Doppler vibrometer (Polytec, Inc.) (OFV-505 laser sensor head and OFV-5000 controller with VD-09 decoder). The method of laser Doppler vibrometry allows measuring the velocity within the laser beam spot parallel to the direction of lasing. The laser in the experiment was adjusted perpendicular to the lateral surface of the specimen, so the experimentally obtained velocity values corresponded to the normal component of the lateral surface velocity. The time resolution during the experiments was 20.83 μs (at the recording frequency 48 kHz), the precision of measurements allows for registering as small velocity as 0.1 μm/s and the laser spot diameter in the gage site was about 50 μm.

Shown in Fig. 1 is a typical time dependence of the free surface velocity during the transition from a quasi-stationary stage of damage accumulation to a catastrophic macroscopic fracture. The last stage before fracture is worth noting. It is evident that the lateral surface displacement velocity in the stage of catastrophic fracture rapidly increases by three orders of magnitude. Actually, only the last 100 ms of the deformation the velocities exceed the noise by a factor of 2-3 and could be taken into consideration (Fig. 1a). This stage corresponds to the SOC state and stress-strain state (SSS) evolution in the blow-up regime. The last 20 ms before failure at the point of time 98.0198 s (Fig. 1b) could be conventionally treated as the development of fracture as a macrocatastrophe. During the entire quasi-stationary stage (from 0 to 97.9 s), the noise from the external impact is comparable in amplitude with the useful signal, that is why this stage was not included into analysis (Fig. 1c, d).

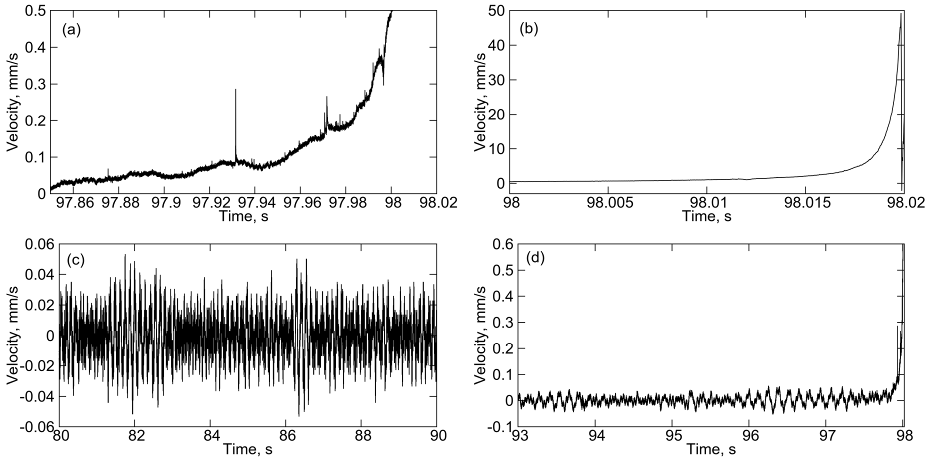

Fig. 1 - Temporal dependence of the free surface velocity of the specimen under compression

In the experiments on investigation of life span of small-sized specimens of marble and artificial marble as a function of applied loading, two stages of damage accumulation and specimen fracture have been identified - a lengthy quasi-stationary phase and a superfast catastrophic stage occupying no more than a thousandth fraction of the total life span, t^*. The catastrophic stage, as a blow-up fracture mode, has been conventionally defined as a deviation from the slow, practically linear, microdamage accumulation in the quasi-stationary stage. Its duration has been estimated to lie within 100 - 70 ms. The duration of a sharp increase in the surface velocity, where its amplitude exceeds that in the quasi-stationary stage, has been found to be 10-20 ms. The velocity amplitudes for the lateral surface in the quasi-stationary stage were as low as noise, which is due to the instrument sensitivity. To determine the time of fracture transition into a blow-up stage is the primary objective in the study of the mechanisms of fracture focus formation and evolution of SSS in the course of deformation. Reaching this objective would help predicting the onset of a catastrophic fracture stage. We believe the pattern of flicker-noise, caused by multiple microscopic fracture events, to be a sufficiently reliable characteristic capable of differentiating the stages of SSS evolution.

AKNOWLEDGEMENTS

This work is funded by the grant of RFBR No. 15-05-05002.