The influence of materials structure on the main features of the fracture process in rocks: Discrete Elements Method and Laboratory Experiment

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A computer model of fracture of the heterogeneous materials (including rocks) is proposed is based on the Discrete Element Method (DEM). We used the bonded particle model (BPM [1]), various modifications of which are widely used in the study the fracture process. The material is represented as a set of spherical particles (simulating polycrystalline grains) connected by bonds (simulating grain boundaries) at the points of particle contacts. In BPM model, the initiation of cracks is determined by the bonds breakage, and their propagation is provided by the coalescence of many broken bonds [2].

Computer experiments were carried for the materials with different features (various grain mechanical properties and sizes, various mechanical properties of the grain boundaries), in order to find out the influence of these parameters on local stresses and the defect formation. The calculations were carried out in the free software MUSEN [3].

The modeled cylindrical samples were filled with spherical particles of the same or different radii. The parameters of materials for grains and bonds between them (grain boundaries) were taken corresponding to such minerals and rocks as granite, quartz, orthoclase, oligoclase, and glass. The sample was placed in a virtual press, in which the lower plate was stationary, and the upper plate moved towards the lower one at a constant velocity until the sample was destroyed.

The calculation of the maximum local stresses showed that the homogeneity of material leads to greater space heterogeneity of local stresses and vice versa, heterogeneity contributes to their greater uniformity. A similar behavior of local internal stresses calculated on the basis of the kinetic concept of S.N. Zhurkov [4], was observed in laboratory experiments on the deformation of samples of Westerly granite and Berea sandstone [5].

The proposed model of polycrystalline materials realistically describes some features of their destruction in cases where the main processes occur along grain boundaries. These features include: the brittle nature of fracture of homogeneous materials and the presence of nonlinear elasticity (plasticity) for more heterogeneous ones, revealed using the stress-strain diagram and the time behavior of "acoustic activity"– the number of broken bonds per unit time. For heterogeneous materials, the model demonstrates a two-stage character of fracture process, when at the first stage the accumulation of defects occurs uniformly over the sample, and at the second stage – the formation and growth of the fracture site.

We assume that further computer experiments and their analysis will make it possible to compare the defect size distribution evolving in the fracture process and the energy distribution of acoustic emission signals. This will make it possible to find out under what conditions the transition from the Markov process to the state of self-organized criticality occurs.

References

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