NONLOCAL CONDITIONS FOR THE TRANSITION DAMAGE TO A LOCALIZED FAILURE IN GRANULAR AND FIBRE-REINFORCED COMPOSITES UNDER QUASISTATIC LOADING

A. V. Zaitsev
Perm State Technical University, Perm, Russia

1. Introduction

The investigation of inelastic deformation and failure of composites is associated with the necessity to develop mechanical models for the correct description of the behaviour of damaged heterogeneous materials in elements of structure. Besides, there is a need to improve the procedures of strength analysis in order to take into account actual loading conditions and the evolution and character of the collective interaction in a system of defects which determines the instant of macrofailure, when the damage accumulation becomes unstable. Without understanding the regularities and mechanisms of damage accumulation, without evaluating its stability and determining the conditions of localization begining, the macrofracture of composites will remain latent and poorly predictable phenomenon of internal structure evolution of the material.

2. Regularities of damage evolution in granular composites

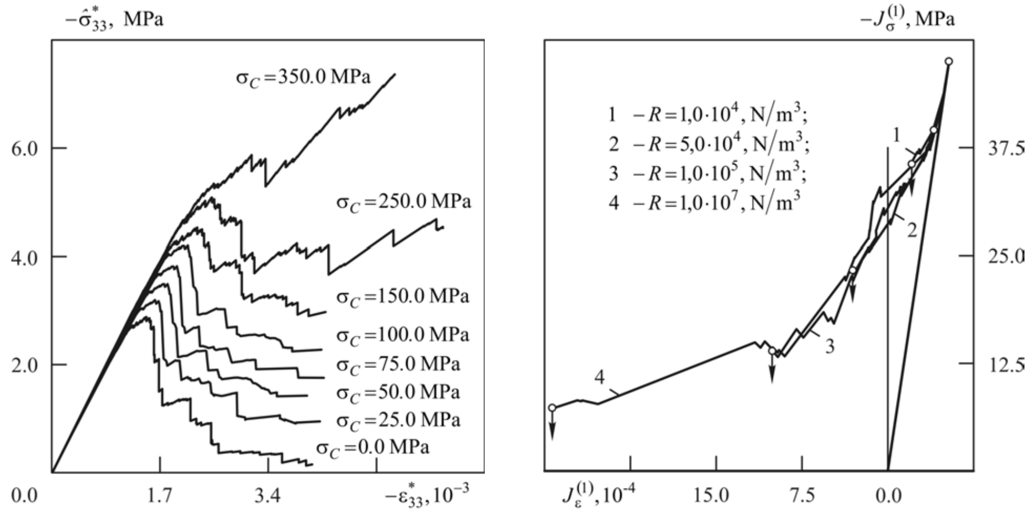

Figure 1. Uniaxial compression stress-strain diagrams under different lateral pressure σ_C (a). Dilatation under uniaxial compression with different stiffness of the loading system R (b). Stable stress-strain states corresponding to the instant of macrofailure are marked by arrows

The two-level-phenomenological structural model for granular composite was developed with the aim to study the character of collective multi-particle interaction in the defect ensemble, the general laws and the change in failure mechanisms and scale levels of damage evolution under combined triaxial quasistatic loading. A partial or complete loss of load-carrying capacity by structure elements is connected with violation of strength conditions and, as consequence, with jump-like changes of deformational characteristics. The model allowed us to describe the inelastic deformation accompanied by inclination and coarsening of defects as a multistage process of damage accumulation and to determine the instant of composite macrofailure as a result of loss of stability of this process. In the course of computational experiments, we found and analyzed such regularities of mechanical behaviour of granular composites as the strains corresponding to the instant of macrofailure and the character of damage evolution in relation to the stiffness of the loading system, the effect of lateral pressure on strain-softening (Fig. 1, a), the dilatation under uniaxial compression (Fig. 1, b), the unequal resistance of heterogeneous bodies, and the self-supported accumulation of defects. A nonlocal critical dimensional lengths constant for damaged solids is found to exist, which does not depend on the type of stress-strain state and quasistatic proportional and nonproportional loading modes. The constant determines the instant of transition from the stage of accumulation of disperse damage to a localized failure and to the strain-softening. The new nonlocal criterion allow one to determine a unique quantitative relation between the connection of damaged domains and the regularities in the behaviour of isotropic and anisotropic media.

3. Micro- and macrofailure of fibre-reinforced composites

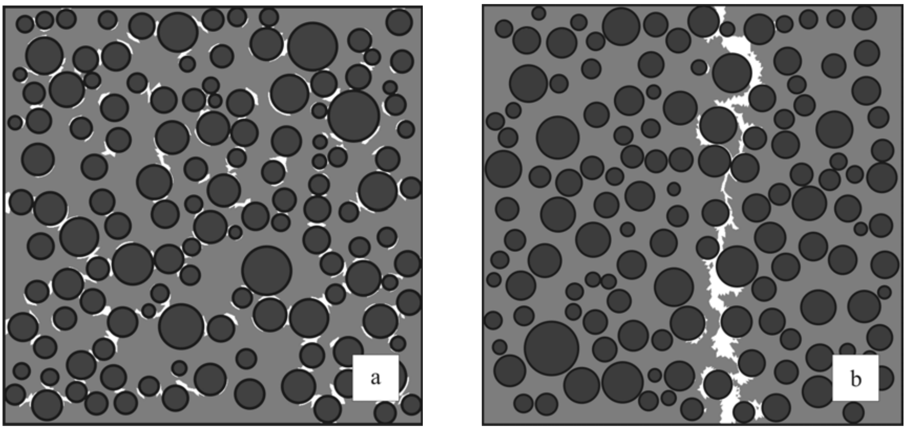

Figure 2. Effect of 'quantum' damage evolution under hydrostatic displacement-controlled compression $\varepsilon_{11}^* = \varepsilon_{22}^* = -\varepsilon_{33}^*$, $\varepsilon_{33}^* > 0$ (a) and macrofailure of glass-epoxi plastic with fibre void fraction $v_f = 0.4$ under antiplane shear $\varepsilon_{13}^* > 0$ (b)

The structural stochasticity of unidirectional composites is caused by randomness of the shape, relative arrangement and orientation of fibres and the scatter of fibre diameters. Computational experiments in transverse shear and tension, uniform tension in the reinforcement direction, and antiplane shear showed that the effective elastic moduli, which were determined for the representative volume element of composites with account of multiparticle interaction in the system of reinforcement elements, did not depend on the symmetry and asymmetry aspects of the distribution laws. But the asymmetry aspect was influenced significantly by the fractional structure of the materials, as well as by the character of multiparticle interaction at distances from half to two averaged fibre diameters. These length scales predetermined the character of strain and stress inhomogeneities in undamaged composites and significantly influenced the damage evolution scenario at the initial stage of quasistatic loading. The effect of 'quantum' damage evolution under hydrostatic compression (Fig. 2, a), which not depends on the type of statistical distribution law of fibre diameters, was found out and investigated. Qualitative coincidence of macrofailure in computational experiments (Fig. 2, b) with results of mechanical tests in antipain shear of glass-epoxi plastics is shown.

4. Acknowledgements

The author acknowledge the support of the Russian Foundation for Basic Research (Grant RFBR–Urals No 07–01–96056).