QUASIMICROPLASTIC PROPERTIES OF SOLIDS AT PRE-FRACTURE STAGE

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ABSTRACT

Study of mechanical properties of solids showed, that they possess the property of quasimicroplasticity in the area of rather small deformation. Quasimicroplasticity of solids manifests itself in the fact, that in the area of deformations $\varepsilon = 10^{-6} - 10^{-3}$ together with elastic deformations residual deformations are registered. The discovered phenomenon of quasimicroplasticity is observed in various classes of solids, which are distinguished by their nature, physical and mechanical properties, structure. Quasimicroplasticity of solids has amplitude-dependent and non-linear character, which causes physical nonlinearity of materials and effects their structural-mechanical properties at pre-fracture stage.

KEYWORDS

Quasimicroplasticity, fatigue, pre-fracture, physical nonlinearity, minerals, rocks, metals, polymeric materials.

QUASIMICROPLASTIC PROPERTES OF SOLIDS

Solids are traditionally classified according to deformation properties into elastic, plastic, elastically plastic and viscous elastic. Depending on the conditions of deformation these or other properties of solids are manifested. It is believed, that elastic properties of solids are manifested under the loads up to the limit of proportionality, which is achieved at sufficiently large stresses.

We investigated mechanical properties of solids by the method of three-point bending under standard conditions in the area of small deformations on plane-parallel samples with the sizes of $5 \times 3 \times 70$ mm^3. Testing was conducted in periodic under-load - off-load duty. Measurement of the deformation value was carried out by optical method with the sensitivity of $5 \cdot 10^{-7}$. Measurement error at 10^{-6} deformation made up $\sim 20\%$. Increasing deformation improves the accuracy of measurements. These investigation allowed us to detect quasimicroplasticity effect in solids. Manifestation of this effect consists in the fact, that in the areas of even small deformations ($\varepsilon \sim 10^{-6}$) alongside with elastic properties irreversible processes in solids are found, which are accompanied by residual deformations (e. g. in brittle rocks, fig. 1), the values of which may by compared with the elastic deformations or even exceed them (Mashinsky and Kochegarov, 1990). Accumulation of residual deformations takes place with the increase of loading on the sample. At off-loading of the sample the elastic deformation is

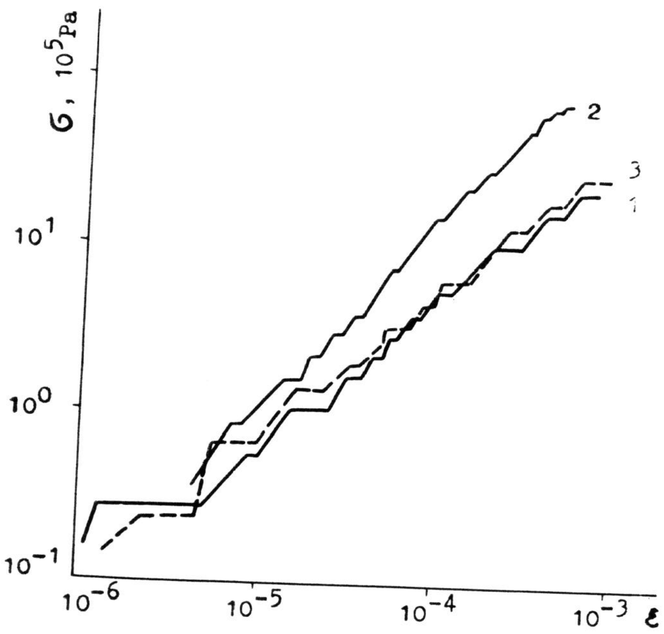

Fig. 1. Diagramm $\sigma(\varepsilon)$ of sedimentary rocks: 1 - fine-grained sandstone, 2 - marl, 3 - aleurolite.

removed and only residual deformation, which is a total deformation accumulated during the whole loading cycle, is registered. The residual deformation measured here, unlike viscous-elastic deformation, is independent of time.

Investigations conducted on coarse-grained marble, glass, vinyplast and polymethilmetacrilate (fig. 2) allowed us to detect quasimicroplasticity effect in the area of small deformations as well. Repeated deformation of several identical samples cut out of the same piece of the material showed good coincidence, when plotting the function $\sigma = f(\varepsilon)$, where σ is the stress, ε is the deformation. On all the diagrams of deformation of materials with different physico-mechanical properties a characteristic step-wise shape of the function of the residual deformation versus loading is observed.

Of particular interest are the results obtained on monocrystals of quartz and on the sample of chilled pig iron casting which, according to literature data, refer to typically brit-

tle materials. In accordance with the data (Stockes, 1972), quartz under standard conditions do not manifest properties of plastic deformation up to the loads causing fracture of the material. In fig. 3 one can see the dependence of residual ε_o and elastic ε_y components on total deformation (ε) for monocrystals of natural and synthesized quartz and chilled pig

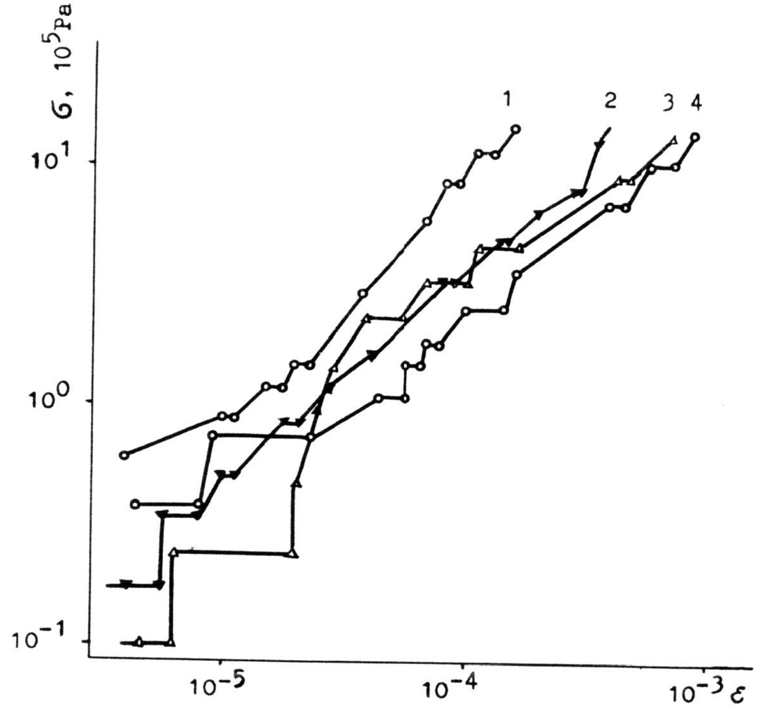

Fig. 2. Diagramm of deformation of materials: 1 - glass, 2 - coarse-grained marble, 3 - vinyplast, 4 - polymethilmetacrilate.

iron plotted on the basis of the obtained deformation diagrams. They show that all these materials possess quasimicroplasticity property as well. With the increase of total deformation the growth of both residual deformation occurs non-uniformly and its contribution into total deformation decreases as the latter grows. It is worth to note, that natural quartz as well as synthesized one at the initial stage of deformation has only quasimicroplastic deformation while the elastic deformation is absent.

Earlier it was shown, that on the level of mechanical stresses which are considerably lower than the level of fracture stresses not only plastic, but brittle materials as well e.g. quartz (Kochegarov, 1986) are capable of plastic deformation. The

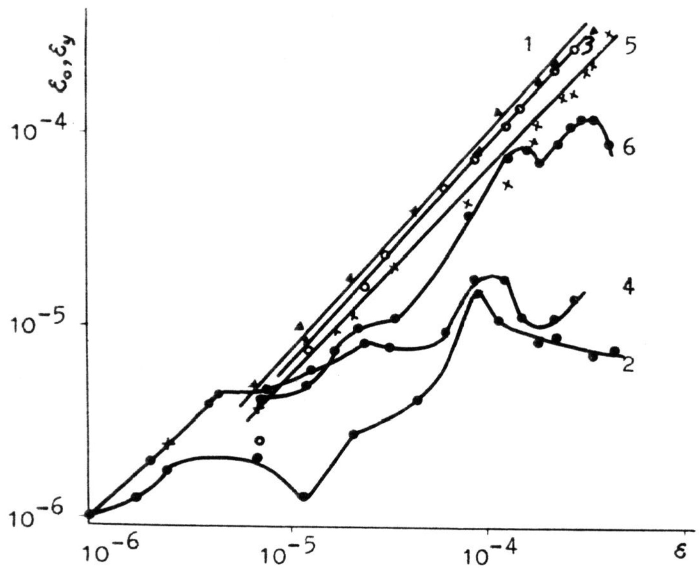

Fig. 3. Dependence of residual and elastic deformations on total deformation for monocrystals of natural (1,2) and synthesized (3,4) quartz and pig iron (5,6); 1,3,5 - $\varepsilon_y(\varepsilon)$ dependence; 2,4,6 - $\varepsilon_o(\varepsilon)$ dependence.

obtained results on quasimicroplasticity of solids agree with these conclusions. One can believe, that the detected phenomenon of quasimicroplasticity causing physical nonlinearity in the area of small deformations in different classes of solids, which are distinguished by their nature, degree of lattice crystallinity, structure, physical and mechanical properties, is a fundamental property inherent to all solids.

According to the data (Troschenko, 1971) change of nonelastic deformation by a cycle of loading at fatigue effect of the load is a stage process the first step of which is an incubation period of changing the energetic state of the material. Quasimicroplasticity effect substantiates the ways of accumulating nonelastic deformation at stresses, considerably smaller stresses of cyclic fatigue in the incubation period of the fatigue effect at mechanical loads and at fracture of materials. Accumulation of nonelastic deformation as a consequence of physical nonlinearity of the deformation process at small loads causes irreversible structural changes in a solid, which are

stress concentrators under conditions of the applied external load and represent nucleation sites and development of submicroslots in the material.

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