

# Computer modeling of nonlinear dynamic processes in structured geophysical media

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In different kinds of deformation processes practically all rocks reveal specific properties such as nonlinearity, hysteresis, dilatancy and dependence on the rate of deformation. These nonlinear properties are usually attributed to the structural constitution of the materials and to the processes taking place on contacts of structural elements: crystals, grains, granules, etc. The experiments with neutron diffraction [Darling et al., 2004] confirm the dependence of the non-classical properties of sedimentary rocks (sandstones, marble and limestone) on the deformation processes of small material volumes near bonds and contacts, inhomogeneous stresses in the grains and the pore space available for grain motion. For the explicit study of this dependence the computer simulation of dynamic deformation processes in the structured medium has been performed.

The structured medium is modeled by the discrete system of 2D deformed elements (grains).

Three types of grain interaction: a) elastic, b) viscoelastic and c) elastoplastic are considered. The

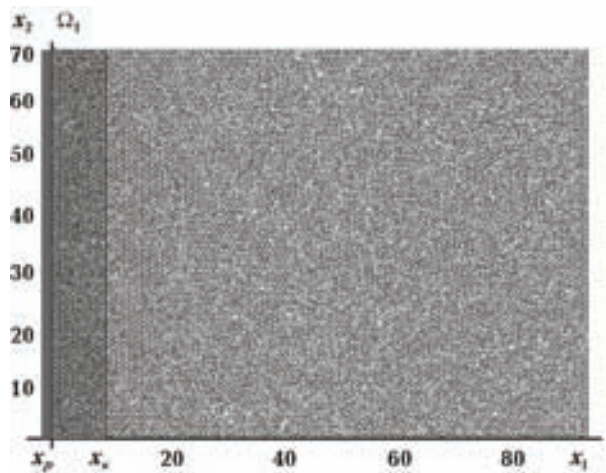


Fig. 1. The grains massif.

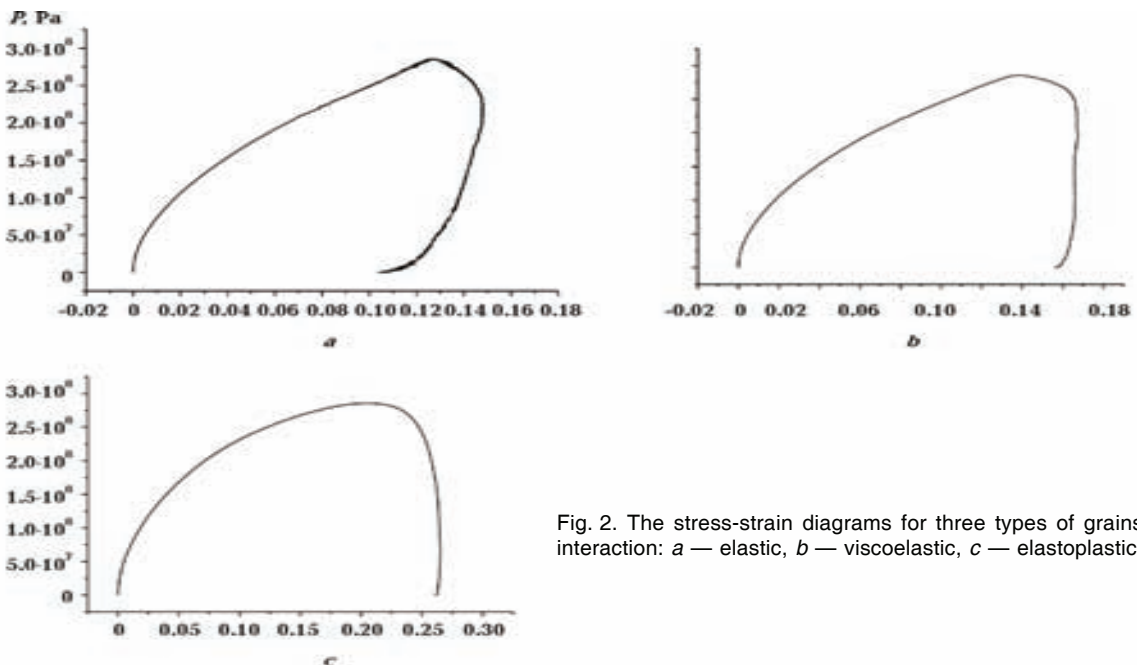


Fig. 2. The stress-strain diagrams for three types of grains interaction: a — elastic, b — viscoelastic, c — elastoplastic.

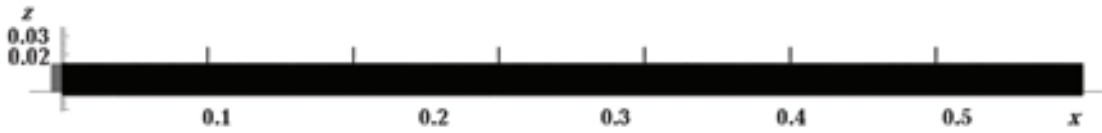


Fig. 3. The structured massif in which propagates the nonlinear wave.

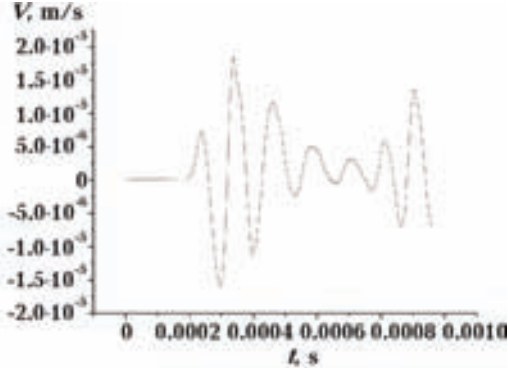


Fig. 4. Averaged velocities  $V_x$  vs. time  $t$  at the distance  $x=0.16$ .

molecular dynamic technique is used for simulation the dynamic of the discrete medium [Cundall, Strack, 1979]. The grains massif is placed in a rectangular area (Fig. 1). The massif is deformed by the piston, which is driven by the force acting in the  $x$ -direction

$$f = f_0 \sin^2(\pi t / t_{\max}). \quad (1)$$

The thin wall with the coordinate  $x_s$  is located inside the massif. Knowing coordinates of piston  $x_p$  and  $x_s$  one can determine the actual strain  $\varepsilon(t)$  of the thin layer  $\Omega_1$

$$\varepsilon(t) = 1 - \frac{x_s(t) - x_p(t)}{x_s(t_0) - x_p(t_0)} \quad (2)$$

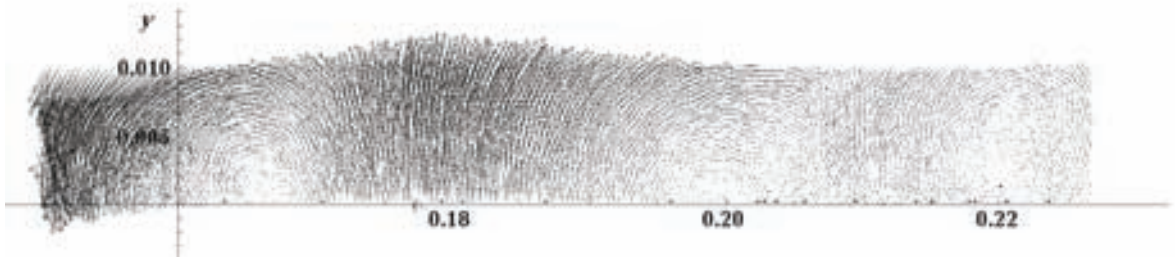


Fig. 5. The vector field at the time  $t=0.96$  ms.

and to build the stress-strain diagram. The stress-strain diagrams for three types of grains interaction are presented in Fig. 2. All diagrams are nonlinear and hysteretic. The hysteresis squares in the viscoelastic and elastoplastic cases are greater than in the elastic one.

The second part of the report is devoted to the propagation of nonlinear wave in structured media in gravitation field. The massif consists of 56000 elements with the elastic Hertzian contacts (Fig. 3). The wave is generated by the same procedure as in

the first case. Averaged mass velocities are calculated at six distances away from the piston by averaging the velocities of particles in thin layers. The dependences of the averaged velocities on time are presented in Fig. 4. The propagating wave rapidly decays being transformed then into a periodically one. Fig. 5 shows that in the massif periodical wave structures are formed. If the massif is in a prestressed state the wave attenuates slowly and the wave structures do not arise. The prestressed state is created by the  $z$ -direction weighting.

### References

- Cundall P. A., Strack O. D. L.* A discrete numerical model for granular assemblies // *Geotechnique*. — 1979. — **29**, № 1. — P. 47—65.
- Darling T. W., TenCate J. A., Brown D. W., Clausen B., Fogel S. C.* Neutron diffraction study of grain contacts to nonlinear stress-strain behavior // *Geophys. Res. Lett.* — 2004. — **31**. — P. L166041—L166044.