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Parallel Program Systems for the Analysis of Wave Processes in Elastic-Plastic, Granular, Porous and Multi-Blocky Media

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Under modeling the wave propagation processes in geomaterials (granular and porous media, soils and rocks) it is necessary to take into account the structural inhomogeneity of these materials. Parallel program systems for numerical solution of 2D and 3D problems of the dynamics of deformable media with constitutive relationships of rather general form on the basis of universal mathematical model describing small strains of elastic, elastic-plastic, granular and porous materials are worked out. In the case of an elastic material, the model is reduced to the system of equations, hyperbolic by Friedrichs, written in terms of velocities and stresses in a symmetric form. In the case of an elastic-plastic material, the model is a special formulation of the Prandtl–Reuss theory in the form of variational inequality with one-sided constraints on the stress tensor. Generalization of the model to describe granularity and the collapse of pores is obtained by means of the rheological approach, taking into account different resistance of materials to tension and compression. Rotational motion of particles in the material microstructure is considered within the framework of a mathematical model of the Cosserat continuum. Computational domain may have a blocky structure, composed of an arbitrary number of layers, strips in a layer and blocks in a strip from different materials with self-consistent curvilinear interfaces. At the external boundaries of computational domain the main types of dissipative boundary conditions in terms of velocities, stresses or mixed boundary conditions can be given. Shock-capturing algorithm is proposed for implementation of the model on supercomputers with cluster architecture. It is based on the two-cyclic splitting method with respect to spatial variables and the special procedures of the stresses correction to take into account plasticity, granularity or porosity of a material. An explicit monotone ENO-scheme is applied for solving one-dimensional systems of equations at the stages of splitting method. The parallelizing of computations is carried out using the MPI library and the SPMD technology. The data exchange between processors occurs at step “predictor” of the finite-difference scheme. Program systems allow simulate the propagation of waves produced by external mechanical effects in a medium, aggregated of arbitrary number of heterogeneous blocks. Some computations of dynamic problems with and without taking into account the moment properties of a material were performed on clusters of ICM SB RAS (Krasnoyarsk) and JSCC RAS (Moscow). Parallel program systems 2Dyn_Granular, 3Dyn_Granular, 2Dyn_Cosserat, 3Dyn_Cosserat and 2Dyn_Blocks_MPI for numerical solution of 2D and 3D elastic-plastic problems of the dynamics of granular media and problems of the Cosserat elasticity theory, as well as for modeling of the dynamic processes in multi-blocky media with pliant viscoelastic, porous and fluid-saturated interlayers on cluster systems were registered by Rospatent.