MODELING of VISCOELASTIC and FUNCTIONALLY-GRADED MATERIALS on THE BASE ASIMPTOTIC HOMOGENIZATION

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RESUME

The paper deals with structurally heterogeneous (composite, including soils, as composites of natural formation) materials which mechanical characteristics have viscoelastic properties [1] and depend on temperature. The behavior of such materials is described by integrodifferential equations of the theory of elasticity with coefficients that depend on spatial coordinates and temperature. The defining relations of such materials are integral time equations with relaxation kernels of a different type which can be described with the aid of the Laplace integral transformation through complex modules based on an elastic analogy between the images of stresses and deformations. As a result, a composite material with rheonomic properties is described by equations of the theory of elasticity with complex coefficients that depend on spatial coordinates, temperature, and fast variables describing changes at distances on the order of the characteristic size of the inclusions. In this description, not only viscoelastic but also functional-gradient composite materials are modeled, the properties of which smoothly vary in space and depend on temperature complex coefficients that depend on spatial coordinates, temperature, and fast variables describing changes at distances on the order of the characteristic size of the inclusions. The asymptotic averaging method [2] in the parametric space [3], generalized to quasi-periodic equations with complex coefficients, is applied to the equations considered above, and it is shown that from the position of asymptotic averaging, smooth non-periodic dependencies are resolved parametrically in the functions of fast variables. As a result, to solve problems in structurally heterogeneous materials, a two-level scheme for representing the solution is formulated and an algorithm for calculating the effective mechanical characteristics is found, considering the viscoelastic and functional gradient properties of the material. To solve lower-level problems (on a “representative” cell for fast-variable functions), an analytical-numerical approach develops that allows us to construct complete systems of functions for the high-precision approximation of solutions that accurately consider contact conditions at interphase boundaries for spherical and cylindrical inclusions with an interphase interface. With the help of these functions, the problem of averaging materials with an irregular and random structure of inclusions represented by a periodic pattern with a set of individual blocks solved based on the constructed systems of functions using the block least-squares method, is effectively solved. Regarding this approach, parallel algorithms and high-performance computations are developed on cluster systems with distributed and shared memory, oriented to solving systems of linear algebraic equations of block-sparse structure, but with densely filled matrices of arbitrary size. Accordingly, for solving top-level problems (with effective characteristics), their finite-element approaches develop that consider the specific nature of the problem. These methods are embodied in the developed by the authors of the finite-element complex Uway.

REFERENCES

1. Ferry J.D. Viscoelastic properties of polymers. John Wiley & Sons, 1980. -641 p.
2. Bakhvalov N. S., Panasenko G. P. Homogenization: Averaging Processes in Periodic Media, in: Mathematical Problems in the Mechanics of Composite Materials. Dortrecht: Kluwer Academic, 1989.
3. Vlasov A.N., Volkov-Bogorodskiy D.B. Parametricheskij metod asimptoticheskogo usredneniya dlya nelinejnyh uravnenij termouprugosti // Mekhanika kompozicionnyh materialov i konstrukcij. 2014. T. 20, № 4. S. 491-507 (in Russian).