

DESCRIPTION FOR THE GENERAL PUBLIC (IN ENGLISH)

The aim of the project is the development of new methods and computer codes for analysis and optimization of microstructures of materials, in which many voids, inclusions and cracks exist. Porous and composite materials will be investigated. Particular materials, which will be considered in the project are nanocomposites and electronic composites, in which coupling between mechanical, electric and magnetic fields occur.

Voids in porous engineering materials are manufactured during technological processes and are material defects or are purposely introduced in order, for example, to decrease mass density. Modern technological processes allow obtaining different distribution of porosity. Inclusions are material defects or are purposely introduced components of composites. Composites which contain different materials can have better physical properties than each component. During loading on surfaces of voids, in the vicinity of cracks and at interfaces between different materials, stress concentration occur, which can cause plastic deformation, fracture and crack growth. Therefore very important is strength analysis of such materials. Distribution of voids, cracks and inclusions, their size, shape and number have influence on stiffness, strength and other physical properties. Through the proper selection of geometry of microstructure and physical properties of porous and composite materials we can obtain desired properties of materials. Analysis of these problems is particularly difficult and is important during design of new engineering materials.

In the process of design of new materials effective material properties are used. These properties are obtained by analytical, experimental and computer methods. Analytical methods are applied to simple shapes of voids and inclusions (spherical, ellipsoidal, cylindrical). Experimental methods require time consuming and expensive tests on real materials. Because of complexity of presented problems materials are analyzed using different computer methods. Computer methods allow analysis of microstructures having complex geometry, material properties and boundary conditions. The most popular methods are the finite element method (FEM) and the boundary element method (BEM). The effective properties can be applied for modeling deformable bodies as continuous and homogeneous in the macroscale, which significantly simplifies the analysis.

Microstructures with complex geometry and material properties will be analyzed by the boundary element method (BEM) or the fast multipole boundary element method (FMBEM), which is applied to very complex structures. Many problems can be solved by the BEM by description of geometry and physical quantities along surfaces of bodies. Therefore, the preparation of data input and its modification is very simple. This advantage is very important when the influence of different microstructures on physical properties is investigated. Usually the solutions obtained by the BEM are very accurate, particularly for problems with strongly changing stresses.

The aim of optimization will be, for example, maximum of strength and stiffness of material or coupling between mechanical, electric or magnetic fields. The design variables are distribution, size, shape and properties of constituents of composites. Optimization problems will be solved using artificial intelligence methods, for example, evolutionary algorithms, artificial immune systems, harmonic search methods, etc. The methods do not require knowledge of influence of design variables on the criterion of optimization. These methods are characterized by simplicity of application and allow finding the optimal solution with high probability.

The computer codes can be used to analyze physical quantities on the micro level and for design of new materials. This aim is important because modern engineering materials are used in intensively developing branches of industry, for example, automotive, aviation, aerospace industry. In the opinion of the authors, taking into account scientific and practical aspects, the proposed research project is important and in agreement with modern trends in science.