The purpose of this work is to analyze the effect of microstructures of particle-reinforced metal matrix composites on their strength and damage resistance by carrying out 3D numerical simulations of deformation and damage evolution in the composite.

Numerical (finite element) mesomechanical simulations of the deformation and damage evolution of Al/SiC composites are carried out for different microstructures (i.e., different particle arrangements and shapes) of the composites. The systematic numerical testing of the composite was used to determine the optimal microstructures of the composites [1, 2], and to find possibilities of the materials improvement.

In order to generate and mesh 3D artificial microstructures of the composites with different particle arrangements and shapes, a new program for the automatic design of three-dimensional FE meshes was developed (Fig.1). The program produces artificial microstructures on the basis of given parameters and probability distributions of particle coordinates and sizes, and generates databases for the finite element analysis of the materials with the required artificial microstructures.

The following arrangements of SiC particles in the composite were considered: uniform, random, regular, gradient, clustered arrangements, with different distributions of particle sites, sizes and local strengths. Some examples of the designed microstructures are shown in Figure 2. The damage in particles was modeled as a local weakening of a finite element in which the damage criterion (maximum principal stress) exceeded a critical value [3-5].

The force-displacement curves and the dependence of the amount of failed particles on the applied displacement were determined numerically for each of the microstructures (Figures 3, 4).

Figure 1. Schema of the program “Meso3D“.
It has been shown that the regular (homogeneous) particle arrangements ensures maximum strength and average damage resistance of the composite. Clustered arrangement of SiC particles in the composite leads to very low damage resistance, and to a quick failure of the materials. Gradient particle arrangements ensures relatively low strength, but also very low rate of damage growth.

On the basis of the numerical experiments, some recommendations for the improvement of the microstructures of the particle-reinforced composites have been suggested.

References: