# 3D Mesomechanical Simulation of Damage Evolution in Particle Reinforced Composites

Leon Mishnaevsky Jr.

University of Stuttgart, MPA, Pfaffenwaldring 32, D-70569 Stuttgart, Germany
and
Institute of Mechanics IV, Darmstadt University of Technology, Germany
Email: mishnaevsky@web.de

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).

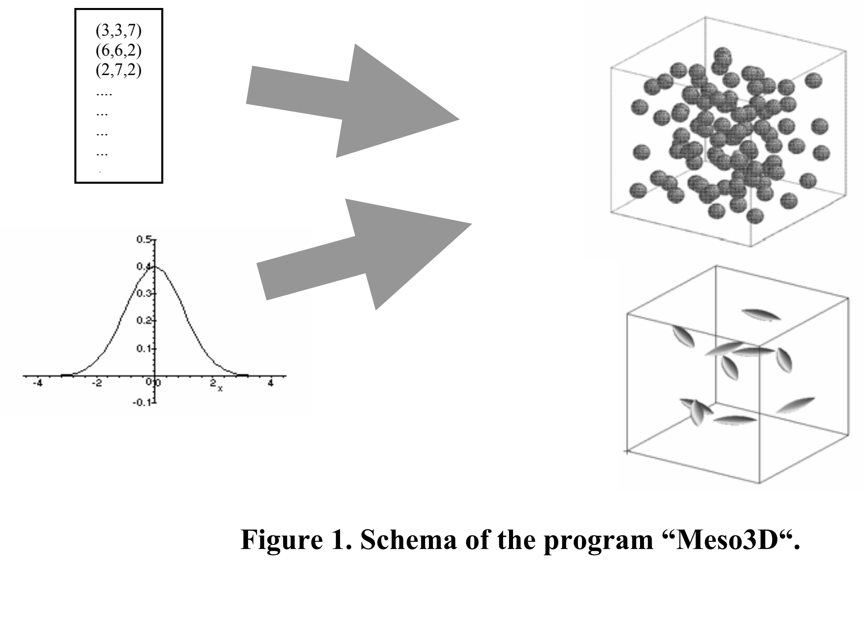


**Figure 1. Schema of the program “Meso3D“.**

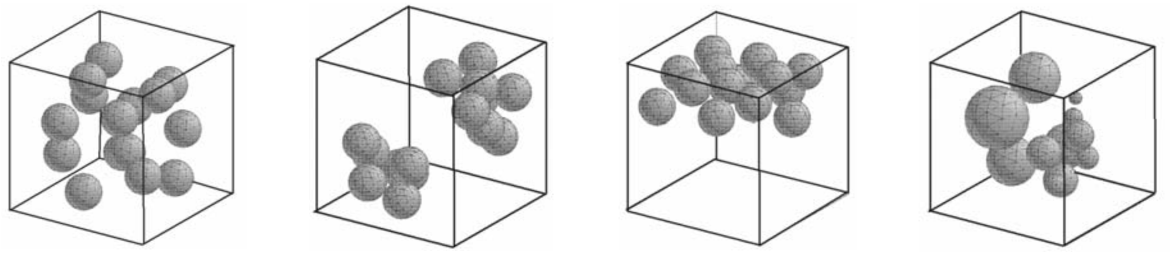


**Figure 2. Examples of Designed Artificial Microstructures. Volume content of the hard phase and the amount of particles can be varied ( 5%, 10%, 15% and 5, 10, 15 particles)**

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.

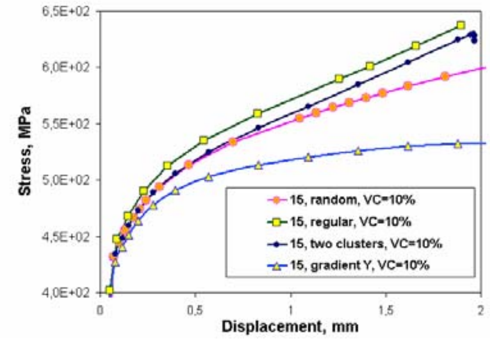


**Figure 3. Numerical stress-displacement curves for different particle arrangements (15 particles in unit cell, volume content 10%)**

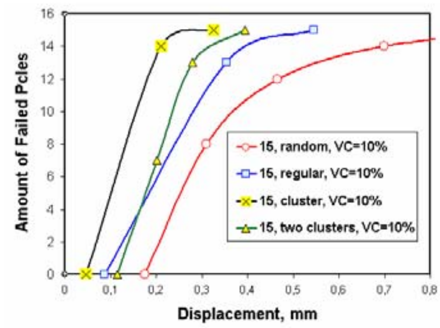


**Figure 4. Amount of failed particles versus applied displacement curves for different particle arrangements (15 particles in unit cell, volume content 10%)**

**References:**

1. L. Mishnaevsky Jr and S. Schmauder, Continuum Mesomechanical Finite Element Modeling in Materials Development: a State-of-the-Art Review, *Appl. Mech Rev*, Vol. 54, 1, 2001, pp. 49-69
2. L. Mishnaevsky Jr, Computational Mesomechanics of Materials: Virtual Testing of Microstructures and Possibilities of the Materials Optimization, Continuum Models and Discrete Systems (CMDS10), NATO Advanced Research Workshop, Shoresh, Israel, 30 June - 4 July 2003
3. L. Mishnaevsky Jr, *Damage and Fracture of Heterogeneous Materials: Modelling and Application to the Improvement and Design of Drilling Tools*, Balkema, 230 pp. 1998
4. L. Mishnaevsky Jr et al., Computational Mesomechanics of Particle-Reinforced Composites, *Comp. Mater. Sci.*, Vol. 16, 1999, No. 1-4, pp. 133-143
5. L. Mishnaevsky Jr, N. Lippmann and S. Schmauder, Micromechanisms and Modelling of Crack Initiation and Growth in Tool Steels: Role of Primary Carbides, *Zeitschrift f. Metallkunde*, 94, 2003, 6, pp. 676-681
6. L. Mishnaevsky Jr, N. Lippmann and S. Schmauder, Computational Modeling of Crack Propagation in Real Microstructures of Steels and Virtual Testing of Artificially Designed Materials, *Int. J. Fracture* Vol. 120, Nr. 4, 2003, pp. 581-600
7. L. Mishnaevsky Jr, Methods of the Theory of Complex Systems in Modelling of Fracture: a Brief Review, *Eng. Fract. Mech.,* Vol.56, No.1, pp.47-56, 1997