MODELLING OF EFFECTIVE ELASTIC PROPERTIES OF INTERPENETRATING METAL-CERAMIC NETWORKS

Z. Poniznik[1], ***V. Salit***[2], ***M. Basista***[1] *and* ***D. Gross***[2]
[1] *Institute of Fundamental Technological Research, Warsaw, Poland*
[2] *Darmstadt University of Technology, Darmstadt, Germany*

1. Introduction

The interpenetrating phase composites (IPC), or interpenetrating metal-ceramic networks, are advanced engineering materials which consist of entirely interconnected networks of solid phases. The rationale behind designing the IPC is to achieve a highly durable material that would combine the most desirable properties of the constituent phases. The detailed description of IPC and their applicability is given e.g. in [1]. The methods of estimation of the effective elastic properties of the IPC's are presented and compared ([2], [3], [4]). A numerical method for calculating random composite structure model was developed. Numerical methods for calculating real composite microstructures were developed and used for Al_2O_3-Cu IPC microstructure acquired from the computer micro-tomography (CT). The results of measurements of Young's modulus for different types of Al_2O_3-Cu interpenetrating composites are also presented and compared with the analytical approximations and numerical calculations.

2. FEM modeling of the interpenetrating structure

The calculations were made for the 3D interpenetrating cross structure, shown in Fig. 1, for the random voxel structure, and for the real structure obtained from computer tomography. There were three effective elastic constants calculated: Young's modulus, Poisson's ratio and shear modulus. To model Young's modulus and Poisson's ratio, tensile load was applied as the uniform displacement field applied to one side of the cube, with fixing boundary conditions on the opposite side. To model shear modulus, tangent displacements were applied together with antisymmetric boundary conditions.

There were convergence studies made to compare the results for different mesh densities for the calculations of Young's modulus, Poisson's ratio and shear modulus. The method of extrapolation to other composite components was proposed. The effect of porosity of the porous ceramics on the effective properties was also investigated.

The calculations for the real structure of the Al_2O_3-Cu interpenetrating composite obtained from computer tomography were made. The inner part of the image, with the shape of the cube of the dimensions 400×400×400 voxels, was extracted to be used for calculations. The real structure of the material was represented as cubic voxels, where each voxel was made of only one material. Each voxel was modeled as 8-node brick element. Due to complexity of such a big model the whole structure was divided into 512 equal in size cubic parts and then each part was calculated separately. The applied loads and boundary conditions were analogous to the applied for the cross structure.

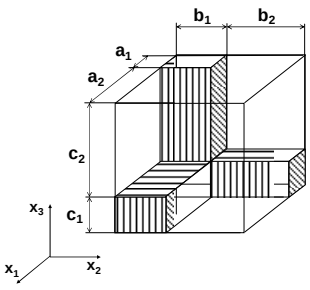

Fig. 1. Unit cubic cell of the IPC model according to [2]

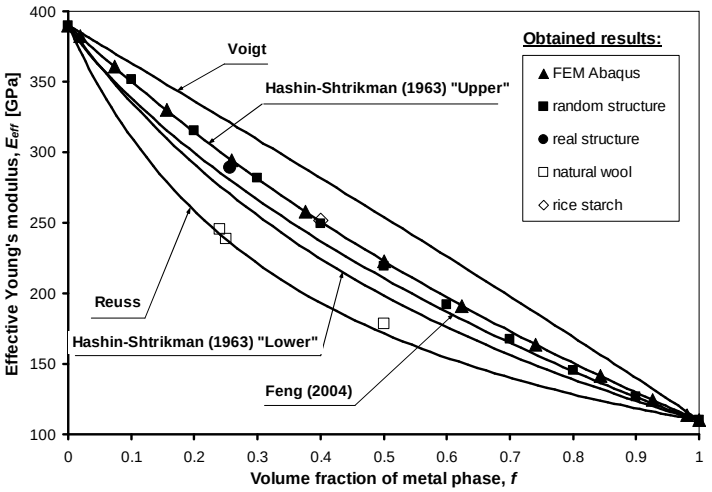

Fig. 2. Effective Young's modulus of Al_2O_3-Cu IPC – analytical and numerical models and CT measurements results.

The numerical results for the effective Young's moduli are presented in Fig. 2, compared with theoretical predictions and results of measurements of the Al_2O_3-Cu interpenetrating composites. It can be seen that these numerical results fit between Hashin-Shtrikman bounds [4] and are closer to the upper bound. The influence of the composite microstructure on the effective properties can be also seen.

3. Conclusions

The numerical methods of estimating the effective properties of interpenetrating phase composites were presented and compared with existing theoretical models and results of measurements of IPC's of different microstructures. The developed numerical methods are in accordance with the existing theoretical models applicable to the IPC's.

From the presented results it could also be seen that computational methods offer the best possibilities for modeling the features of the real material, such as porosity, microcracking, debonding between phases and thermal stresses. Further investigation of these methods should then be made.

4. References

[1] Basista M. and Weglewski W. (2006). Modelling of damage and fracture in ceramic-matrix composites - an overview, *J. Theor. Appl. Mech.*, **44**, 455-484.

[2] Feng X., Tian Z., Liu Y. and Yu S. (2004). Effective elastic and plastic properties of interpenetrating multiphase composites, *Appl. Comp. Mater.*, **11**, 33-55.

[3] Gross D. and Seelig T. (2006). *Fracture Mechanics with an Introduction to Micromechanics*, Springer.

[4] Hashin Z. and Shtrikman S. (1963). A variational approach to the theory of the elastic behaviour of multiphase materials, *J. Mech. Phys. Sol.*, **11**, 127-140.