Proceedings of the 7th International Conference on Mechanics and Materials in Design,
Albufeira/Portugal 11-15 June 2017. Editors J.F. Silva Gomes and S.A. Meguid.
Publ. INEGI/FEUP (2017)

PAPER REF: 6692

PROBABILISTIC MODELLING POROUS STRUCTURE AND NUMERICAL SIMULATION OF MECHANICAL BEHAVIOUR OF POROUS CERAMICS

Igor Yu. Smolin[1,2(*)], Pavel V. Makarov[1,2], Mikhail O. Eremin[1,2], Kirill S. Matyko[1]
[1]Tomsk State University, Tomsk, Russia
[2]Institute of Strength Physics and Materials Science SB RAS, Tomsk, Russia
[(*)]*Email:* ismolin@ftf.tsu.ru

ABSTRACT

To study the mechanical response of porous ceramics at mesoscale, first, digital voxel models of porous samples were generated and, second, their deformation in compression and simple shear was numerically modelled. Two types of pore space morphology were considered explicitly: overlapping spherical pores and overlapping spherical solids. For deformation modelling the evolutionary approach was applied, that include the nonlinear constitutive equations to describe damage accumulation and its impact on the degradation of the strength properties of the solid frame. Based on the computer modelling results the influence of both porosity and pore morphology on the stress-strain curves and effective elastic and strength characteristics is analysed. The calculated results fit well experimental data for zirconia and alumina porous ceramics.

Keywords: ceramics, porous structure, modelling, structure - property relationship, damage.

INTRODUCTION

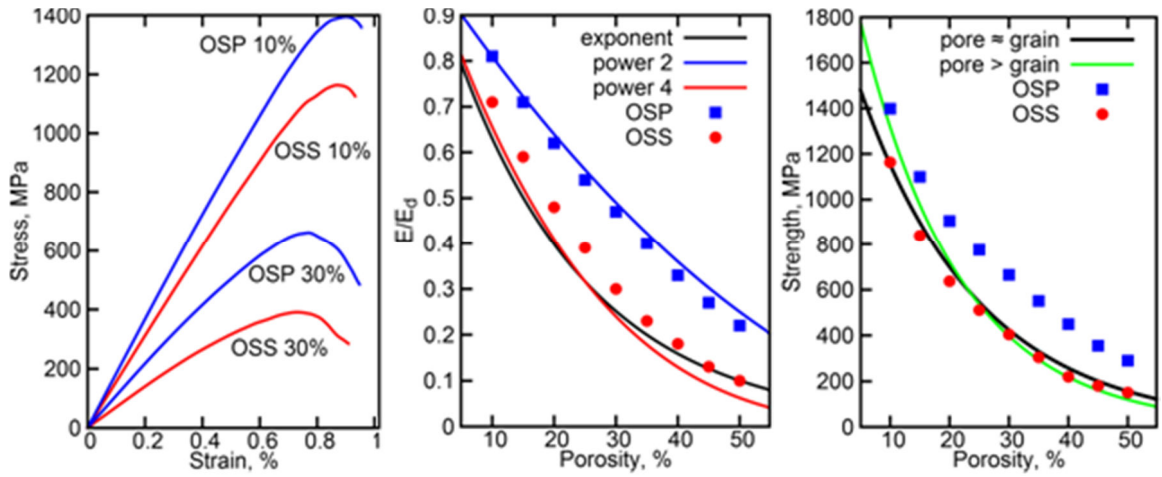
Because of the manufacturing process, all ceramics acquire a certain degree of porosity. Of special interest are the highly porous ceramics that are widely used as filters, thermal insulator, dielectric resonator, catalyst, prosthetics etc. The problems of modeling of porous materials can refer to three areas: (i) modeling the porous structure per se; (ii) determining the effective properties of porous materials; (iii) direct simulation of deformation and fracture of porous materials at different scales. While there is a vast literature devoted to all of the three, quite a number of problematic issues still exist. The computational approach is found to be promising to solve problems in all three areas.

A basic problem of the simulation of different materials is the construction of constitutive equations describing all aspects of the mechanical behavior of these materials, including the deformation response and especially the failure. The constitutive equations must take into account both the characteristics of local damage accumulation and the pore space evolution in various loading conditions.

The evolutionary methodology developed by the authors (Makarov, 2008) seems to be an effective approach to solve this problem. The purpose of this paper is to demonstrate the possibilities of combination of a known approach to modelling porous structure of materials (a geometrical problem) and a new approach to simulation of mechanical behaviour (deformation, damage accumulation and fracture) of porous material mesovolumes.

RESULTS AND CONCLUSIONS

The simulation of inelastic deformation and fracture of porous quasi-brittle media were performed by solving the total set of equations in a three-dimensional formulation using the finite difference scheme described in detail in (Wilkins, 1999). The modelling of mechanical behaviour of the generated model structures of porous materials was carried out for the conditions of uniaxial compression and simple shear. Some results obtained in simulation for zirconia based ceramics are sown in Fig. 1.



(a) (b) (c)

Fig. 1 - The computational results: (*a*) stress-strain curves for different morphologies and porosity; (*b*) the dependences of reduced effective modulus of elasticity for porous samples in comparison with analytical and experimental data (Kulkov et al, 2003); (*c*) the influence of porosity on the compressive strength of porous samples in comparison with experimental data (Kulkov et al, 2003)

This study shows that the evolutionary approach is quite promising for future research of effects of complex nonlinear behavior with instabilities of various materials including porous ceramics.

ACKNOWLEDGMENTS

This research was supported by the Tomsk State University Academic D.I. Mendeleev Fund Program, grant 8.2.19.2015 and the Program of basic scientific research of the Russian Academy of Sciences in 2013-2020, project 23.2.3.

REFERENCES

[1]-Kulkov S.N., Buyakova S.P., Maslovsky V.I. Structure, phase composition and mechanical properties of zirconia based ceramics. Bull Tomsk State Univ., 2003, 13, p. 34-57. (*in Russian*).

[2]-Makarov P.V. Mathematical theory of evolution of loaded solids and media. Phys Mesomech, 2008, 5-6, p. 213-227.

[3]-Wilkins M.L. Computer simulation of dynamic phenomena. Springer, Berlin, 1999.