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MODELLING POROUS STRUCTURES AND MECHANICAL BEHAVIOUR OF CERAMICS USING PROBABALISTIC APPROACH

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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. In both cases positions of elements in space and their sizes were randomly assigned. 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 solid frame strength. Based on the computer modelling results the influence of both porosity and pore morphology on the stress-strain curves and the effective elastic and strength characteristics is analysed. The calculated results were shown to 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 modelling of porous materials can refer to three areas: (i) modelling 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 behaviour 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 continuum mechanics 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 shown in Figure 1.

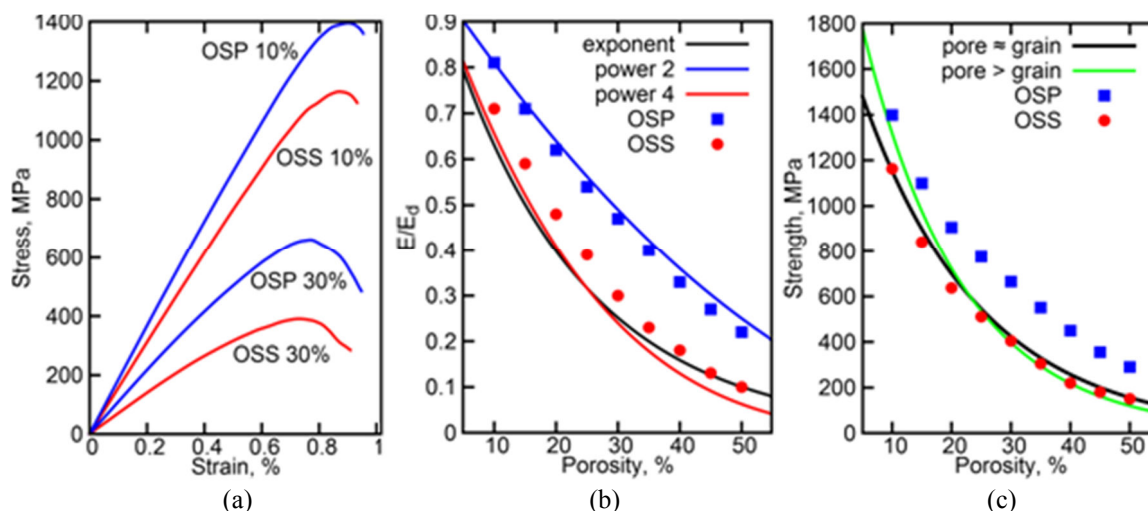


Fig. 1 - The computational results: (a) stress-strain curves for different pore morphologies and porosity; (b) the dependences of reduced effective modulus of elasticity for porous samples in comparison with analytical and experimental data (Kulkov *et al.*, 2003); (c) the influence of porosity on the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

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