Micromechanics-based multiscale modelling of porous materials with two-scale pressured voids

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In this study, a micromechanics-based multiscale modelling for a closed-cell porous material is presented, which contains two-scale voids with different pressures, such as polycrystalline uranium dioxide (UO_2) material used mainly as nuclear fuel. The two-scale voids are: a) nano-scale voids, located in the interior of the grains; and b) meso-scale pores which are positioned right at the grain boundary. The two types of voids contain nuclear fission gases, with possibly different pressures depending on their sizes. In this work, a multiscale analysis combining a nonlinear second-order moment micromechanics model and a homogenization-based numerical approach with taking the two gas pressures into account are established to investigate the effects of the different pressures on the homogenized elastoplastic behavior of the materials.

The analytical method agrees well with numerical simulation using the finite element method (FEM), especially for the case of relatively low porosity and gas pressures. The results show that the two populations of gas pressures can induce the tension-compression asymmetry of the uniaxial stress-strain curves and the nominal Poisson's ratio of nonlinear deformation. When the two gas pressures are identical, the yield surface of the porous material with gas pressures can be simply obtained from that of the porous material without inner pressures by a shift along the negative direction of the hydrostatic stress axis. However, when the two pressures are different, in addition to a translation along the hydrostatic axis, the yield surface undergoes a change in shape and size, and the maximal equivalent stress is lowered by a difference in gas pressures. Furthermore, the inner pressures have an important effect to reduce the yield strength of the closed-cell porous material.