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Effective elastic properties of nanoporous materials with spherical and ellipsoidal in shape voids

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This work is devoted to the modeling of the effective elastic properties of nanoporous materials containing spherical and ellipsoidal in shape voids, typically the highly irradiated uranium dioxide (UO₂) studied by the French “Institut de Radioprotection et de Sûreté Nucléaire” to investigate the response of fuel rods under accident conditions. As a first approximation, this material exhibits two populations of cavities: (1) intragranular bubbles, almost spherical in shape with a typical diameter of a few nanometers, (2) at a larger scale, intergranular bubbles, roughly ellipsoidal in shape with a typical size of a few microns and located at grain boundaries. Molecular dynamics results¹ show the existence of a non-neglectible surface effect on the effective elastic behavior for uranium dioxide at the intragranular bubbles scale, particularly when the surface/volume ratio is important.

Analytical micromechanical models^{2,3,4} concerning materials with an isotropic distribution of nano-sized spherical inclusions are extended here to the case of materials with two populations of voids, one relative to spherical voids and the other relative to ellipsoidal voids. The spatial distribution is assumed to be generally ellipsoidal. The proposed model follows the general framework of the so-called ‘morphologically representative pattern approach’⁵ and is compared to existing models (with or without surface effects). Particularly, the present model generalizes the Ponte Castañeda model⁶ to the case of porous media with surface effects. The voids size effect and the influence of the aspect ratio of the ellipsoidal voids on the effective elastic properties are illustrated in Figure 1.

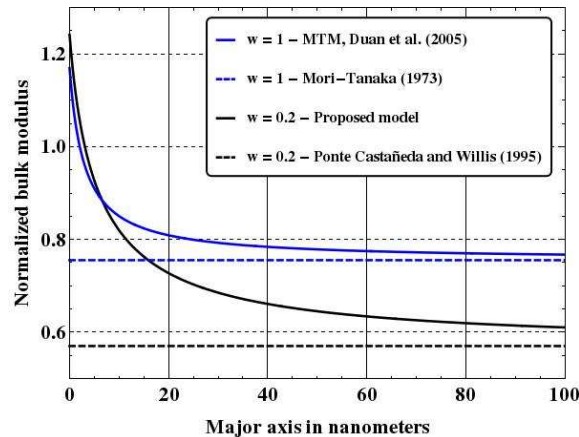


Figure 1: Porous medium containing only one population of randomly oriented ellipsoidal voids (porosity 10%): effective bulk modulus normalized by the matrix bulk modulus versus the length of the ellipsoid major axis b

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