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# Effective thermal properties of ceramic materials with networks of intergranular micro-cracks: quantitative predictions based on 2D and 3D imaging

Léo Moutin<sup>1</sup>, Joane Meynard<sup>1</sup>, Frédéric Adenot<sup>1</sup>, Vincent Bouineau<sup>1</sup>, Christelle Duguay<sup>1</sup>, Laurent Fayette<sup>1</sup>, Marc Josien<sup>1</sup>, Andrew King<sup>2</sup>, Renaud Masson<sup>1</sup>, Michel Bornert<sup>3</sup>

<sup>1</sup>) CEA, DES, IRESNE, DEC, Cadarache F-13018 Saint-Paul-lez-Durance, France

<sup>2</sup>) Psiche Beamline, Synchrotron Soleil, F-91192 St-Aubin, France

<sup>3</sup>) Laboratoire Navier, Ecole des Ponts, Univ. Gustave Eiffel, CNRS, 6-8 avenue Blaise Pascal, Champs-sur-Marne, F-77455 Marne-la-Vallée Cedex, France  
michel.bornert@enpc.fr

The overall thermal conductivity of materials is highly sensitive to the presence of non-conductive micro-cracks. While various models from literature are able to capture these effects in the case of weakly interacting, well-separated cracks, much less are able to address situations with complex networks of more or less connected micro-cracks. The present work is focused on the specific situation of cracks located at the interface between grains in a granular microstructure, in view of an application to ceramics used in the nuclear industry. A simple microstructural model has been developed to capture the dominant features relative to such a case [1]. It is based on the generation of virtual networks of cracks obtained as the intersections of Voronoï tessellation representing the grain boundaries and boolean models of overlapping spheres, providing the location of the cracks at these boundaries. It essentially relies on two non-dimensional morphological parameters: the ratio of grains to spheres sizes and the proportions of cracked interfaces. While FFT-based numerical simulations provide effective thermal conductions in all cases, some specific situations can be addressed by simpler but still accurate analytical evaluations. In addition, an empirical closed-form expression allows to fit all situations, covering a rather wide range of effective properties. The parameters of these 3D model can be adjusted so as to reproduce at best some morphological properties, including intercepts length distributions, Matheron's granulometry, geodesic length of cracks, length of individual segments, which are obtained from 2D optical images of real samples, appropriately filtered to extract the major thermal barriers at grain interfaces, without excessive details nor smoothing. The obtained models have been first validated by a detailed comparisons of thermal properties computed on 2D cross-sections of real materials and on cuts through the 3D models, not only in terms of effective properties but also of local fields statistics: distribution function, two-point correlation functions, size and spatial organisation of low gradient domains... In addition, the real materials have been imaged in 3D by synchrotron X-Rays micro-computed tomography, with a specific setup adapted to the very strong attenuation of these materials. First qualitative comparisons between observed 3D crack networks and simulated ones with parameters adjusted from 2D observations will be complemented by more quantitative ones.

[1] Meynard et al, 2022, *J. Mech. Phys. Solids* , 158, 04647