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A MULTIFIELD CONTINUUM MODEL FOR MICROPOROUS CERAMIC MATRIX COMPOSITES

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The investigation of the mechanical behaviour of composite, multiphase, structured complex materials presenting different kinds of heterogeneities requires the development of appropriate models bridging several scales of observation. The ability to design such materials and to derive their macroscopic properties relies, in turn, on the ability to describe their internal structure. Shape, texture and scale of the microcostituents, whose size can span several orders of magnitude starting from the submicron to millimeter scale or even larger scales, strongly affect in fact the macroscopic behaviour. A basic problem in the mechanical modeling of these complex materials is the identification of suitable constitutive laws of continua with microstructure (microcontinua) able to take into account the relevant microscopic features, avoiding a direct modeling of the microstructure, whose discretization can lead to cumbersome problems with many degrees of freedom. To this aim, since many years, several homogenization or coarse-graining methods have been introduced, requiring the accurate definition of the domain sizes involved in the scale transition process. Here, we propose a two–scale discrete–continuum equivalence procedure developed within the general framework of the principle of virtual work, which provides a guidance to the choice of the continuum approximations for such heterogeneous media, generally leading to continua with additional strain descriptors and degrees of freedom (micromorphic, multifield, etc.) [1, 2].
In this work we focus on porous metal-ceramic composites (MCC), such as tungsten or titanium carbides (WC/Co, TiC/Mo_2C), or ceramic matrix composites (CMC), such as alumina/zirconia (Al_2O_3/ZrO_2). The thermal resistance of such composites increases with the rate of porosity, which conversely influences mechanical properties such as resistance and stiffness that exhibit a decay when porosity increases [3]. The architecture of the considered composites consists of a polycrystalline structure made of grains, whose shape is approximately hexagonal, interacting through interfaces (grain boundaries) of micrometric size, generally filled by Cobalt. Based on microscopic observations of the composite structure [3], it is assumed that the pores are localized at the interface, reducing the contact area between grains. The presence of voids is here accounted for by means of an additional displacement field [5] leading to a multifield equivalent model, which can be

considered a non–local model: i.e. a model with internal length and dispersion properties [7]. This model can be in a sense referred to the model in [6]. The constitutive relationships of the microcontinuum are identified requiring its equivalence in terms of virtual work to a lattice description of the given material. It will be pointed out that some modeling aspects are crucial, that is the choice of the constitutive functions for the internal actions in the lattice model. In this work we pay special attention to the description of the interactions between particles and voids. The results of a parametric study obtained by varying the size and density of the pores as well as the size of the grains relative to the sample size are compared to experimental results [4]. The effect of the grade of non–locality of the macromodel is also investigated by introducing higher order deformations fields and their dynamic work–conjugated counterparts.

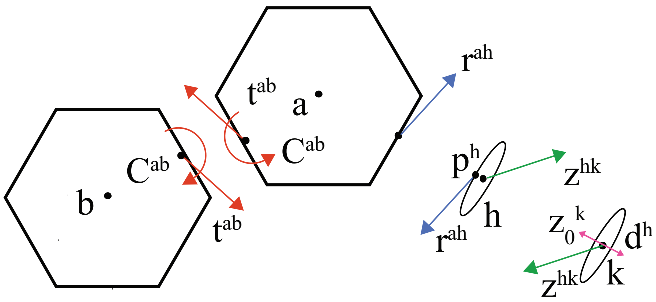

Figure 1: Sketch of the micromodel interactions

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