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Constitutive modeling and simulation of cold forming of ceramic powders

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ABSTRACT

Advanced as well as traditional ceramics are obtained by cold powder compaction, a process in which granular materials are made cohesive through mechanical densification. Subsequent sintering usually completes the treatment and yields the desired mechanical properties of the final piece.

The mechanical characteristics of the solid obtained after cold forming, the so-called ”green body”, strongly affect the subsequent sintering process and thus the mechanical properties of the final piece. There is therefore a strong interest by the ceramic industries in having a tool capable of modeling and simulating the powder compaction process. This tool is almost at hand for most of the ceramic industries, because they already have commercial FEM codes, such as Abaqus or Ansys, available and running on their computers. For instance, the huge and massive presses used for ceramic tiles forming are designed and validated by FEM analysis. However, commercial FEM codes completely lack adequate constitutive models for ceramic powders.

Therefore, the need arise for the development and implementation in commercial FEM codes of new constitutive models, capable of describing the mechanical behaviour of ceramic powders during the densification process. The constitutive description of this process faces the formidable problem that granular and dense materials have completely different mechanical behaviours, which must both be, in a sense, included in the formulation (Piccolroaz et al., 2006).

A treatment of this problem is presented here, which includes the formulation of a phenomenological elastoplastic constitutive model, the calibration of the model by experimental data and the implementation of the model in both Abaqus and Ansys codes. The main features of the model are: a yield surface sufficiently general to be able to describe the transition between the shape of a yield surface typical of a granular material to that typical of a fully dense material (Bigoni and Piccolroaz, 2004); a novel use of elastoplastic coupling to describe the dependence of elastic properties on the plastic strain (Hueckel,

1975); the dependence of cohesion on the volumetric plastic deformation, so that the gain in cohesion is taken into account.

The model has been tested and validated in collaboration with a ceramic industry. As a simple case, numerical simulations of forming of a ceramic tile are presented.

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