# A NUMERICAL INVESTIGATION OF THE INFLUENCE OF THE MATERIAL MICROSTRUCTURE ON THE FAILURE MODE OF METAL-CERAMIC COMPOSITES

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## 1. Abstract

Metal failure is often initiated by strain localization in narrow bands. In metal-matrix composites, the occurrence and the consequences of this phenomenon are influenced by the material microstructure. This dependency has been numerically investigated by considering periodic and quasi-periodic arrangement of ceramic fibers in the matrix. In this study, the metal behavior has been simulated by the widely used Gurson-Tvergaard-Needleman continuum plasticity model with an embedded damage evolution law based on local porosity. The onset of failure is thus identified by the critical growth of micro voids inducing a softening response at the macro scale. The effects of the material microstructure, the role of the imperfections and the influence of the discretization have been specifically analysed.

## 2. Introduction

Metal matrix composites (MMCs) are extensively used in several industrial application due to their good mechanical characteristics, which can be achieved by a proper selection of several design parameters, including the material combination, the volume and shape of the inclusions, the fabrication method [1]. MMC manufacturing techniques can induce porosity in the metal phase and raise difficulties in achieving a uniform distribution of the reinforcement ([2, 3]). The properties of the components and the material microstructure can have a substantial influence on the overall strength and ductility of the composite, which have been determined in this contribution by numerical homogenization.

## 3. Material model

The present study considers unidirectional fiber reinforced MMCs with periodic and quasi-periodic arrays of cylindrical ceramic inclusions arranged in a square pattern, with volume fraction varying between 10% and 50%. The macroscopic material response in the direction orthogonal the main fiber axis is recovered by numerical simulations performed on the representative volume elements visualized for instance in Fig. 1. The fibers are assumed to be linear elastic, homogeneous and isotropic. The metal phase is modeled by an elastoplastic relationship, characterized by isotropic exponential hardening rule. The presence and the evolution of micro voids is explicitly introduced by Gurson-Tvergaard-Needleman failure criterion [4, 5]. The local values of the material parameters used as input of some preliminary explorative analyses are taken from the literature. Homogenized quantities are evaluated by numerical integration.

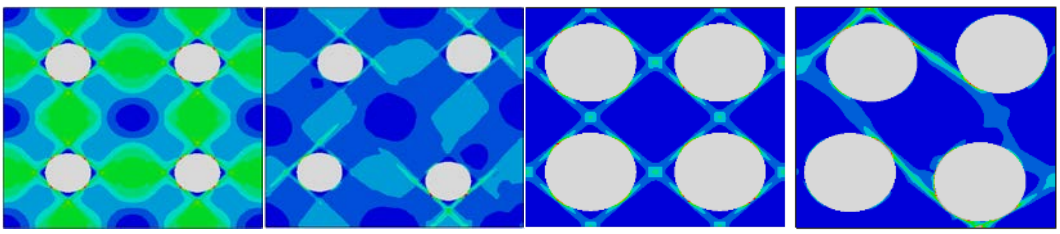

Figure 1. Strain distribution and localization in the case of periodic or quasi-periodic microstructure for 10% and 40% volume fraction of the embedded ceramic fibers.

## 4. Results and discussion

The macroscopic mechanical response of the considered MMCs has been evaluated on different finite element models with regular (radial) and free (random) meshes. Some representative results are summarized in Fig. 2. The overall resistance of the investigated material system is defined by the onset of strain localization in the metal phase. The phenomenon is initiated in correspondence of the reinforcement and develops as shown for instance in Fig. 1. The spread of the damage around the interface between the two dissimilar materials is never observed [6]. As a consequence, the macroscopic strength is almost insensitive to the fiber content. The details of the microstructure have main influence on the ductility of the material system, here measured by the macroscopic strain attained at the maximum stress. In fact, the post-peak softening curves resulting from the present analyses and represented in Fig. 2 are rather immaterial due to the quite significant effect of the discretization.

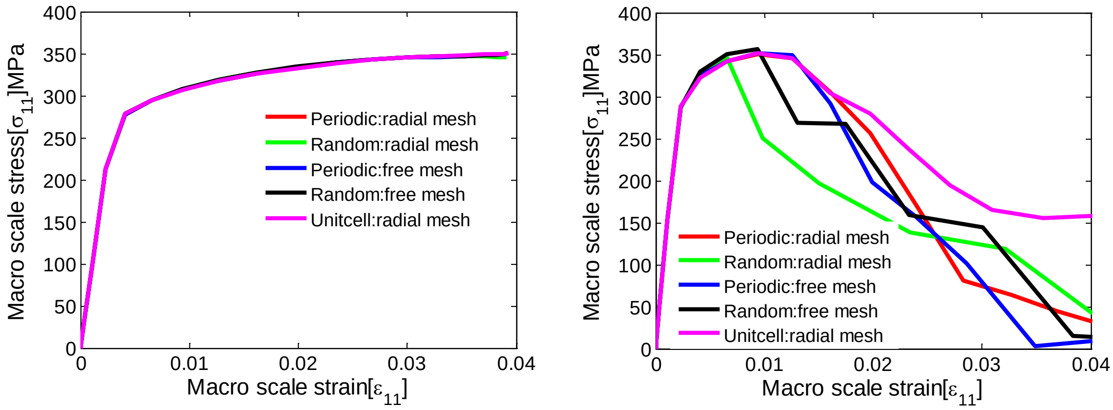


Figure 2. Macro mechanical response for 10% (left) and 40% (right) ceramic content.

## 5. Closing remarks

Preliminary investigations carried out on different representative volume elements of fiber-reinforced MMCs permit to evidence the role of physical and numerical parameters in the homogenized material response. The concurrent evaluation of the sensitivity of measurable macroscopic quantities to the microstructure characteristics may allow to determine the influence of the production processes on the local material properties, which are hardly determined by direct measurements.

## 6. References


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