Micromechanical simulations of coalescence in a random porous material

Clément Cadet*†[1] and Ouali Ferhi[1]

[1]CEA DAM DIF – CEA DAM DIF, F-91297 Arpajon – France

Abstract

For ductile materials, the failure process is commonly divided in three stages: void nucleation, growth and coalescence. In the widely-used Gurson-Tvergaard-Needlemann (1) model for ductile materials, coalescence is represented by a phenomenological effective porosity higher than the real porosity. This effective porosity allows to account for a quicker damage increase than predicted by the sole growth model, only relevant for an isolated void. The difference between the effective and real porosity values thus represents the effect of void interactions. We focus on pressure-dominated loading (typical of shock loading), for which experimental studies on tantalum (2) have shown that coalescence takes place by a direct impingement mechanism rather than plastic localization. As for percolation phenomena, in this situation, the geometry of the void distribution plays a key role and the concept of effective porosity has a clearer physical basis.

In this study, coalescence and especially the effect of void interactions are investigated using micromechanical analyses explicitly considering multiple voids. The objective is to suggest a physically justified expression for the effective porosity (instead of the classical purely phenomenological piecewise-linear expression of the GTN model). As for previous studies on the yield surface (3) or the onset of coalescence (4) of random porous materials, finite element simulations are carried out on a representative volume element consisting of a population of randomly dispersed spherical voids in an elastoplastic matrix. Simulations are analyzed after the onset of coalescence ; by comparison with the GTN model, an expression for the effective porosity can be deduced from the stress-porosity relation. Furthermore, the comparison between multi-void simulations and single-void analytical models can also be performed for a purely elastic model. We thus also investigate the difference in effective porosity between the elastic and elastoplastic cases.

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*Speaker
†Corresponding author: clement.cadet@cea.fr