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3D Damage Analysis of Sheet Metal

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ABSTRACT

Introduction of the new advanced high strength steels to the automotive industry in the last decades induced a renewed interest in ductile damage and fracture of sheet metal. There have been many reports showing that the currently used experimental (forming limit curves) and numerical (continuum damage models) tools cannot predict damage-induced failure. Detailed ductile damage analysis is therefore crucial to increase the predictive capabilities of forming simulations. However precise measurement techniques leading to quantitative microvoid analysis (e.g. syncrothron tomography) are time-consuming and not very practical. Today, the most frequently used tools in microvoid analysis are still optical and more frequently scanning electron microscopes. In analysis with such microscopes, a major drawback of damage analysis is that the results rely highly on conventional metallographic specimen preparation techniques, which include grinding, polishing, etc. These techniques by nature alter the microvoid morphology of interest. In this work, we propose a methodology that minimizes plastic deformation during specimen preparation, and provides a 3D representation of the microvoid morphology. This methodology involves opening up damaged (tensile test) specimens under the ductile-to-brittle transition temperature of metals to yield two 'symmetrical' parts in a brittle manner. The occurrence of brittle fracture is validated by reconstructing the detailed, unaltered 3D morphology of the microvoids from SEM characterization and surface profilometry mapping of sets of two parts. It is found that this technique yields additional valuable information regarding the size, morphology and nucleation mechanisms of ductile damage. Finally, this technique is applied to study the damage evolution in a number of different steels (IF, dual-phase, etc.).