

Micromechanical modeling of damage induced by Fe-rich intermetallic particles in recycled aluminum sheets: FE models based on in-situ nano-tomography observations

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Abstract

Metallic alloys are designed with tailored combinations of alloying elements according to their in-use targeted properties. During recycling, metallic parts are sorted by material type but different grades can be mixed, reducing control over the chemical composition of recycled alloys. In aluminum, melting different grades promotes the formation of new intermetallic phases. In addition, precipitation of an iron-rich phase is expected as iron is poorly soluble in aluminum and commonly present in scrap. By contrast, stamped aluminum parts, such as automotive body panels, require process-specific alloy grades. These alloys are engineered for enhanced ductility to ensure

fracture-free forming of complex geometries. During deformation, second phase particles act as preferential damage nucleation sites, either by fracture or by decohesion from the matrix. As a result, producing stamped parts out of recycled aluminum sheets is challenging as the iron-rich particles will trigger earlier nucleation. The Recycal project aims at improving the understanding of the role of these Fe-rich particles on damage in the forming of recycled aluminum sheets. One part of the project consists in performing in-situ nano-tomography experiments on samples in plane strain tension to observe damage mechanisms at the microstructure scale. The present work aims at developing micromechanical simulations able to model these damage mechanisms at the scale of the inclusions. The objective is to numerically reproduce the phenomena observed during in-situ tests. Once validated against experiments, the simulations will be used to explore new microstructures and loading conditions to guide the design of improved recycled aluminum sheets. The accuracy of these simulations relies on several essential ingredients which are addressed in this study. Considering the complexity of modeling failure of heterogeneous microstructures, 2D domains are commonly used since they are less computationally demanding and rely on data that can be accessed more easily using conventional SEM for instance. In our work, 3D data are available and will be used once 2D numerical failure criteria are validated. In this work we will address how to model properly nucleation criterion by particle failure. A region of interest (ROI) containing two particles surrounded by an aluminum matrix phase is studied. The ROI, extracted from in-situ nano-tomography tensile tests, captures the sequential nucleation of multiple cracks within the particles. It is meshed using mixed velocity–pressure P1+/P1 elements, with boundary conditions derived from experiments. Particle failure is modeled by inserting a crack once a critical principal stress, identified from in-situ images, is reached. Different approaches for triggering and positioning cracks are compared, and the influence of matrix–particle interface voids on failure initiation is discussed. Finally, possible extensions to three-dimensional configurations are considered.

Keywords:

FEM Damage Particle induced nucleation Aluminum In-situ nano-tomography