

Microstructural heterogeneity effects on damage resistance of 6xxx series Aluminium alloys

Damage evolution in ductile metals is characterized by the nucleation, growth and coalescence of small internal voids. In 6XXX aluminium alloys, the void population generally nucleates by the decohesion or fracture of the iron rich intermetallic particles.

The objective of this study is to understand and model the effect of microstructure heterogeneities on damage accumulation in three 6xxx series aluminium alloys. The three alloys, i.e. Al 6005A, Al 6061 and Al 6056, exhibit a volume fraction of iron rich particles close to 1%. However, samples of similar yield strengths, owing to appropriate heat treatments, show major differences in the true fracture strain for these three alloys. Furthermore, while relatively low plastic anisotropy is observed for these three alloys, the anisotropy in the fracture strains is very clear for the Al 6056: the fracture strain is increased when loading in the rolling direction compare to transverse direction.

A cellular automaton model, involving a high number of particles with distribution of position, sizes and void nucleation stress is developed to predict fracture [1]. The model treats local interaction between neighbouring cavities in a simplified way and captures cluster effects on coalescence. The model parameters are extracted from a three-dimensional microstructure analysis.

High resolution 3D X-ray synchrotron tomography is used to characterize the size and position distribution of the iron-rich intermetallics and initial cavities in the three alloys. A detailed analysis of the intermetallic spatial distribution reveals a stronger particle clustering along the rolling direction for the Al 6056, providing an easy percolating crack path when loading in the transverse direction. In addition, a statistical study of void nucleation has been performed on 2D metallographic sections of interrupted tensile tests, as well as on 3D microtomography scan of broken tensile samples. This analysis allows to extract the probability of fracture as a function of the size of the intermetallic particle for both loading directions. Finally, in situ tensile tests in X-ray tomography allow a quantitative characterization of the damage anisotropy in the Al 6056 alloy.

The analysis reveals that the key element controlling the ductile fracture process and its anisotropic response is the effect of particle size distribution and spatial distribution on the void nucleation and coalescence processes.

[1] F. Hannard, T. Pardoen, E. Maire, C. Le Bourlot, R. Mokso, A. Simar, Characterization and micromechanical modelling of microstructural heterogeneity effects on ductile fracture of 6xxx aluminium alloys, *Acta Materialia*, Volume 103, 15 January 2016, Pages 558-572