Thickness effects on the cracking resistance of aluminum sheets: an experimental and modeling study of Al2050 and Al6061

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Fracture toughness is a key criterion in material selection for structural design. In thin metallic sheets, it is however not an intrinsic material property; but it depends, sometimes strongly, on sheet thickness. Prior work indicates that the cracking resistance tends to increase with thickness at small thicknesses in the plane stress regime, reaches a maximum and then decreases before approaching a near constant plateau as plane strain conditions become dominant [1]. Despite the importance of the effect, the thickness range at which the maximum occurs and the mechanisms driving this transition remain insufficiently understood and modelled. This study combines experimental testing with numerical modeling to clarify thickness driven variations in the cracking resistance and the origin of it in the context of Al alloys.

Crack Tip Opening Displacement (CTOD) measurements are performed on double edge notched tension specimens for two aluminum alloys with major industrial relevance. Al2050-T8, a high-strength aerospace alloy, and Al6061-T4, a heat-treatable alloy typically exhibiting lower strength and higher ductility. Specimens are tested over a wide range of thicknesses to map the thickness dependency of fracture toughness, to identify the cracking resistance peak in terms of critical CTOD at crack initiation, and to quantify specific differences in thickness sensitivity [2]. The critical CTOD depends strongly on sheet thickness. Complementary in situ synchrotron laminography provides 3D observations of damage development ahead of the crack tip. It enables direct tracking of particle cracking, void nucleation and growth, and the transition from flat to slant crack growth during ductile tearing. These measurements therefore provide a basis for interpreting how damage processes and constraint evolution with thickness influence the cracking resistance. The strength and ductility balance are deliberately tuned, particularly for the Al6061 series enabling a systematic assessment of how strength and ductility govern fracture toughness and consequently the effect of thickness

On the modelling side, finite element simulations are first carried out using a J2 elastoplastic framework in both 2D and 3D. A simple non-coupled ductile fracture initiation criterion generates a first assessment of the thickness effect. In this approach, damage is linked to the history of stress triaxiality through the nucleation, growth and coalescence of voids under plastic straining, providing an indicator for the onset of ductile crack initiation. An advanced nonlocal Gurson-Tvergaard-Needleman (GTN) model is further used to address crack propagation [3]. The choices made in the damage model are further justified by the analysis of the laminography results.

References

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