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Effect of hardening and strain hardening on fracture toughness and its thickness dependence in thin stainless steel sheets

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Abstract

Materials with high strain-hardening capacity and large fracture strain exhibit a pronounced thickness dependence of the cracking resistance with a peak attained at an intermediate thickness in the millimeter range. However, the factors governing this thickness dependence, and how they can be adjusted or optimized to achieve the highest possible peak fracture toughness at a thickness relevant for a particular application, are not yet well understood. In this context, SS316L, recognized for its exceptionally high fracture toughness and high strain hardening capacity [1], is selected as the material of interest. Its strength can be mechanically modified through various cold-working treatments. To investigate the influence of strength and strain hardening capacity on the evolution of fracture toughness with thickness, an experimental dataset is generated using mechanically modified SS316L. Slabs of 8-mm-thick SS316L are pre-tensioned to different levels of plastic deformation, thereby altering

both their yield strength and strain-hardening capacity. Fracture toughness at crack initiation is assessed using the interrupted-loading multi-specimen methodology for critical crack tip opening displacement (δ_c) [2] applied to double-edge notched tension (DENT) specimens and high-resolution 3D X-ray microtomography that provides 3D images of the crack opening and crack extension along the thickness, offering a complete view of the crack front. Critical J integral J_C at initiation is also extracted. For each strengthening level, three to four specimen thicknesses are tested. The results show clear thickness-dependent trends of δ_c with the degree of dependence varying across the different strength levels. The experimental findings are complemented by micromechanically based 3D finite element simulations with both J2 plasticity and non-local Gurson-based model. This offers quantitative explanation for the origin of the thickness effect and clarifying the contribution of material properties to observed behavior.

Keywords:

Thickness dependency Fracture toughness Strain hardening CTOD X-ray microtomography

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