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Thickness effect on fracture toughness of thin metallic sheets

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Abstract

Fracture toughness is a critical parameter in material selection and structural design. For thin metallic sheets, however, it is not solely an intrinsic material property but is strongly influenced by sheet thickness. While it is known that fracture toughness increases with thickness, reaches a peak in the low-thickness regime, and then decreases toward a plateau associated with plane-strain conditions, the mechanisms governing this non-monotonic trend—and the factors controlling the magnitude and location of the toughness peak—are not fully established. Accurate prediction of fracture toughness in such thin-sheet configurations remains a central challenge due to strong microstructural sensitivity and pronounced size effects [1–2]. This work presents a numerical investigation using an advanced nonlocal Gurson damage model [3], formulated to capture void growth, nucleation, coalescence, and intrinsic length-scale effects governing ductile fracture. The model is applied to two complementary configurations: (i) double-edge notched tension (DENT) panels, representative of structural sheet components, and (ii) a small-scale yielding (SSY) framework that eliminates geometry-induced effects. The nonlocal Gurson model is first validated against experimental data for three different metallic materials, demonstrating its ability to reproduce key features of ductile fracture behavior. A systematic parametric study is then performed to quantify the influence of initial porosity, void nucleation, strain hardening, and the nonlocal length on the predicted fracture resistance. Particular attention is given to the magnitude of the peak fracture toughness and its corresponding peak effective thickness. Overall, the findings provide new insight into ductile fracture mechanisms in thin metallic sheets and offer practical

guidance for the calibration and application of nonlocal damage models in the design of fracture-resistant sheet-metal components.

Keywords:

Fracture toughness metallic structures nonlocal Gurson model

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