Fracture toughness thickness dependence in thin SS316L sheets

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Abstract

The fracture toughness (FT) of thin ductile metallic plates is not an intrinsic property but varies with thickness, sometimes significantly. For metals with pronounced strain-hardening capacity and sufficiently large fracture strain, the FT of the sheet increases with thickness, reaches a peak, and then levels off to reach the well-defined plane strain value. However, the factors governing this thickness dependence and its potential for designing lighter, tougher thin-walled structures remain underexplored.

In this study, an experimental investigation is conducted on thin SS316L sheets of varying thicknesses to identify the key factors influencing FT. SS316L, with its high strain-hardening exponent, is expected to reach the FT peak at an approximate thickness of 10 mm. Double-edge notched tension (DENT) specimens with varying ligament lengths were tested. Some specimens were deformed to the point of fracture, while others were arrested after experiencing varying degrees of plastic strain. For specimens deformed to fracture, the essential work of fracture (EWF) methodology was applied to separate the contributions of necking and damage within the fracture process zone (FPZ) from the plastic work occurring in the diffuse plastic zone (DPZ). These contributions are further interpreted in the context of earlier models discussed in (1) and (2).

For the arrested specimens, the crack tip opening displacement (CTOD) method was utilized to assess fracture toughness at the initiation stage by using the Shih factor (3) and also relying on original 3D computed x-ray microtomography data. The results exhibit thickness-dependent trends consistent with the fracture toughness values derived from fully fractured tests, encompassing both initiation and propagation stages. The findings for SS316L are compared with those for SS304LN and literature data, providing deeper insights into the factors affecting fracture toughness and its peak behavior.

References

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