
Abstract

Plane-strain elastic-plastic crack-tip fields at a constant $J$ and various elastic $T$-stress levels were obtained in a modified boundary layer (MBL) formulation similar to that of Betegón and Hancock but with a slightly different power law hardening stress-strain law. The analyses were based upon small geometry change formulation and deformation theory plasticity. To verify the two-parameter characterization of elastic-plastic crack-tip fields, three-dimensional (3-D) elastic-plastic finite element (FE) analyses were performed on plates with deep ($a/t = 0.60$) and shallow ($a/t = 0.15$) semielliptical surface cracks under both remote tension and bending. Here $t$ is the plate thickness and $a$ is the maximum penetration of the crack through the plate thickness. In topological planes perpendicular to the semielliptical crack fronts, the crack-opening stress fields, normalized by the local $J$, were compared with the plane-strain MBL predictions based upon the local $J$ and $T$. In all four cases studied, better than 94% agreement between the 3-D FE solutions and the plane-strain solutions was obtained for loads up to general yielding. This remarkable agreement held throughout all crack-front locations where the stress fields could be resolved accurately. Given the vastly different distributions of $J$, $T$, and crack-opening stress profiles along the collective set of respective crack fronts, the elastic $T$-stress appears to be a tractable, predictive parameter in quantifying elastic-plastic crack-front stress constraint.

Keywords
Crack-tip constraint, $T$-stress, Two-parameter characterization, $J$-dominance, Surface cracked plates, Three-dimensional, Finite element analysis