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CORRECTIONS TO THE SMEARED-CRACK APPROACH FOR USE WITH CONVENTIONAL FINITE ELEMENTS

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The smeared-crack approach has fallen out-of-favor as a numerical method for predicting crack propagation because of large errors that can arise when cracks are not aligned with element boundaries. The problem is so pervasive that most of the current research involves the introduction of additional basis fumnctions in the vicinity of the crack tip. Although these new methods definitely provide the rigor and accuracy that is needed, there is the penalty of a much more complicated algorithm that can also fail when a large number of cracks are active simultaneously. Because of the relative simplicity of incorporating smeared cracks, this study involved an investigation into the fundamental reasons of why the smeared crack approach fails and the proposed solutions to rectify the problems.

Cracks are modeled with a cohesive law that is activated only when a critical traction is reached. The kinematic assumption is made that each crack has piecewise constant width across each element and smeared crack strains are computed in the standard manner. It can be shown analytically that when a crack is not parallel to an element boundary, increments in crack opening produce spurious strains and, hence, stresses that are not consistent with the cohesive constitutive equation. The solution is to simply set these spurious stresses to zero for each load step and this removes the shear locking and stress-field misalignment around the crack tip.

As a crack propagates through a general mesh, there arises the situation where crack continuation crosses an adjacent leg of two quadrilateral elements, with the result that twice as much crack energy is dissipated per unit length of crack as compared with the situation when a crack only crosses opposite edges of a single element. Part of the solution to this problem is to monitor the crack extension and enforce continuity of the crack from one element to the next. Then when a crack extension passes through adjacent legs, the second part of the solution is to modify the area of the element used in the cohesive constitutive equation so that the fracture energy per unit length remains a constant.

Numerical examples are given to show that solutions display convergence with mesh refinement, solutions are independent of mesh orientation, and that curved cracks can be predicted similar to those displayed by experiments on double-notch specimens subjected to combined axial and transverse loads.