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Effect of Cohesive Law Parameters on Instability of Crack Growth

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In many materials, like fibre composites where the occurrence of crack bridging during crack growth results in a large-scale fracture process zone, non-linear fracture mechanics, e.g. cohesive zone modelling [1], should be used. The fracture process zone is represented by surface tractions along the crack faces and the relationship between the local traction, σ, and local opening, δ, is considered as a material property called cohesive law, $\sigma(\delta)$.

Crack bridging raises the fracture resistance (R-curve behaviour [2]), up to a maximum value, steady-state (J_{ss}), when the end opening (δ^*) of the fracture process zone attains the critical separation, δ_o, and therefore $\sigma(\delta_o) = 0$. Attainment of the steady-state fracture resistance is possible for steady-state specimens. Most practical applications, however, do not meet this requirement. After the onset of fracture, the fracture can be initially stable, but then transform to unstable fracture. The instability depends on both the cohesive/bridging law and the load and structure. Unstable fracture usually occurs before steady state fracture resistance is reached.

A criterion for the instability can be expressed in terms of the cohesive law $\sigma(\delta)$ [4]. This is analogous to Hutchinson and Paris [3] who analysed the stability of a growing crack in an elastic-plastic solid using the J integral approach. The crack stability criterion is given by:

$$\frac{\partial J \,/\, \partial \alpha}{\partial \delta^* / \,\partial \alpha} \leq \sigma(\delta^*) \qquad (1)$$

where J is the energy released per unit cracked area and α is the crack length. This stability criterion can be used as a guide on how to modify the cohesive law parameters e.g. peak stress, critical separation and shape (material optimisation) in order to delay or even prevent the onset of unstable crack growth leading to safer designs.

As an example of application of the stability criterion, a DCB specimen loaded with forces or displacements will be presented. It will be shown, that by changing these parameters, a more controlled crack growth can be obtained.

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