Unified formulation of a cohesive interface model for fracture, fatigue and creep in materials

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ABSTRACT

Cohesive zone models are efficient tools for describing the material degradation behaviour in engineering structures, mainly used for crack propagation of ductile and brittle materials under monotonous loading. A new formulation for the traction-separation behaviour of a cohesive zone has been set-up and implemented for crack propagation under various thermo-mechanical loading conditions, not only for increasing load, but also for cyclic (fatigue) or constant (creep) load. For the model presented, the separation vector \([\mathbf{u}]\) is additively split into an elastic, a plastic and a creep part:

\[ \mathbf{u} = \mathbf{u}_{el} + \mathbf{u}_{pl} + \mathbf{u}_{creep} \]

The traction vector, \(\mathbf{t}\), is then calculated based on the elastic separation by a simple elastic law, reduced by a damage variable, \(d\):

\[ \mathbf{t} = (1 - d)\mathbf{t}_{el} = (1 - d)C[\mathbf{u}]_{el} \]

Plasticity is implemented by a yield function and potential; the plastic separation rate is thus defined by the derivative of the potential with respect to the traction: \([\dot{\mathbf{u}}]_{pl} = \lambda \partial g/\partial \mathbf{t}\). Notice that the term plasticity used here must not be confused with metal plasticity, which represents the dislocation motion within a material. In contrast, the term \([\mathbf{u}]_{pl}\) is just a mathematical construct to incorporate an inelastic and irreversible separation, which does not affect the elastic behaviour, if unloading occurs. Creep is defined as by a relation between the traction and the creep separation rate, incorporating also the temperature \([\dot{\mathbf{u}}]_{creep} = f(t, \theta)\).

In order to simulate the degradation of the interface, several damage mechanisms are considered, each with a separate evolution law: one for monotonous loading, one for fatigue loading and one for creep. The total damage is simply the sum of the three damage variables \(d = \sum_i d_i = d_{mon} + d_{cyc} + d_{creep}\). The evolution law for the monotonous damage variable \(d_{mon}\) is based on the plastic deformation and uses a damage potential, the evolution for cyclic damage is based on the energy release rate, \(Y = 1/2 [\mathbf{u}]_{el} \cdot C \cdot [\mathbf{u}]_{el}^r\), and the creep damage depends on the effective creep separation.

Results will be shown for monotonic as well as cyclic loading conditions in order to demonstrate the capabilities of the model for the prediction of crack propagation in precracked specimens.

REFERENCES