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A combined cohesive zone model for delamination and adhesive failure of a composite bonded joint

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Cohesive zone modeling has turned out to be a computational effective technique to model the elastic and degradation behavior of interfaces. Cohesive laws have been developed for pure mode as well as mixed mode loading conditions. This has been applied to the simulation of delamination and adhesive layers for example in a bonded structure. However the computational costs and modeling effort are quite high, when the degradation of bonded joints with laminated adherends has to be modeled. This can be the case in crash scenarios.

A cohesive zone model for the simulation of the crash behavior of composite bonded joints will be presented, that combines the adhesive mechanical and failure behavior as well as the delamination failure behaviour in one cohesive zone. The mechanical behavior of the combined cohesive law is assumed to be the adhesive mechanical behavior initially. The reason is, that in many structural applications the joint compliance is dominated by the rather compliant adhesive compared to a relatively stiff delamination. A central point of the combined approach is to find a criterion when delamination or adhesive failure occurs. Two methods are implemented.

The first approach uses a maximum stress criterion. Here the maximum bearable stress of the delamination $\sigma_{max,del}$ is compared to the current stress σ_{adh} in the adhesive. The cohesive model switches to delamination failure when

$$\sigma_{max,del} < \sigma_{adh}$$

The second approach uses an energy based criterion. When the work done by the adhesive W_{adh} exceeds the fracture toughness of the delamination $G_{c,del}$, the cohesive behavior changes to delamination behavior.

$$G_{c,del} < W_{adh}$$

Both methods of a combined cohesive zone are compared to a reference simulation where adhesive and delamination are modeled in two separate cohesive zones. The cohesive law for delamination is a mixed-mode triangular traction-separation-law. For the adhesive, a mixed-mode traction-separation-law with nonlinear damage behavior is used. All cohesive laws are implemented in the VUMAT framework of Abaqus.