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Composite Delamination Modeling Approaches at MSC.Software

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ABSTRACT

The work presented here focuses on the implementation of various methodologies for modeling composite delamination and crack propagation in commercial software at MSC.Software.

Real world modeling of composite structures often involves large models. Composites are often modeled with shell elements with multiple layers in order to keep the number of nodal points at a reasonable number. In modeling delamination between layers of the composite, one typically wants to use stacked solid elements in order to allow new free surfaces to be created due to the delamination process. Here we discuss methods for dealing with this in an automatic and efficient fashion.

Once a mesh with stacked elements is available in the region where delamination is likely to occur, we need procedures for introducing and possibly growing the delamination zone. Here we present a number of methods for this problem. Criteria for introducing a new delamination zone are discussed, and together with this we present methods for automatically breaking up the finite element mesh to form the delamination zone. Established methods like VCCT and cohesive zone models are combined with mesh splitting and remeshing techniques. We further pay attention to general crack propagation approaches as well as progressive failure analysis methods relevant to the study of composite delamination.

In implementing new methods in commercial software we not only need to use theoretically sound methods, we also need to make them easy to use. For VCCT, we use the well-established formulation given in reference [1], see also [2]. The user gives the crack tip or crack front, and the fracture toughness for crack growth. The rest is done automatically. We calculate the energy release rate, and the formulation for VCCT automatically gives the contribution from each of modes I, II and III. Using the maximum hoop stress criterion with the energy release rates from each mode we get an estimated crack growth direction. In order to grow the crack we now have a number of options. If the crack is in the interface between two contact bodies that are glued together, we can release the glued contact segment by segment. We can break up the mesh along element edges, automatically picking the edge closest to the estimated crack

growth direction. This will of course restrict the growth to follow the element mesh. More general would be to use automatic remeshing, which we use for two-dimensional structures. For layered composite structures this approach is less useful, though. For cohesive zone modeling we have a comprehensive set of cohesive elements and materials, see reference [2]. Also here it is important to simplify the usage of this technique for the users. We have pre-processing tools for automatically splitting up the finite element mesh and inserting the cohesive elements. Special care has been taken to make sure that these special elements (typically with initially zero thickness) work as expected together with contact, and in particular glued contact. You can for example glue a layer of cohesive elements between two parts with non-matching meshes.

With VCCT you need an existing or assumed initial crack in order to model delamination. With cohesive zone elements you typically insert cohesive elements between layers where you anticipate that delamination will occur. Both methods have their merits and drawbacks. If you have an initial delamination then VCCT is often a good choice. If you do not, then you have to make a number of assumptions of crack locations. The cohesive zone model can be used both if you have an initial delamination or not. The presence of cohesive elements between two layers gives an elastic interface which may or may not be a problem.

Another method we use for modeling delamination is a breaking criterion. The composite modeled with stacked elements has no double nodes initially. In the interface between layers we calculate the normal and tangential stress and use the following breaking criterion:

$$\frac{\sigma_{norm}^{m}}{S_n} + \frac{\sigma_{\tan}^{n}}{S_t} > 1$$

where m, n, S_n and S_t are user defined material properties. When this criterion indicates failure, the mesh is automatically broken up by adding new nodes and changing the element connectivity. With this technique, the mesh has no special properties like double nodes or interface properties until failure occurs. A disadvantage is that once a free surface has been created there are stress singularities where the free surfaces start. Here one could activate VCCT calculations with the newly generated crack fronts. We use another apporach here. We insert delamination elements where the mesh is broken up. This approach combines the benefits of having no initial assumptions of cracks or initial interface stiffness and the cohesive zone material behavior when failure has occurred. User friendliness is obtained by only requiring the user to specify the stress limits and the cohesive material properties. The rest is automatic.

REFERENCES

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