

DESIGNING SOLID COMPOSITES

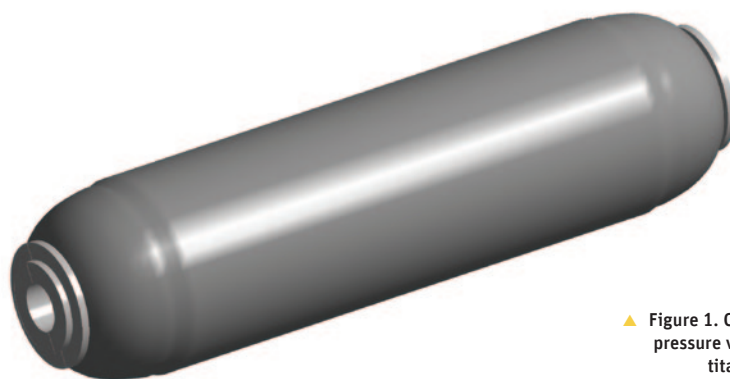
Employing ANSYS Workbench workflow streamlines simulation of solid composites.

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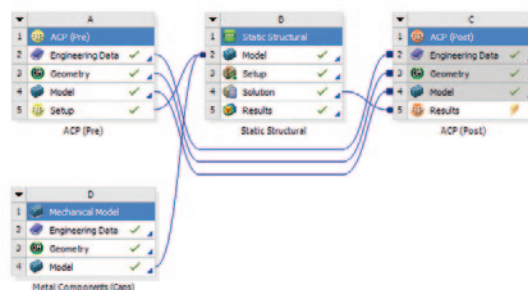
Traditionally, layered composites structures are modeled as thin structures using shell elements. This approach is valid when designing thin parts, such as hollow tubes for bikes, panels for airframes and wind turbine blades. But when the parts are more massive, such as gas turbine blades or stringers for pressure vessels, using shell elements is not appropriate. In such cases, both stresses in the direction of the thickness and shear stresses out of plane are significant, and solid models are required. Solid models are also appropriate when loads are applied in the direction of the thickness or when the structure is subject to large deformations.

While defining thin-layered composites poses several challenges, the definition of solid composites is even more complex. The shapes usually are not simple and require special treatment – a turbine blade, for example. Composites products generally include noncomposites parts that must be included in the simulation. Consequently, the engineering team needs an efficient workflow for the design of products made of layered solid composites and other parts. An effective process starts by examining the layer definition, based on the same method as used for thin structures, then moves on to create solid composites by extrusion. This is followed by the assembly of composites and noncomposites parts, culminating in analysis of potential failure of the overall structure.

To highlight this workflow, the example presented is a pressure vessel (Figure 1). The entire simulation process is performed in ANSYS Workbench (Figure 2) using ANSYS Composite PrepPost (ACP). The workflow begins by defining the geometry. The model is split into shell composites parts (A) and solid noncomposites parts (D), which are recombined as solids to create the final description of the analysis (B). This combined solid assembly includes connections between parts, loads and boundary conditions, as well as results such as stresses or deformations. The investigation of composites failure occurs as the last step in this process (C).



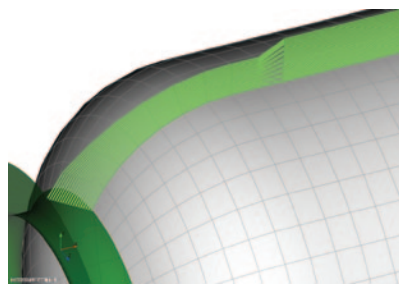
▲ Figure 1. Composites pressure vessel with titanium caps



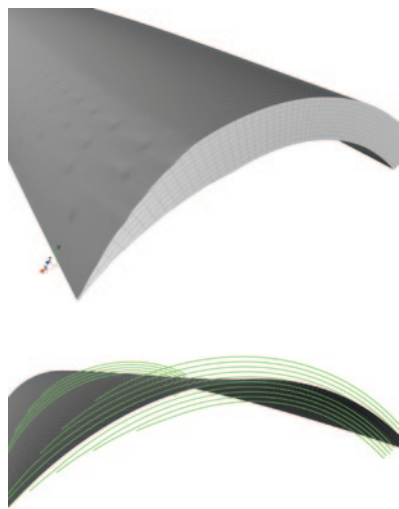
▲ Figure 2. Workflow for design of a composites pressure vessel

The entire simulation process is based on a workflow in ANSYS Workbench using ANSYS Composite PrepPost.

To start, define the layers on a surface mesh (Figure 3). The surface generally will be the inner or outer surface of the product being designed. Define the layers in the following sequence: definition of materials, fabrics (and, optionally, stackups), orientation of the various surfaces of the composites (possibly including draping for highly curved surfaces) and, finally, ply sequence. This approach is very close to the actual manufacturing process. An analogy can be made between the initial surface and a mold, and the ply sequence defined within the simulation tool can be the same as the actual fabric layup within the mold. However, the simulation tool obviously offers more flexibility in ply ordering, as plies can be swapped easily, modified or removed to achieve the required stiffness, weight and cost requirements.



▲ Figure 3. Definition of ply sequence on inner surface of vessel



▲ Figure 3a. Ply tapering

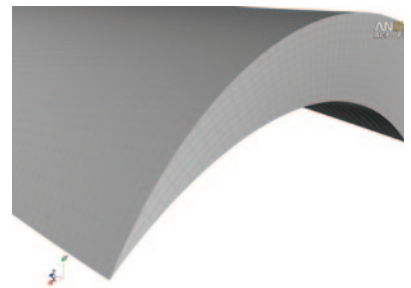
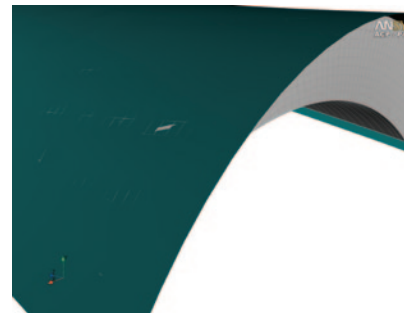
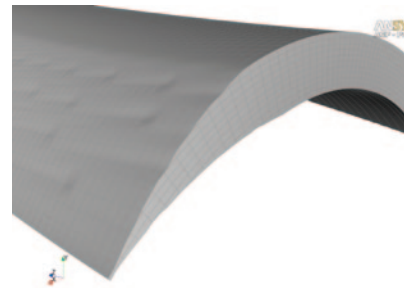
The critical area in the creation of solid composites is generating a solid model of the layup using a solid extrusion, based on the previous surface definition of the plies. Advanced capabilities, such as ply tapering, surface smoothing or extrusion guidelines, are available to deal with complex shapes (Figures 3a, 3b and 3c). You may apply ply tapering using cutoff rules. Surface smoothing can be performed using the snap-to-geometry feature to fit the extruded model to a given CAD surface. Extrusion guidelines help to extrude the surface model along arbitrary directions.

Another important aspect is handling drop-offs. Ply drop-offs can cause damage and delamination in a composite layup. In simulation models, drop-off elements are represented by degenerated brick elements. They usually are made of a homogeneous material such as resin.

Once the solid model has been created, it is automatically merged into the final assembly along with the noncomposites parts (Figure 4). Automated contact detection between parts, loads and boundary conditions, and solution settings all can be specified as you normally do for any regular model in ANSYS Mechanical. The transfer of the composites material definition in the full assembly is completely automated. Once the model has been solved, standard results such as deformations or stresses can be displayed on the full model.

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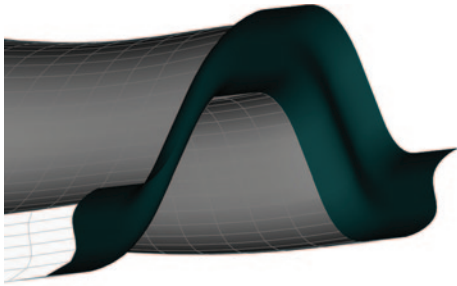
Additional capabilities are available to analyze potential failure of the composites parts. Three-dimensional failure criteria (maximum stress, maximum strain, Tsai-Wu, Tsai-Hill, Puck, Hashin, Cuntze) are available. A typical failure plot gives the analyst information on the risk of



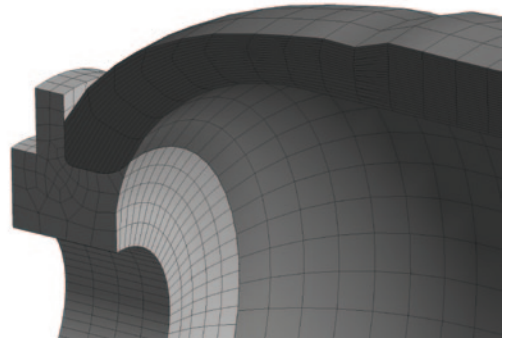
▲ Figure 3b. Surface smoothing using CAD surface (in green)

failure and the potentially problematic elements and layers in the assembly (Figure 6). You can even create a graph to show failure criteria values through all of the layers at a given location on the model.

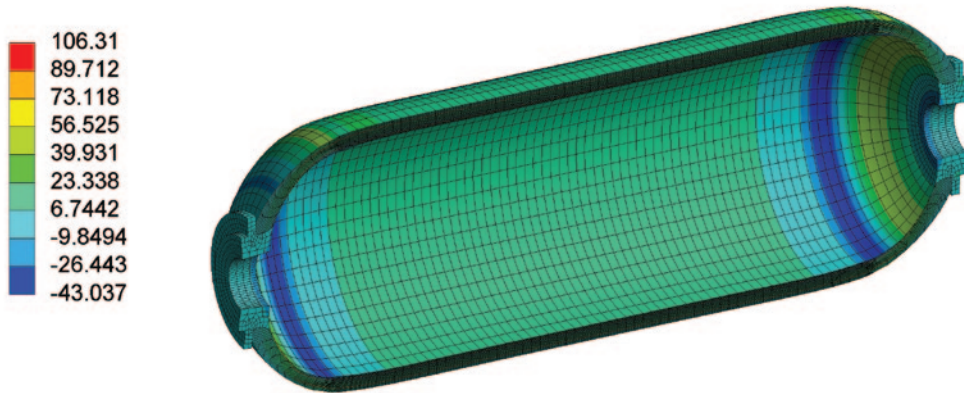
Employing the Workbench-based workflow for solid composites delivers benefits from additional capabilities. If the composites parts are subject to pressure from a flow environment, you can easily add the fluid flow simulation to the simulation, and pressures can be mapped automatically on the structural model. Users also have the ability to parameterize a model to perform sensitivity or optimization studies based on geometry or composites variations (thicknesses, orientation, etc.) using the failure criteria as a performance indicator of the design. ▲



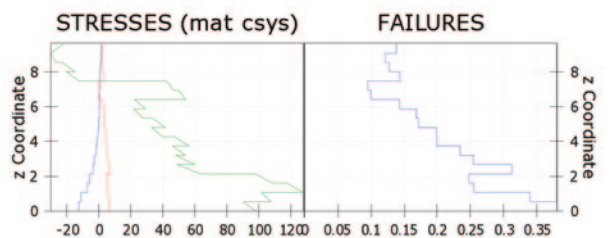
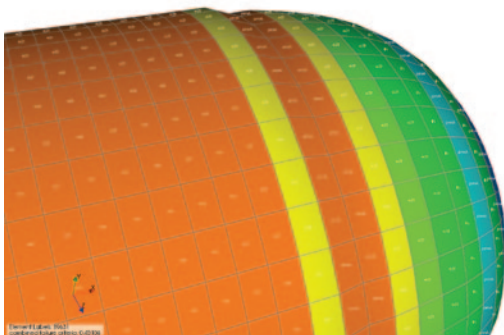
▲ Figure 3c. Extrusion guidelines



▲ Figure 4. Assembled model showing composites and noncomposites parts (metallic caps in light gray)



▲ Figure 5. Stresses on assembled model



▲ Figure 6. Post-processing composites showing failure on full model (left) or through element layers (right) in charts