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SANDWICH COMPOSITE PANEL ANALYSIS

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In this issue:

Challenges of Composite Design and Analysis

The greatest challenge in designing composite structures, as well as their most useful and unique attribute, is that the material system behaves orthotropically (i.e., the material responds differently along the fibers, lateral to the fibers in-plane, and through the laminate stack). Therefore, stacking sequences and ply shapes must be tailored to accommodate both the geometry and the loading of a component. It follows that accurate finite element (FE) models are required to properly analyze the complex behavior exhibited. The following details the design and analysis of a sandwich composite panel utilizing optimization tools.

Sandwich Composite Panel

The sandwich composite panel analyzed herein is used in a weatherproofed structural dome. A series of panels interlock and fasten along the perimeter. These dome structures are often situated in harsh climates and must withstand loads from all environmental factors. The following design process was verified by applying wind loads to a single panel. An initial set of wind load results are shown in Figure 1. Notably, the strain is discontinuous due to the orthotropic nature and is most obvious in the inner circle of the panel.

Material Selection and Stacking Sequence Design

The material systems considered for this analysis were limited to fiberglass/epoxy composites as they are typically used in weatherproofed dome structures. The next requirement is to match a material system with the geometry and loading of the component. A fiberglass weave was chosen to improve the lateral performance relative to the stiff fiber direction. However, unidirectional fiberglass would be acceptable as well.

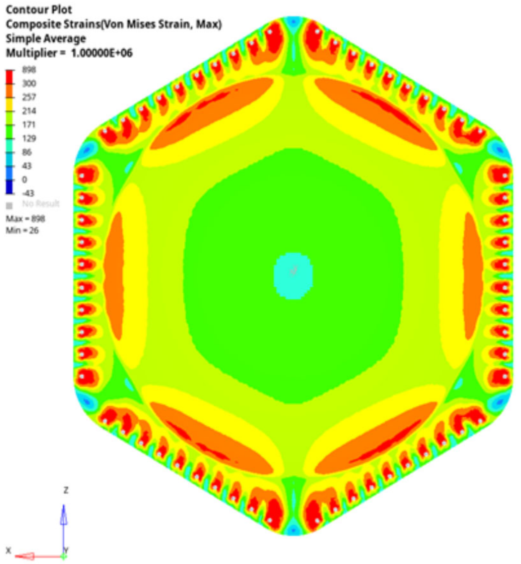

Figure 1. Strain contour resulting from 150 mph wind loading

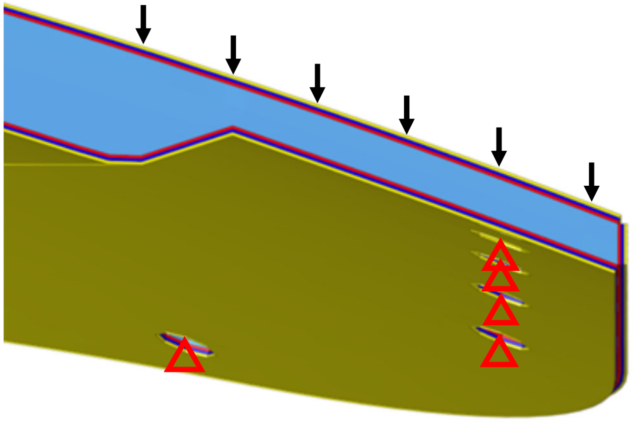

Figure 2. Model wind pressure and model constraints

Composite Model Setup

The core of the sandwich composite was modeled with 3D elements, and the fiberglass plies were modeled as 2D composite shell elements. This setup accommodated the decreased thickness where the panels interlock while providing the ability to easily model the laminate and any stacking sequence. The loading and constraints used for both stacking sequences are shown in Figure 2. The models were constrained in directions 1-3 at each bolt hole location indicated by the red triangles, and a 150 mph wind pressure was applied to the exterior surface indicated by the black arrows. Composite stresses, strains, and strength ratios were extracted from each model. The acceptance criterion was chosen to be a minimum safety factor rating of 2.

Quasi-isotropic Sequence

The stress results for the quasi-isotropic stacking sequence are shown in Figure 3 for the sandwich composite. The contour limits are adjusted to illustrate the behavior and do not correspond to a particular failure. Notably, the stress profile is the same for each ply orientation creating symmetric stress distributions around the panel. This is expected because the sequence used causes the in-plane response to behave in an isotropic manner. The highest stress occurs at the thinned edges identifying locations to inspect for failure.

To determine if the design achieved the goal of a safety factor equal to 2, the composite strength ratios are used. Strength ratios are a linear scaling between the loading and the failure criteria and identify any value less than 1 as failing. The strength ratios for the quasi-isotropic sequence are shown in Figure 4. In alignment with the high stresses from Figure 3, the lowest strength ratios occur at the thinned edges. However, the minimum strength ratio occurring in this design (SR=9) is well above the required ratio of 2 to achieve the design goal. Therefore, the quasi-isotropic sequence exceeds the design goal. While containing many ideal properties, this design could be optimized to reduce the component's mass.

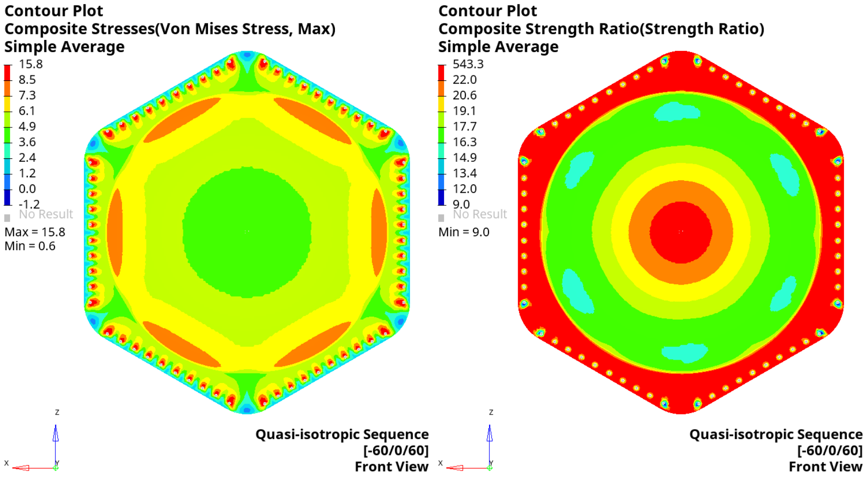

Figure 3. Stress results (left) and strength ratios (right) for the quasi-isotropic stacking sequence

Cross-ply Sequence

Similar to the results above, the stress results for the cross-ply stacking sequence are shown in Figure 5 and use the same contour limits from above to allow for easy comparison. Most notably, the stress profile is no longer symmetric. As can be observed in the image, different stress profiles are exhibited in the x and z directions identified in the figure. The strength ratios are shown in Figure 6 and illustrate the change in response as well. However, the minimum strength ratio of 7.7 is again well above the goal.

Given that no other factors influence the design (e.g., residual thermal stresses coupled with large temperature differences), the cross-ply stacking sequence is sufficient to meet the design requirements.

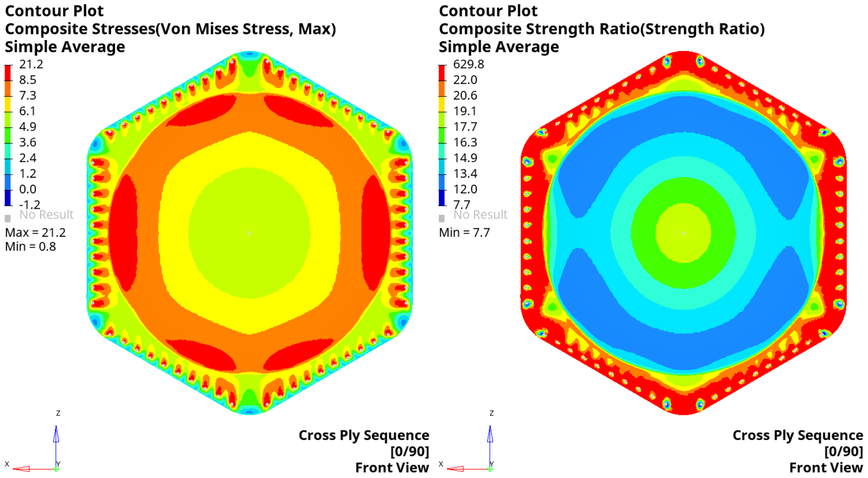

Figure 4. Stress results (left) and strength ratios (right) for the cross-ply stacking sequence

Summary

The details herein provide background of a process utilized to optimize composite and sandwich composite designs for material consumption and cost reduction. Ground effects, other environmental loading, and optimization for RF frequency were not considered for this particular newsletter. The process of ply sequence optimization is applicable over a wide range of industries. With adequate information regarding mechanical loading and a material system's mechanical, thermal, and failure properties, these structure's mass and stress-strain response can be optimized while maintaining critical safety margins.