Shell- and Solid Modeling of Composite Structures as a Base for Simulation driven Optimization Processes

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Analysis of Composites with ANSYS Composite Prep-Post

ANSYS Composite PrepPost for laminar approach

Features:

Pre-processing:
- Define materials and lay-ups,
- Evaluate draping influence,
- Generate a solid model from defined lay-up.

Post-processing:
- Last developed composite failure criteria,
- Fast sight over result information.
Analysis of Composites with ANSYS Composite Prep-Post

ANSYS Composite PrepPost in the context of ANSYS Workbench

**ANSYS Workbench**
- Transfer of the model through `wb_model_SYS.dat`
- Create an `wb_model_SYS.acp`

**Prepare the geometry and the boundary conditions**

**Pre-processing**

**Alternative Way**
- ANSYS Mechanical APDL

- Write *.dat file with defined lay-ups
- Launch solver

**Post-processing**

- Import the results (rst files) for post-processing

**SOLVER**
Example

Double curved beam

[±45, 0_{15}]_{s} layup

Layer thickness 6.2 mm

Woven and UD T700 prepreg material of carbon fibers

Total length 180 mm, width 24 mm

Right side longitudinal displacement 3.6 mm (tension)

Left side clamped
Comparison of Shell and Solid modeling for composite structures

Layered Shell Model

Maximum inverse reserve factors of Max Stress

2D

3D

- 2D failure analysis predicts matrix failure ($s_{2t}$) and high fiber stresses ($s_{1t}$)
- 3D failure analysis predicts delamination ($s_{3t}$) in the entire area
- 3D failure analysis predicts more reliable results
Comparison of Shell and Solid modeling for composit structures

Layered Solid Model

Maximum inverse reserve factors of Max Stress

2D failure analysis predicts matrix failure identifies larger region compared to shell modeling

3D failure analysis similar to shell modeling

Already the INS evaluation method for layered shell model provides accurate results
**Edge Effect**

**Example**

- Length 100 mm
- Width 50 mm
- Layup [30, -30, 30, -30, 90]_s
- Carbon T700 prepreg
- Clamping left side
- Longitudinal tension 1 mm
- Reference element size 2mm
- Solid model extrusion is used to generate element type solid 186 (20 node brick)
- Each layer represented by one layered solid element
- Interlaminar stresses are shown at the cross section
Local stress concentration and high stress gradients
Need for mesh refinement towards the free edge can be seen
Combination of anisotropic material properties and stacking sequence causes warping an interlaminar stresses
Turbin Blade

- 3D part
- Layered shell approach not feasible
- CAD geometry must to be meshed
- Stacking must be represented
- Suitable element orientation needed
- Laminate thickness normally unknown during design phase
- Moving nodes of the solids extrusion onto the selected surface enables to follow the defined shape
Solid Extrusion

Wing Profile

- Starting with reference surface
- Applying core thickness functionality of ACP the thickness of the core is defined in this case by two geometries
- Added plies on top and bottom „Snap“ two outer faces
- Layered solid model representing the profile of the wind and the layup of a composite.
Optimization

Workflow

DesignModeller → ANSYS - Mechanical → ACP - Preprocessing → ANSYS (Batch-Run) → ACP - Postprocessing → optiSLang

Model Preparation → Mesh Boundary conditions → Layer orientation Position of Layers Layer thickness

{ Input Parameter

Deformation IRF-factor

{ Output Parameter

New Parameterset → optiSLang

Postprocessing
Optimization

Example

Python object tree of ACP

Correlation Matrix
Correlation of Inpt- and Output Parameters

INPUT: \( f_d \) vs. OUTPUT: Force_Reaction_Z, (linear) \( r = -0.607 \)

- Good to very good correlation for:
  - Loading position
  - Layer thickness

Anthill-Plot
Impact on output parameter due to variation of input parameter
‡ Good determination
Optimization

β Sensitivity study
β „What are the most sensitive and relevant variables?“

β Multidisciplinary optimization
β „What are the fittest optimization methodologies for this assignment?“

β Robustness evaluation and reliability analysis
β „How sensitive is the reaction of the design regarding production scatter and how is the reliability in the mass-production?“

β Robust design optimization
β „How safe and robust is this detected optimized design with influence of production scatter?“
Summary and Outlook

- The availability of powerful modeling methods in ANSYS Composite PrepPost (ACP) is shown.
- Edge effects and complex models can be handled.
- Scripting of ACP allows access to all modeling parameters for software driven optimization.
- Usage of optiSLang enables optimization and robust design analysis.
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