Element Technology and Composites
Extended Composite Analysis Capabilities for ANSYS

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Outline

• ESAComp background
• ESAComp capabilities overview
• ESAComp with ANSYS
• Example cases
ESAComp Background

• Development initiated by the European Space Agency (ESA) in early 1990’s

• Motivation
  – European space industry was using numerous in-house software tools for composites specific analyses
  – One single standard software combining various composites tools under a unified graphical user interface was desired
ESAComp Background

• Development started at Helsinki University of Technology in 1992
• ESAComp 1.0 was released in 1998
• Activities transferred to Componeering in 2000
• Collaboration with ESA continues
Scope of ESAComp Software

• Analysis and design software for layered composite structures
• For use in conceptual and preliminary design, FE post processing, analyses of details,…
• Interfaces with other design/simulation software products
Material Data

- Data Bank includes data for commonly-used composite materials and material systems
- Ply specification tool utilizes material symmetry rules during the definition process
- Ply engineering constants, CTE and CME can also be derived based on fiber and matrix data

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Laminate Analyses

- Lay-up tool provides practical way to create and modify laminates
- Constitutive and thermal / moisture behavior of laminates are based on the laminate theory (CLT)
- Probabilistic behavior is based on Monte Carlo simulation and statistical distributions of ply properties
Laminate Analyses

- Predicts laminate failure based on first ply failure (FPF)
- Covers advanced failure criteria for reinforced plies
- Includes sandwich specific failure modes and interlaminar shear
- Predicts the stress or strain failure space in terms of envelopes
Laminate Evaluation

- The user specifies a design target by setting constraints and objectives for various design attributes
- Based on multi-objective design approach, the laminate evaluation tool establishes the feasibility and quality of candidate laminates
Details

- Notched laminate analysis for circular and elliptic holes
- Layer drop-off analysis for local bending effects
- Out-of-plane stresses at layer interfaces close to free edge
- Structural behavior of bonded joints
- Mechanical joints under uniaxial loads
Beam Analyses

- Includes various cross sections and analysis options
- The effect of shear deformation can be studied
- Helps in deriving material properties from bending tests
Plate Analyses

- Rectangular plates can be loaded with a combination of load types
- T, I, C or Z stiffeners can be defined on bottom of the plate
- Load response / failure, buckling, natural frequencies
Cylindrical Shell Analyses

- Preliminary design tool for conical structures with circular cross section
- Takes into account the change of the laminate structure along the longitudinal axis
- Various load cases and analysis options will be available
- Considers geometric non-linearity
Componeering is ANSYS Enhanced Solution Partner

- Use of composites is increasing - there is demand for efficient design solutions
- ESAComp brings composites specific features in ANSYS environment
- These solutions speed-up the design cycle
- The learning aspect for composites is also addressed
Material properties and laminate lay-ups for layered composite elements
- Real Constants and material failure (TB) data for shell91 and shell99, solid46 and solid191
- Section Data and material failure data (FC) for shell181 and solsh190
WB Commands Object

- Allows to define full laminate data
- Failure values of an orthotropic material are not available in EDM
- ESAComp FE export fully supports commands object
Pre-integrated

- Laminate stiffness can be given in the matrix form
- Serves users with specific laminate families
- The limitation for number of layers in ANSYS can be overcome
- Available for shell99 and will be for sectype, #, gens

\[
\begin{align*}
N & = [A \ B \ C \ D] \\
M & = [B^T \ D] \\
\varepsilon & = \kappa
\end{align*}
\]

\[
S_1 = \begin{bmatrix} E_{11} & E_{12} & \gamma_1 \\ E_{21} & E_{22} & \gamma_2 \end{bmatrix}
\]

\[
\begin{bmatrix} N \\ M \end{bmatrix} = \left( \theta - \theta^T \right) \begin{bmatrix} M^T \\ B^T \end{bmatrix}
\]
**ANSYS – ESACComp Interface**

- **ESACComp works as a composite specific failure post processor**
- **Utilizes APDL**

**Flowchart:**
- **ANSYS** → **FE Pre processor** → **FE Solve** → **FE Post processor**
  - **ESACComp**
    - Material selection, Preliminary design
    - Failure analysis (FPF, wrinkling, ILS,…) in batch mode with user default analysis options
  - **Use “esapost” command to:**
    - Write text file containing:
      - Laminates
      - Material data
      - Options related to FEA
      - N_{11}, N_{22}, N_{12}
      - M_{11}, M_{22}, M_{12}
      - Q_{13}, Q_{23}
  - **Use “esaplot” command to:**
    - Write text file containing:
      - 1/RF failure modes
      - Critical layers

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Use

- *Esapost* is accessed from the Command Prompt or in batch run
- ESAComp results are accessed with *esaplot* and are saved in ANSYS db-file
- Failure criteria and units are selected from ESAComp
Benefit

- The most critical ply of the stack determines the criticality of the element
- Failure analysis results are shown with contours
- Failure modes and critical layers are displayed on elements
- ESAComp capabilities are available in ANSYS environment in easy-to-use and efficient way
WB Procedure

- Geometry import
- Laminate data, meshing, B.C., loads
- Save WB database file (.dsdb) and exit Simulation Task
- Open analysis in ANSYS and perform solve
- Perform esapost
Future Development

• ESAComp pre and post processing will be integrated in WB
• Support for solsh190 will be provided similarly as for shell181
• FE export will support layered thermal shells 131 and 132
• Cluster-computing is considered to speed up heavy post processing
• Internal loads will be taken into account in post processing
• Interlaminar shear strength is added as a laminate property
Development Partners

• ESTECO
  – modeFRONTIER-ESAComp integration
  – Composites optimization using ANSYS and ESAComp

• IDAC
  – Additional WB integrated composites capabilities
  – Ply-based modeling and draping analysis
Example Case

- Planar section wall for liquid hauling tank?
Example Case

- The structure is dimensioned based on test pressure and transportation loads
- Materials used for solid laminates are GFRP rowings and biaxials
- Studied cores include e.g. PVC-foam, balsa, and honeycomb
- Reserve factors in the level of 8-10
- Strain allowables 0.2%
Example Case

- The simplified shell model is analyzed with face sheet wrinkling predicted (lower failure contour) and without.
- Different failure modes (inter fiber failure, core shear, wrinkling) are displayed on elements.
Example Case

• Real geometry is modeled with shell and solid elements
• All data is in one image and user gets information on where the problems are and how to improve the design
• More detailed data is available for each element through ESAComp GUI
• ESAComp makes the design process of composite products more efficient
  – material selection and preliminary laminate design is done in dedicated composites design environment
  – the starting point when going to FE analysis of the full structure is better
  – specific details can be analyzed without the use of general FE tools
• ESAComp makes the design process more reliable
  – specific composites failure modes are covered
• Integration of ESAComp capabilities in ANSYS WB is under way