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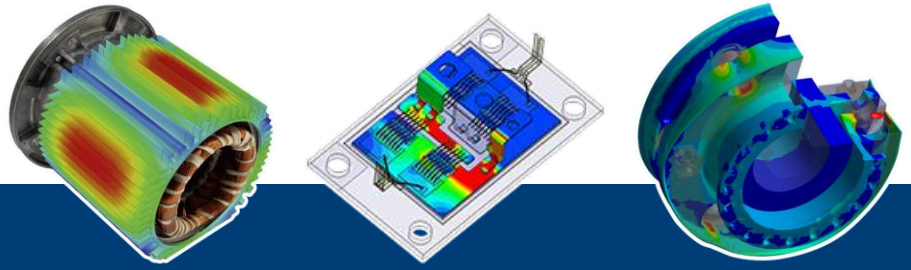
ANSYS

Competence Center FEM

Simulation ist mehr als Software®



ANSYS Composite PrepPost (ACP)

„Composite modellieren, simulieren und bewerten“

5. Fachkongress Composite Simulation am 24. und 25. Februar 2016 in Hamburg

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CADFEM

Shell-based Composite Analysis

Solid Composite Analysis

Additional Features

Define Variable Material Properties

ANSYS Composite Cure Simulation

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Simulation macht vieles möglich

- Wegweisende Innovationen entwickeln
- Maßstäbe in der Produktqualität setzen
- Kosten und Entwicklungszeiten reduzieren

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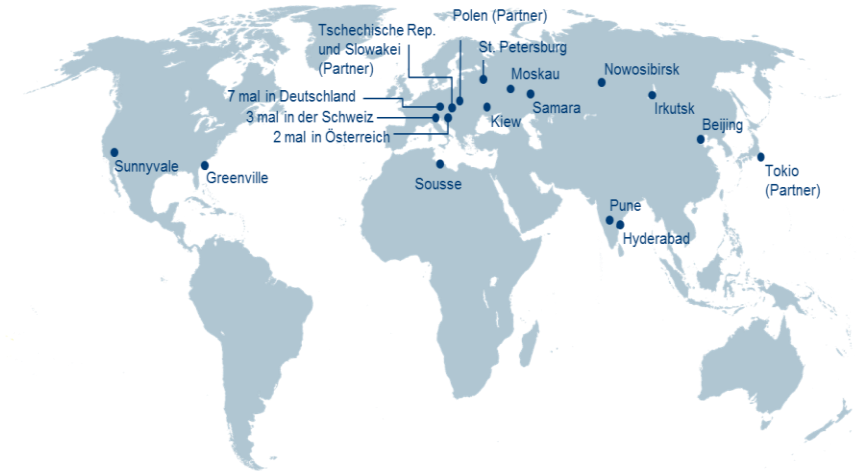
CADFEM – CAE-Simulation seit 1985

- CADFEM in D, A, CH
  - 1985 gegründet
  - 12 Standorte
  - 185 Mitarbeiter
  - 60 Millionen Euro Umsatz
  - 2.300 Kunden



- CADFEM worldwide >250 Mitarbeiter

- ANSYS Competence Center FEM in Zentraleuropa
- Teamwork mit ANSYS Germany, ANSYS Competence Center CFD

ANSYS Competence Center FEM

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Weil Software allein noch keinen Simulationserfolg garantiert, bietet CADFEM alles, auf was es ankommt, aus einer Hand:

Produkte

Systemhaus:

Software und IT-Lösungen

Service

Ingenieurdienstleister:

Beratung, Support, Engineering

Wissen

Wissensanbieter:

Know-how-Transfer

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Shell-based Composite Analysis

Solid Composite Analysis

Additional Features

Define Variable Material Properties

ANSYS Composite Cure Simulation

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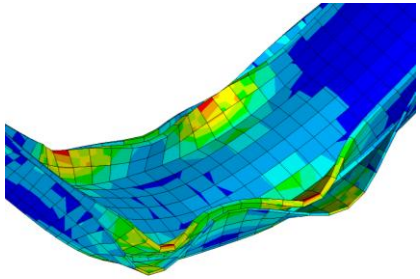
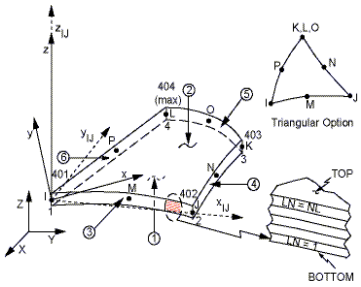
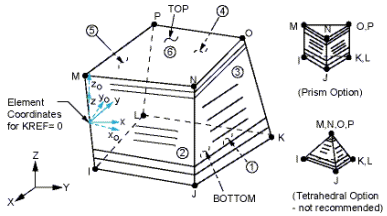
Shell-based Composite Analysis

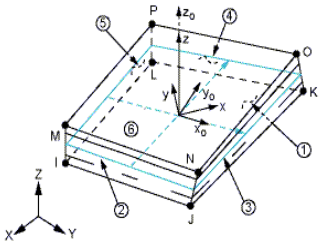
ANSYS and Composites

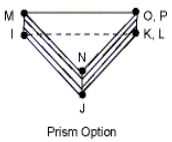
- ANSYS is not new to composite simulations.
  - Layered shell and solid elements for more than two decades.
  - Rich variety of elements for composite modeling from 1D to 3D.

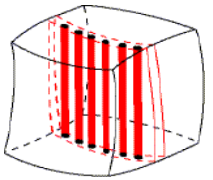












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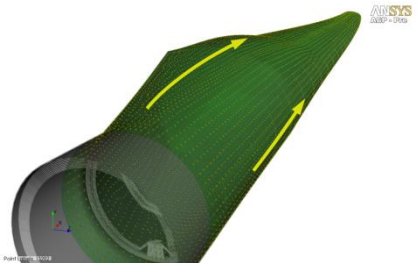
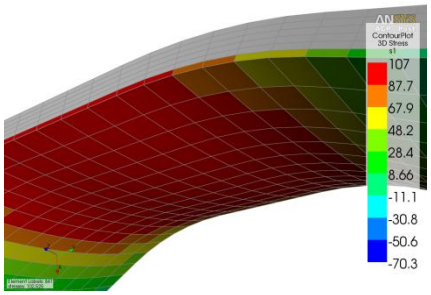
Shell-based Composite Analysis

What can I do with ANSYS Composite PrepPost?



- Build up your Composite Design
  - Define the composite layup
  - Define fiber directions



- Evaluate your Composite Design
  - Evaluate stresses in the layers
  - Evaluate failure criteria

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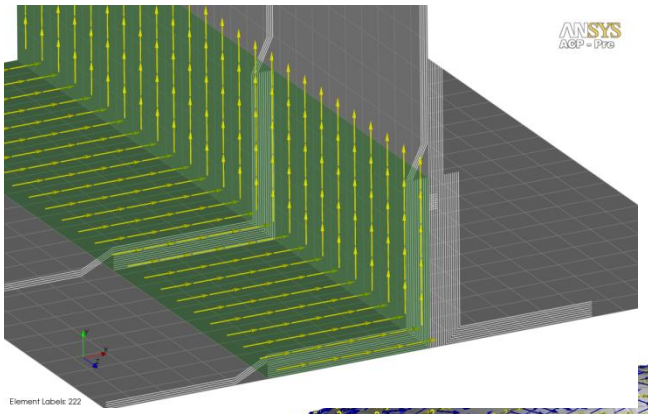
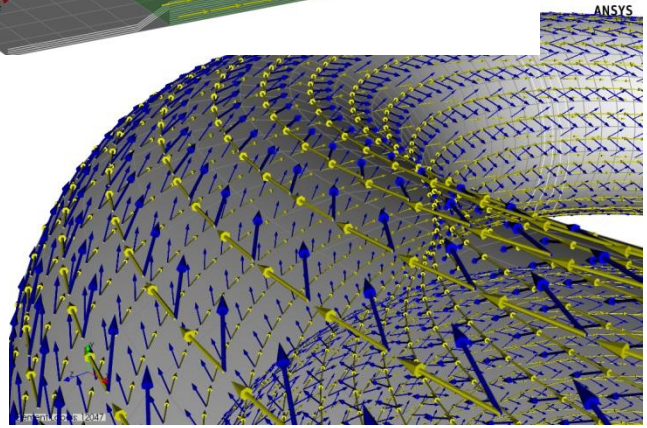
Shell-based Composite Analysis

ANSYS Composite PrepPost is the Next Step

- Intuitive workflow for composite modeling.
- Different options to define fiber orientations.
- Quick setup of composite layup.
- Quick postprocessing.
- Allows design studies of different composite designs.





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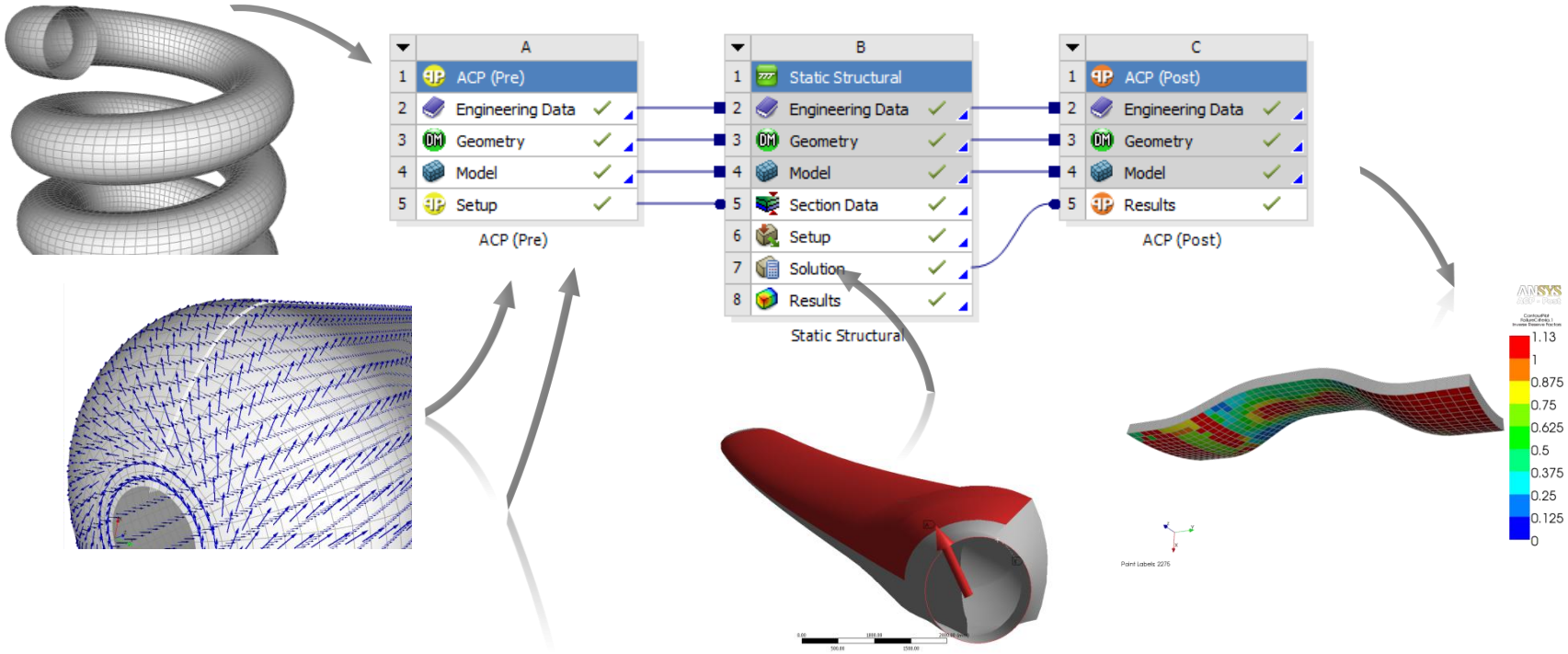
Shell-based Composite Analysis

The Workflow in ANSYS Workbench



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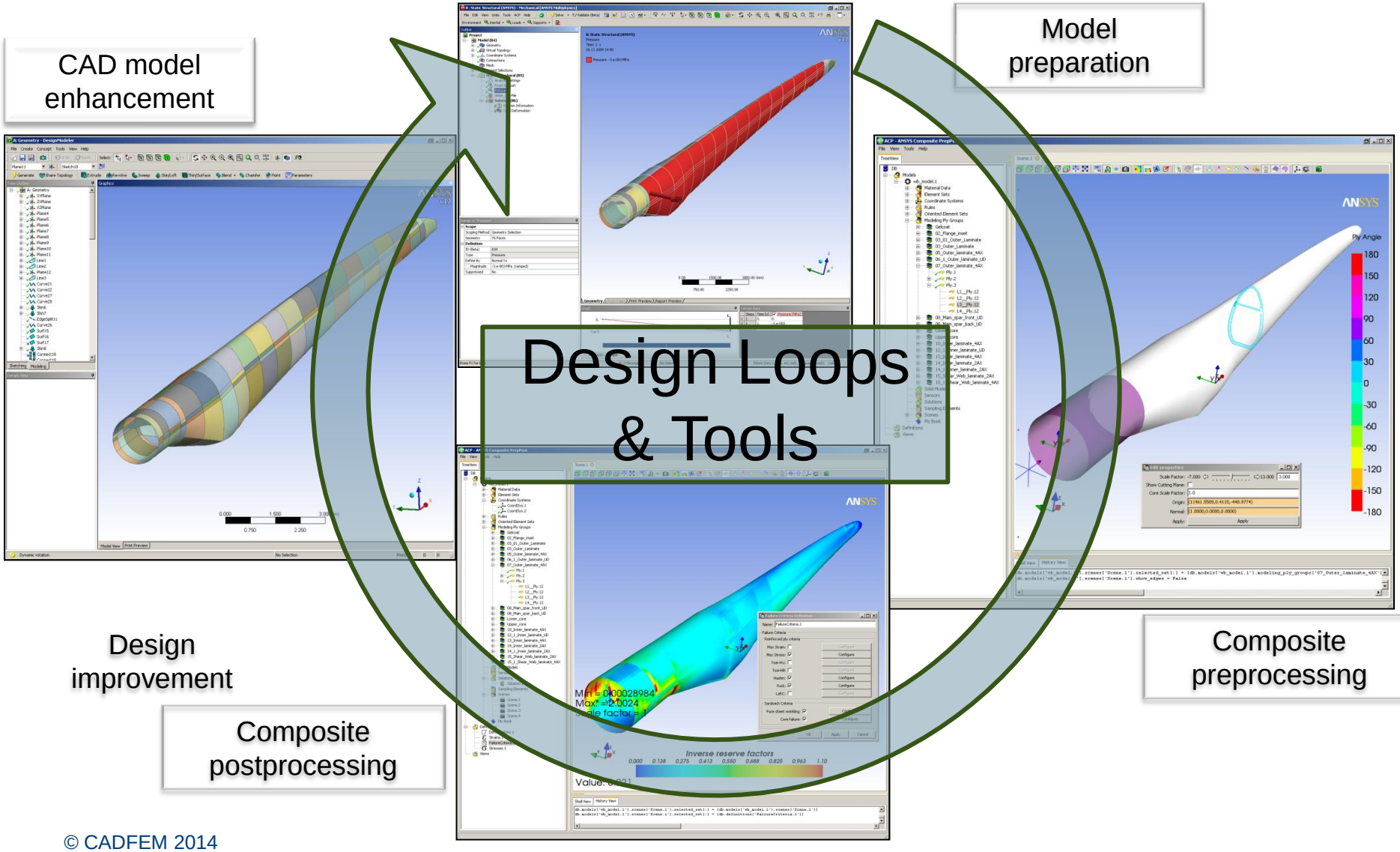
Shell-based Composite Analysis



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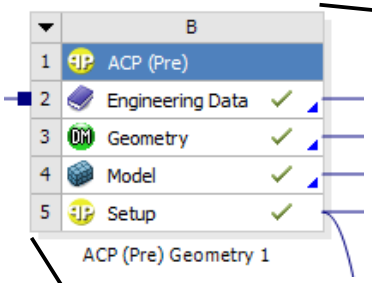
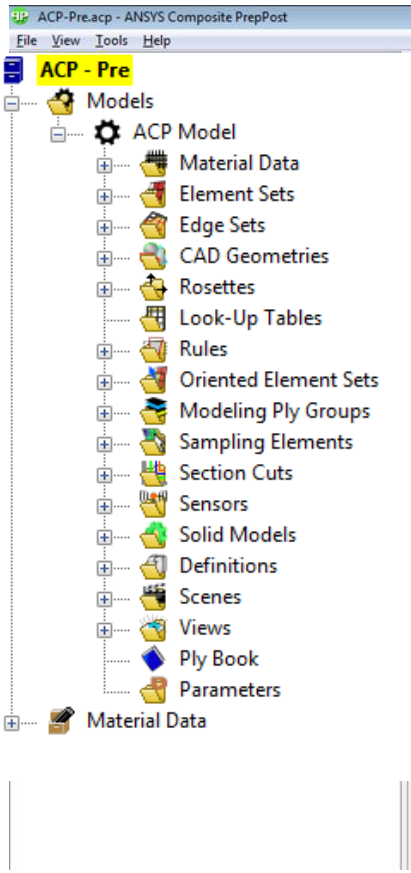
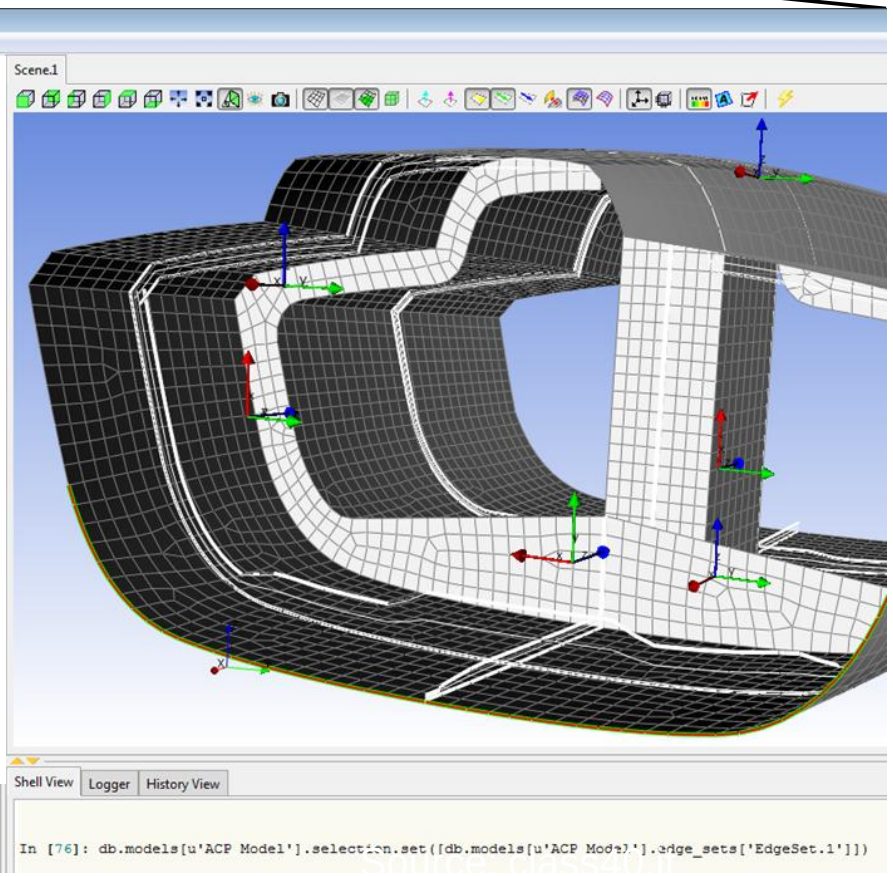
Shell-based Composite Analysis



Logic Work-Flow





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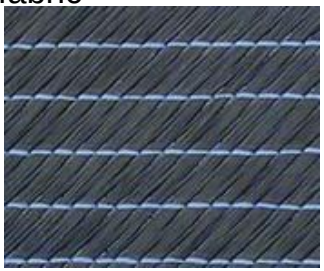
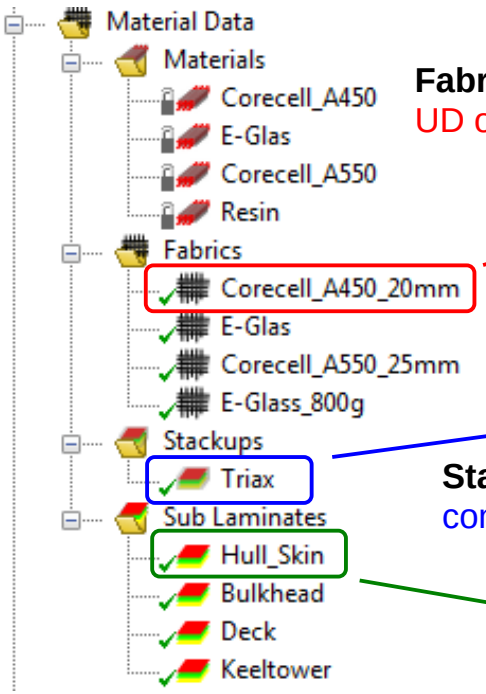
Shell-based Composite Analysis

Typical **Fabric**:
Carbon UD

Typical **Stackup**:
Non-crimped fabric



Material Level



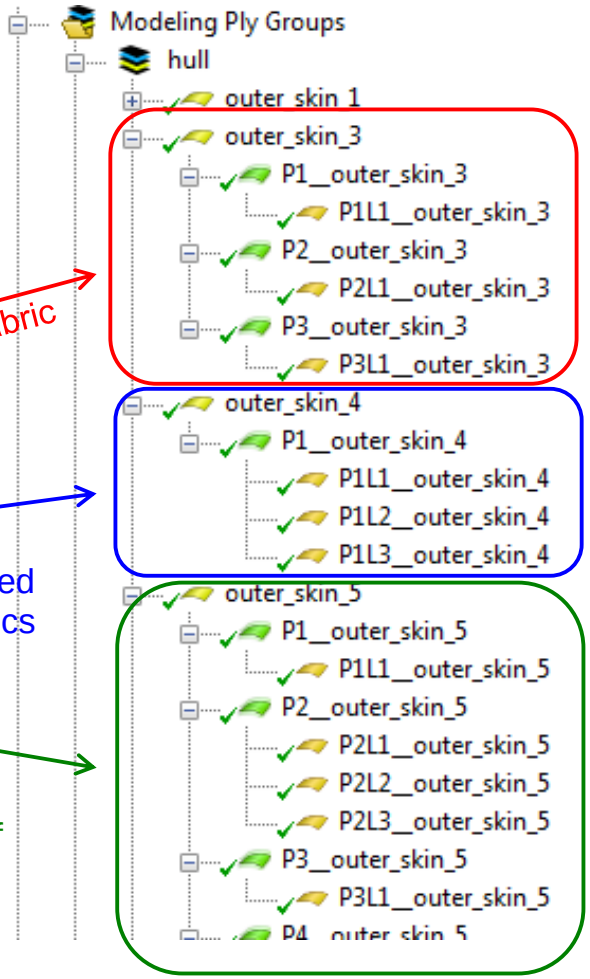
Fabric Single ply, UD or Woven

3-times same fabric

Stackup Prearranged combination of fabrics

Sub Laminate Collection of fabrics or stackups

Ply Level



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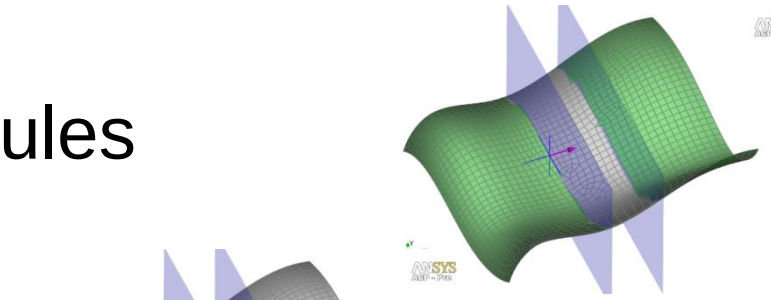
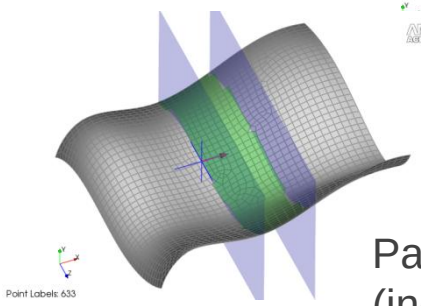
Shell-based Composite Analysis

Layup Surfaces defined by Rules

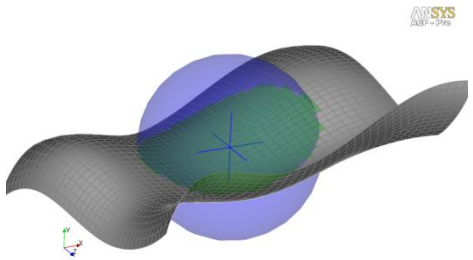
- Rules can be used as include or exclude rule.
- A parallel rule selects all elements between two locations.
- Cylindrical or spherical rules are used to reselect elements within a cylinder or sphere.



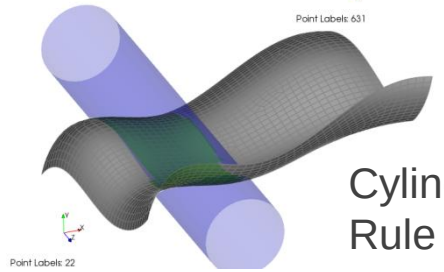
Parallel Rule (exclude)



Parallel Rule (include)



Spherical Rule



Cylindrical Rule

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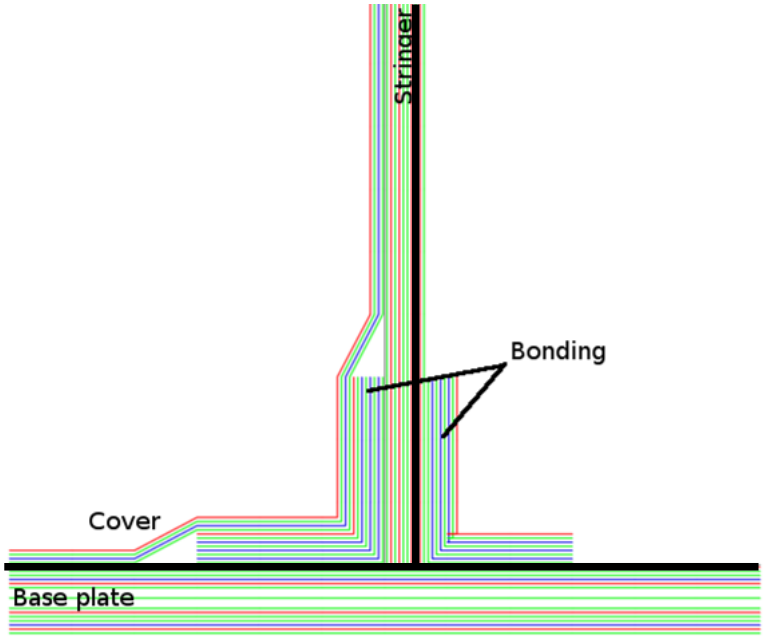
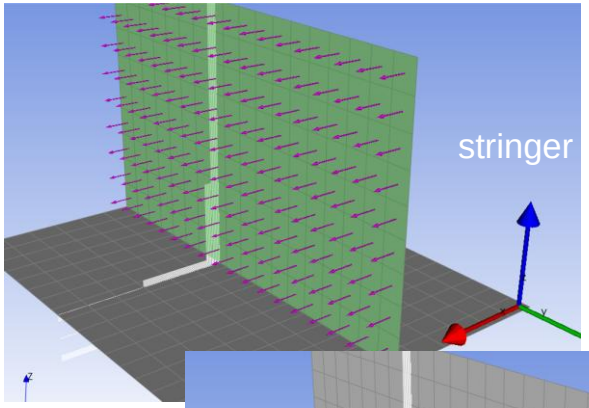
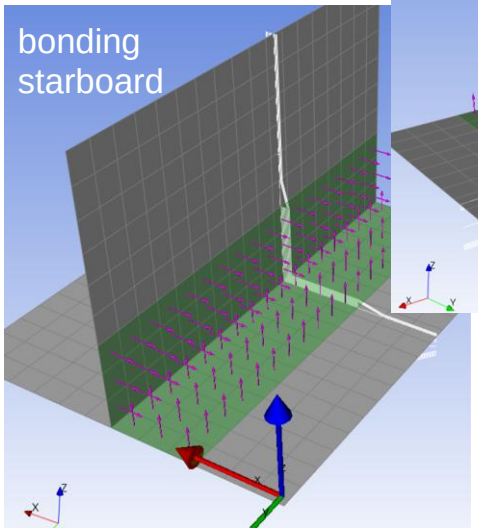
Shell-based Composite Analysis

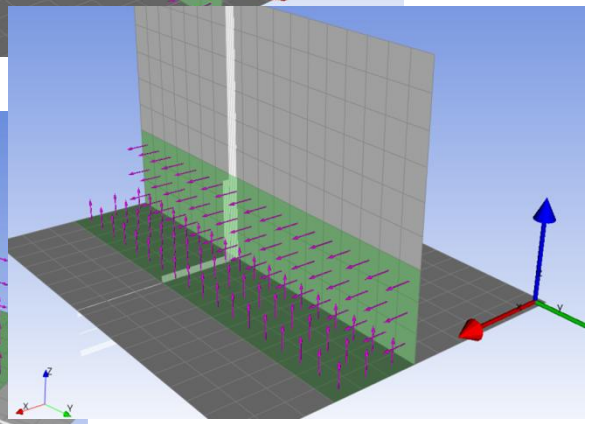
How to manage arbitrary layup directions?

- Define Oriented Element Sets based on Mechanical's Named Selections
- Define multiple Layup Directions per Element









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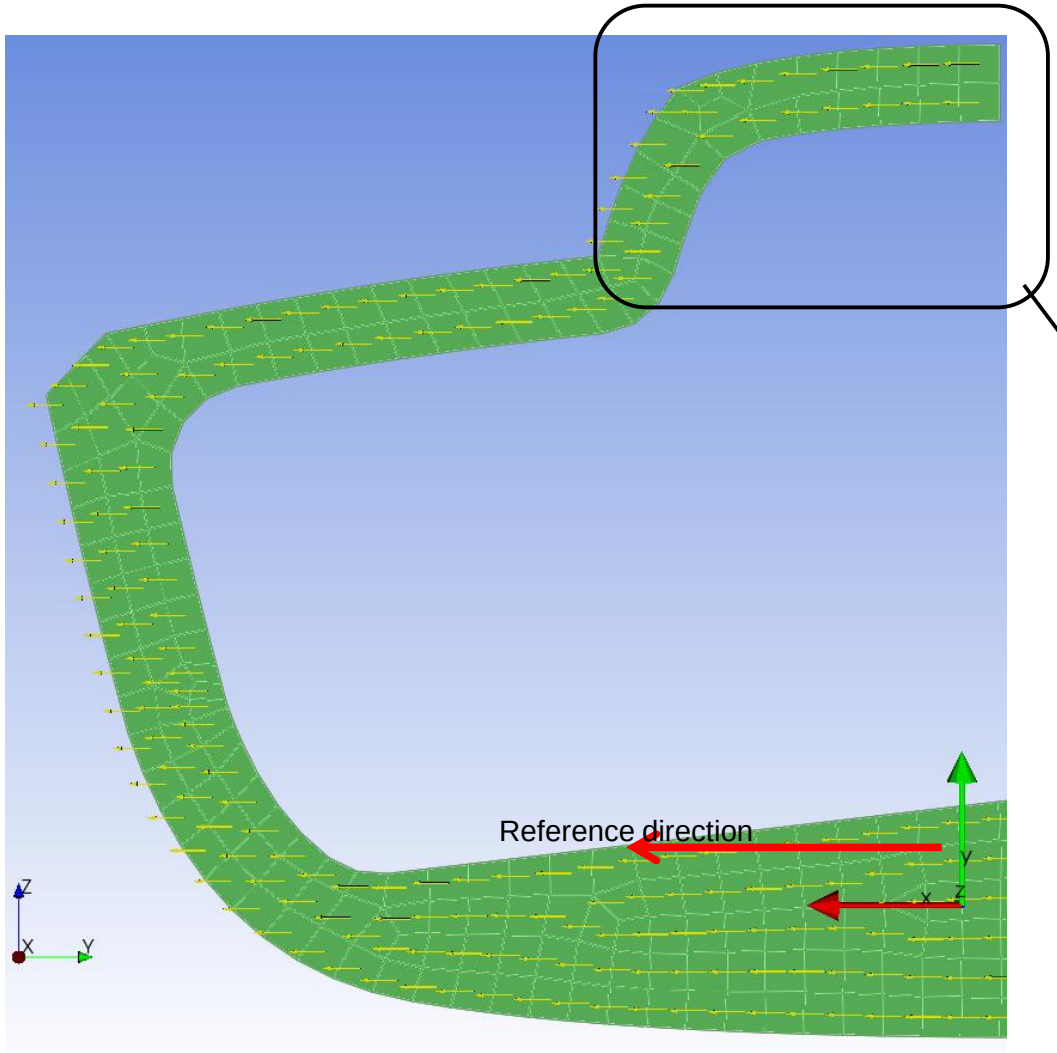
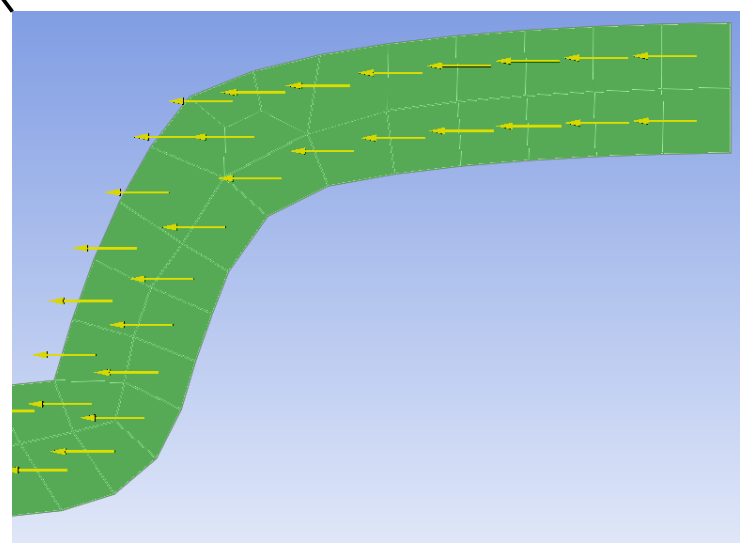
Shell-based Composite Analysis



- **Cartesian, cylindrical, spherical and edge-wise rosettes**
- **Combination methods**



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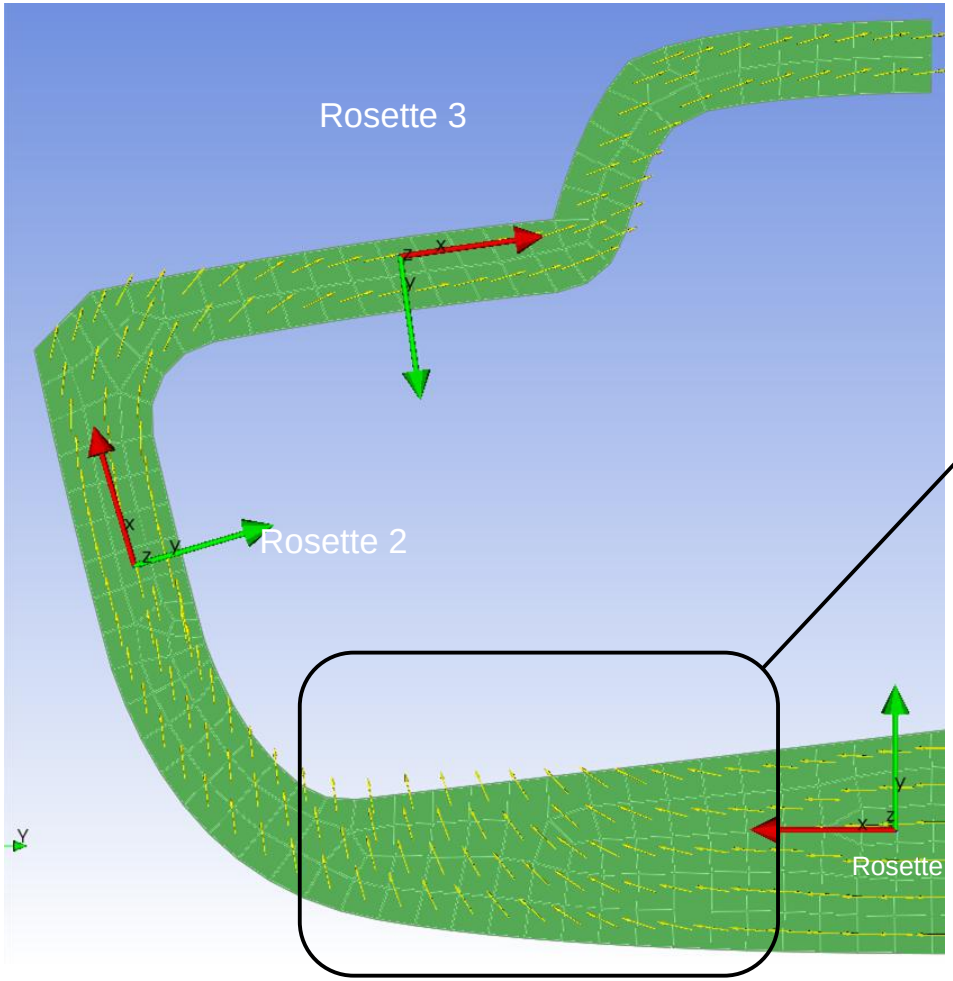
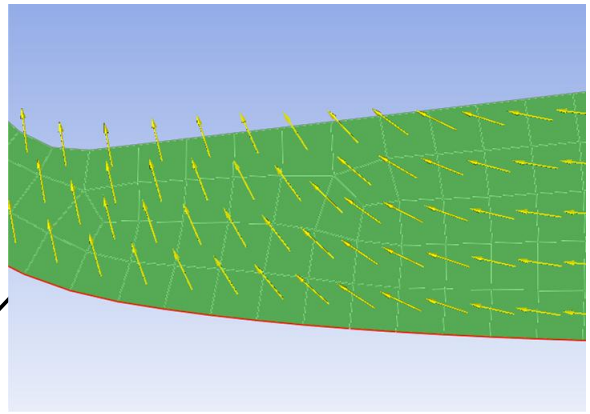
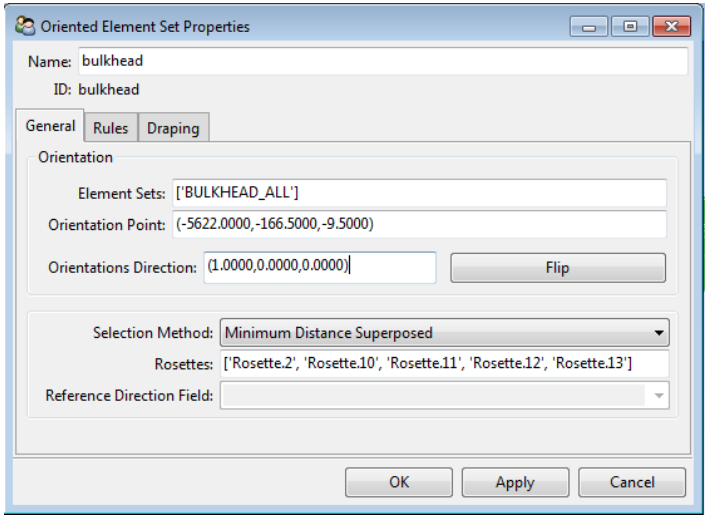
Shell-based Composite Analysis







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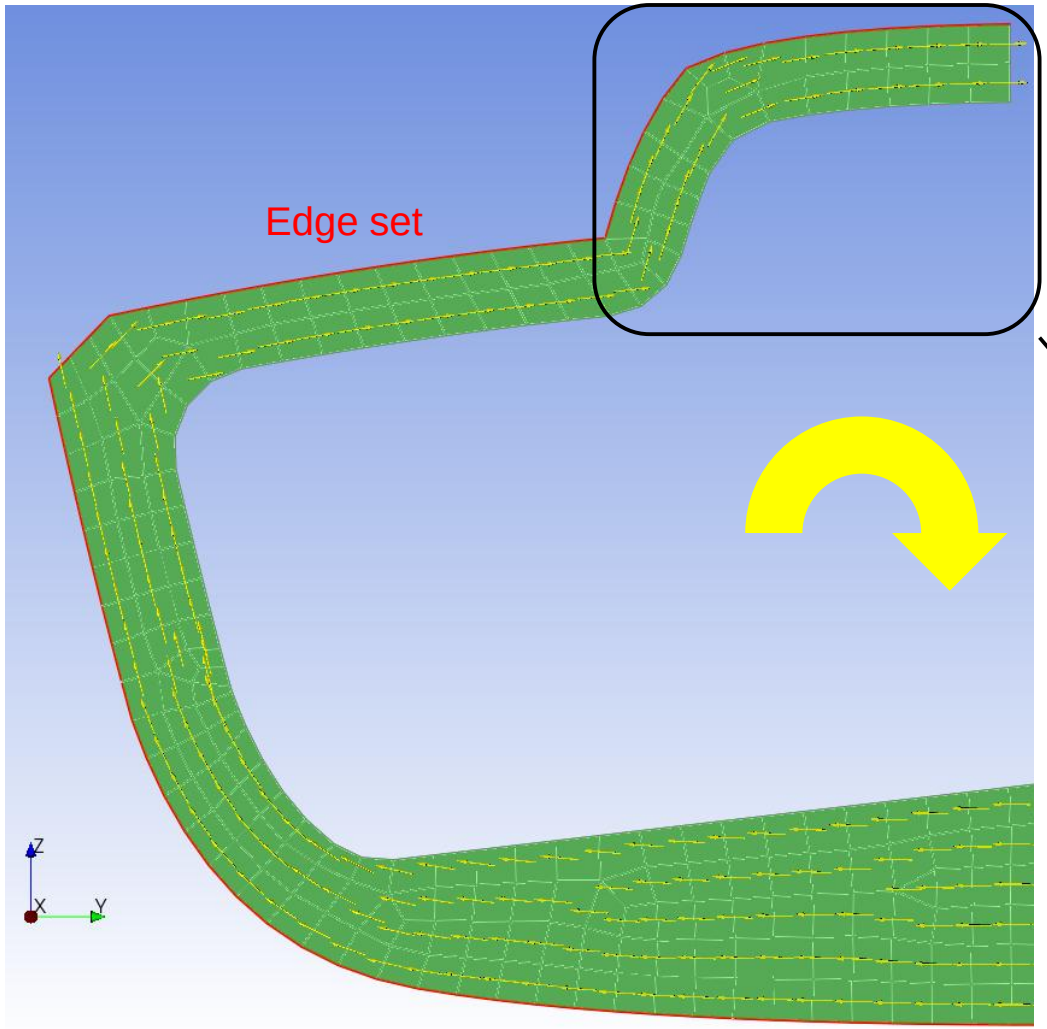
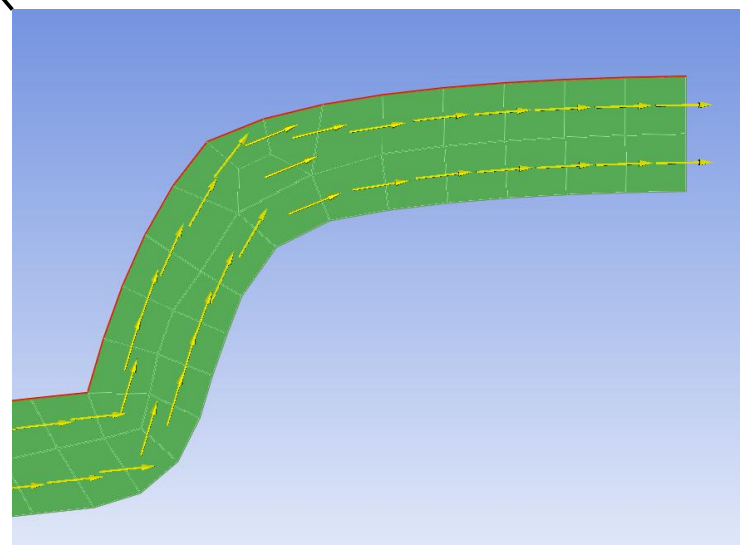


Edge-wise rosettes are very handy to define the reference direction along an edge guide



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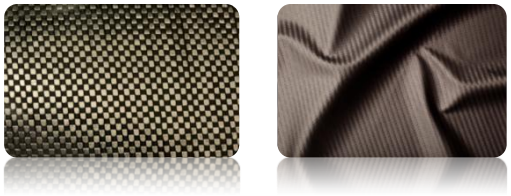
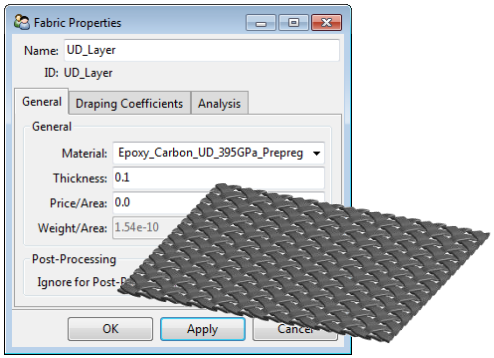
Shell-based Composite Analysis

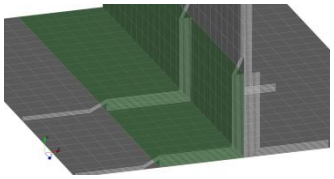
Three steps to a composite layup

Material and Fabrics

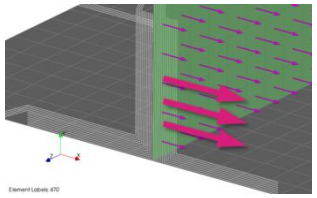




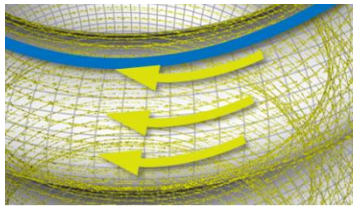
Oriented Element Sets



Layup Surface

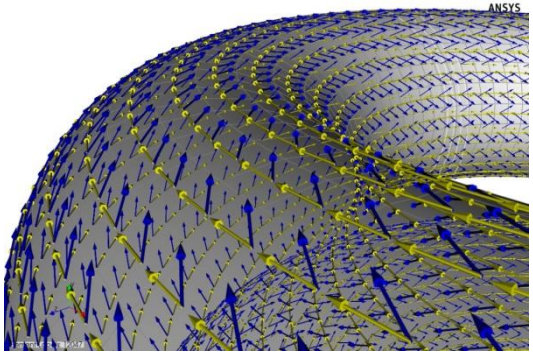


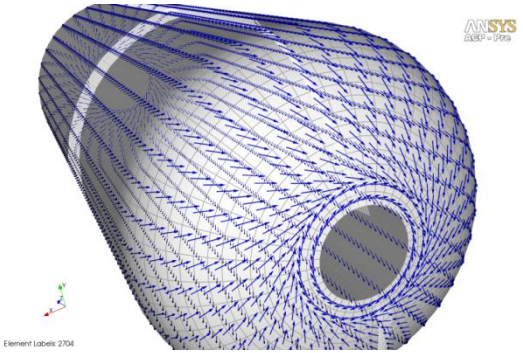
Layup Direction



Fiber Orientation

Composite Layup





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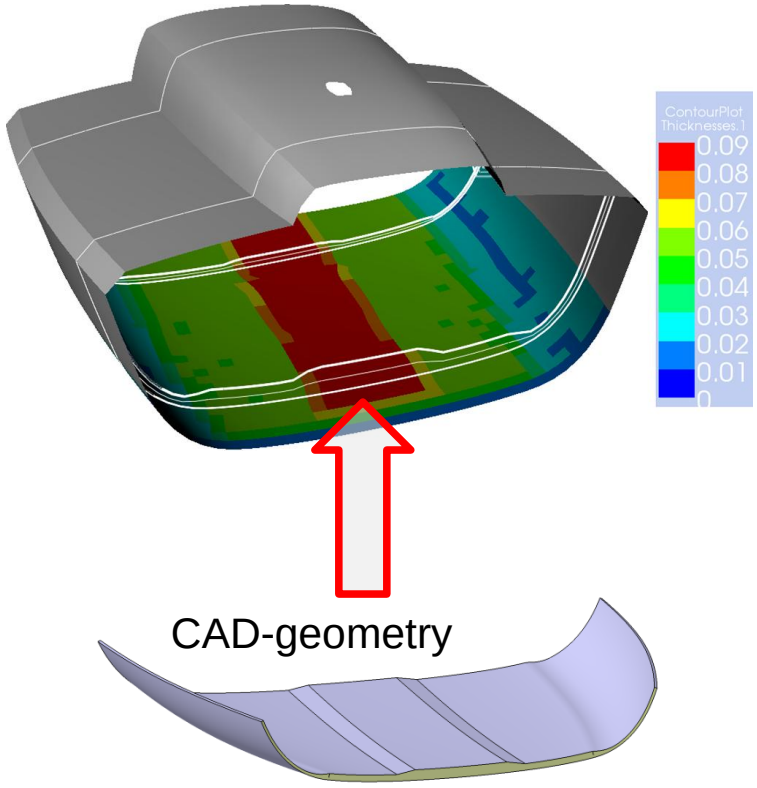
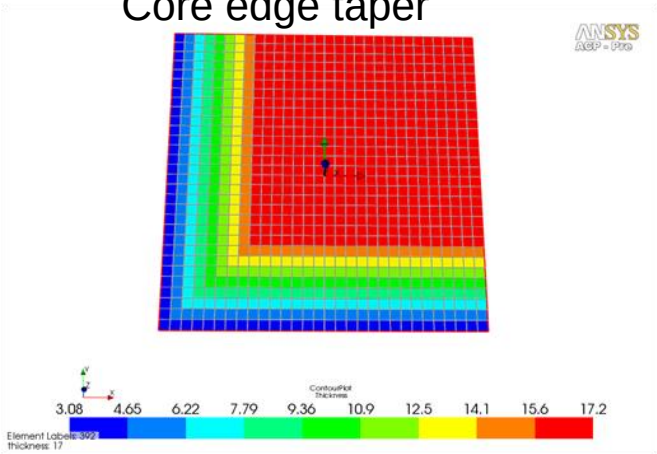
Shell-based Composite Analysis

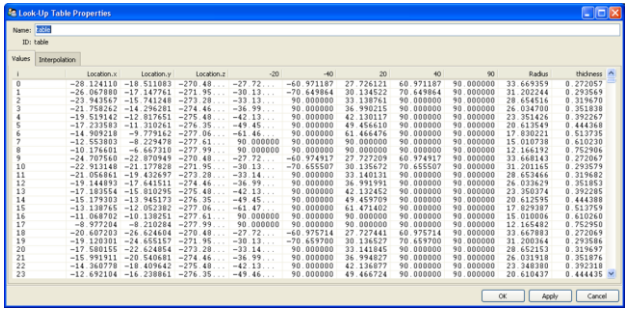
Core thickness set by CAD geometry



Core edge taper



Ply thickness entered with a Look Up Table



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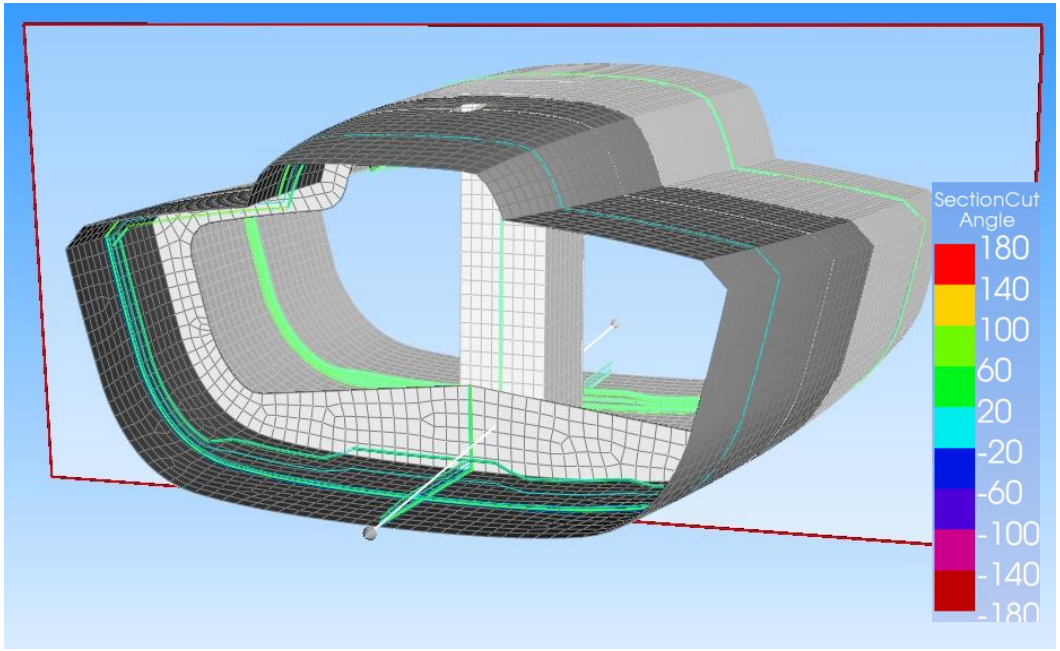
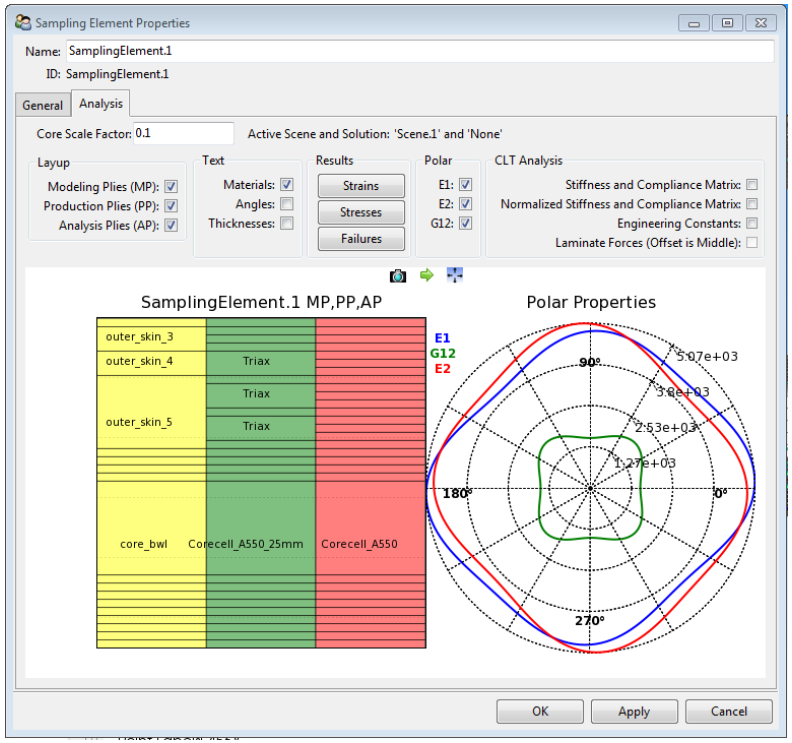
Shell-based Composite Analysis

- Stacking sequence and composite thickness can be displayed on arbitrarily Sections or the entire model
- Sampling elements are a powerful tool to analyze the layup





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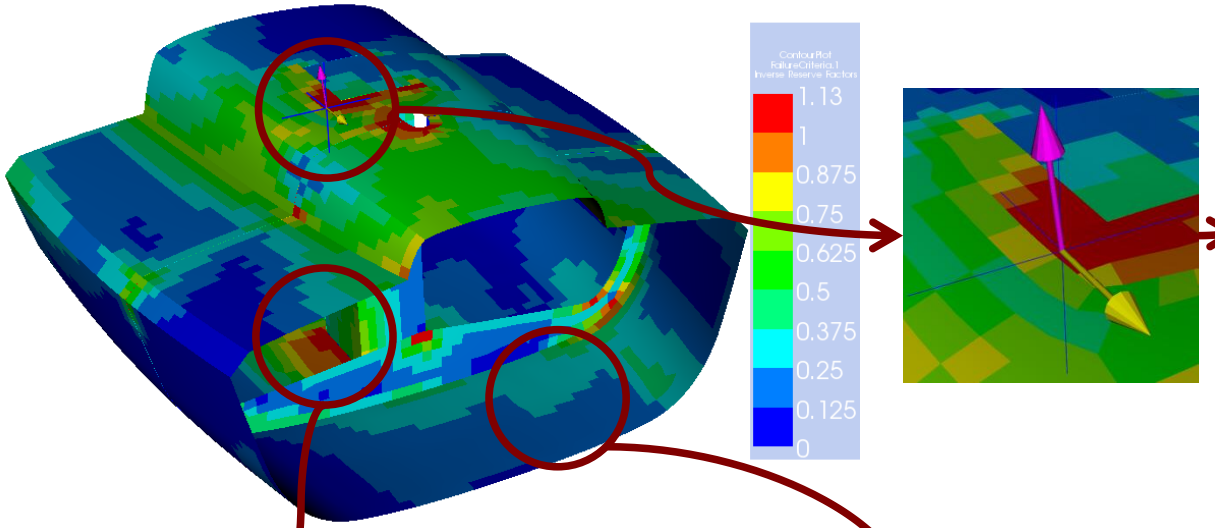
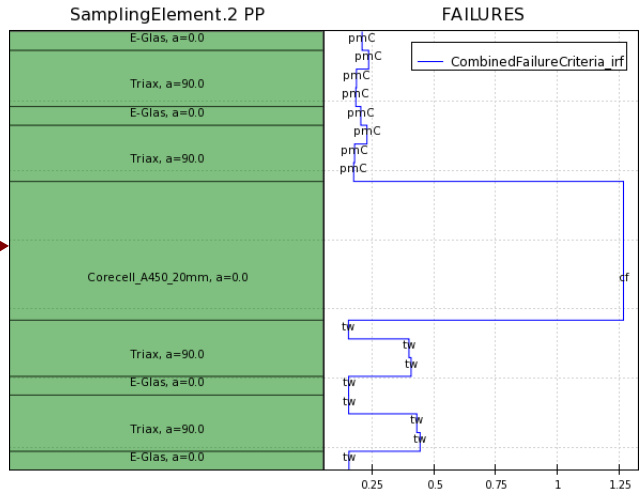
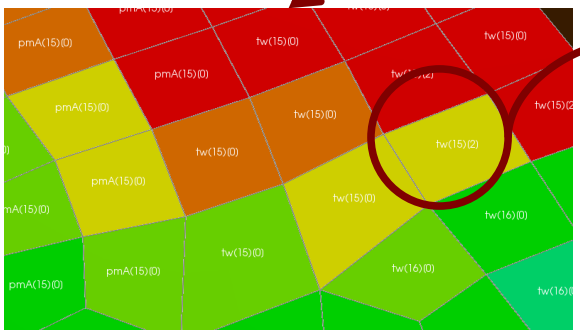
Shell-based Composite Analysis

IRF plot of entire structure



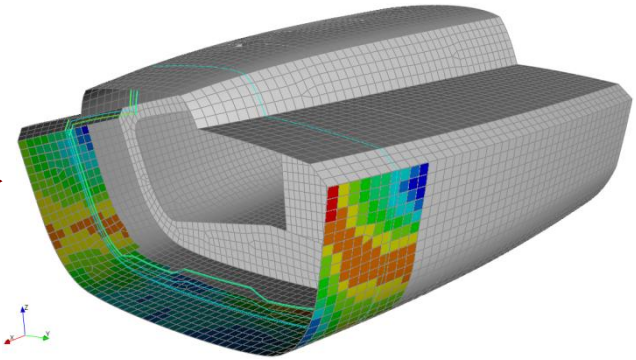
Assess utilization of each ply with a Sampling Element





Tw(15)(2): Tsai-Wu Layer 15, Loadcase 2

Analyze structure ply-by-ply



Gain an overview of critical failure mode, layer and load case

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Shell-based Composite Analysis

Solid Composite Analysis

Additional Features

Define Variable Material Properties

ANSYS Composite Cure Simulation

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Why Solid Modeling?

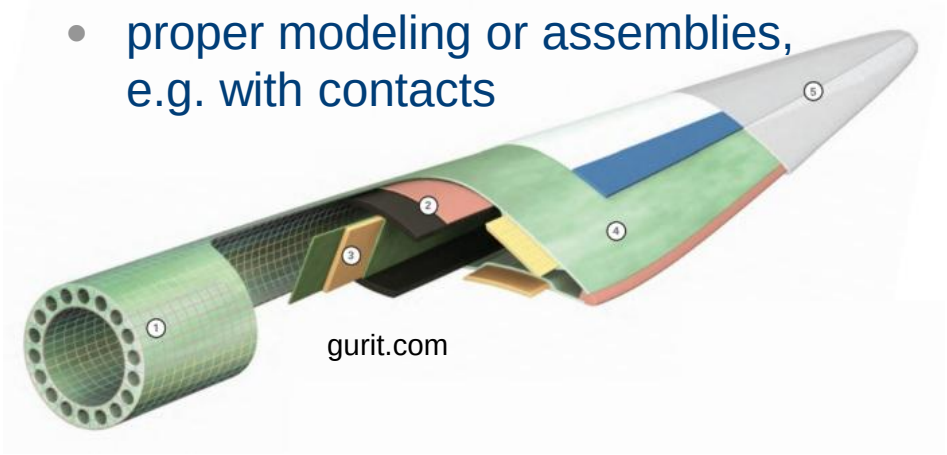
Account for

- out-of-plane normal stresses
- out-of-plane shear stresses

gereports.com

Relevant for

- „thick-walled“ composite structures
- e.g. buckling analyses of such
- proper modeling or assemblies, e.g. with contacts



gurit.com

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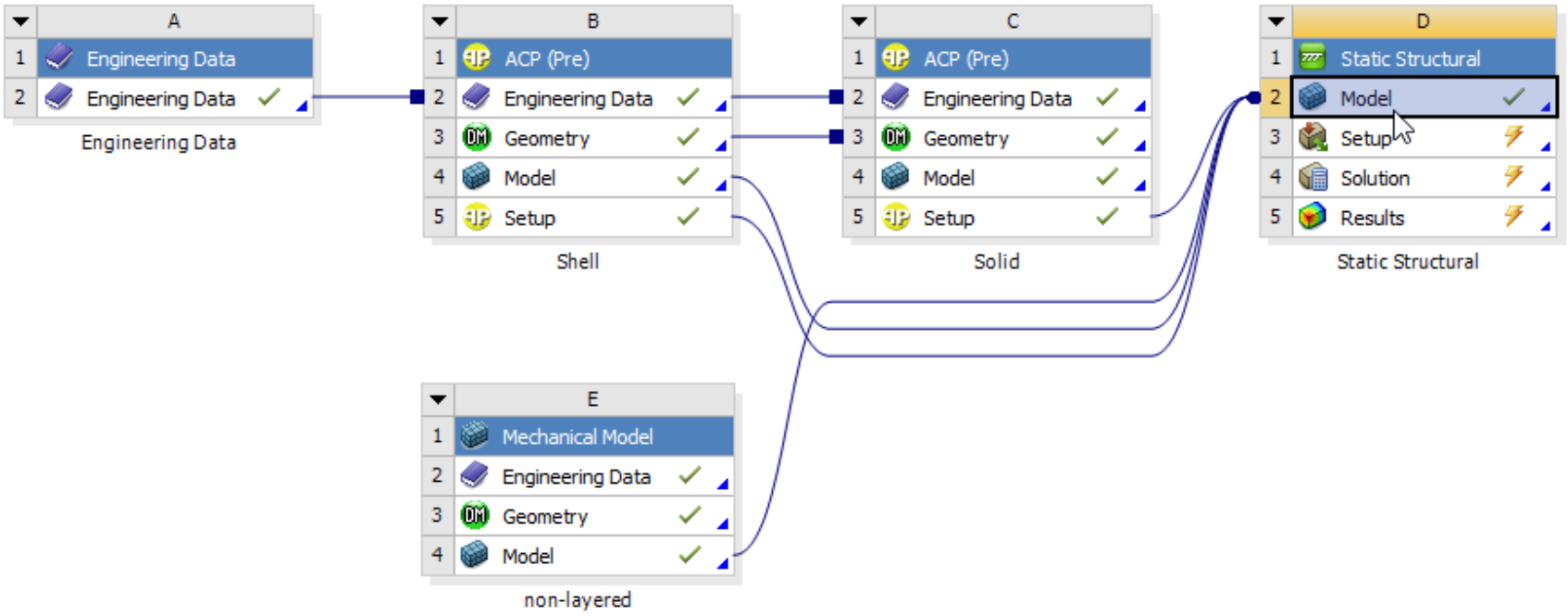
Unified approach to handle Shells and Solids in R17

- User can now assemble multiple Shell and Solid models from ACP in a single system.
- In addition, non-layered models (from Mechanical, External Model etc.) can be assembled along with the composite models.



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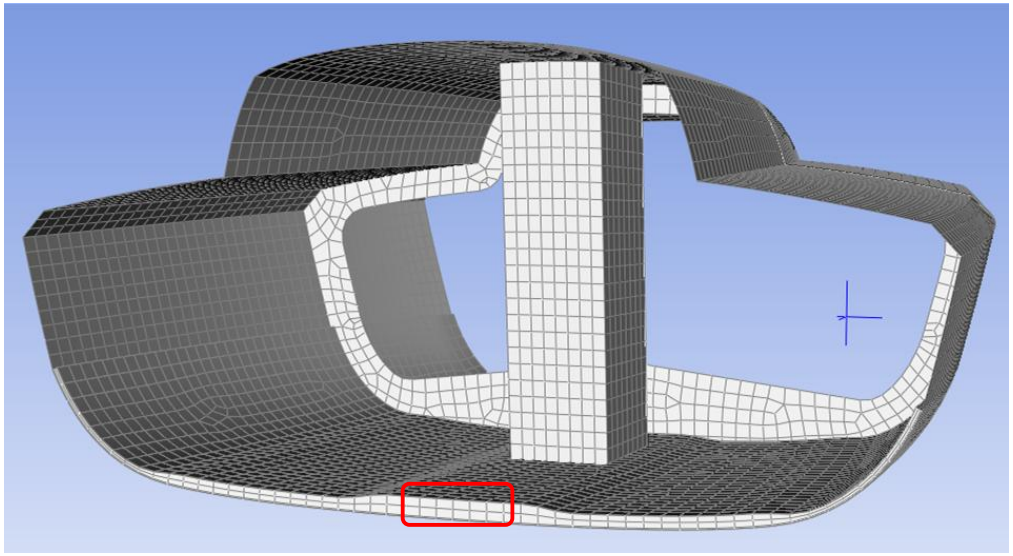
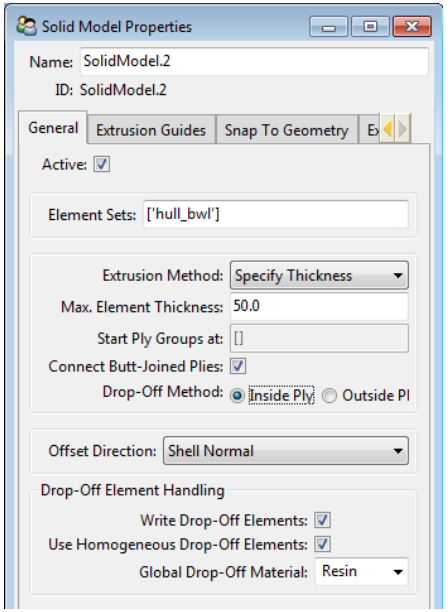
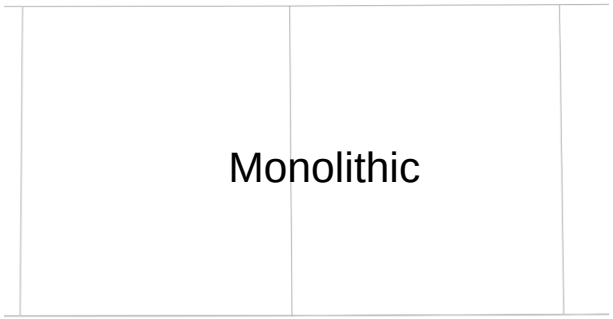
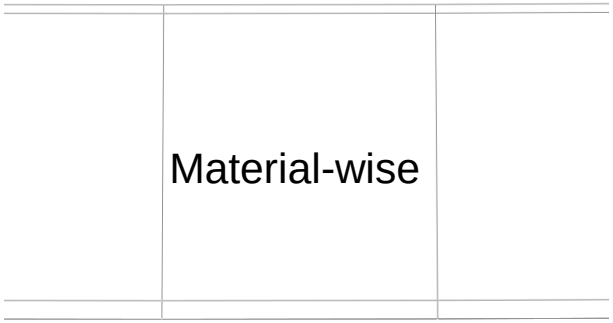
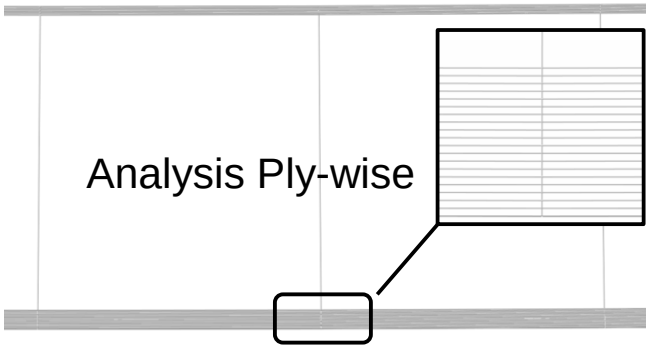
Solid Composite Analysis











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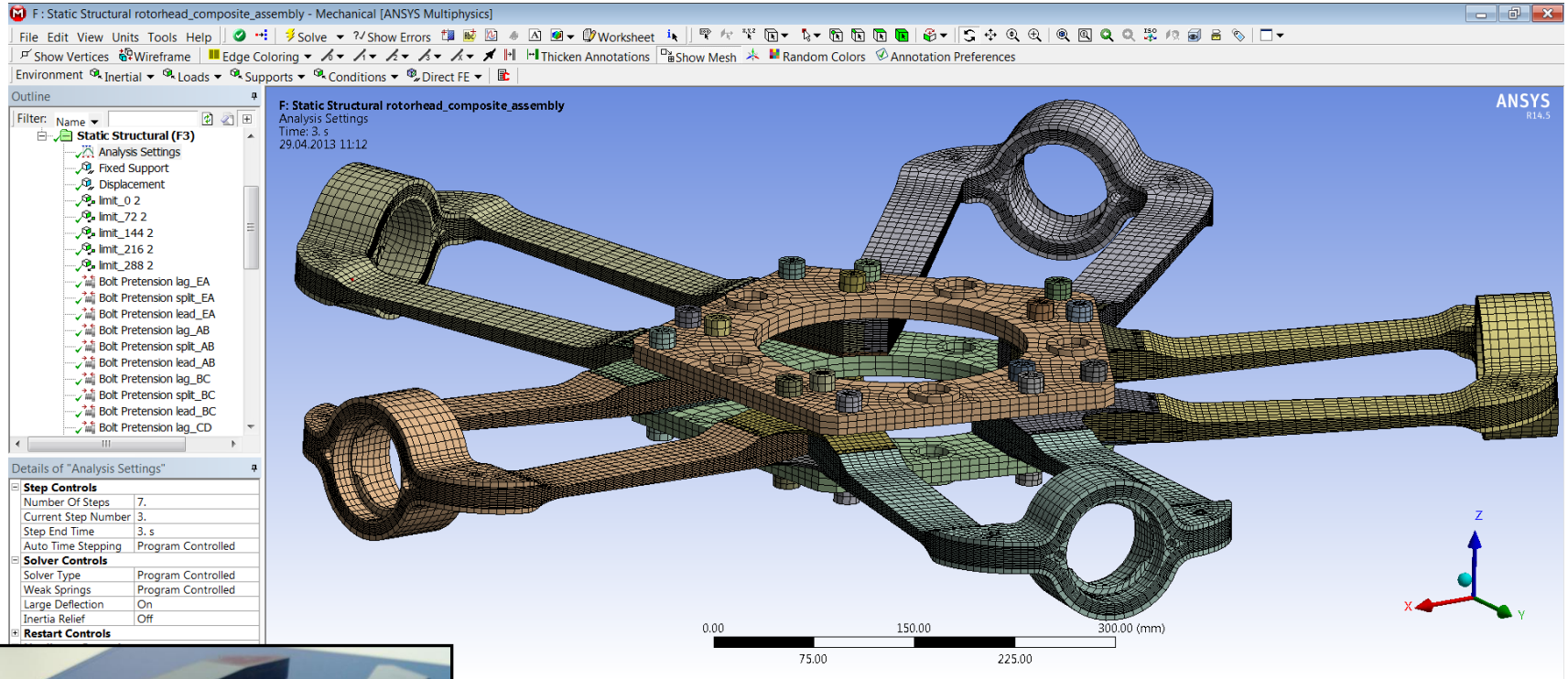
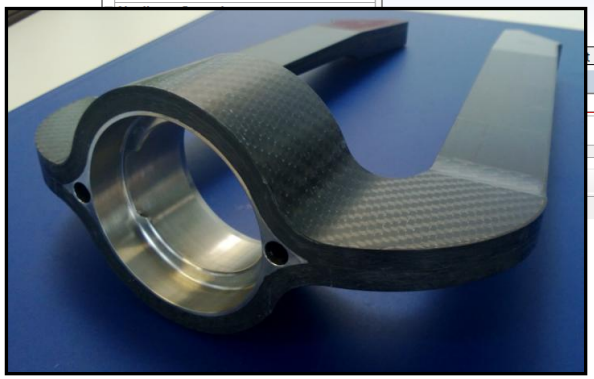
Solid Composite Analysis





By courtesy of:
Marenco Swisshelicopter Ltd

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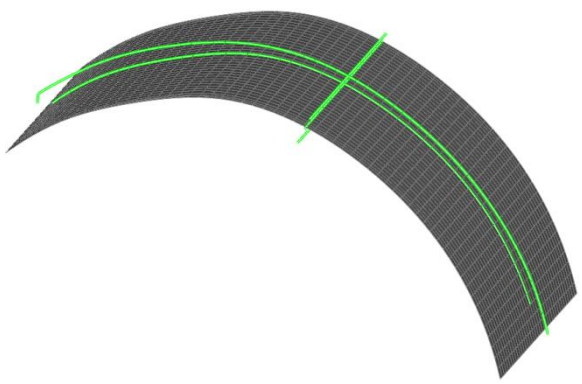
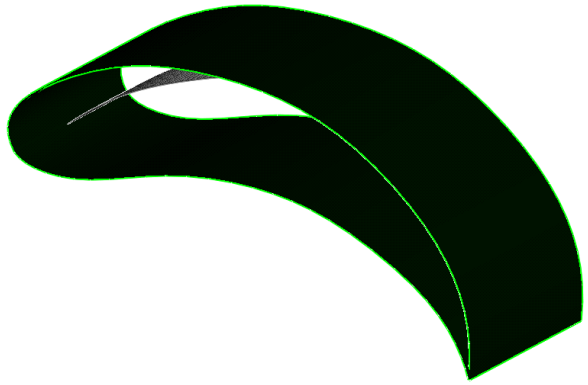
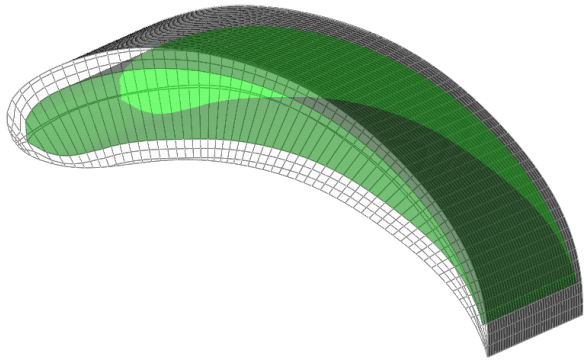
Solid Composite Analysis

- An Extruded Solid Model can be additionally shaped with external geometries to generate desired shapes

Start with shell geometry and composite layup → **Define extrusion guides and snap to geometry** → **Specifiy element thickness and extrude Solid Model**







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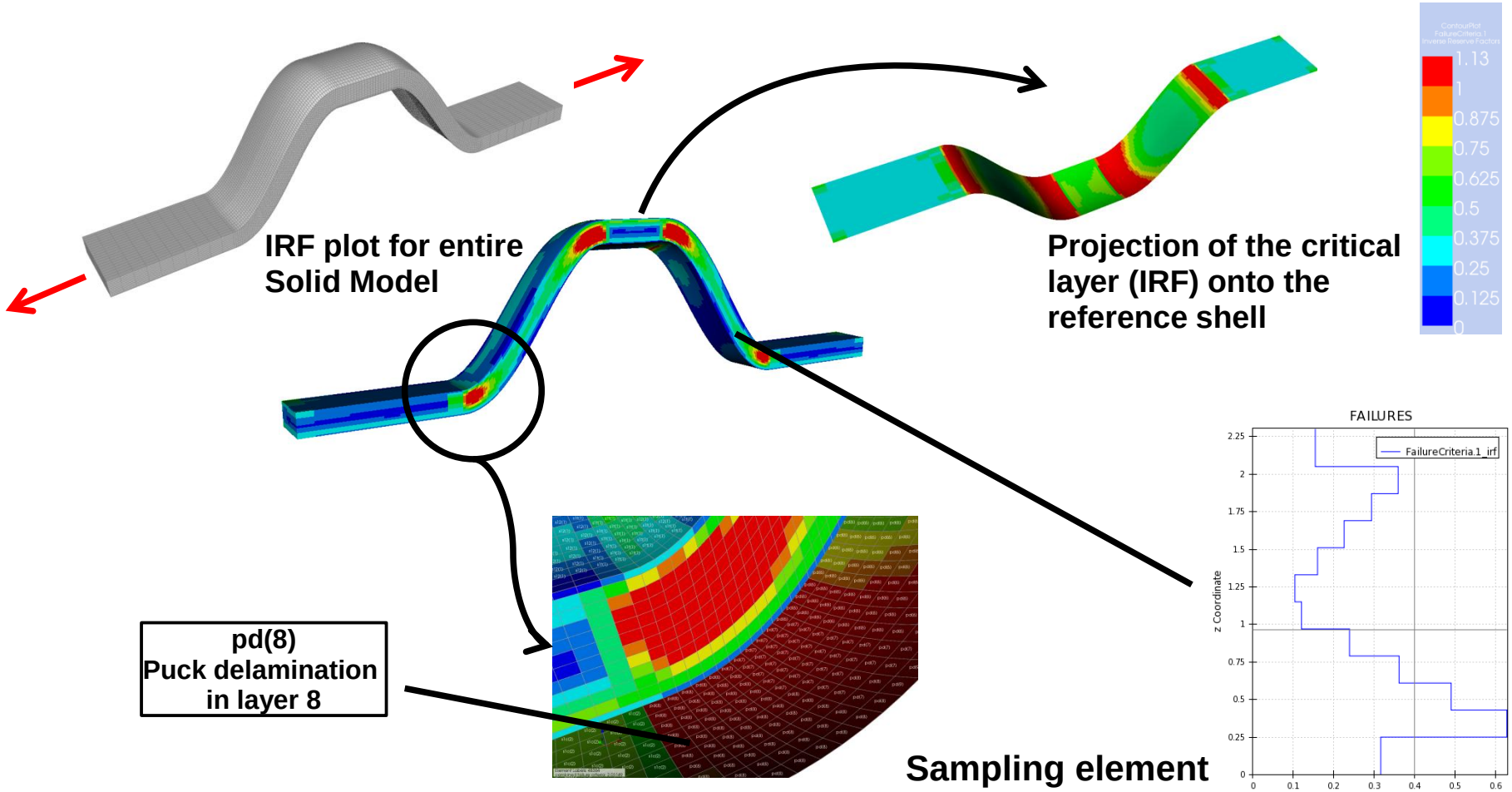
Solid Composite Analysis

All features of Shell-Model Postprocessing are retained



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Shell-based Composite Analysis

Solid Composite Analysis

Additional Features

Define Variable Material Properties

ANSYS Composite Cure Simulation

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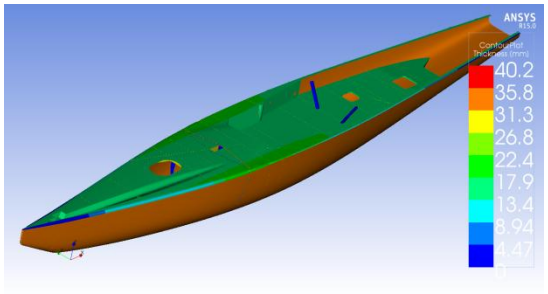
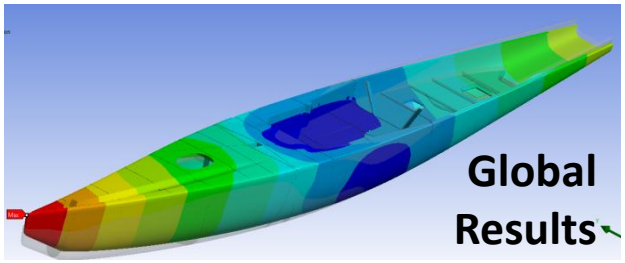
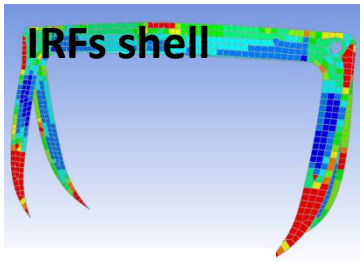
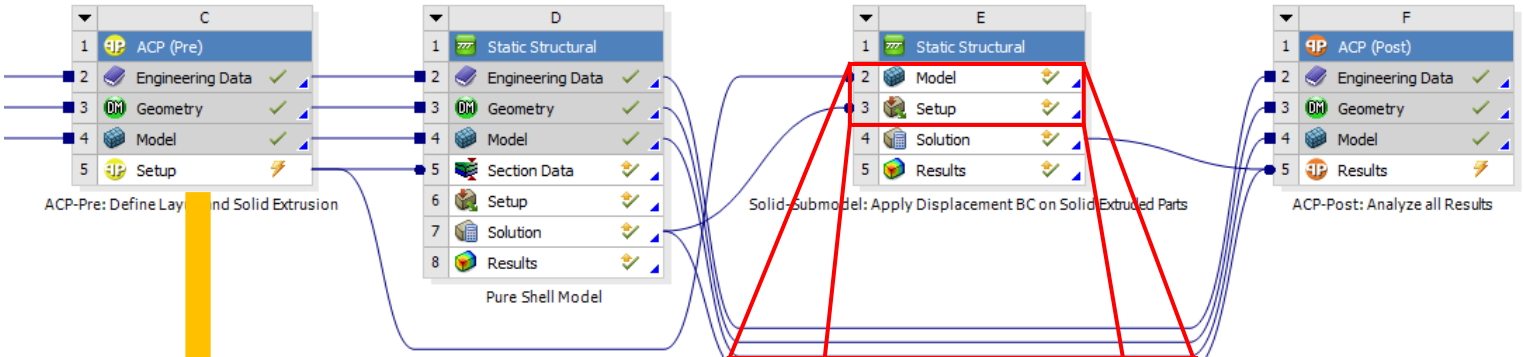
Additional Features

SHELL





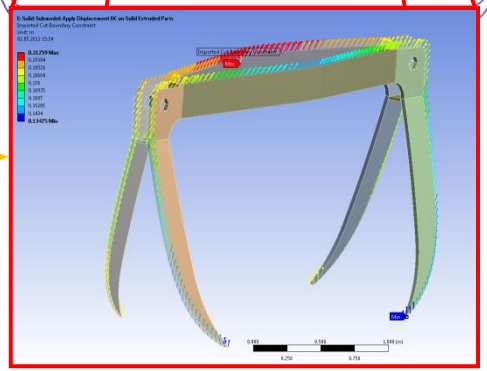


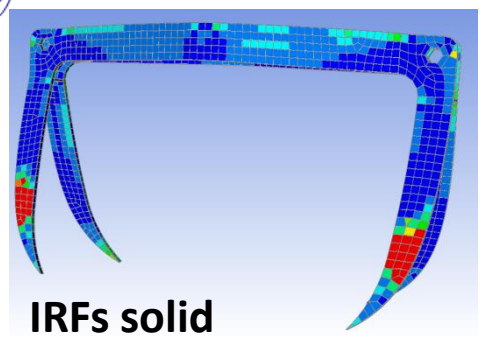


SOLID

Create solid model of critical part (C5 – E2)

and map shell results to the cut faces (D7 - E3)





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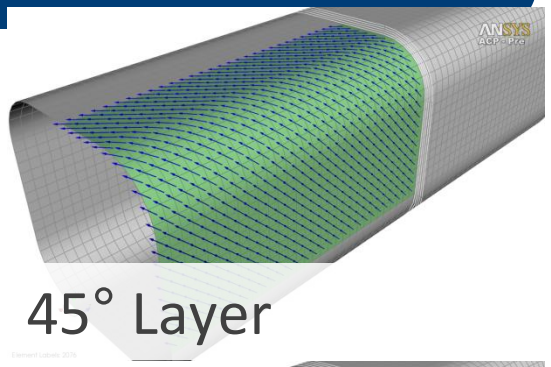
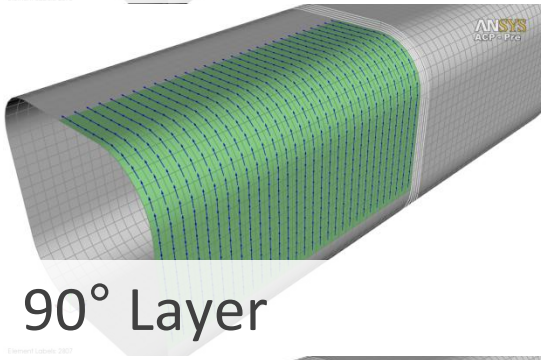
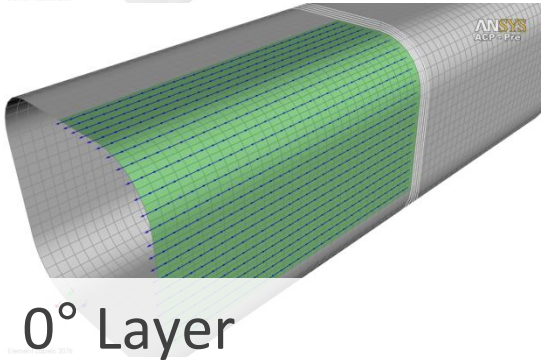
Additional Features

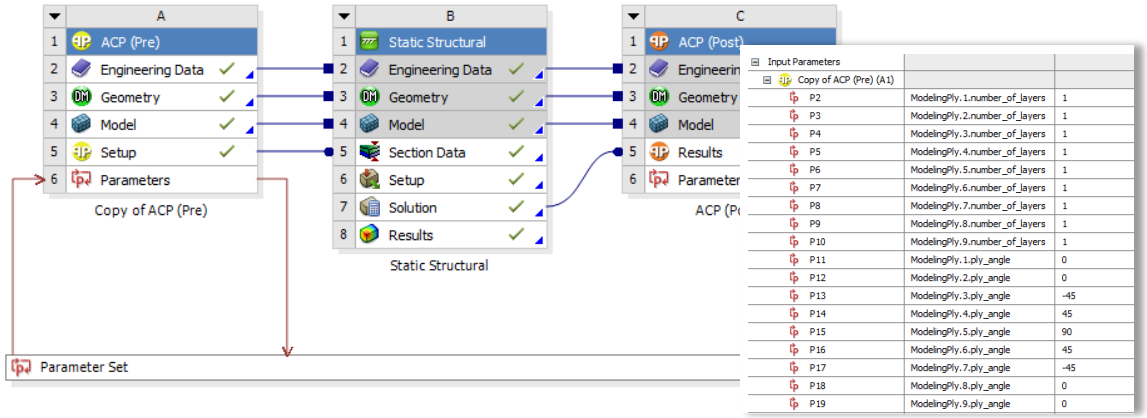
Composite Parameter Studies

- ANSYS Composite PrepPost allows the user to define parameters for fiber angles.
- All parameters are accessible in the ANSYS Workbench parameter manager.









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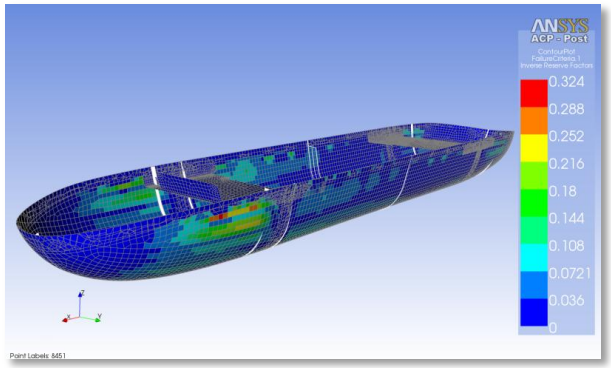
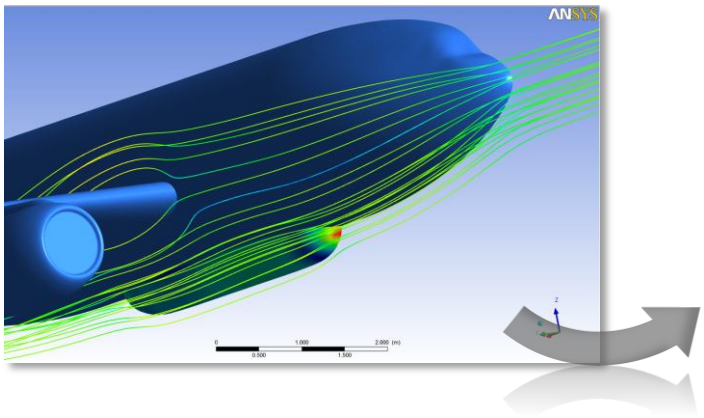
Additional Features

Fluid-Structure Interaction and Composites

- Apply loads from CFD directly.
- One-way and two-way fluid structure interaction is possible.





A	
1	ACP (Pre)
2	Engineering Data
3	Geometry
4	Model
5	Setup

ACP (Pre)

B	
1	Static Structural
2	Engineering Data
3	Geometry
4	Model
5	Section Data
6	Setup
7	Solution
8	Results

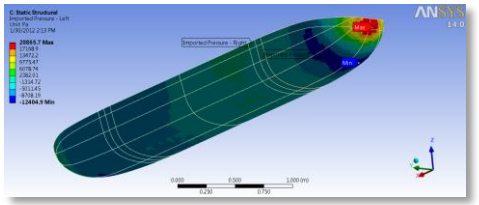
Static Structural

C	
1	ACP (Post)
2	Engineering Data
3	Geometry
4	Model
5	Results

ACP (Post)

D	
1	Fluid Flow (Fluent)
2	Geometry
3	Mesh
4	Setup
5	Solution
6	Results

Fluid Flow (Fluent)



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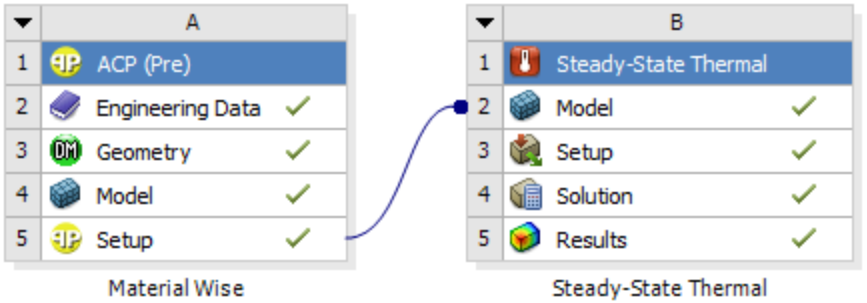
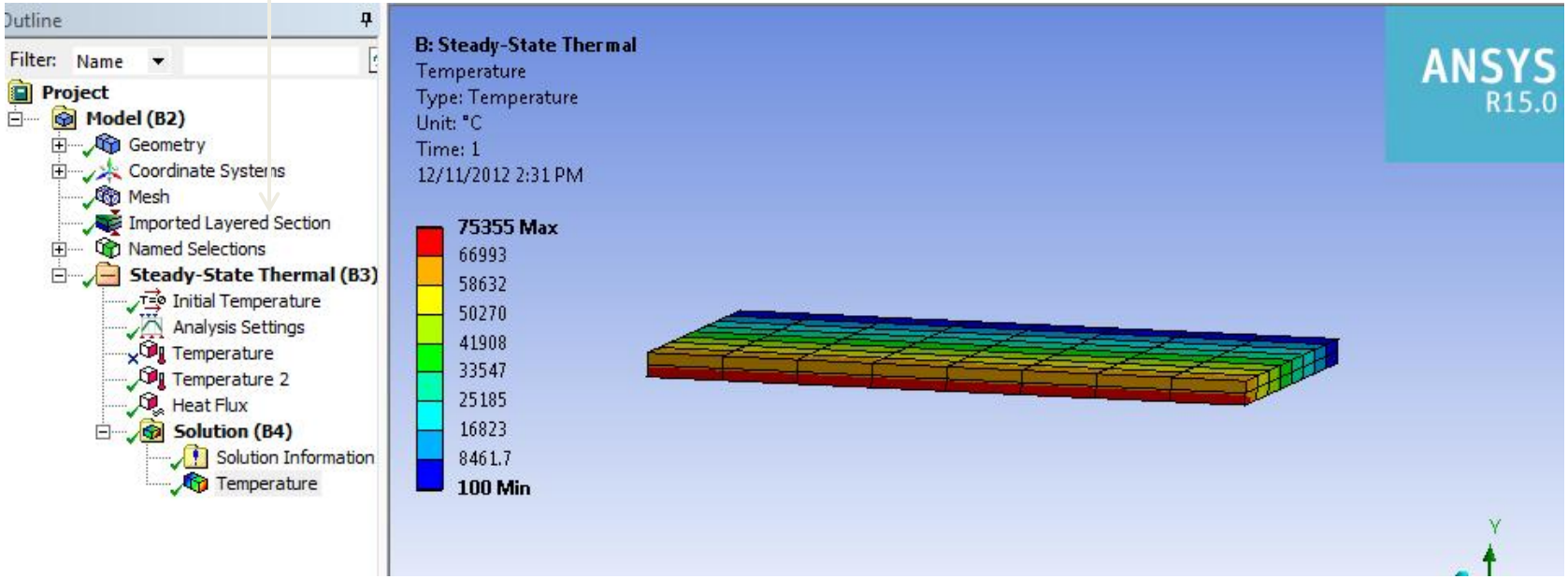
Additional Features

Thermal analysis now supports solid layer elements SOLID278/SOLID279

Thermal solid composites are now supported in models with Imported Layered Sections.





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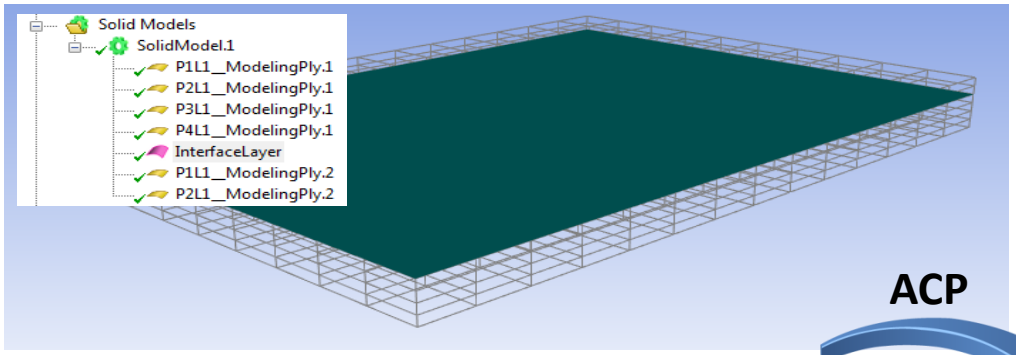
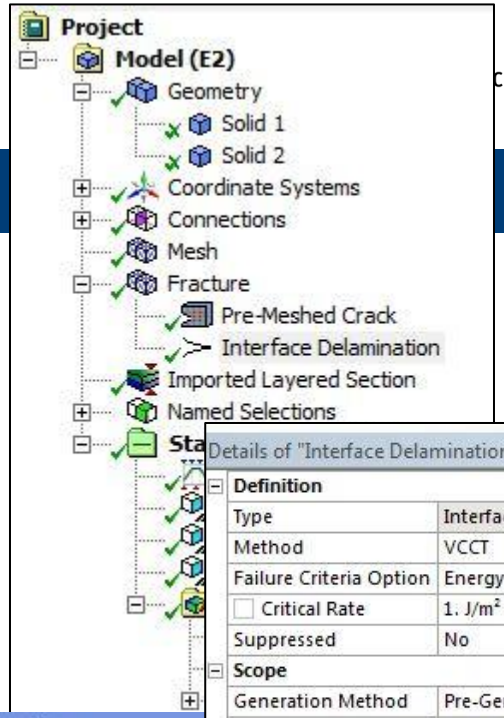
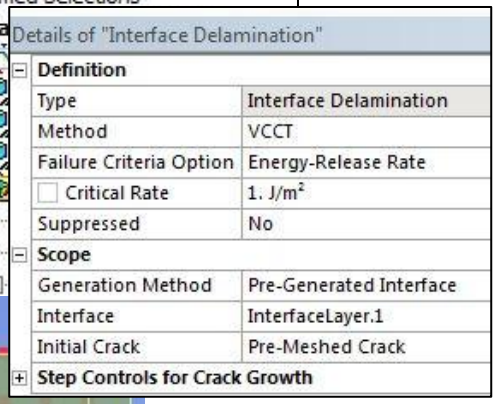
Center FEM

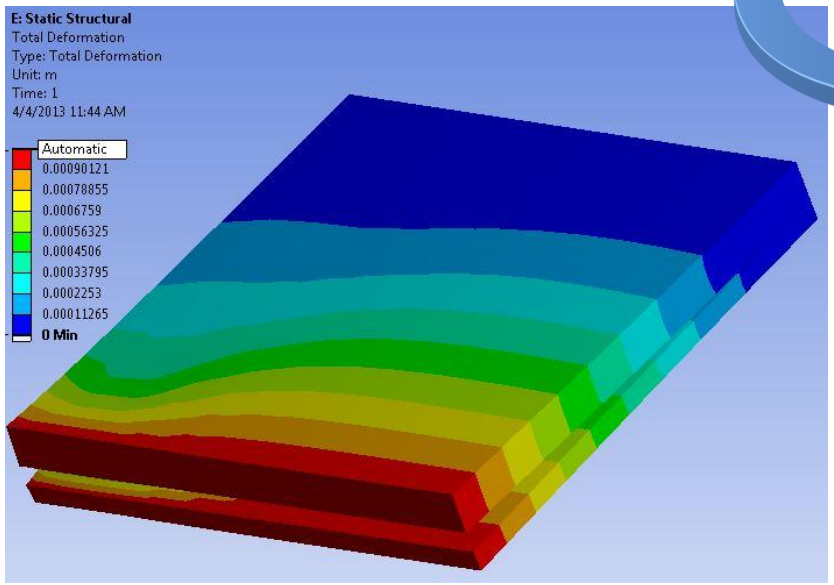
Additional Features

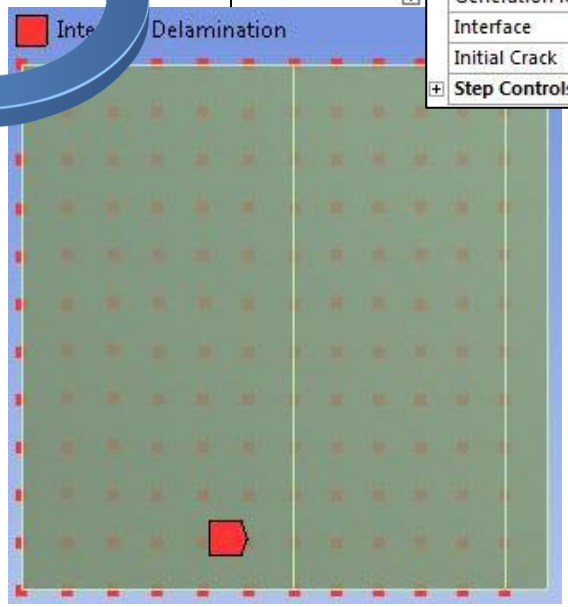






ACP





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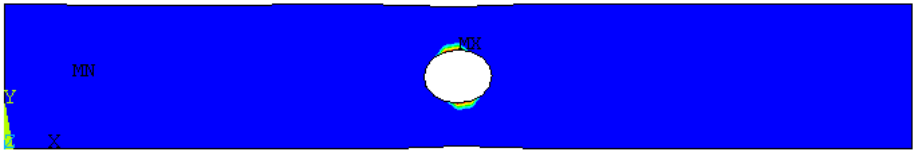
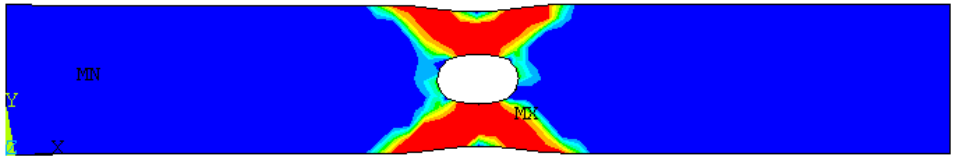
Additional Features

- New nonlinear solution process to simulate the damage propagation in composites beyond first ply failure
- Damage evolution with Continuum Damage Mechanics (CDM) method

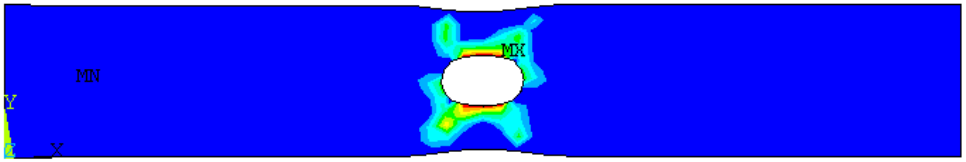
- Example: progressive damage of a composite plate under stretch load



Start of damage (layer 1)



Progressed damage (layer 1)



Progressed damage (layer 3)

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Shell-based Composite Analysis

Solid Composite Analysis

Additional Features

Define Variable Material Properties

ANSYS Composite Cure Simulation

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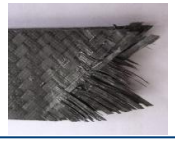
Variable Material Data: Background

Raw materials

- **Multiple constituents:**
  Volume fractions, fiber distributions, interactions, imperfections, ….

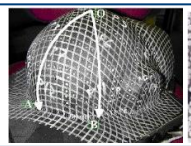
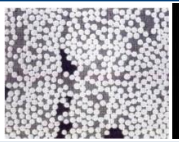
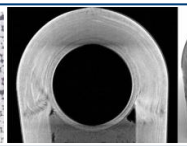

Testing

- **Simple coupon tests:**
  Only a subset of the effective material properties can directly be assessed

Part

- **Manufacturing:**
  Draping, curing, voids, interfaces, fiber debonding, …

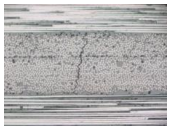





Assembly

- **Finish and assemble parts:**
  Milling, bonding, cutting, riveting, …


Operation

- **Daily wear:**
  Environmental and aging impacts, progressive failure, …




Degradation of the compound material properties

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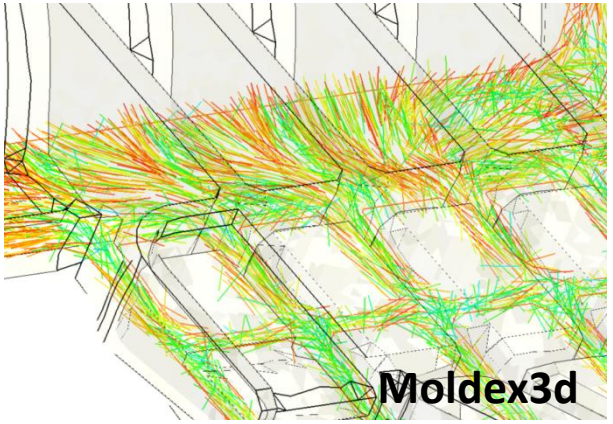
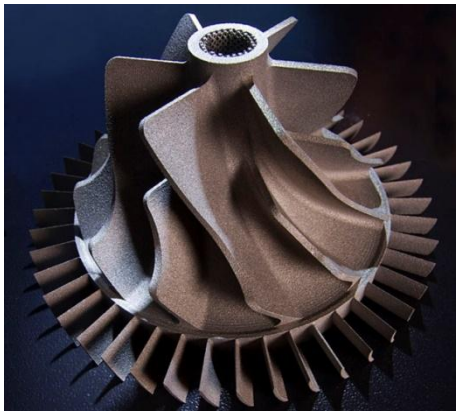
Variable Material Data: Challenges

- Each composite structure has its individual challenges!



- Consider degraded material properties in region with low fiber volume content, voids and folding
- Analyse draping shear angle and fiber orientation
- Consider environmental conditions such as temperature and humidity



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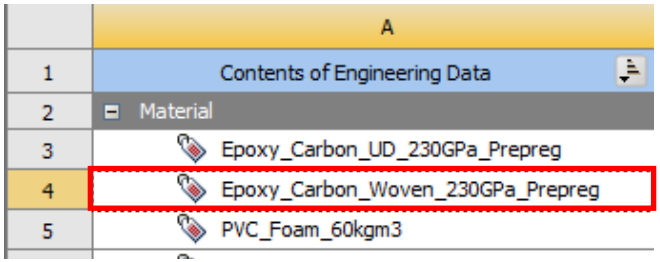
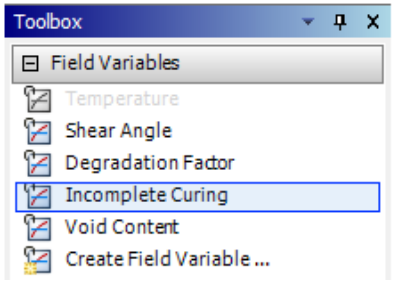
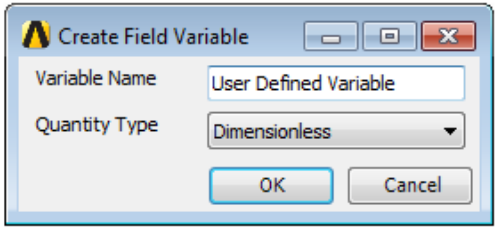
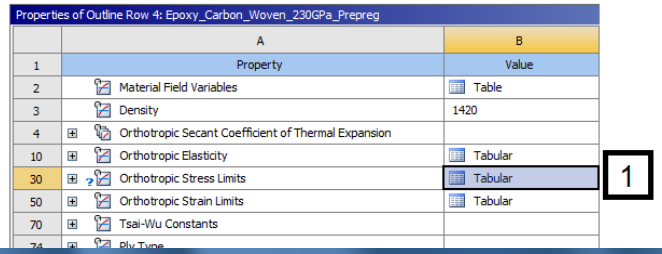
1. Define Variable Material Properties

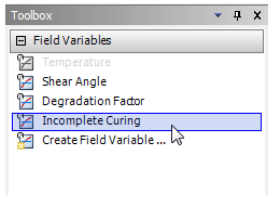
- In Engineering Data:
- Define up to 9 arbitrary field variables
  - Shear
  - Degradation Factor
  - Temperature
  - Void content
  - …
- Supported properties in R17.0:
  - Elasticity
  - Stress limits
  - Strain limits
  - Puck for woven
- Benefit from new Excel interface to fill tabular data

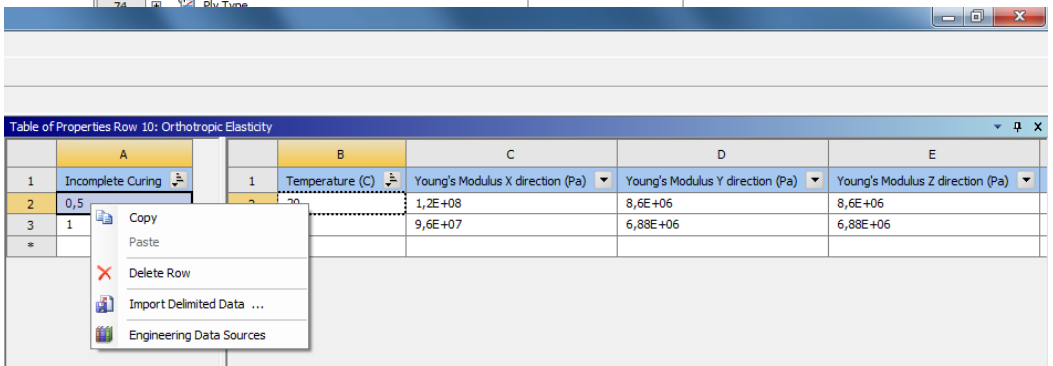












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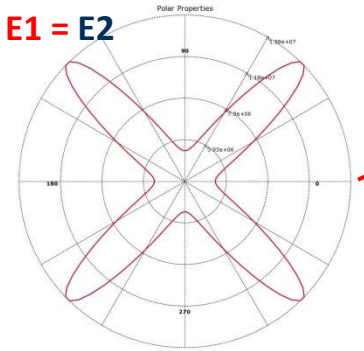
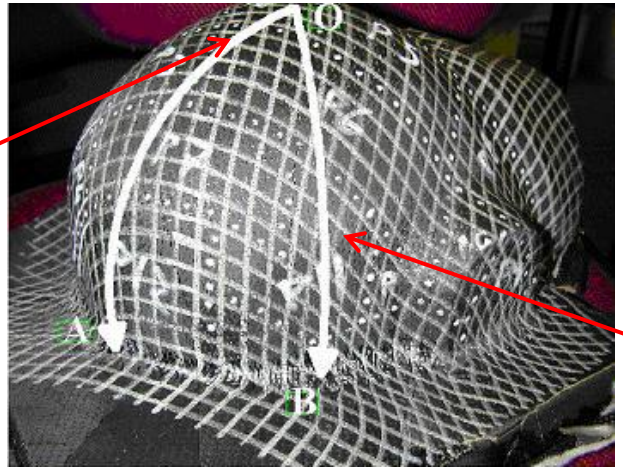
Why Shear Dependency?

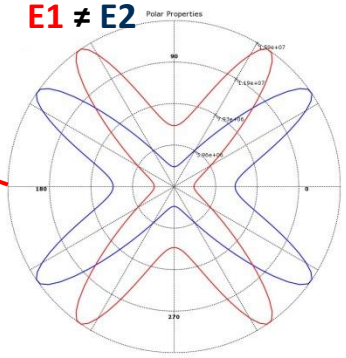
- Draping simulation or direct measurements allow you to include the shear distortion effect of a fabric in your simulation.



No shear



Composite draping: shear and wrinkling
(Dr M Sutcliffe, University of Cambridge, UK)



30° shear

Shear has significant influence on the effective material characteristics.

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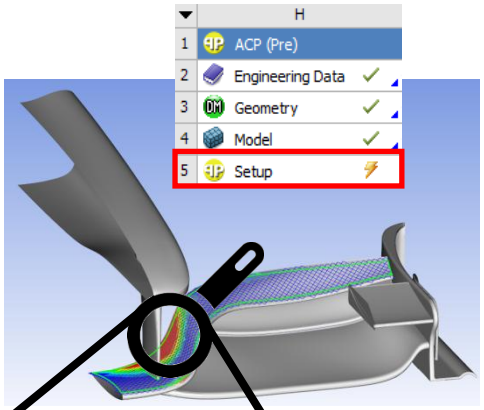
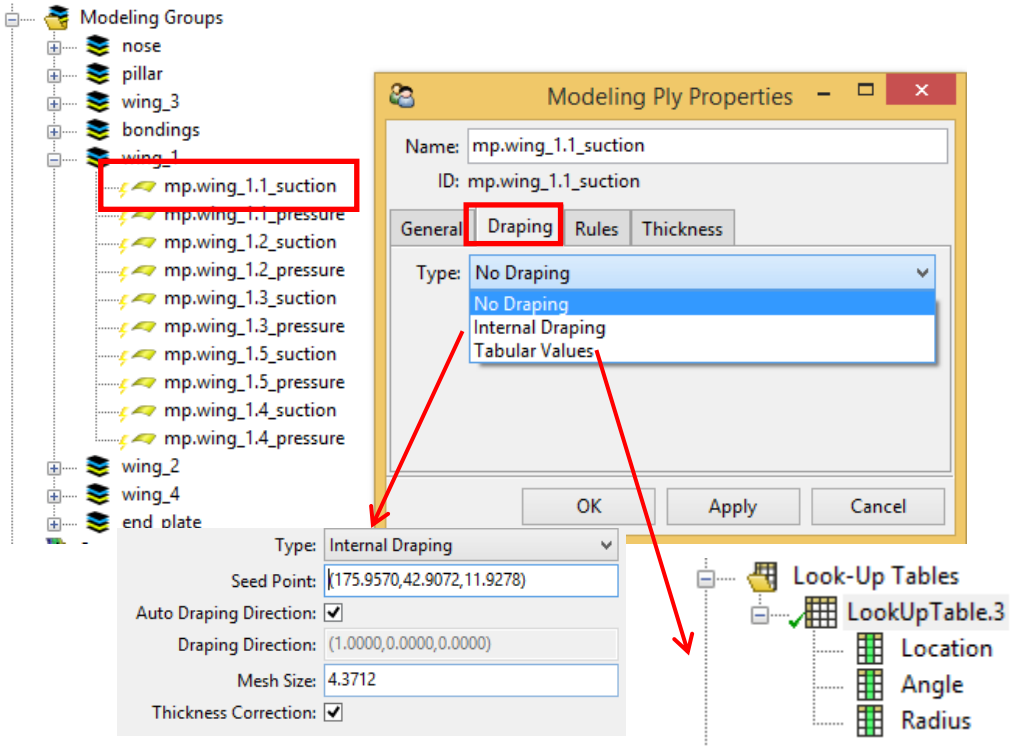
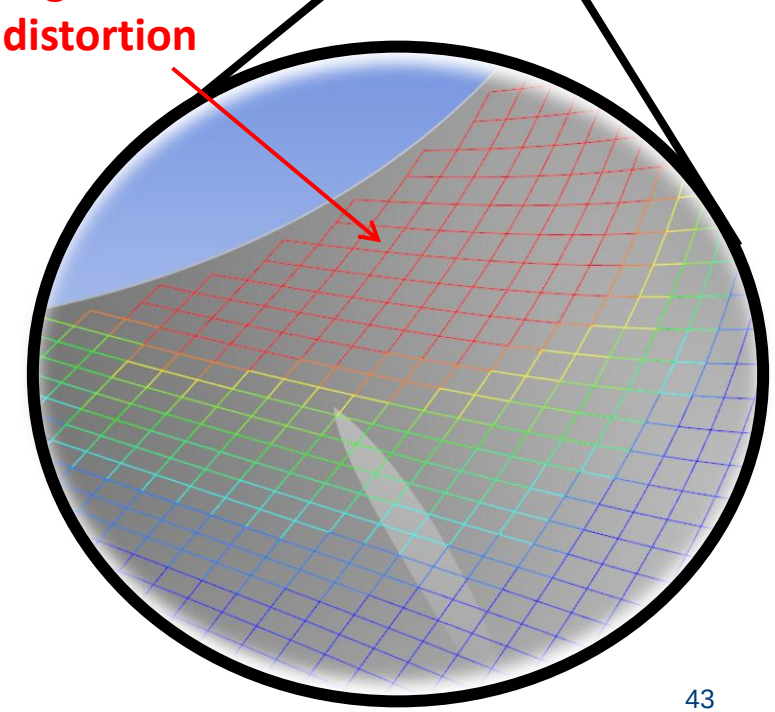
2. Draping in ACP

- Draping allows you to evaluate the shear angle by
  - Simulation
  - External data: LookUp Table (CSV)







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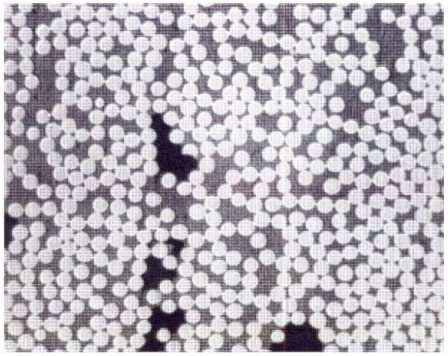
Degradation of Composites

Voids in Carbon-epoxy cross-section

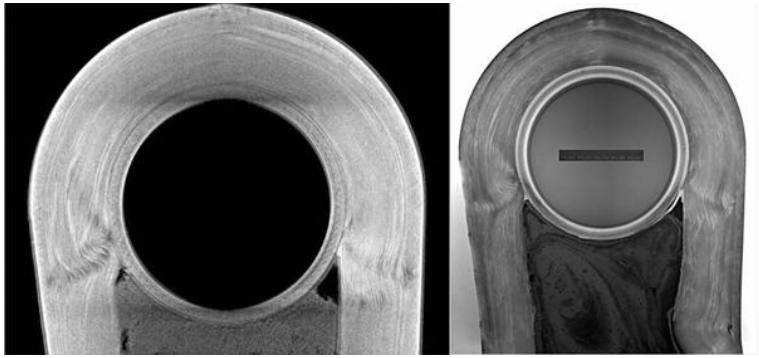
→ Reduction of the transverse and out-of-plane properties



(Prof IM Daniel, Northwestern University, USA)

Fiber waviness and uncured sections

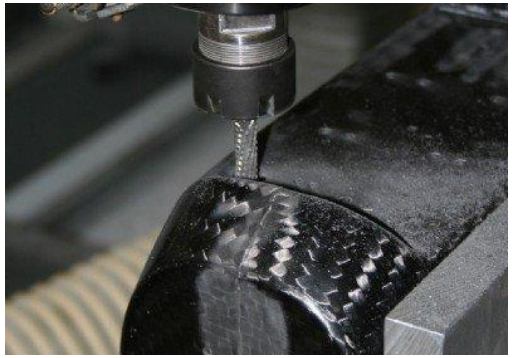
→ High variation in stiffness and strength



http://www.dtbtest.com/

Finishing (milling cutting etc.)

→ Introduction of failure origins



http://www.mtdcnc.com/

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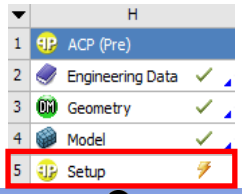
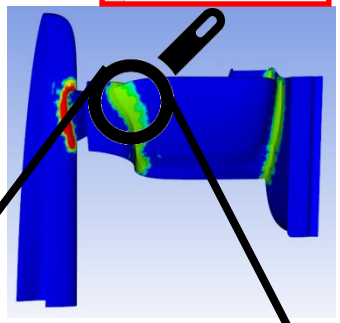
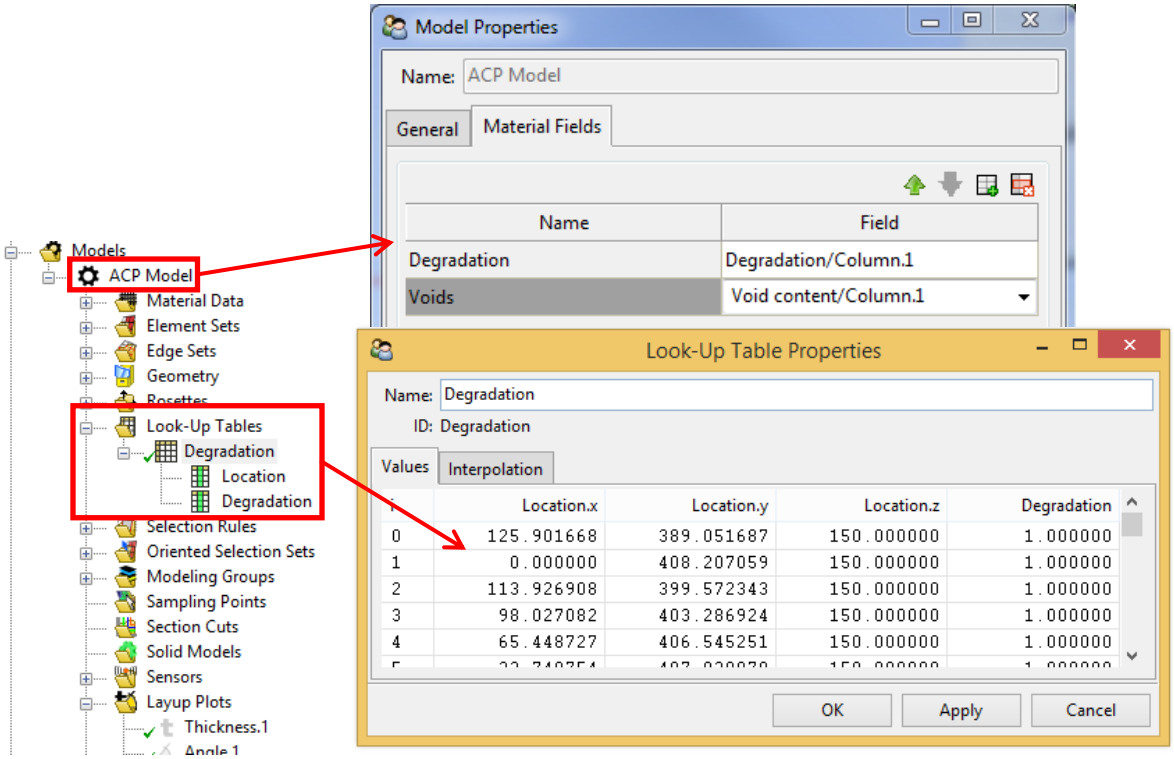
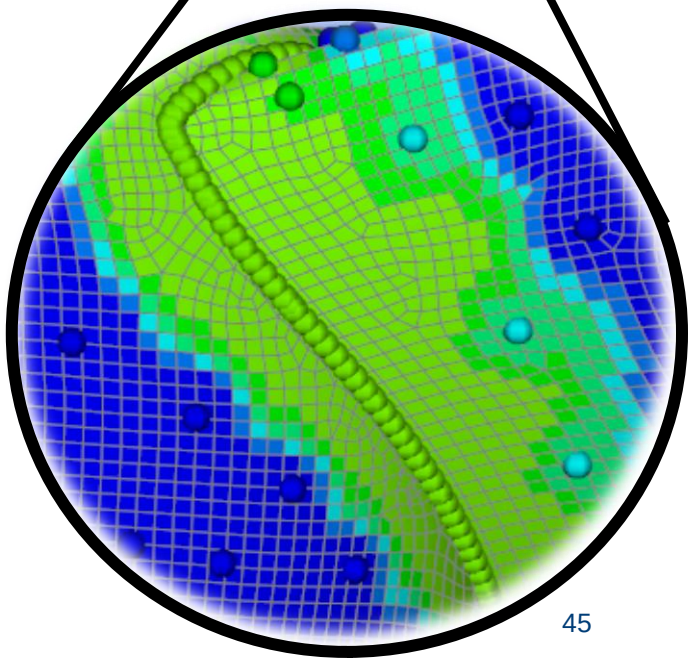
3. Specify Variable Material Fields

- Define a 3D look-up table (CSV interface)
- Mark as material field
- Fully considered by the solver and in ACP Post.









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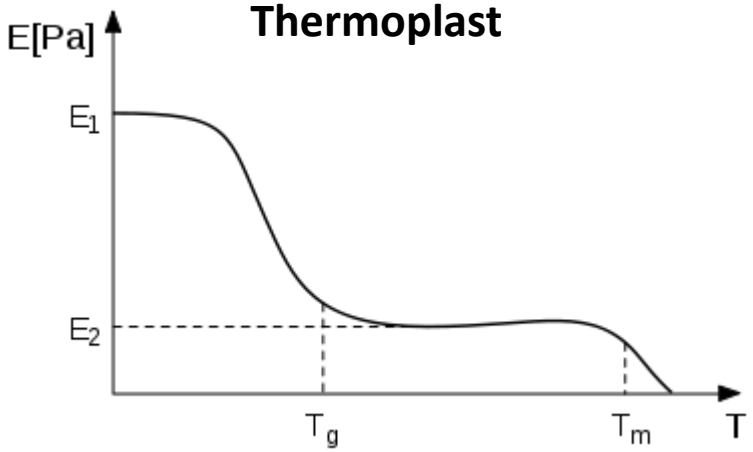
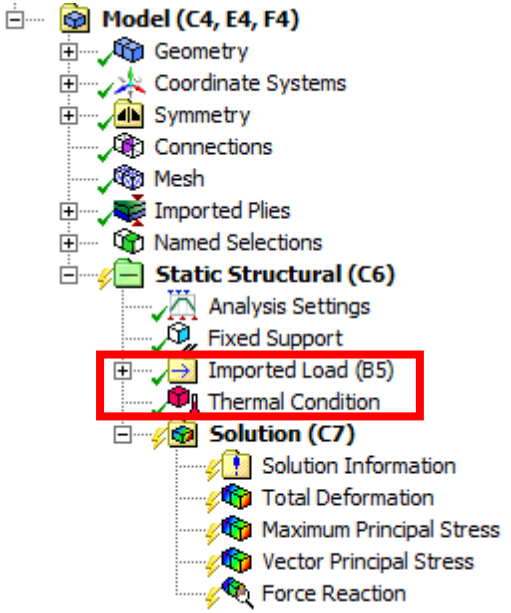
4. Temperature

- Most resin systems and therefore also composites are sensitive to temperature.

- Thermal loading can be defined through different methods:
  - Thermal analysis
  - Mechanical
  - External data





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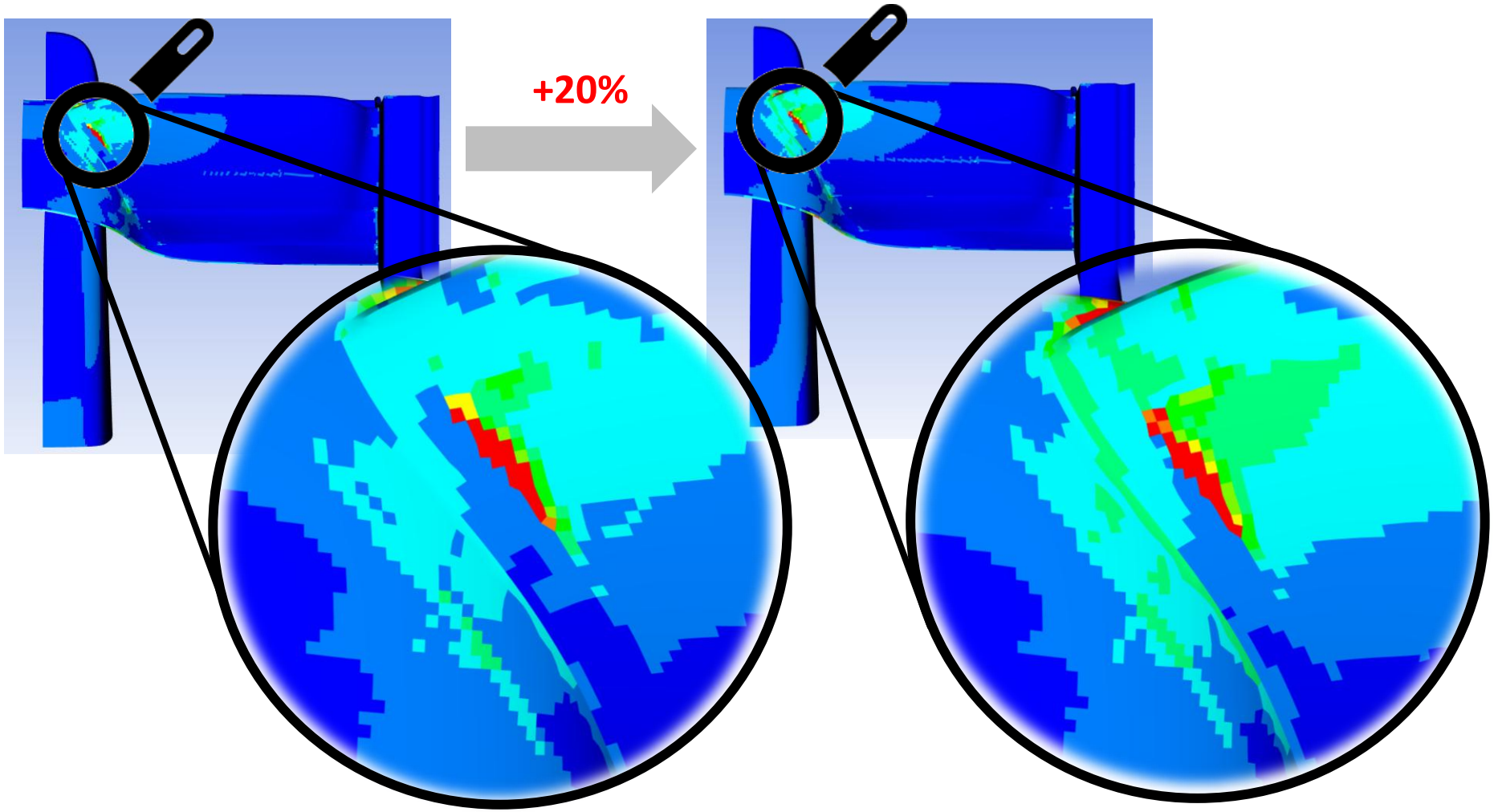
Inverse Reserve Factors – Constant vs. Variable Material Data



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Shell-based Composite Analysis

Solid Composite Analysis

Additional Features

Define Variable Material Properties

ANSYS Composite Cure Simulation

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Why cure simulation is needed?

- Prediction of final shape
  - Springback
  - Compensation in tool geometry
  - Residual stresses

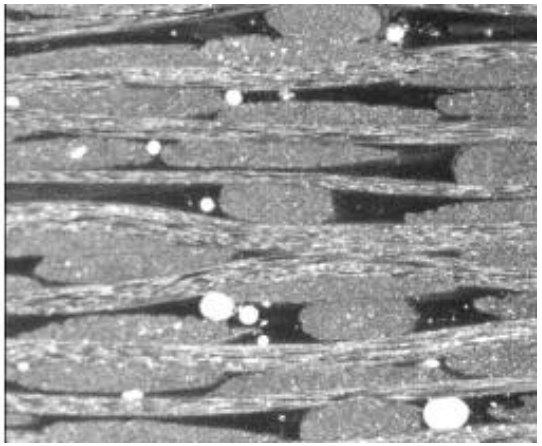
→ Dimensional Accuracy

- Prediction of cure quality
  - Cure status
  - Resin burn
  - Thermal tool cooling, …

→ Structural Accuracy

→ impacting on final product performance and quality

http://www.compositesworld.com/articles/composites-steady-radio-telescope-reflector



https://www.fose1.plymouth.ac.uk/sme/MATS347/MATS347C6%20RTM.htm

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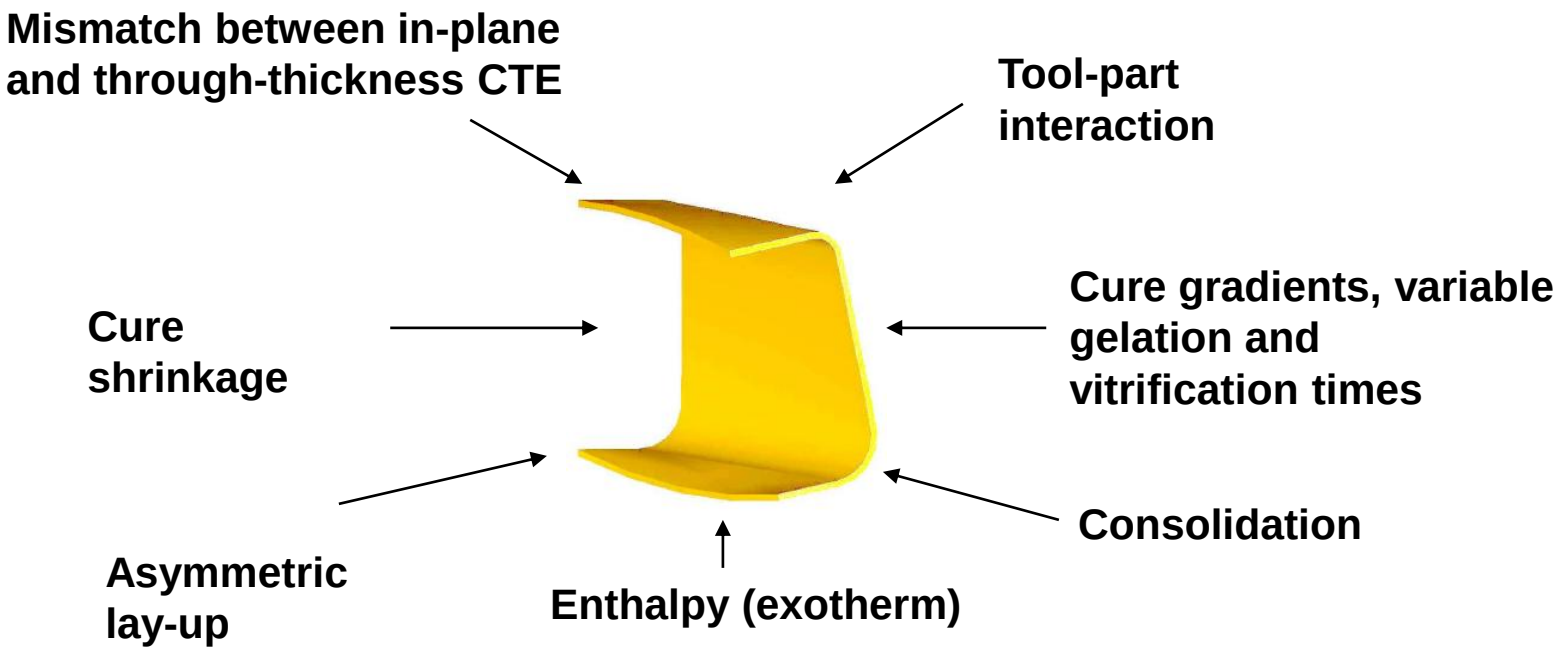
Sources of residual stresses and distortions



- Residual stresses that develop during cure lead to distortion and/or cracking significantly impacting on the final product performance
- Developed in partnership with LMAT Ltd.

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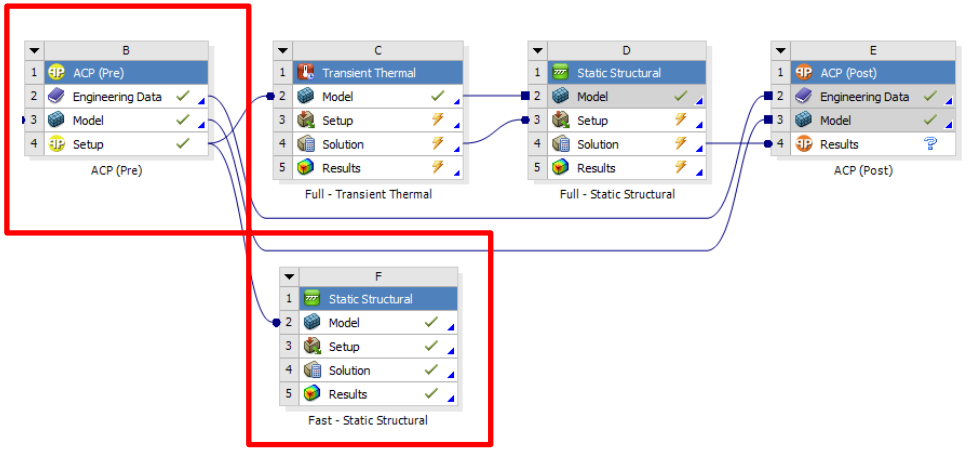
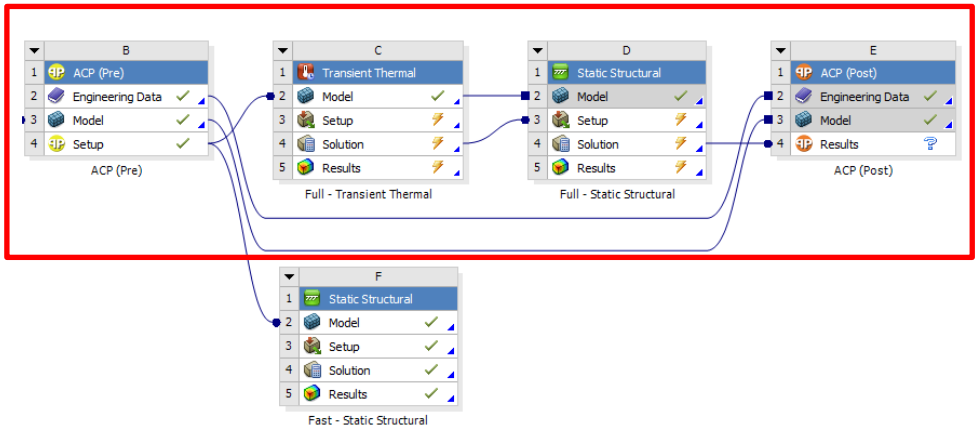
New ANSYS Cure Simulation Solution

- Fast cure simulation
  - For thin composite structures assuming known and uniform temperature distribution within the structure
  - Focus on prediction for distortion wrt. changes in laminate layup
    → designer level



- Full cure simulation
  - For thick composite structures where thermal heat generation from chemical reaction is dominant and non uniform
  - Transient thermal problem is solved and coupled to structural analysis
  - Focus on prediction for distortion and residual stresses as well as cure status, consolidation status
    → expert level with highest accuracy



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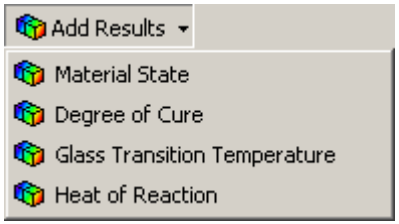
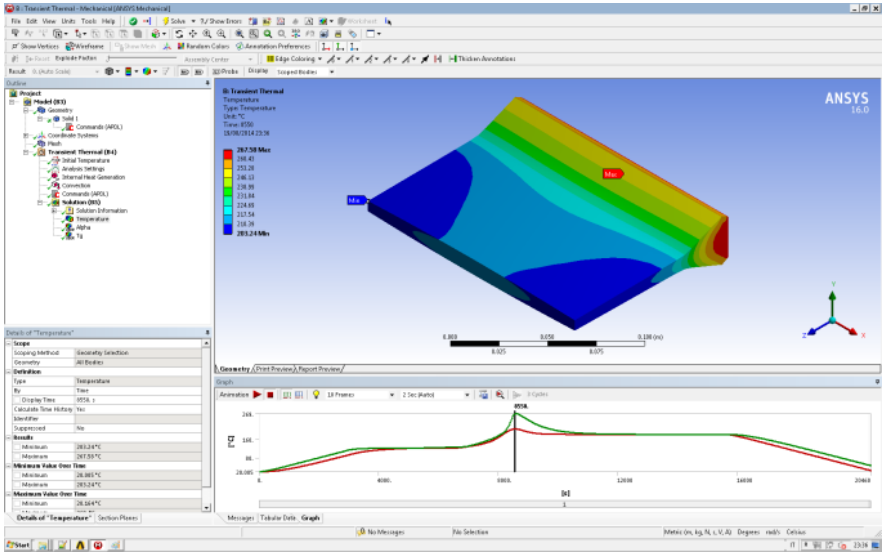
New ANSYS Cure Simulation Solution – Full Cure Simulation

- Results in Thermal & Mechanical



- Results in Mechanical



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Summary

- Intuitive workflow for composite modeling
- Quick postprocessing
- Solid modeling of composites
  uses the same workflow
- Composite design studies - Optimize your design before you build the first prototype
- Simple “drag-and-drop” multiphysics
- One single framework - ANSYS Workbench
- Input of Variable Material Properties
- ANSYS Composite Cure Simulation

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Vielen Dank für Ihr Interesse!

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