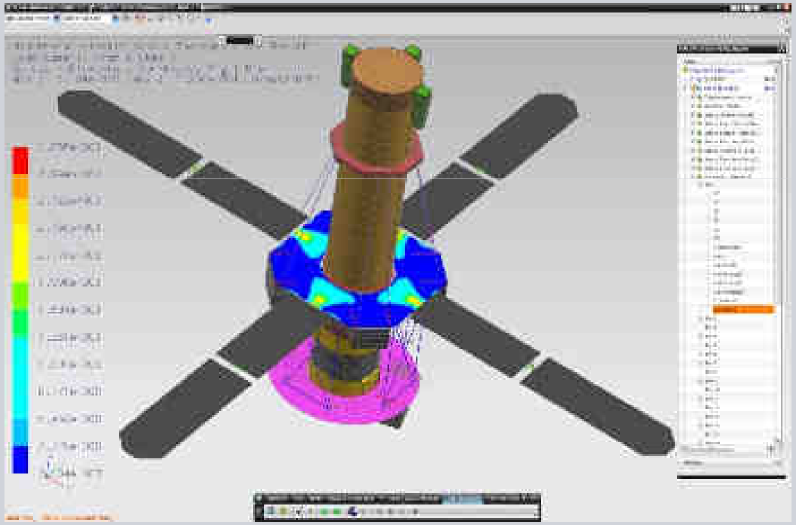
NX Laminate Composites

Product Overview

NX Laminate Composites Overview

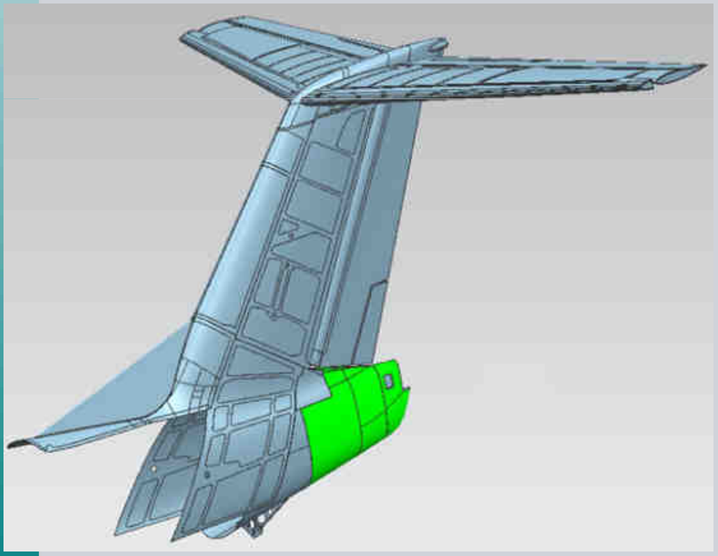
NX CAE product for finite element analysis of laminate structures featuring:

- Intuitive ply and laminate definition tools
- Efficient validation of composites design
- Powerful laminate optimization engine
- Easy-to-use hand layup manufacturing process simulation using:
  - Ply-based modeling
  - Draping and flat pattern creation



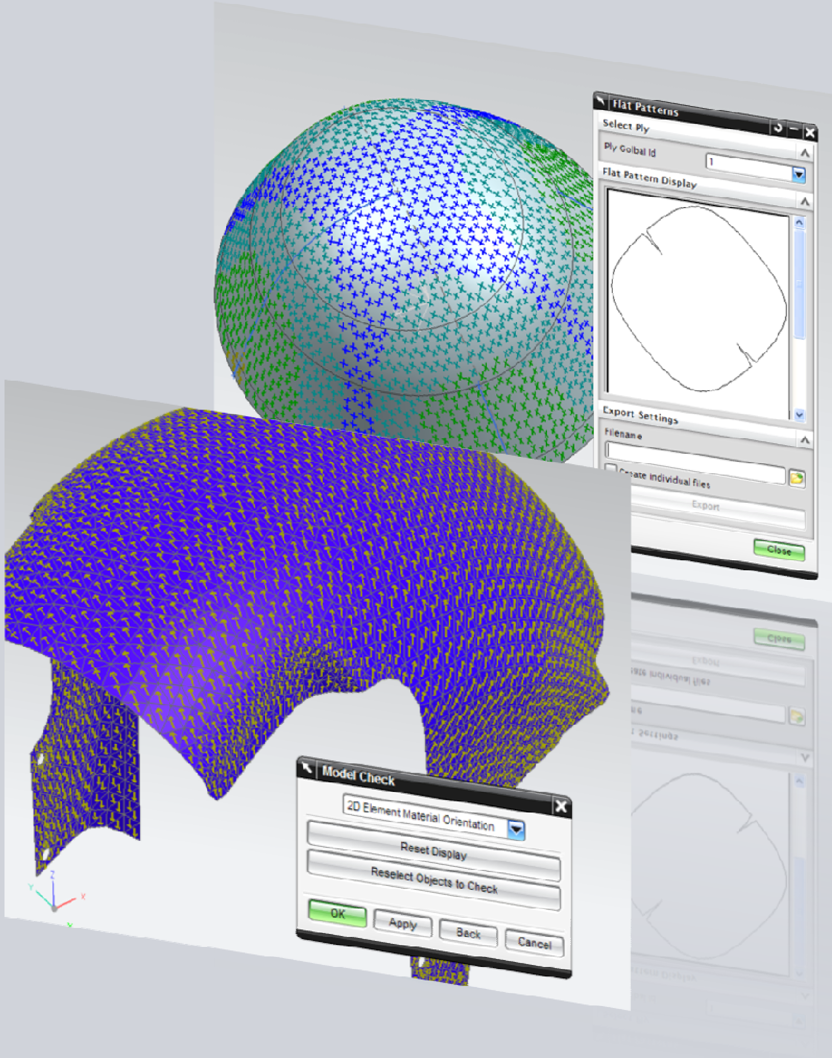
NX Laminate Composites Benefits

- Reduce laminate model creation time
  - Multiple approaches
- Improve finite element modeling accuracy
  - Accounting for distorted fiber orientations
- Enhance manufacturability
  - Assessing and controlling fiber shear
- Quickly assess viability
  - Advanced post-processing tools



NX Laminate Composites Core Capabilities

- Laminate Modeling
- Composite Materials
- Laminate Validation
- Optimization
- Laminate Failure
- NX FE Solver Interfaces
- Laminates Post Reporting



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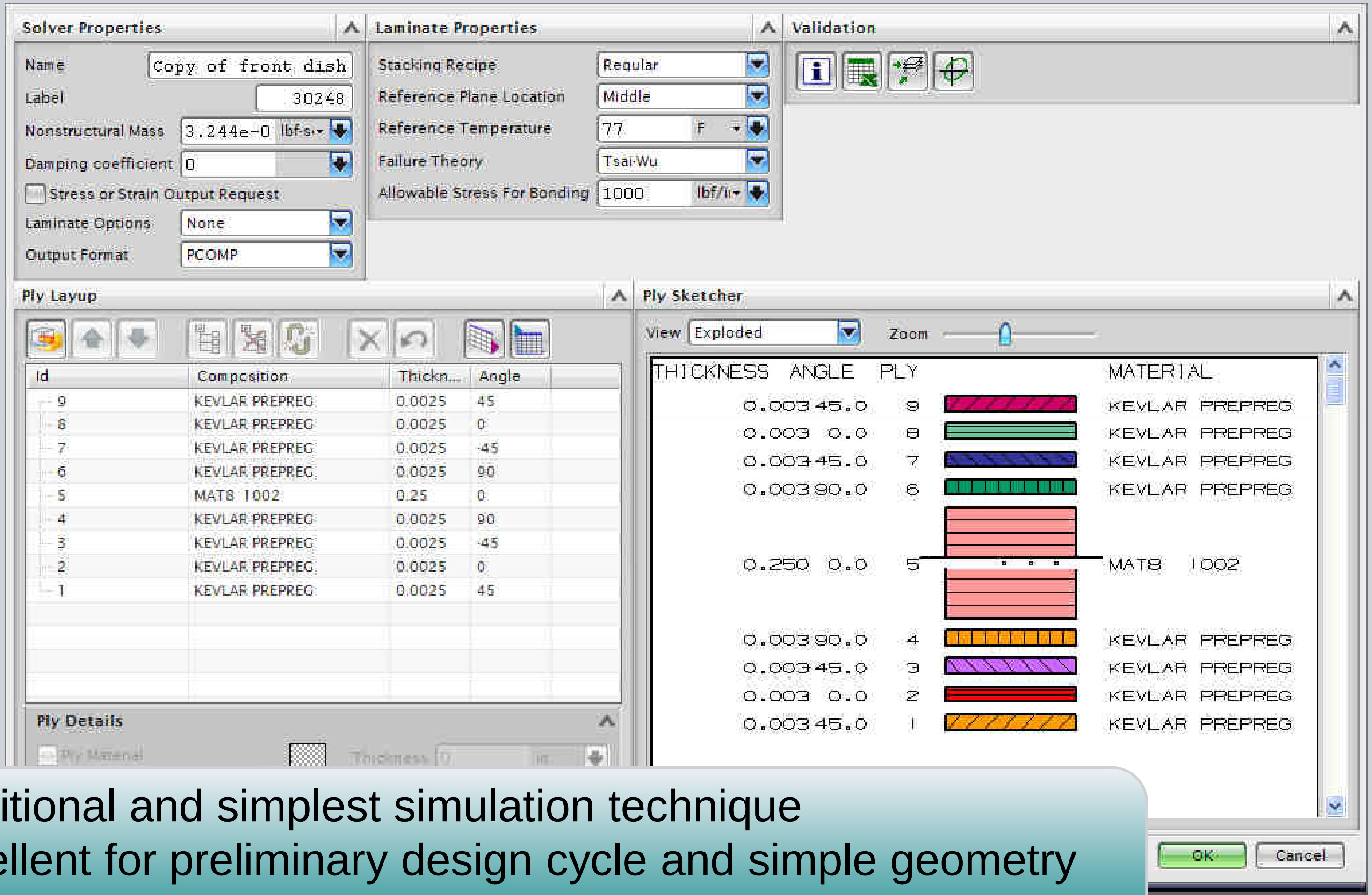
Laminate Modeling: Zone Based



- Traditional and simplest simulation technique
- Excellent for preliminary design cycle and simple geometry
- Laminate definition applied to finite element collectors

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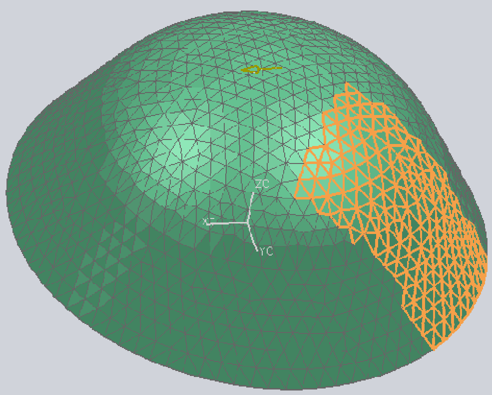
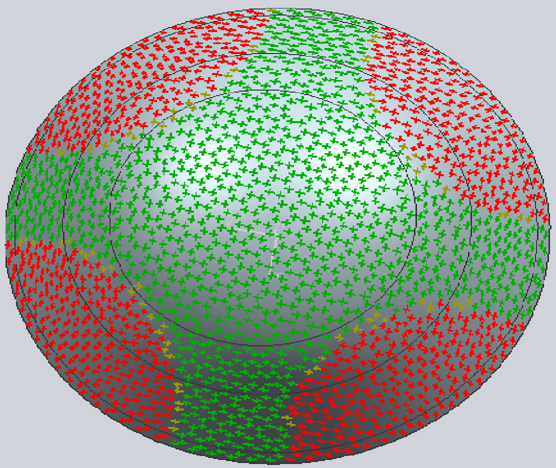
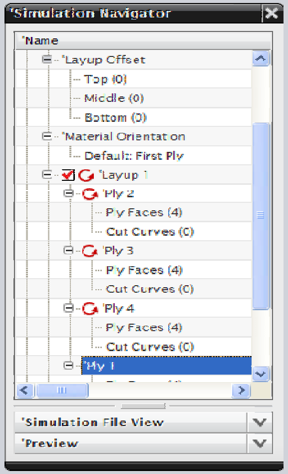
Laminate Modeling: Ply Based

Ply-based modeling

- Plies are laid on CAE polygon faces or shell elements
- Allows for efficient laminate creation in many cases
- Software automatically computes the physical properties based on the ply definitions







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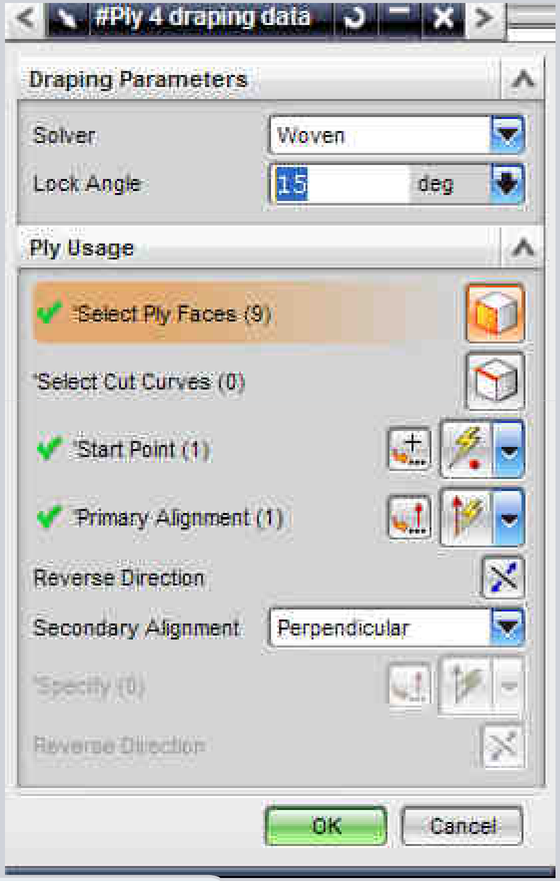
Laminate Modeling: Draping

Draping algorithm options

- Unidirectional
  - Fibers do not stretch and remain parallel
  - Fibers can slide relative to each other
- Woven
  - Fishnet algorithm orients warp & weft fibers
  - Fibers do not stretch, but can rotate (shear) relative to each other
  - Lock angle is the maximum allowed shear between warp & weft fibers
- None
  - Projection of the ply directions using the material orientation as the 0 degree reference



For stability, the draping algorithm uses the 2D mesh associated to the selected surfaces

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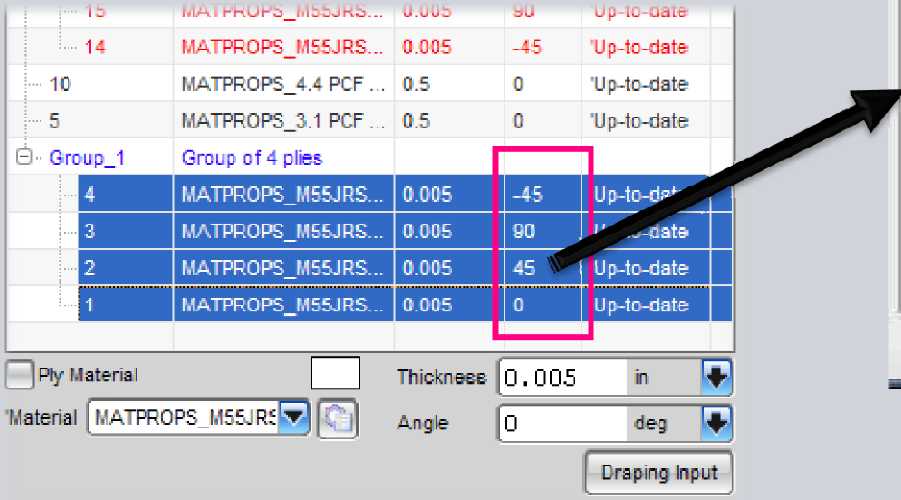
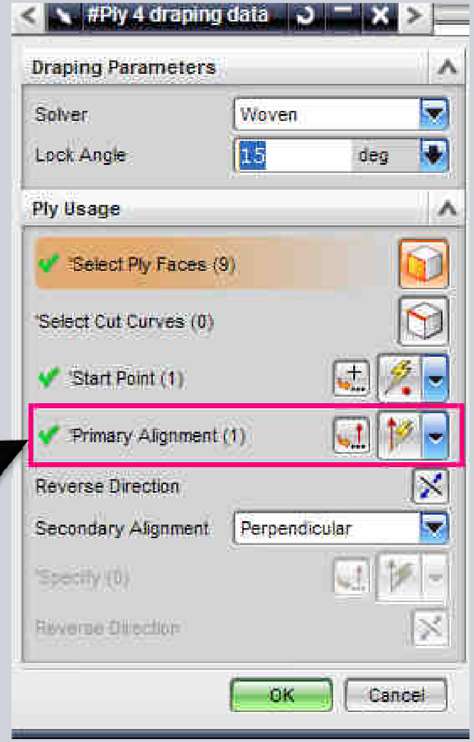
Laminate Modeling: Draping

Primary Alignment

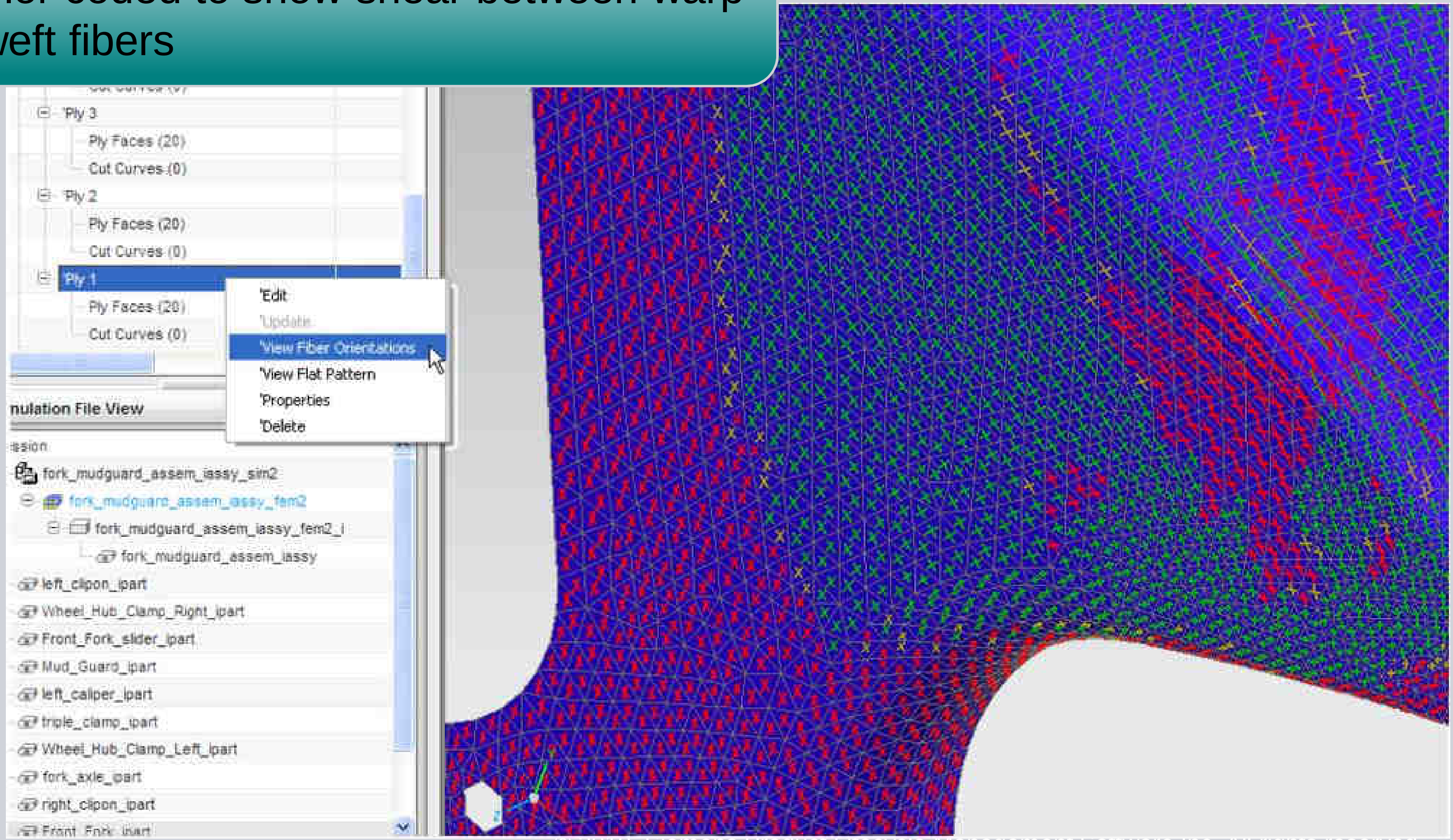
- The angle specified in the Layup Modeler is relative to the primary alignment direction
- This allows fast and efficient orientation of several plies at once





Laminate Modeling: Draping

Draped fiber orientations visualization
- Color coded to show shear between warp & weft fibers



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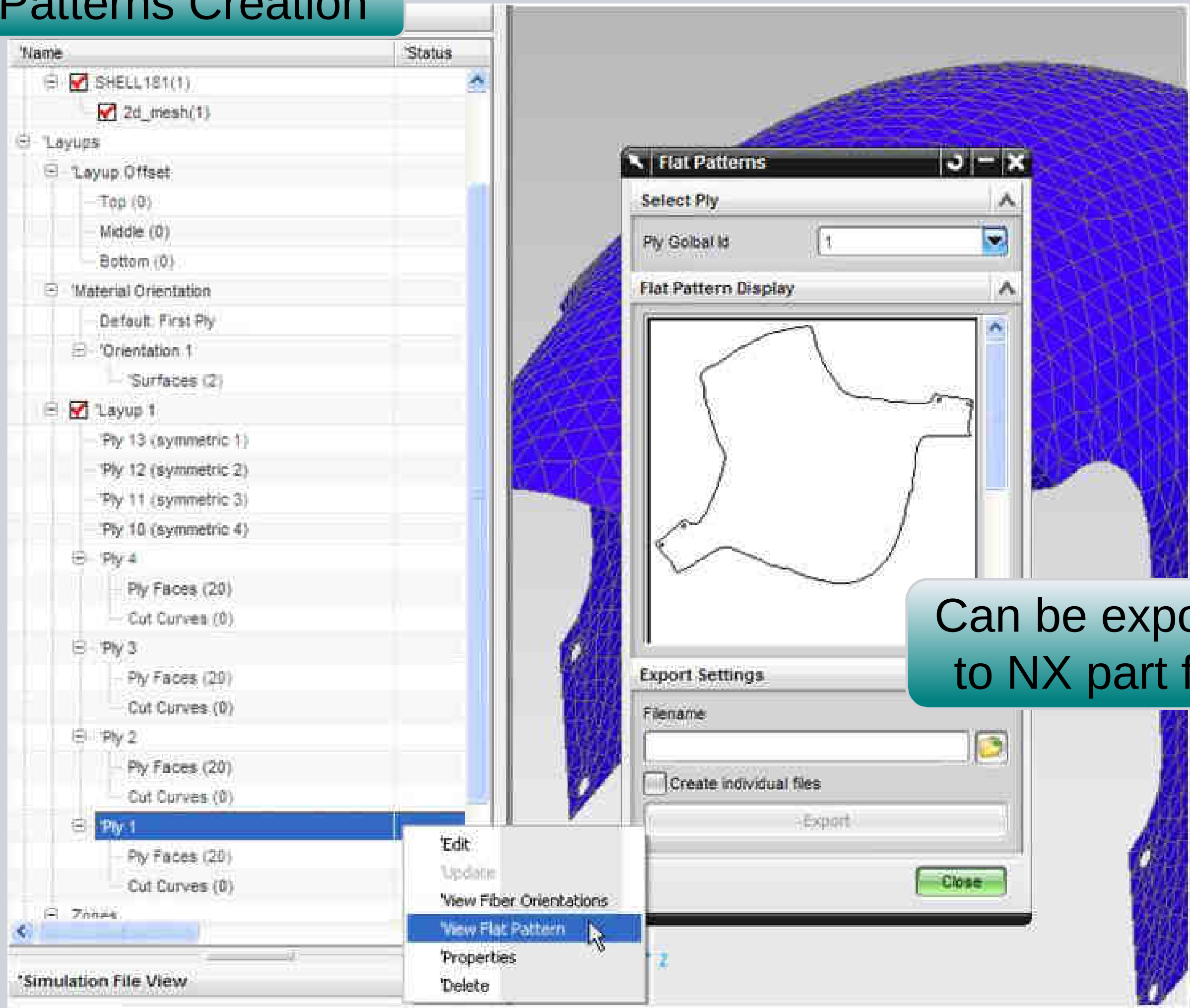
Laminate Modeling: Draping

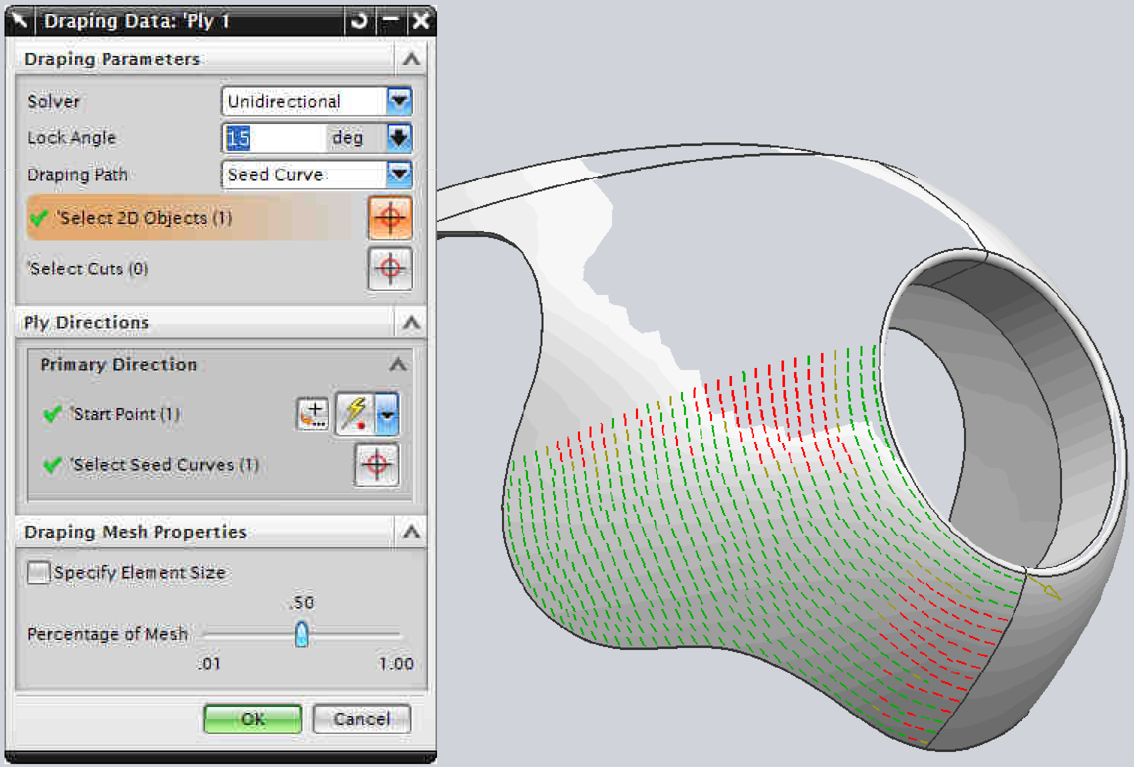
Flat Patterns Creation



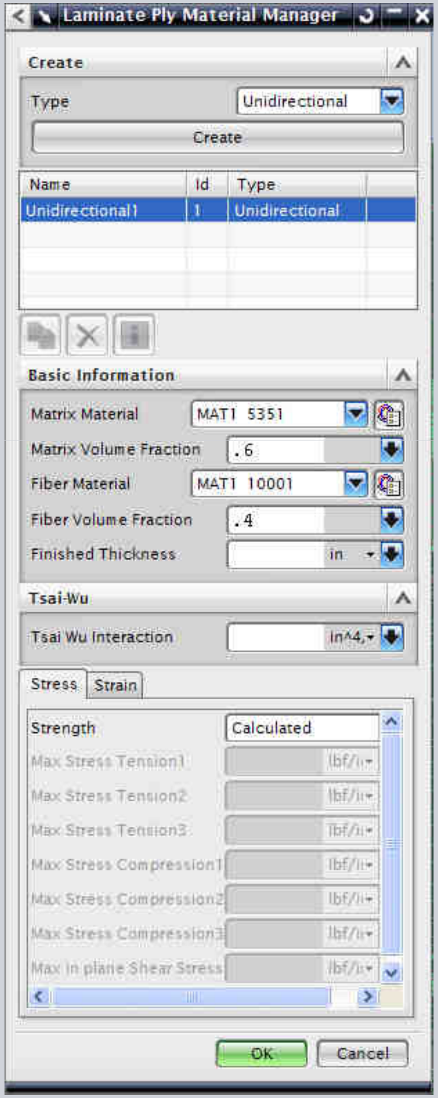
Can be exported to NX part files

Laminate Modeling: Draping

- Seed curves for primary fiber alignment
- User-selectable drape mesh size



Composite Materials
Micromechanics-based Ply Materials



Ply Material Creation

- Create ply material from fiber and matrix materials information

Types

- Unidirectional Fiber
  - Rule of Mixtures, Hyer & al, Daniel & al
- Woven fiber
  - Berthelot
- Particulate Fiber
  - Mital & al
- Randomly Oriented Short Fiber
  - Berthelot

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Laminate Validation

Laminate Validation Output
- Stiffness matrices ABDS
- Equivalent engineering constants

	A	B	C	D	E	F	G	H	I
1	NX Laminate								
2									
3									
4	Laminate Name :		Copy of front dish						
5									
6									
7	Stiffness Matrices A,B,D,S								
8									
9		166.699E+3	86.893E+3	000.000E+0			000.000E+0	000.000E+0	000.000E+0
10	A =	86.893E+3	166.699E+3	000.000E+0		B =	000.000E+0	000.000E+0	000.000E+0
11		000.000E+0	000.000E+0	40.884E+3			000.000E+0	000.000E+0	000.000E+0
12									
13		2.808E+3	1.479E+3	000.000E+0			1.075E+3	000.000E+0	
14	D =	1.479E+3	2.808E+3	000.000E+0		S =	000.000E+0	1.075E+3	
15		000.000E+0	000.000E+0	689.288E+0					
16									
17									
18	Laminate Equivalent Properties								
19									
20	Laminate is symmetric.								
21	Laminate is balanced.								
22									
23	Mass Density	3.704E-6	lbf-sec^2/in^4						
24									
25									
26		x	y	xy	yx	xz	yz		
27	E	449.650E+3	449.650E+3					lbf/in^2(psi)	
28	E (bending)	1.237E+6	1.237E+6					lbf/in^2(psi)	
29	NU			0.521	0.521			Unitless	
30	G			151.421E+3		3.980E+3	3.980E+3	lbf/in^2(psi)	
31	G (bending)			420.233E+3				lbf/in^2(psi)	
32	alpha	000.000E+0	000.000E+0	000.000E+0				1/F	
33	K	45.000E+3	45.000E+3	000.000E+0				Btu/sec-in-F	
34									

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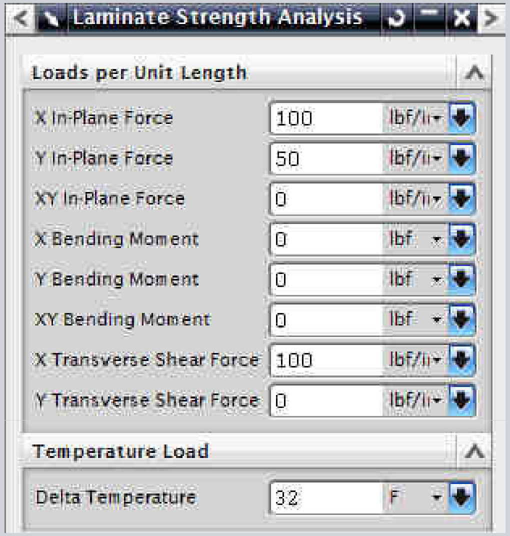
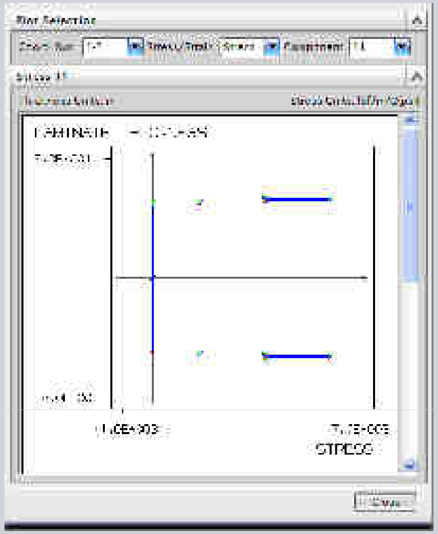
Laminate Validation



Strength Analysis
- Compute failure indices and margins of safety
- Compute ply strains and stresses



Summary Table															
Component	Ply ID	Computatio Location	Stress11	Stress22	Stress12	Stress Stress23	Stress31	Maximum Principal	Minimum Principal	Maximum Shear	Failure Index Ply	Bond	Margin of Safety Ply	Bond
			mN/mm^2(kPa)	mN/mm^2(kPa)	mN/mm^2(kPa)	mN/mm^2(kPa)	mN/mm^2(kPa)	mN/mm^2(kPa)	mN/mm^2(kPa)	mN/mm^2(kPa)	Unitless	Unitless	Unitless	Unitless
Stress11	1	Bottom	**9.4E+04**	-2.1E+03	2.5E-01	0.0E+00	0.0E+00	9.4E+04	-2.1E+03	4.8E+04	4.8E-03	0.0E+00	2.1E+02	Infinity
Stress22	10	Bottom	1.5E+04	**2.3E+04**	-7.1E+03	-7.3E+01	4.2E+01	2.7E+04	1.1E+04	8.2E+03	7.0E-03	5.3E-03	1.4E+02	1.9E+02
Stress12	10	Bottom	1.5E+04	2.3E+04	**-7.1E+03**	-7.3E+01	4.2E+01	2.7E+04	1.1E+04	8.2E+03	7.0E-03	5.3E-03	1.4E+02	1.9E+02
Stress23	7	Bottom	3.0E+03	2.3E+03	9.6E-02	**-1.3E+02**	0.0E+00	3.0E+03	2.3E+03	3.9E+02	3.7E-02	9.2E-03	2.6E+01	1.1E+02
Stress31	5	Middle	8.0E+01	-1.2E+01	2.2E-03	0.0E+00	**1.4E+02**	8.0E+01	-1.2E+01	4.6E+01	8.0E-09	1.0E-02	1.2E+08	9.9E+01
Maximum Principal	1	Bottom	9.4E+04	-2.1E+03	2.5E-01	0.0E+00	0.0E+00	**9.4E+04**	-2.1E+03	4.8E+04	4.8E-03	0.0E+00	2.1E+02	Infinity
Minimum Principal	3	Bottom	-5.9E+04	5.4E+03	-2.5E-01	-1.0E+02	0.0E+00	5.4E+03	**-5.9E+04**	3.2E+04	2.8E-01	7.4E-03	2.6E+00	1.3E+02
Maximum Shear	1	Bottom	9.4E+04	-2.1E+03	2.5E-01	0.0E+00	0.0E+00	9.4E+04	-2.1E+03	**4.8E+04**	4.8E-03	0.0E+00	2.1E+02	Infinity
Failure Index - Ply	3	Bottom	-5.9E+04	5.4E+03	-2.5E-01	-1.0E+02	0.0E+00	5.4E+03	-5.9E+04	3.2E+04	**2.8E-01**	7.4E-03	2.6E+00	1.3E+02
Failure Index - Bond	5	Middle	8.0E+01	-1.2E+01	2.2E-03	0.0E+00	1.4E+02	8.0E+01	-1.2E+01	4.6E+01	8.0E-09	**1.0E-02**	1.2E+08	9.9E+01
Margin of Safety - Ply	3	Bottom	-5.9E+04	5.4E+03	-2.5E-01	-1.0E+02	0.0E+00	5.4E+03	-5.9E+04	3.2E+04	2.8E-01	7.4E-03	**2.6E+00**	1.3E+02
Margin of Safety - Bond	5	Middle	8.0E+01	-1.2E+01	2.2E-03	0.0E+00	1.4E+02	8.0E+01	-1.2E+01	4.6E+01	8.0E-09	1.0E-02	1.2E+08	**9.9E+01**
Absolute Maximum			**9.4E+04**	**2.3E+04**	**-7.1E+03**	**-1.3E+02**	**1.4E+02**	**9.4E+04**	**-5.9E+04**	**4.8E+04**	**2.8E-01**	**1.0E-02**		
Absolute Minimum													**2.6E+00**	**9.9E+01**

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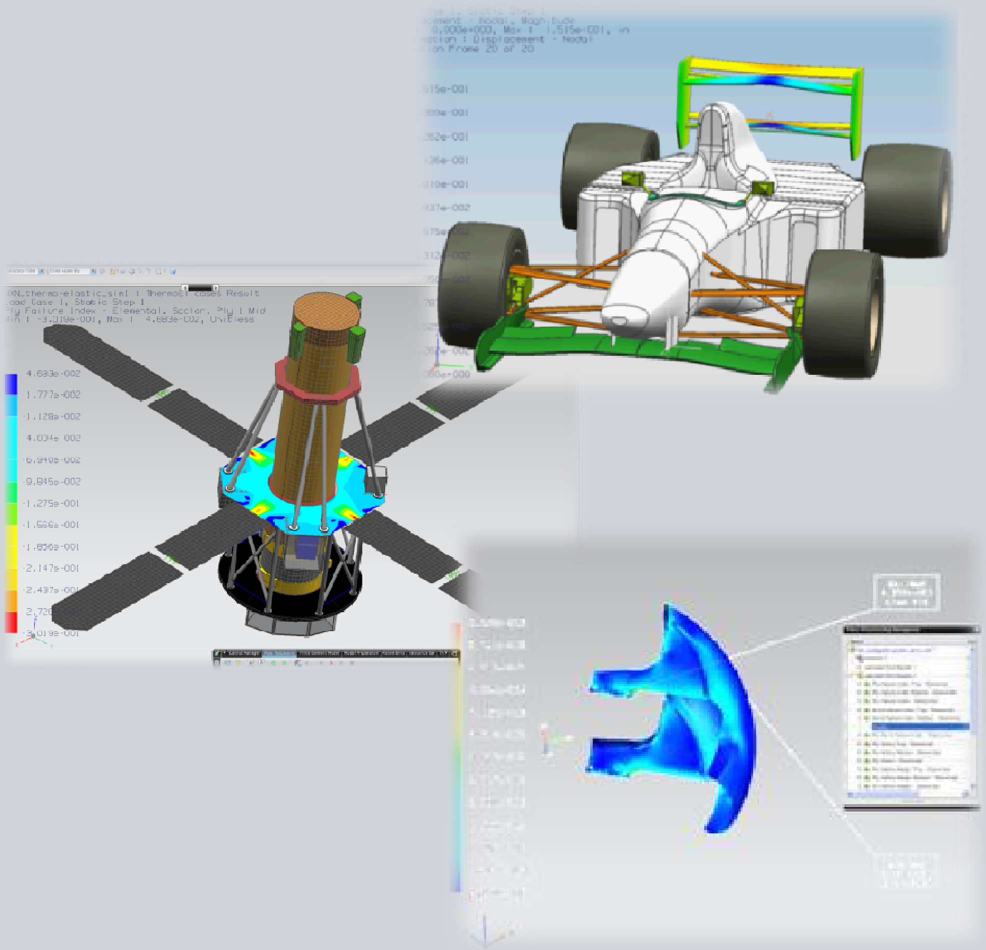
Laminate Failure

Supported Classical Failure Theories:

- Maximum Stress
- Maximum Strain
- Tsai-Wu
- Hill
- Hoffman
- LaRC0* (planned)



Composite Optimization

Laminate Optimization Tool

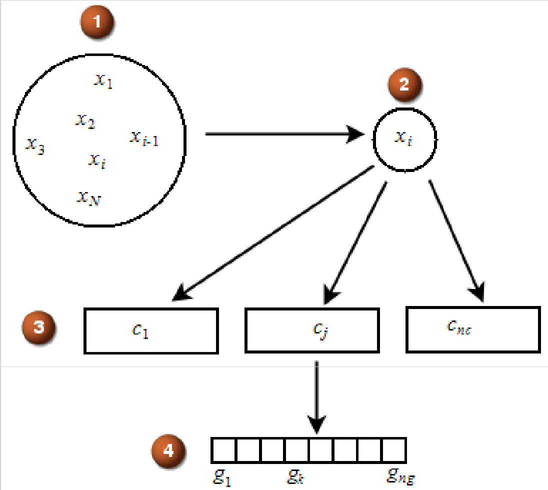
- Goal is to optimize the fundamental behavior of the laminate
- Optimizes a single laminate physical property (equivalent to coupon testing and optimization)

Built around a Genetic optimizer, it can handle

- Continuous variables such as an orientation angle
- Discrete variables such as the existence of a ply or selection of a material from a list

The optimization provides 5 laminate definitions that come the closest to fulfilling the objectives

- You can select one of the five to replace the original laminate

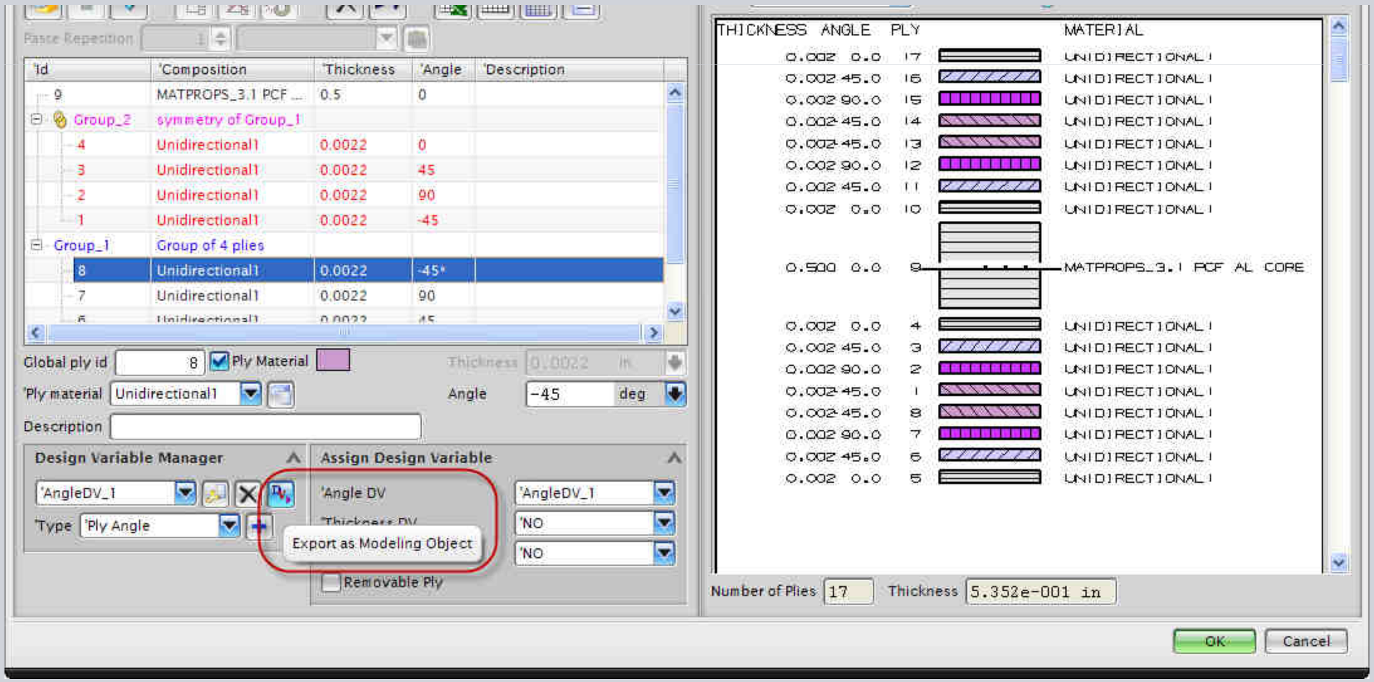


1	Population
2	Individual
3	Chromosomes
4	Genes

Composite Optimization

NASTRAN Design Optimization Solution

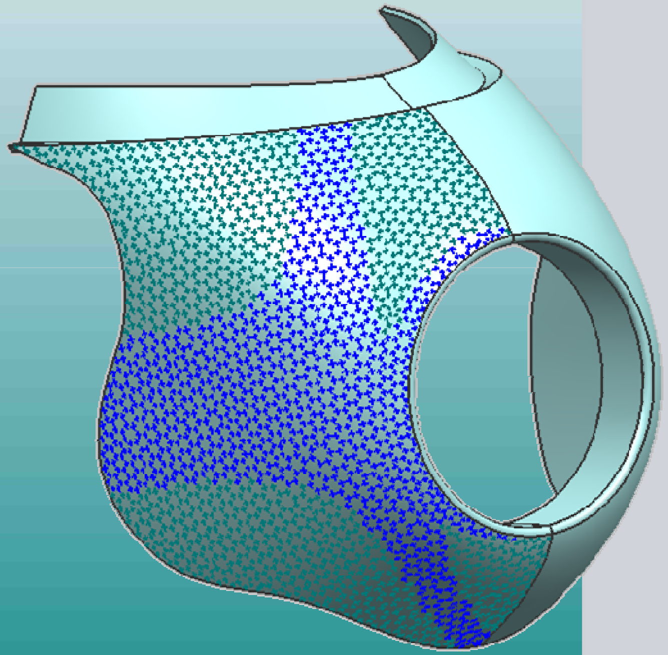
- Graphically create ply thickness and orientation design variables in NXLC Laminate Modeler
- Perform optimization at the simulation level



NX FE Solver Interfaces

Laminate Element Type Support for Each Solver

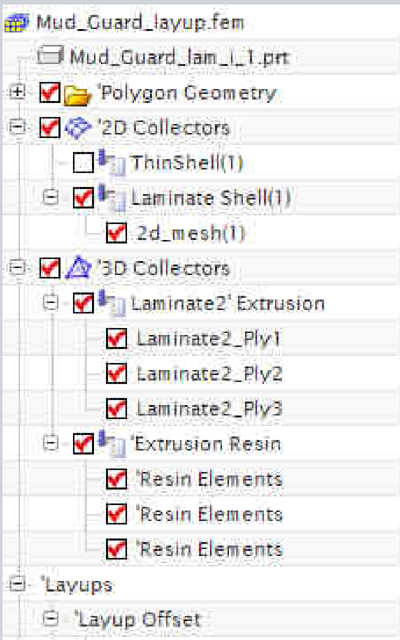
- NASTRAN
  - PCOMP – MEM/BEND/SMEAR/SMCORE
  - PSHELL
- ANSYS
  - 2D
    - SHELL181, SHELL99, SHELL91, SOLSH190
  - 3D
    - SOLID186, SOLID191, SOLSH190
  - Support zero-thickness layers for ANSYS SOLID186
- ABAQUS
  - 2D
    - S8R, S8R5, S4, S4R, STRI65, S3, S3R
  - 3D
    - SC6R, SC8R
- LS-DYNA
  - 2D
    - *ELEMENT_SHELL
  - 3D
    - *ELEMENT_TSHELL

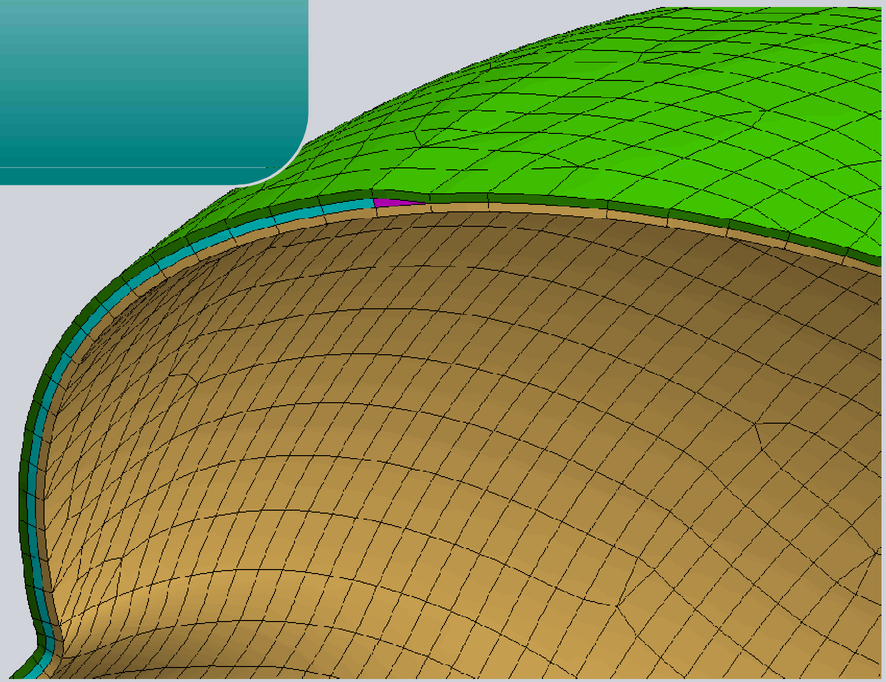


Laminate Modeling: 3D Extrusion

Inflate layup to 3D laminate ANSYS mesh

- Normal extrusion from 2D meshed faces
- Each ply becomes a layer of solids
- Ply drops modeled as wedge, brick or pyramid elements





Laminate Modeling: FiberSIM Interface

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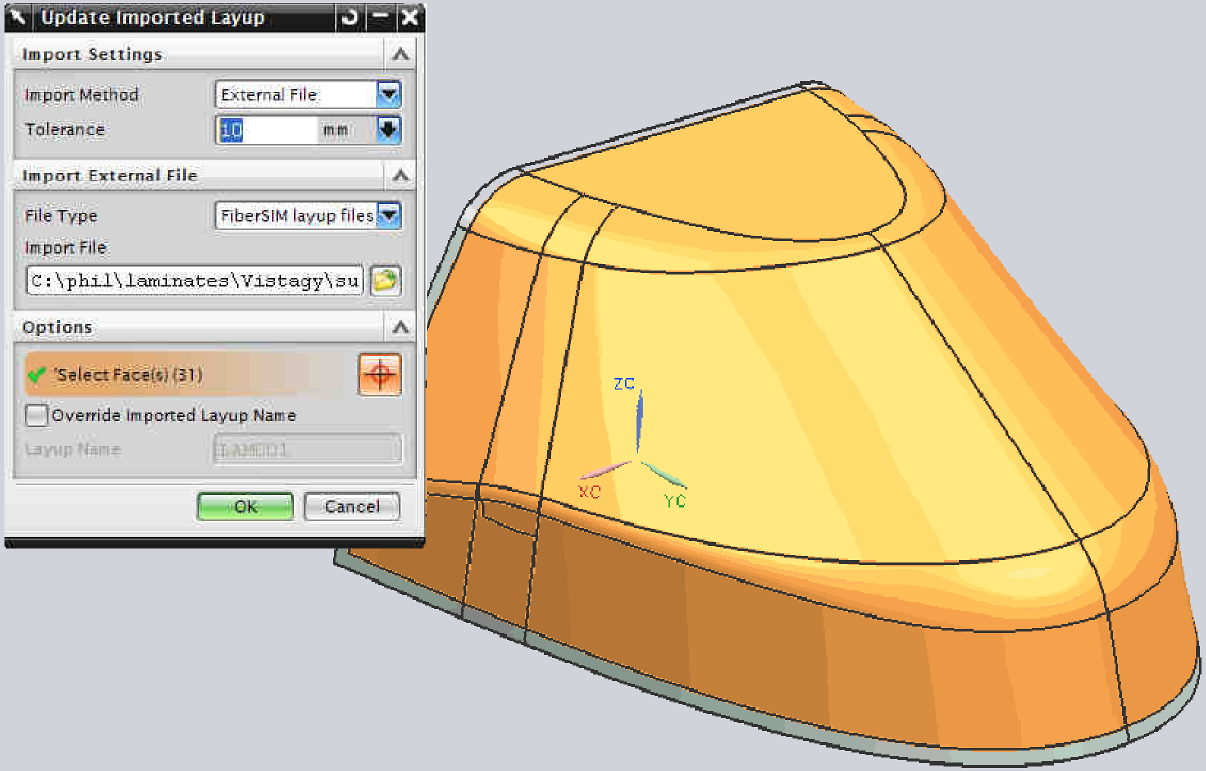
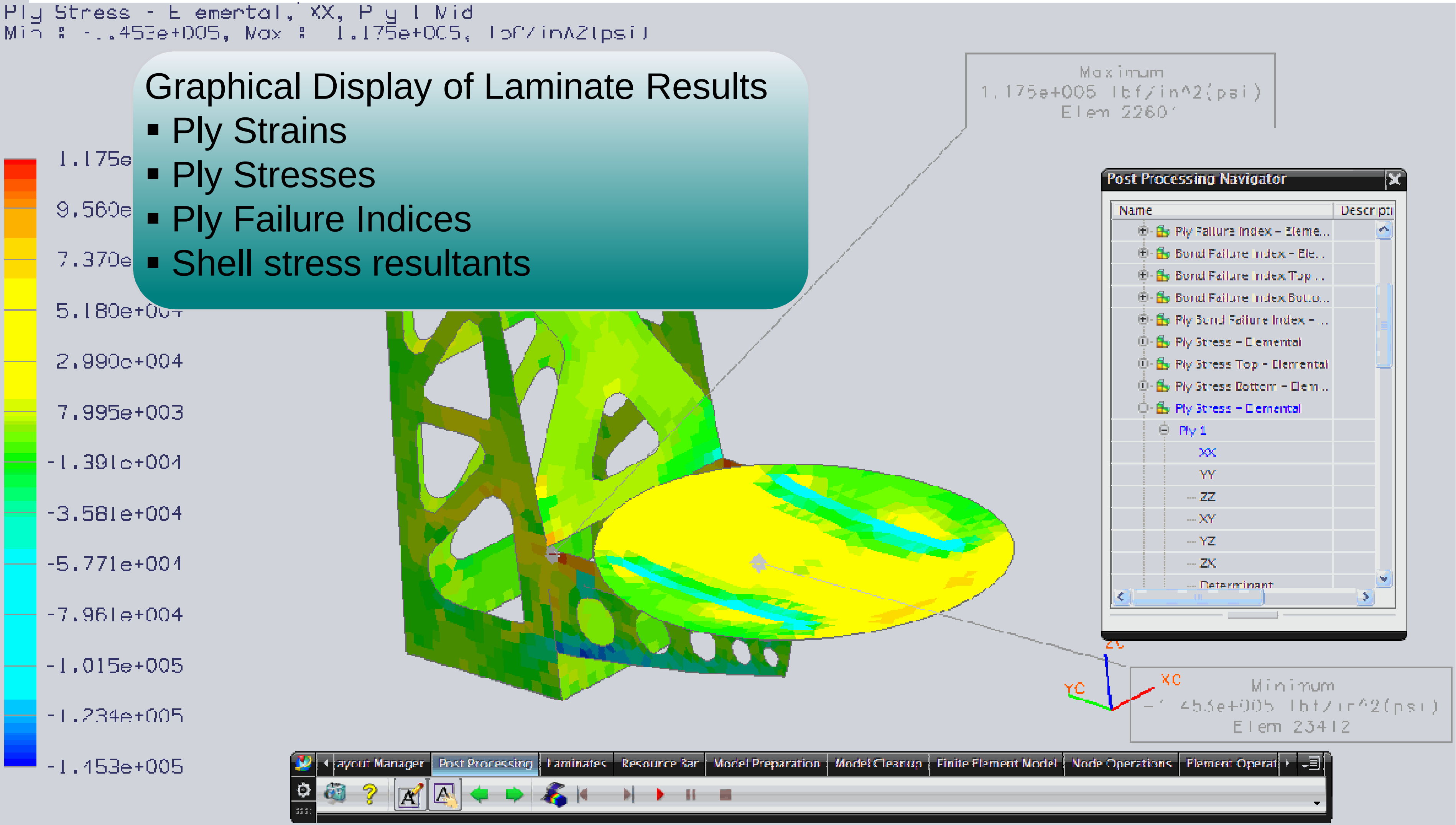
Import layups and fiber orientations from FiberSIM xml file



Laminates Post-Processing

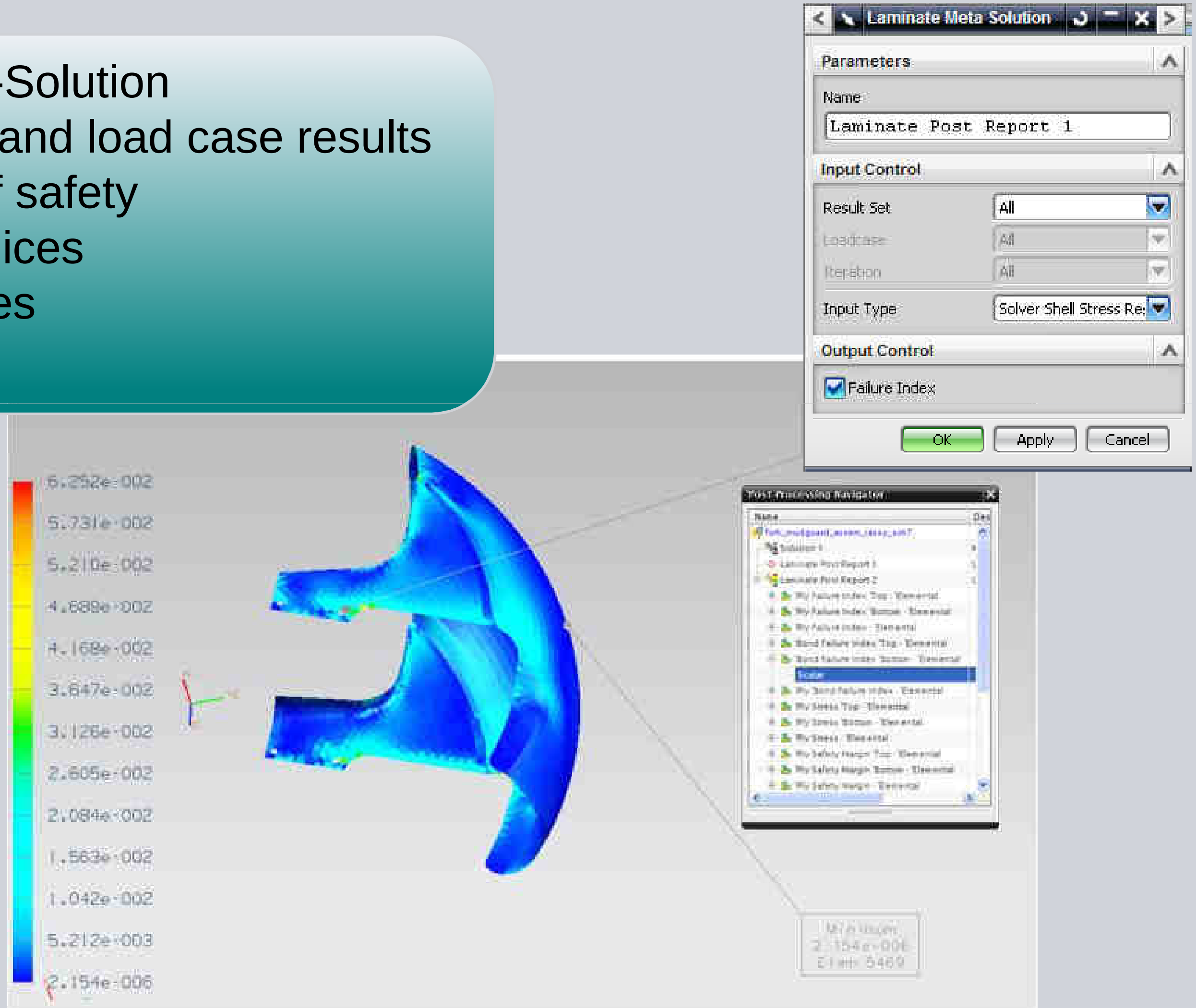
Graphical Display of Laminate Results

- Ply Strains
- Ply Stresses
- Ply Failure Indices
- Shell stress resultants

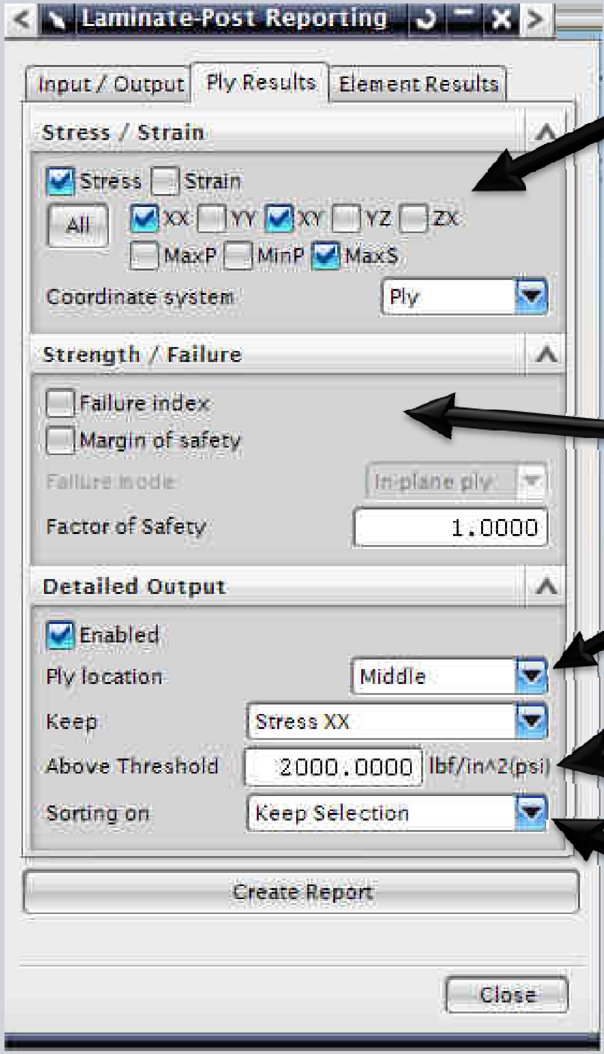


Laminates Reporting

Laminates Meta-Solution
- Envelopes ply and load case results
  - Margins of safety
  - Failure indices
  - Ply stresses
  - Ply strains



NX Laminate Composites Key Capabilities
Laminates Spreadsheet Reporting



Select components of stress or strain

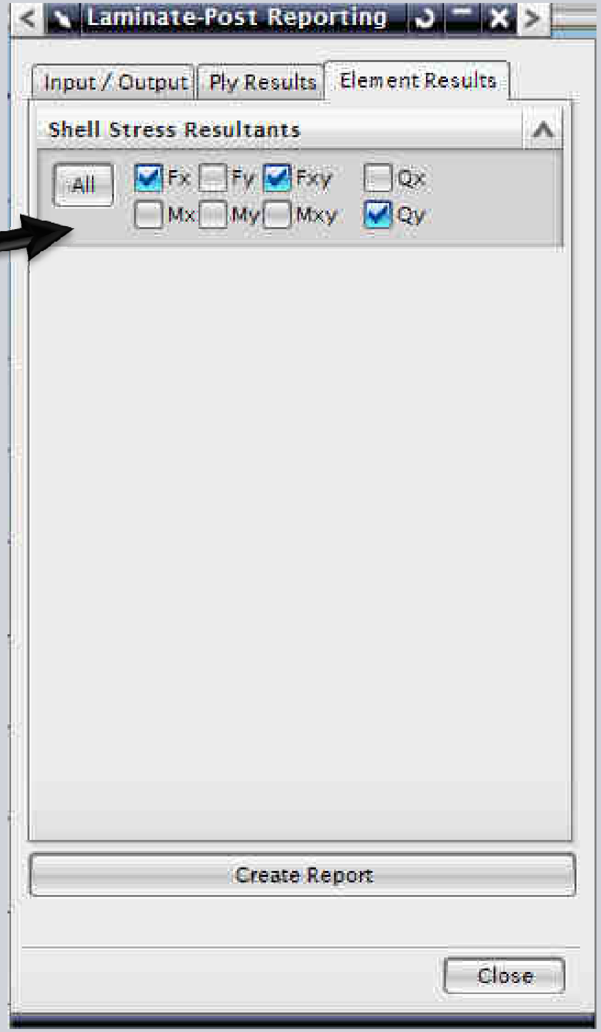
Select components of shell stress resultants

Compute failure indices, margins, or both

Output Location

Filter component and threshold

Sorting Options



NX Laminate Composites Key Capabilities

Laminates Spreadsheet Reporting

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Summary Table

	Results File Id	Subcase Id	Iteration Id	Input Data	Element Id	Ply Id	Computation Location	Laminate Name	Failure Theory	Stress11	Stresses Stress12	Maximum Shear
										lbf/in^2(psi)	lbf/in^2(psi)	lbf/in^2(psi)
Stress 11	1	1	1	Shell Stress	100175	2	Middle	front dish	Tsai-Wu	**5.11E+03**	8.76E+01	3.14E+03
Stress 12	1	1	1	Stress&Strain	100175	1	Middle	front dish	Tsai-Wu	2.61E+03	**4.52E+02**	7.62E+02
Maximum Shear Stress	1	1	1	Shell Stress	100175	2	Middle	front dish	Tsai-Wu	5.11E+03	8.76E+01	**3.14E+03**

Ply Results Table

Sorting Method: Stress 11
Filter Method: Stress 11
Filter Threshold: 2.000E+3

[illegible]	[illegible]	[illegible]	Input Data	Element Id	Ply Id	Computation Location	Laminate Name	Failure Theory	Stress11	Stresses Stress12	Maximum Shear
									lbf/in^2(psi)	lbf/in^2(psi)	lbf/in^2(psi)
[illegible]	[illegible]	[illegible]	Shell Stress	100175	2	Middle	front dish	Tsai-Wu	5.11E+03	8.76E+01	3.14E+03
[illegible]	[illegible]	[illegible]	Stress&Strain	100175	2	Middle	front dish	Tsai-Wu	5.11E+03	8.76E+01	3.14E+03
[illegible]	[illegible]	[illegible]	Shell Stress	100055	4	Middle	front dish	Tsai-Wu	4.91E+03	-1.17E+02	3.08E+03
1	1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] dish	Tsai-Wu	4.91E+03	-1.17E+02	3.08E+03
1	1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] dish	Tsai-Wu	4.85E+03	1.02E+01	3.04E+03
1	1	1	Shell Stress	[illegible]	4	Middle	front dish	Tsai-Wu	4.85E+03	1.02E+01	3.04E+03
1	1	1	Shell Stress	100172	4	Middle	front dish	Tsai-Wu	4.81E+03	5.05E+01	3.00E+03
1	1	1	Stress&Strain	100172	4	Middle	front dish	Tsai-Wu	4.81E+03	5.05E+01	3.00E+03
1	1	1	Stress&Strain	100051	4	Middle	front dish	Tsai-Wu	4.81E+03	-1.64E+02	2.88E+03
1	1	1	Shell Stress	[illegible]	[illegible]	[illegible]	[illegible]	Tsai-Wu	4.81E+03	-1.64E+02	2.88E+03
1	1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Tsai-Wu	4.80E+03	-6.20E+01	2.88E+03
1	1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Tsai-Wu	4.80E+03	-6.20E+01	2.88E+03
1	1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Tsai-Wu	4.74E+03	6.26E+01	2.91E+03
1	1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Tsai-Wu	4.74E+03	6.26E+01	2.91E+03
1	1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Hill	-4.74E+03	1.66E+02	2.08E+03
1	1	1	Shell Stress	[illegible]	[illegible]	[illegible]	tabs	Hill	-4.74E+03	1.66E+02	2.08E+03
1	1	1	Shell Stress	[illegible]	[illegible]	Middle	front dish	Tsai-Wu	4.70E+03	-7.10E+01	2.81E+03
1	1	1	Stress&Strain	[illegible]	2	Middle	front dish	Tsai-Wu	4.70E+03	-7.10E+01	2.81E+03
1	1	1	Stress&Strain	[illegible]	4	Middle	tabs	Hill	-4.60E+03	1.65E+02	2.01E+03
1	1	1	Shell Stress	[illegible]	4	Middle	tabs	Hill	-4.60E+03	1.65E+02	2.01E+03

Sheet tabs: Top Summary / 1-1-1. Shell Stress / 1-1-1. Results (Shell) / 1-1-1. Results (Stress)

Top summary showing filtered and sorted results for all results files and cases

For each results file and load case

Solver shell stress resultants

Results derived from solver shell stress resultants

Solver stresses and derived results

API: NX7.5

NX Open support for:

- Layup Modeler
- Draping Data Dialog
- Laminate Modeler

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Thank you for your attention!