

# **NX Laminate Composites**

**Product Overview** 

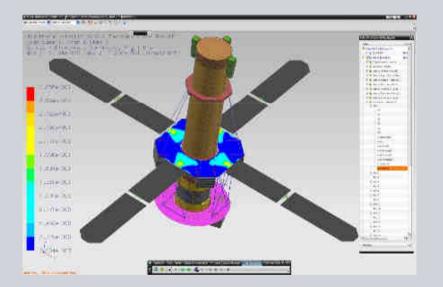




## **NX Laminate Composites Overview**

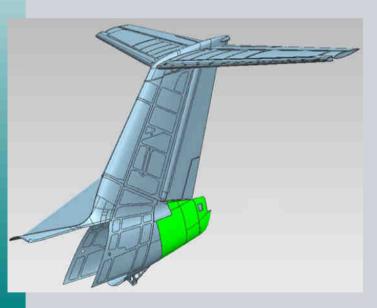
NX CAE product for finite element analysis of laminate structures featuring:

- 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



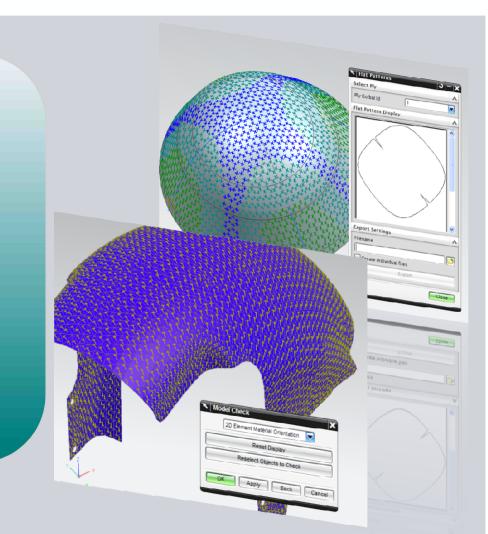
## **NX Laminate Composites Benefits**

- 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



## Laminate Modeling: Zone Based

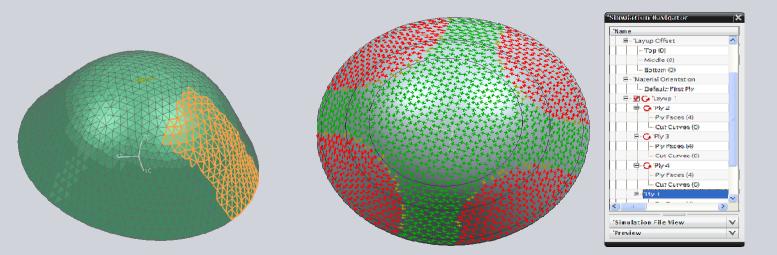
Name Copy of front dish abel 30248 Nonstructural Mass 3.244e-0 lbfs:- Damping coefficient 0	Reference Plane Location Reference Temperature Failure Theory	Regular Middle 77 F • • Tsai-Wu	P
Stress or Strain Output Request	Allowable Stress For Bonding	1000 Ibf/ir 💽	
Dutput Format PCOMP			
ly Layup		A Ply Sketcher	
			0
Id Composition	Thickn Angle	THICKNESS ANGLE PLY	MATERIAL
9 KEVLAR PREPREG	0.0025 45	0.00345.0 9	KEVLAR PREPREC
- 8 KEVLAR PREPREG	0.0025 0	0.003 0.0 8	
7 KEVLAR PREPREG	0.0025 -45	0.00345.0 7	KEVLAR PREPREC
6 KEVLAR PREPREG	0.0025 90	0.00390.0 6	
-5 MAT8 1002	0.25 0	0.003.80.0 0	
4 KEVLAR PREPREG	0.0025 90		
KEVLAR PREPREG KEVLAR PREPREG	0.0025 -45	0.250 0.0 5	MATE 1002
1 KEVLAR PREPREG	0.0025 45	01230 010 3	
T REVENIL FREPRES	0.0023 43		
		0.00390.0 4	KEVLAR PREPREC
		0.00345.0 3	KEVLAR PREPREC
		2 0.0 200.0	
		0.00345.0	KEVLAR PREPREG
Ply Details			

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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



### 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

Solver	Woven		
Lock Angle	15	deg	
Ply Usage			
🗸 "Select Ply Faces (	(9)		
Select Cut Curves (0)		[	9
🞸 'Start Point (1)		<b>E</b>	-
🔮 Primary Alignment	(1)	<b>.</b>	
Reverse Direction			X
Secondary Alignment	Perpend	cular	
Specify (0)			-
Reverse Direction			X

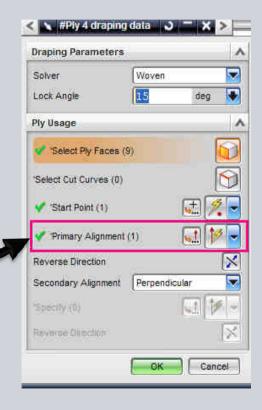
For stability, the draping algorithm uses the 2D mesh associated to the selected surfaces

### 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

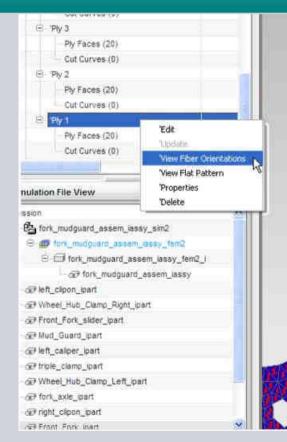
				Draping Input
Material MATPR	OPS M55JR: 🔽 🎑	Angle	0	deg 🖊
Ply Material		Thickness	0.005	in 🖣
-	_			1
1	MATPROPS_M55JRS	0.005	0	Up-to-date
- 2	MATPROPS_M55JRS	0.005	45	Up-to-date
··· <mark>3</mark>	MATPROPS_M55JRS	0.005	90	Udate
4	MATPROPS_M55JRS	0.005	-45	Up-to-det
⊡⊸ Group_1	Group of 4 plies			1
5	MATPROPS_3.1 PCF	0.5	0	'Up-to-date
···· 10	MATPROPS_4.4 PCF	0.5	0	'Up-to-date
14	MATPROPS_M55JRS	0.005	-45	'Up-to-date
- 15	MATPROPS_M55JRS	0.005	90	'Up-to-date

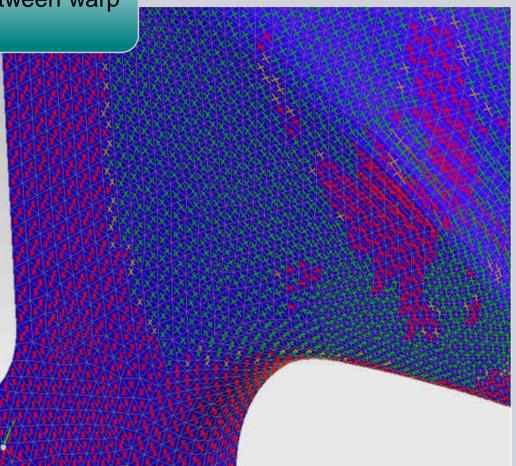


### Laminate Modeling: Draping

Draped fiber orientations visualization

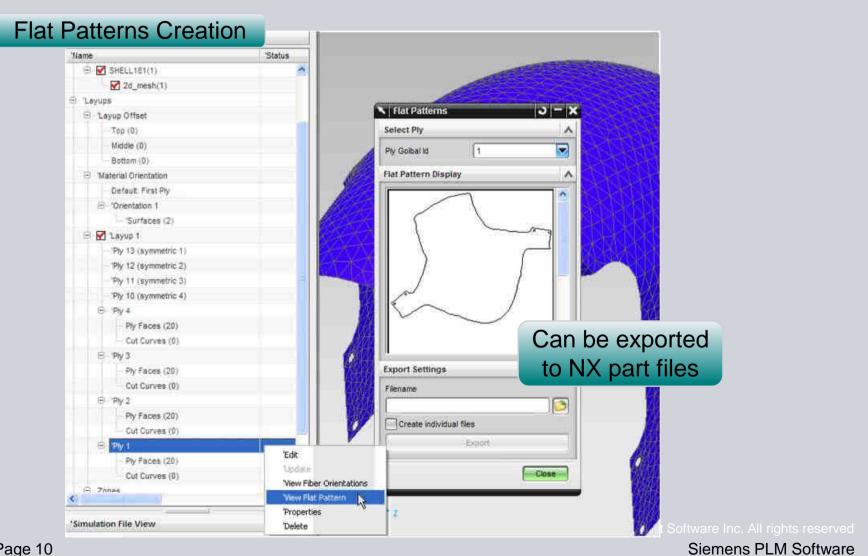
 Color coded to show shear between warp & weft fibers





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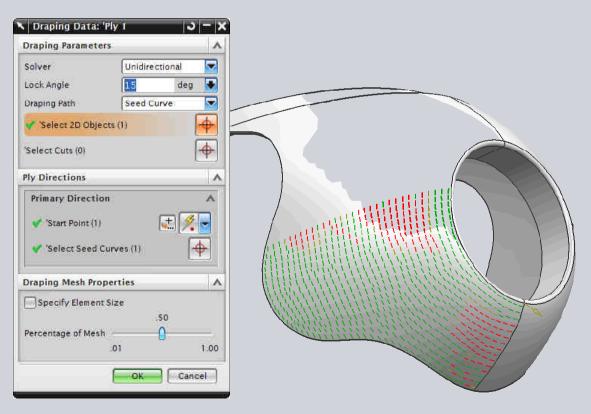
### Laminate Modeling: Draping



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### Laminate Modeling: Draping

Seed curves for primary fiber alignmentUser-selectable drape mesh size



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### **Composite Materials Micromechanics-based Ply Materials**

Гуре		Unidirecti	onal	-
	Crea	ate		
Name	Id	Туре	1	
Unidirectional 1	1	Unidirectio	nal	
Basic Information	1			^
Matrix Material	MA	T1 5351		0
Matrix Volume Frac	tion	.6		•
Fiber Material	MA	TI 10001		6
Fiber Volume Fract	ion	.4		
Finished Thicknes	\$2)	Ì	in 👻	
Tsai-Wu	_	h		
Tsai Wu Interaction	0	Č.	ln^4,+	•
Stress Strain				
Strength		Calculated	Ĩ	~
Max Stress Tensio	n) (n	(	lbf/ur	į
Max Stress Tensio	52	0	Nof/ic+	
Max Stress Tensio	n3	6	The file	
Max Stress Compri	estion	6	list/it+	
Max Stress Compri	sision2	[	16£/94+	
Max Stress Compre	ssion		llsf/u+	
Max in plane Shear	Stress	[	/lbf//it+	×
0			>	

### **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

### **Laminate Validation**

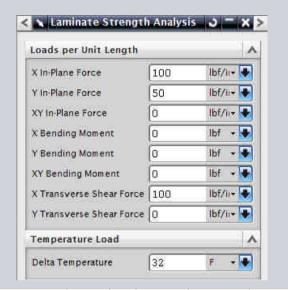
					Lamina	te Valid	lation C	)utput	
	A	В	С	D				•	
1	NX Laminate				Stiffne	ess mat	rices A	BDS	
2					_ ·				
3					Eauly	alent ei	naineer	ing con	stants
4	Laminate Nam	e :	Copy of front dis	h			- <u>J</u>		
5									
6									
7	Stiffness Matric	es A,B,D,S							
8		400,0005.0	00,0005.0	000.0005.0			000.0005.00		000 0005 10
9		166.699E+3		000.000E+0			000.000E+0	000.000E+0	000.000E+0
	A =	86.893E+3		000.000E+0		B =	000.000E+0	000.000E+0	000.000E+0
11 12		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	
	D =	1.479E+3		000.000E+0		S =	000.000E+0	1.075E+3	
15	<b>v</b> -	000.000E+0		689.288E+0		3 -	000.000240	1.073ETJ	
16		000.0002.00		000.2002.10					
17									
18	Laminate Equiv	valent Properti	es						
19	Edininato Equi								
20	Laminate is sym	imetric.							
21	Laminate is bala								
22									
23	Mass Density	3.704E-6	lbf-sec^2/in^4						
24									
25									
26		x		ху	ух	xz	yz		
27	E	449.650E+3						lbf/in^2(psi)	
	E (bending)	1.237E+6	1.237E+6					lbf/in^2(psi)	
	NU			0.521	0.521			Unitless	
	G			151.421E+3		3.980E+3	3.980E+3	lbf/in^2(psi)	
	G (bending)			420.233E+3				lbf/in^2(psi)	
	alpha	000.000E+0		000.000E+0				1/F	
~~	к	45.000E+3	45.000E+3	000.000E+0				Btu/sec-in-F	
34									

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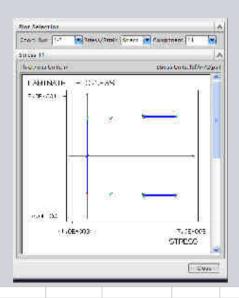
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#### Laminate Validation



#### **Strength Analysis**

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

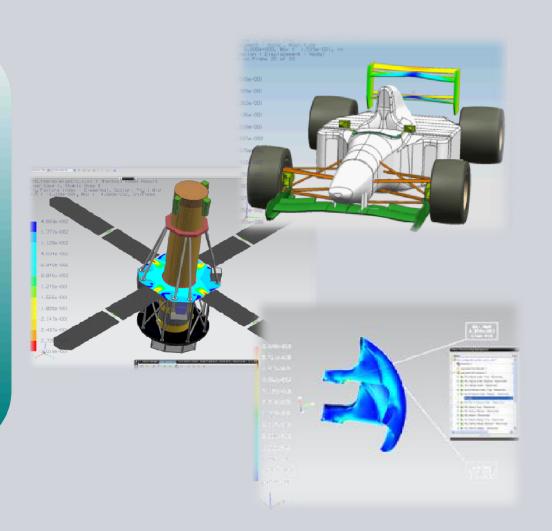


Summary Table													
					Stress					Failure Index	ľv	largin of Safe	ty
Component	Ply ID Computatio	Stress11	Stress22	Stress12	Stress23	Stress31	Maximum	Minimum	Maximum	Ply	Bond	Ply	Bond
	Location						Principal	Principal	Shear				
		mN/mm^2(kPa)	mN/mm^2(kPa)	mN/mm^2(kPa)		mN/mm^2(kPa)	imN/mm^2(kPa)	_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

### Laminate Failure

Supported Classical Failure Theories:

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



### **Composite Optimization**

#### Laminate Optimization Tool

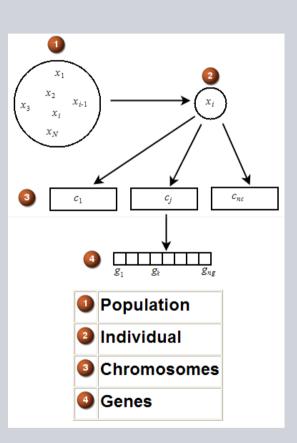
- Goal is to optimize the fundamental behavior of the laminate
- Optimizes a single laminate physical property (equivalent to coupon testing and optimization)

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



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### **Composite Optimization**

NASTRAN Design Optimization Solution

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

asce Repeation	1 🗢	×.	400		THICKNESS ANGLE	PLY 17		MATERIAL
Id	'Composition	Thickness	Angle	Description	0.002 45.0	16	///////	UNIDIRECTIONALI
9	MATPROPS_3.1 PCF	0.5	0	~	0.002 90.0	15		UNIDIRECTIONAL I
9 🛞 Group_2	symmetry of Group_1				0.00245.0	14	C111111	UNIDIRECTIONAL
-4	Unidirectional1	0.0022	0		0.00245.0	13	1111111	UNIDIRECTIONALI
-3	Unidirectional1	0.0022	45		0.002 90.0	12		UNIDIRECTIONAL
-2	Unidirectional1	0.0022	90		0.002 45.0	1.1	2111111	UNIDIRECTIONAL I
	Unidirectional1	0.0022	-45		0.002 0.0	10		UNIDIRECTIONALI
		0.0022	-43					
E Group_1	Group of 4 plies		Marrie 1		0.500 0.0	9-		-MATPROPS_3.1 PCF AL CORE
8	Unidirectional1	0.0022	-45*		0.900 0.0	:31-	-	-MATPROPSIS. I HOP AL CORE
- 7	Unidirectional 1	0.0022	90	~				
б	(Inidirectional)	0.0022	N.C.	>	0.002 0.0	4		UNIDIRECTIONAL I
					0.002 45.0	Э	111111	UNIDIRECTIONAL I
lobal ply id	8 🛛 🛛 Ply Materia		正找到	cliness 010022 In 🔶	0.002.90.0	2		UNID1RECTIONAL I
ly material Unic	directional 1 🔽 🦳		Ang	le 🛛 – 45 deg 😽	0.002 45.0	$-\alpha$		UNIDIRECTIONAL I
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escription					0.002 90.0	7		UNIDIRECTIONAL I
	1.22		ion Vacial	ole A	0.002 45.0	6	2111111	UNIDIRECTIONAL I
Design Variabl	le Manager 🛛 🔨	Assign Desi	gii variai					
Design Variabl			ign varia	<b>N</b>	0.002 0.0	5		UNID1RECTIONAL1
	le Manager 🔨	'Angle DV	igii variai	AngleDV_1	0.002 0.0	5	- <b></b>	UNID1RECTIONAL1
Design Variabl				AngleDV_1	0.002 0.0	5	· • • • • • • • • • • • • • • • • • • •	UNID) RECTIONAL I
Design Variabl		'Angle DV	N/	AngleDV_1	0.002 0.0	5	·	UNIDIRECTIONALI
Design Variabl		'Angle DV	N/	AngleDV_1	0.002 0.0	6		UNIDIRECTIONALI
Design Variabl		'Angle DV Thickness D (port as Model)	w ng Object	AngleDV_1				
Design Variabl		'Angle DV	w ng Object	AngleDV_1			ness 5.352e-0	
Design Variabl		'Angle DV Thickness D (port as Model)	w ng Object	AngleDV_1			ness (5.352e-0	

### **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

#### **2**D

- \*ELEMENT\_SHELL
- 3D
  - \*ELEMENT\_TSHELL

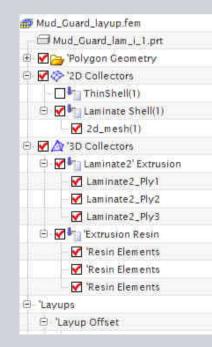
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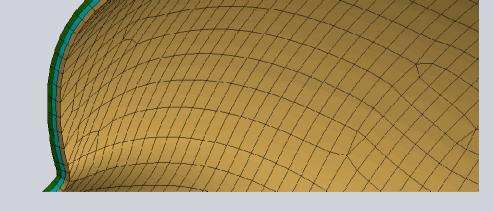
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### Laminate Modeling: 3D Extrusion

Inflate layup to 3D laminate ANSYS mesh

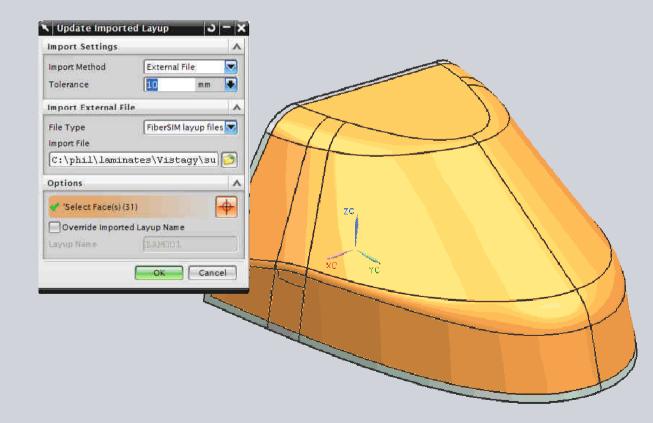
- Normal extrusion from 2D meshed faces
- Each ply becomes a layer of solids
- Ply drops modeled as wedge, brick or pyramid elements





### Laminate Modeling: FiberSIM Interface

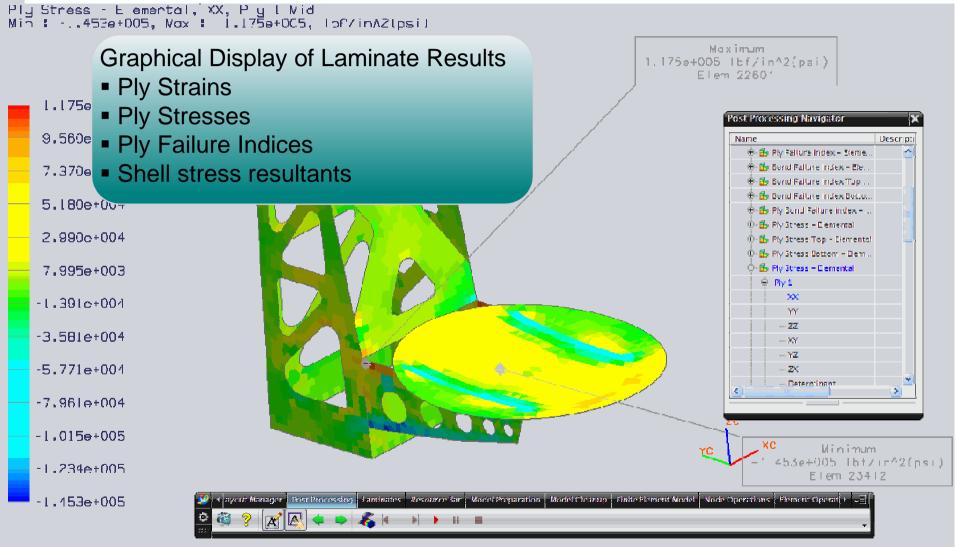
### Import layups and fiber orientations from FiberSIM xml file





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### **Laminates Post-Processing**

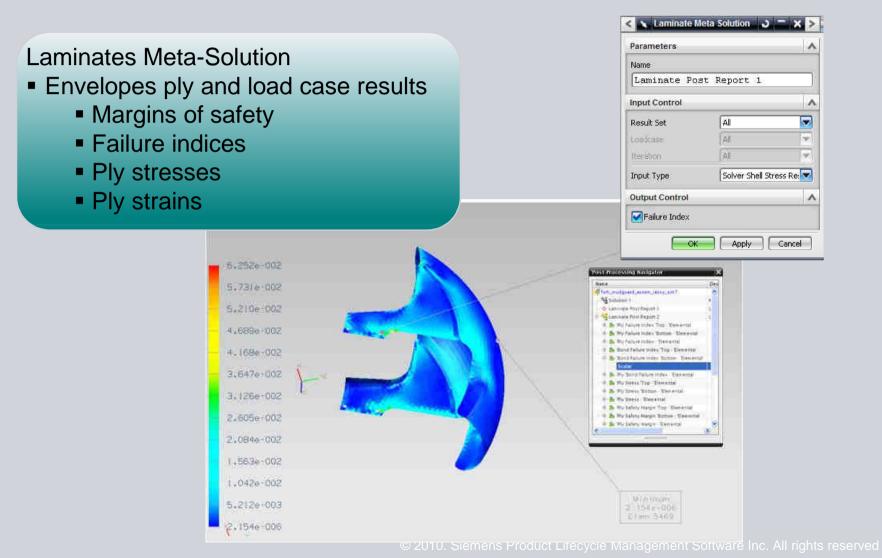


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### **Laminates Reporting**

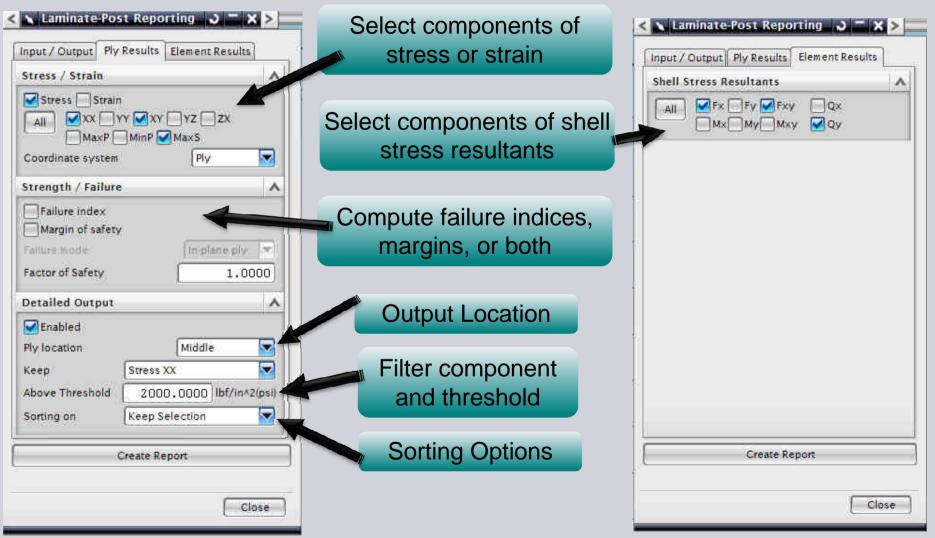


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## NX Laminate Composites Key Capabilities Laminates Spreadsheet Reporting



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## NX Laminate Composites Key Capabilities Laminates Spreadsheet Reporting

A	В	С	D	E	F	G	Н		J	K	L	M	N
5 Summary Table													
3													
7		Results	Subcase	Iteration	Input	Element	Ply	Computation	Laminate	Failure		Stresses	
3		File Id	ld	ld	Data	ld	ld	Location	Name	Theory	Stress11	Stress12	Maximum
9		7								1			Shear
0											lbf/in^2(psi)	lbf/in^2(psi)	lbf/in^2(psi)
1 Stress 11		1	1	1	Shell Stress	100175	2	Middle	front dish	Tsai-Wu	5.11E+03	8.76E+01	3.14E+03
2 Stress 12		1	1	1	Stress&Strain	100175	1	Middle	front dish	Tsai-Wu	2.61E+03	-4.52E+02	7.62E+02
3 Maximum Shear	Stress	1	1	1	Shell Stress	100175	2	Middle	front dish	Tsai-Wu	5.11E+03	8.76E+01	3.14E+03
1							_						]
5													
6													
7 Ply Results Table	9												
3													
Sorting Method	Stress 11	·											
Filter Method	Stress 11												
1 Filter Threshold	2.000E+3												
2													
3 R			Input	Element	Ply	Computation	Laminate	Failure		Stresses			
F Top sum	mary sh	owing	Data	ld	ld	Location	Name	Theory	Stress11	Stress12	Maximum		
	d and so							<b>,</b>			Shear		
interot									lbf/in^2(psi)	lbf/in^2(psi)	lbf/in^2(psi)		
7 results	for all re		Shell Stress	100175	2	Middle	front dish	Tsai-Wu	5.11E+03	8.76E+01	3.14E+03		
files	and case	es	tress&Strain	100175	2	Middle	front dish	Tsai-Wu	5.11E+03	8.76E+01	3.14E+03		
a <b>Lana</b> a ay			Shell Stress	100055	4		front dish	Tsai-Wu	4.91E+03	-1.17E+02	3.08E+03		
1	1	1	S				dish	Tsai-Wu	4.91E+03	-1.17E+02	3.08E+03		
1 1	1	1	s For ea	ich resu	Its file and	load case	dish	Tsai-Wu	4.85E+03	1.02E+01	3.04E+03		
2 1	1	1	Suman contrasts		4	INITIONE	nom dish	Tsai-Wu	4.85E+03	1.02E+01	3.04E+03		
3 1	1	1	Shell Stress	100172	4	Middle	fron <b>y</b> dish	Tsai-Wu	4.81E+03	5.05E+01	3.00E+03		
4 1	1	1	Stress&Strain	100172	4		front dish	Tsai-Wu	4.81E+03	5.05E+01	3.00E+03		
5 1	1	1	Stress&Strain	100051			front dish	Tsai-Wu	4.81E+03	-1.64E+02	2.88E+03		
5 I I	1	1	Shell Stress	100051			<b>h</b> h	Tsai-Wu	4.81E+03	-1.64E+02	2.88E+03		
7 1	1	1		0	lesults	Solve	r sh	Tsai-Wu	4.80E+03	-6.20E+01	2.88E+03		
3 1	1	1	Solver shell			stress		Tsai-Wu	4.80E+03	-6.20E+01	2.88E+03		
9 1	1	1	stress		lerived			Tsai-Wu	4.74E+03	6.26E+01	2.91E+03		
	1	1	resultants		m solver	and deri	b b		4.74E+03	6.26E+01	2.91E+03		
1 1	1	1		she	ell stress	result	S	Hill	-4.74E+03	1.66E+02	2.08E+03		
2 1	1	1	ell Stress	10	sultants	li Alle	tabs	Hill	-4.74E+03	1.66E+02	2.08E+03		
3 1	1	1	nell Stress	10		Judle	front dish	Tsai-Wu	4.70E+03	-7.10E+01	2.81E+03		
4 1	1	1 1	Stress&Strain	1000	2	Middle	front dish	Tsai-Wu Tsai-Wu	4.70E+03	-7.10E+01	2.81E+03		
	1	1	Stress&Strain	100	4 - 1	Middle	tabs	Hill	-4.60E+03	1.65E+02	2.01E+03		
	1		Shell Stress		4	Middle	tabs	Hill	-4.60E+03	1.65E+02	2.01E+03		
-	4			1001	4	Niluale Milatella	Tabs	T==: \06.		1.05E#02	2.010+03		
4 N N Ton Sum	nary / 1-1-1.	Shell Stres	is 🖌 1-1-1. Resu	Its (Shell) /	1-1-1. Results (5	stress) /							

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### **API: NX7.5**

NX Open support for:

- Layup Modeler
- Draping Data Dialog
- Laminate Modeler

## Thank you for your attention!

