

Materials Data Workflow for Simulation of Composites in Transportation Applications



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Composites in Transportation



- Traditional transportation markets
 - Aerospace: low volume, highly reliability product
 - Automotive: emerging but mass production is difficult

- New transportation markets (flying cars, self driving vehicles)

- Requires both mass production and high reliability *
- New Challenges
 - Light-weighting (composite / AM lattice designs) *
 - Design optimization (novel simulation-driven components) *
 - Electrification
 - 5G-cybersecurity

* Topics relevant to this presentation



Outline

- 1 Models for composite simulation
- 2 Typical tests needed
- 3 Material model calibration
- 4 Validation of simulation against physical test
- 5 Documentation and traceability
- 6 Incorporating design allowables
- 7 Storage and deployment to simulation



Nature of Composites

High strength lightweight applications

- Behavior is unlike metals and plastics
- Orthotropic properties can be exploited for maximum benefit
- Need a deep understanding of behavior for successful implementations
- Cost is much higher





Composites are multi-scale materials

Resin + fiber = sheet Sheets in different orientations = layup



Images courtesy: J. Wollschlager, Altair



Testing of composites

Tensile properties Compressive properties Shear properties

Properties are non-linear in certain orientations and modes of deformation.









Composite properties are orthotropic



X

Vary with orientation Vary with test mode



Properties are non-linear in certain orientations.

Composite properties vary with layup



Sheets in different orientations = layup



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Test matrix for simulation

Test certain layups in specific orientations Approaches exist for

- DIGIMAT
- Altair Multiscale Designer
- NASTRAN



Example of test matrix for Altair Multiscale Designer material model

Test	Test Standard	Layup	Specimens per Panel	Total Panels	Total Specimens
0 Tension	ASTM D3039	[0] ₈	3	2	6
90 Tension	ASTM D3039	[90] ₁₆	3	2	6
[45/-45] Tension	ASTM D3518	[45/-45] _{4s}	3	2	6
0 Compression	ASTM D6641	[0] ₁₆	3	2	6
90 Compression	ASTM D6641	[90] ₁₆	3	2	6
[90/0] Tension *	ASTM D3039	[90/0] _{2s}	3	2	6
[90/0] Compression *	ASTM D6641	[90/0] _{4s}	3	2	6
[50/40/10] * OHT	ASTM D5766	[-45/02/45/90 /45/02/- 45/0]s	3	2	6
			Totals	16	48

*Used for validation



Material Model Calibration

Example calibration process for Altair Multiscale Designer

- Simulation predicts behavior of a variety of laminate lay-ups
- Stiffness and failure is modelled

Multi-scale model





Ply test and model calibration



Lobdell, Wollschlager, ATC (2018)

Validation of complex laminate test





Material Model Validation-1

Confirm that the simulation can predict different layups

PICSCI, a Matereality digitalization software is used to compare simulation to test



PicSci Electronic Lab Notebooks can store and compare results of physical tests and simulations





Simulations courtesy: J. Wollschlager, Altair



Material Model Validation-2

Confirm that the simulation can predict complex case

- Complex layup- [-45/02/45/90/45/02/-45/0]s
- Complex test Open hole tension ASTM D5766

Experimental strains by digital image correlation (DIC)







Documenting Composite Material Data



- 1 Composition (layups)
- 2 Processing (autoclaving)
- 3 Properties varying with orientation, temperature, strain rate, other parameters
- 4 Traceability



Composition

Store detailed compositional information about the layup

The Matereality Composition framework allows for the storage of any compositional information on composites.

Such composition templates can be created for any kind of materials.

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Edit Availability	Carbon/Epoxy UD	4	90	0.5				
Edit Aliases	Carbon/Epoxy UD	2	0	0.5				
Transfer Manage Access								



Processing

Autoclaving is typically used

Matereality provides a Processing framework for the storage of process conditions for each processing step.

Any other kind of processing operation can be similarly captured to completely document the production process







Property data

Capture data for each replicate from the physical test Include variation in properties with orientation

Matereality software automatically cross plots multi-variate data for efficient data analysis

Variability bands compute statistical spread of curve data

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Traceability

Capture details of the physical test

- Sample information
- Test parameters
- Test lab and technician

Matereality Data Certificates satisfy the ISO 17025 data reporting requirement.

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		other specimen preparation	varying			- 8	
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		form	Open Hole Tension bar			- 8	
		conditioning	40 hours, 23C, 50%RH			- 8	
		width	37.92 mm			- 8	
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		laboratory humidity	56 %RH			- 18	
		crosshead speed	2 mm/min				
		data source	DatapointLabs				
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Copyright © Matereality 2002-20)19; v12.0				Requ	uest Help	



Incorporating Design Allowables

Testing to CMH-17

- Additional lots and replicates
- Strong statistical basis = Greater design reliability

Matereality software has built-in tools to perform statistical analysis of stored data

Compare - Google Chrome							
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		Carbon/Epoxy Unidirectional [90]16 2	0.557	%			- 15
		Carbon/Epoxy Unidirectional [+-45]4S C2	0.734	%			- 15
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		Carbon/Epoxy Unidirectional (4545)(2)090(4545)2S G-Ten-6	1.17	%			
		Carbon/Epoxy Unidirectional [45/0/-45/90]2s H2	1.88	%			
		Mean	1.12	%			
		Std Deviation	0.461	%			
		M40J/Epoxy Unidirectional [-45/0/45/90]2s - Odeg direction Mean	645	MPa			
		Carbon/Epoxy Unidirectional [0]8 5	1.12E+03	MPa			
		Carbon/Epoxy Unidirectional [90]16 2	43.9	MPa			
		Carbon/Epoxy Unidirectional [+-45]4S C2	97.4	MPa			
	Offset Yield Stress in Tension	Carbon/Epoxy Unidirectional [90/0]2S D3	1.43E+03	MPa			
		Carbon/Epoxy Unidirectional (4545)(2)090(4545)2S G-Ten-6	350	MPa			
pyright © Matereality 2002-2	2019; v12.0					Reque	est Help



Storing Material Cards for Simulation

Library stores material files for any solver

- CAE material files are linked to material
- CAE material files are linked to source material data

Matereality software has built-in tools to create CAE material files from stored data, including data manipulation for non-linear material models, data fitting to equations.





Exporting Material Cards for Simulation

Stores material files can be deployed to solvers

Matereality software has direct connectivity to

- HyperWorks
- ANSA
- Abaqus/CAE
- ANSYS Workbench
- SolidWorks
- NX Nastran
- CATIA
- PTC/Creo





Summary

- 1 Composites are complex materials
- 2 Simulation can reduce the need to test each layup= reduce total number of physical tests
- 3 Validate of simulation is essential to prove accuracy
- 4 Composites generate a large amount of complex data: composition, processing, varying properties
- 5 Design allowables testing increases the quantity of data
- 6 Simulation material models must be well coupled to source data
- 7 Digitalization software is essential to support this activity

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