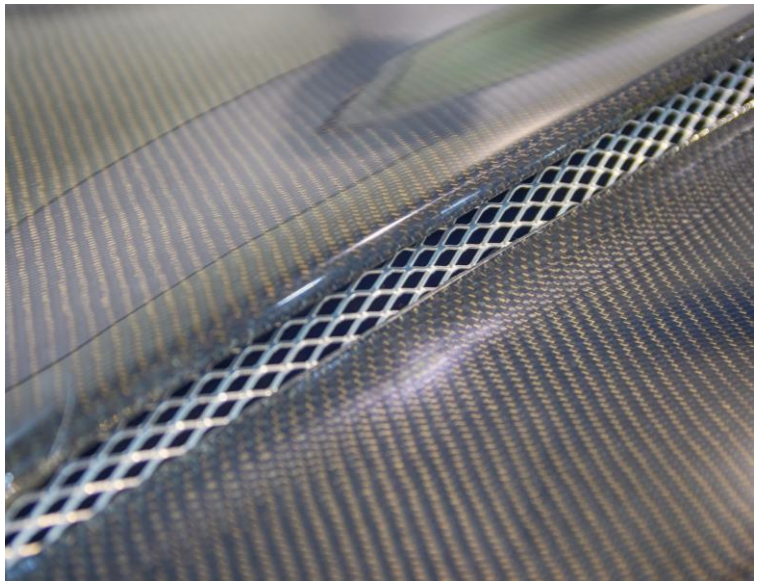
Applus DatapointLabs

Materials Data Workflow for Simulation of Composites in Transportation Applications



Hubert Lobo, President, DatapointLabs

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

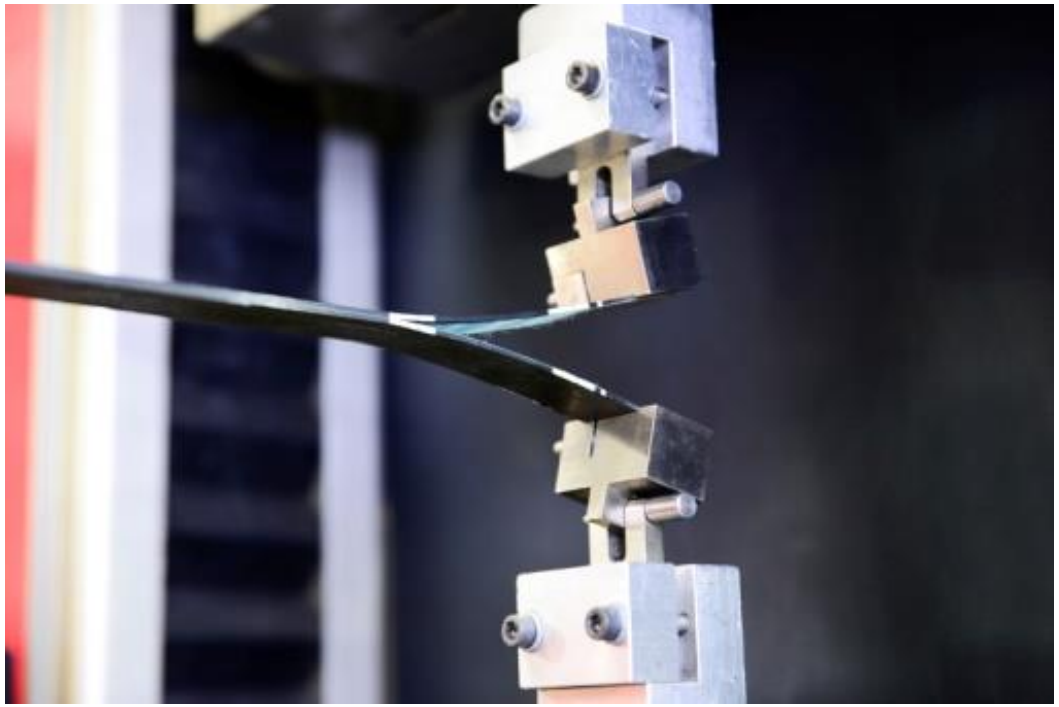
Outline

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

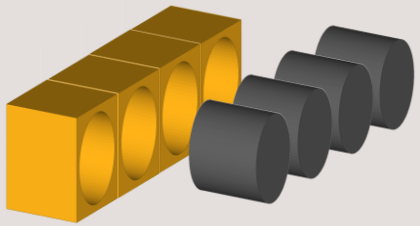
- Behavior is unlike metals and plastics
- Orthotropic properties can be exploited for maximum benefit
- Need a deep understanding of behavior for successful implementations
- Cost is much higher



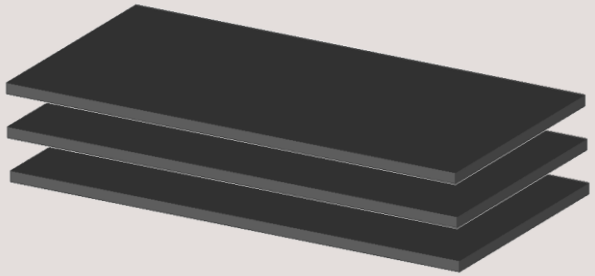
Composites are multi-scale materials

Resin + fiber = sheet
Sheets in different orientations = layup

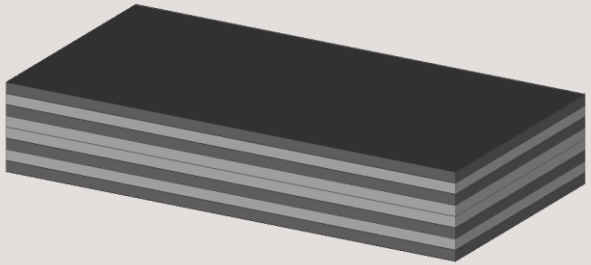
Scale1 ($\sigma^{Fiber/Matrix}$)



Scale2 (σ^{Ply})



Scale3 ($\sigma^{Laminate}$)

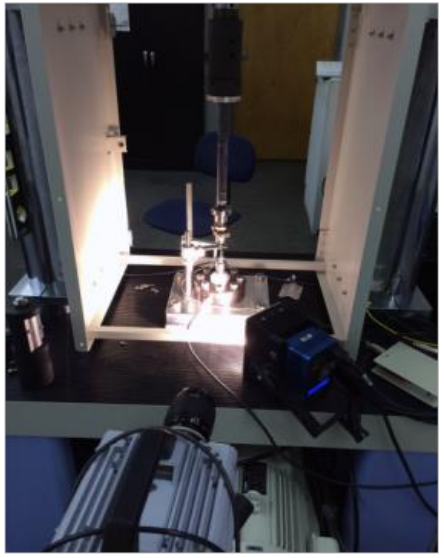


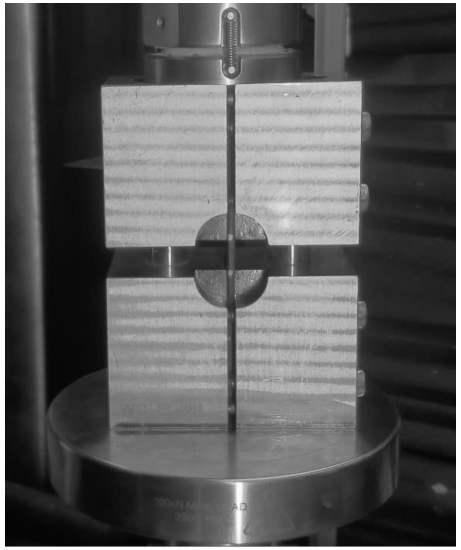
Images courtesy: J. Wollschlager, Altair

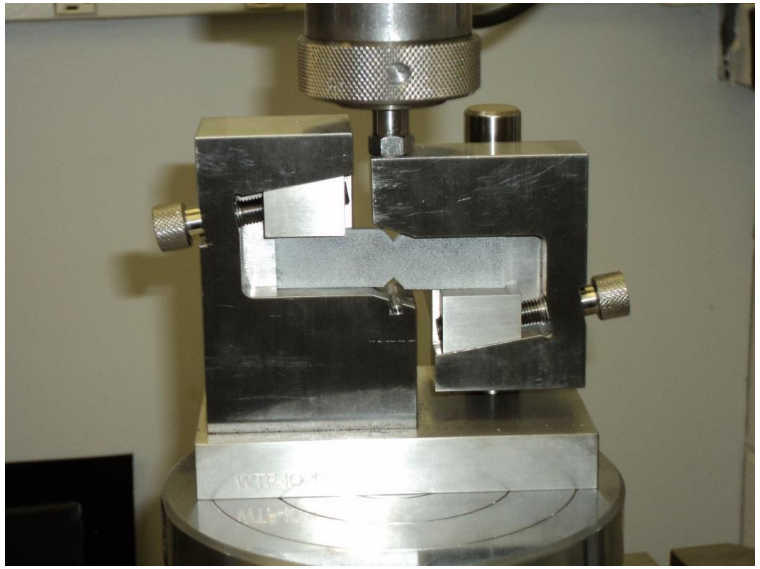
Testing of composites

Tensile properties
Compressive properties
Shear properties

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

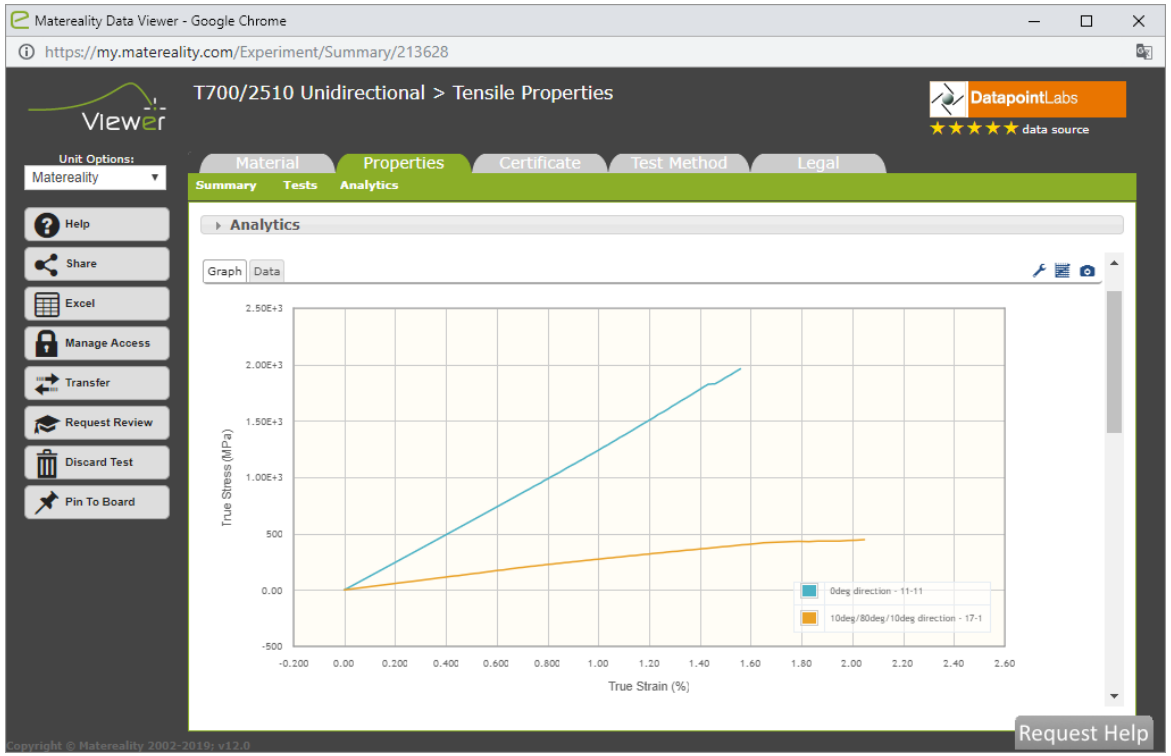


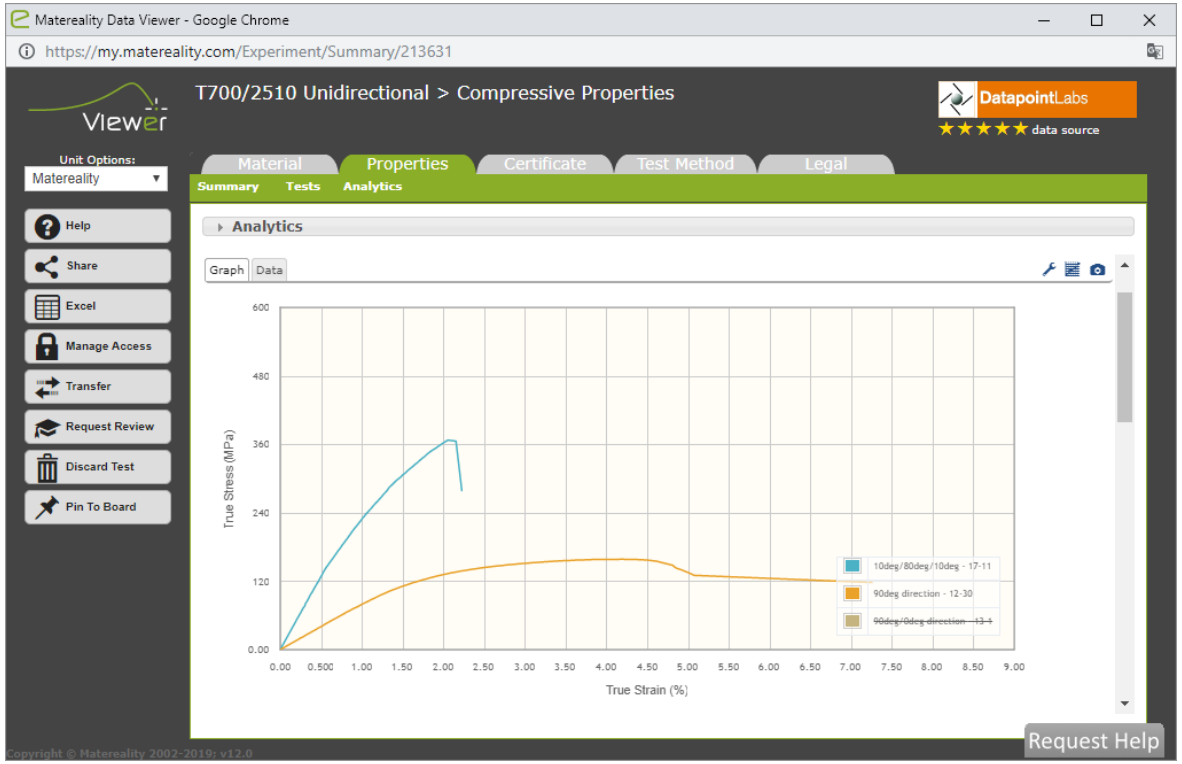




Composite properties are orthotropic

Vary with orientation
Vary with test mode

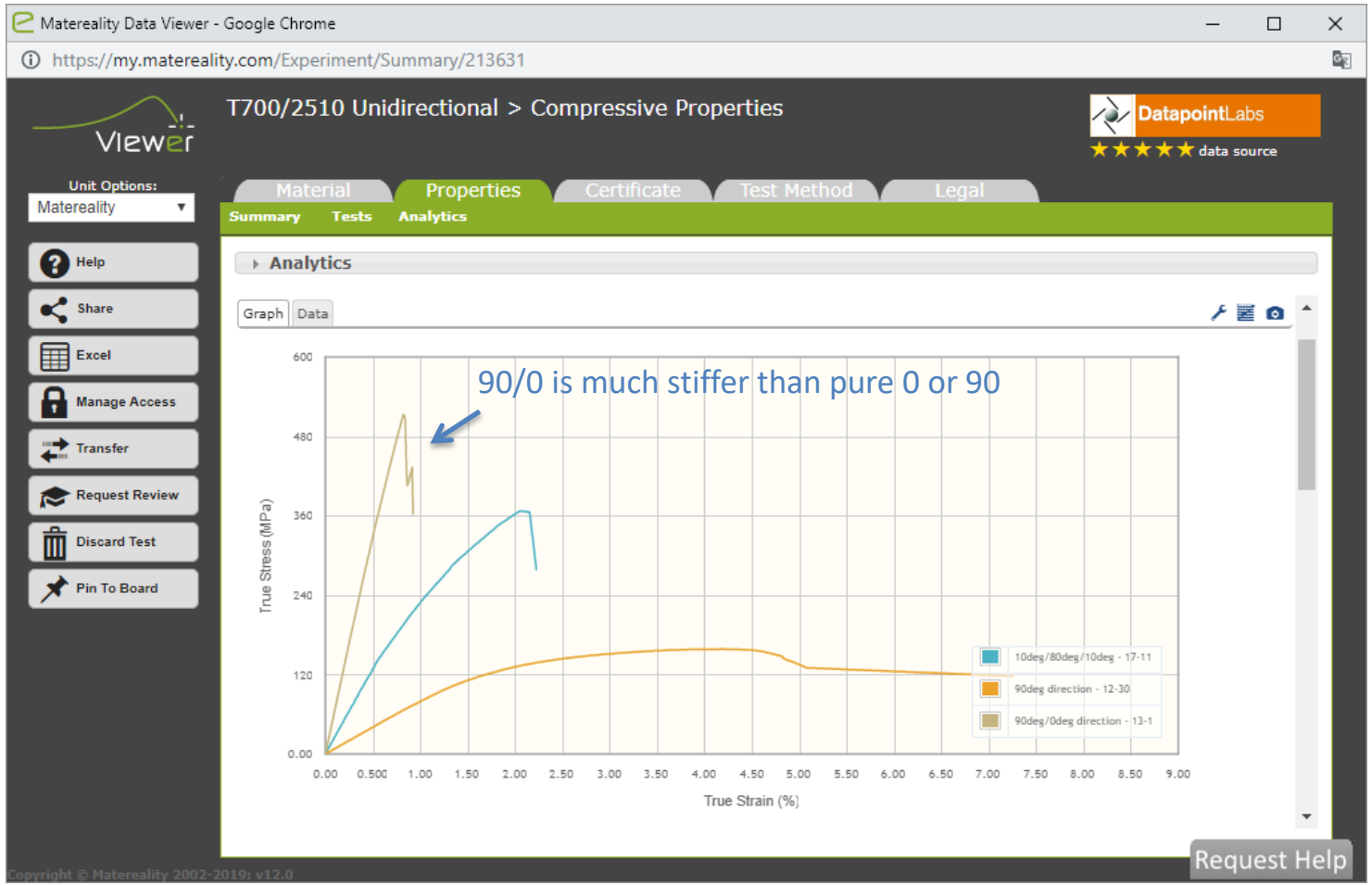




Properties are non-linear in certain orientations.

Composite properties vary with layup

Sheets in different orientations = layup



Test matrix for simulation

Test certain layups in specific orientations

Approaches exist for

- DIGIMAT
- Altair Multiscale Designer
- NASTRAN

TestPaks

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

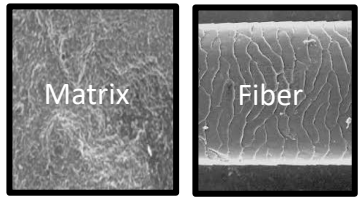
Material Model Calibration

Example calibration process for Altair Multiscale Designer

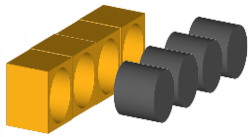
- Simulation predicts behavior of a variety of laminate lay-ups
- Stiffness and failure is modelled

Multi-scale model

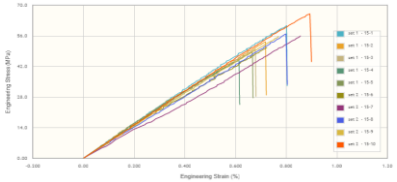
Scale0 ($\sigma^{MicroStructure}$)

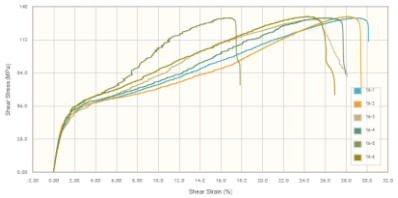


Scale1 ($\sigma^{Fiber/Matrix}$)

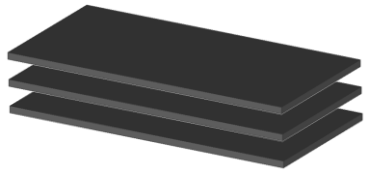


Ply test and model calibration

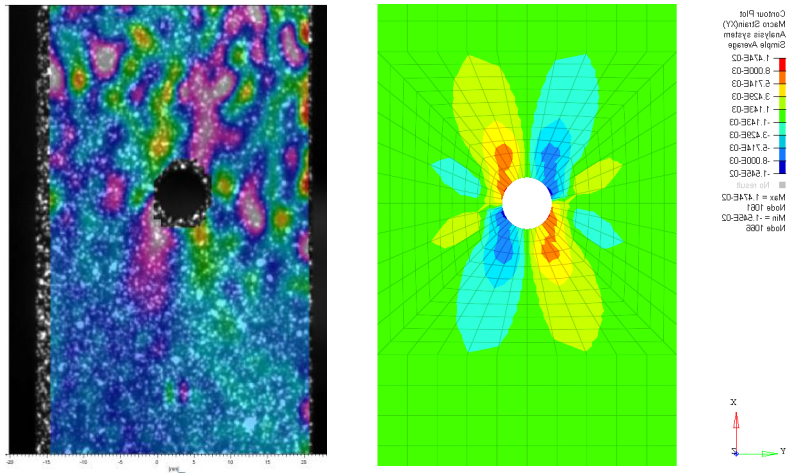




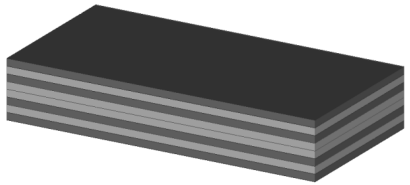
Scale2 (σ^{Ply})



Validation of complex laminate test



Scale3 ($\sigma^{Laminate}$)



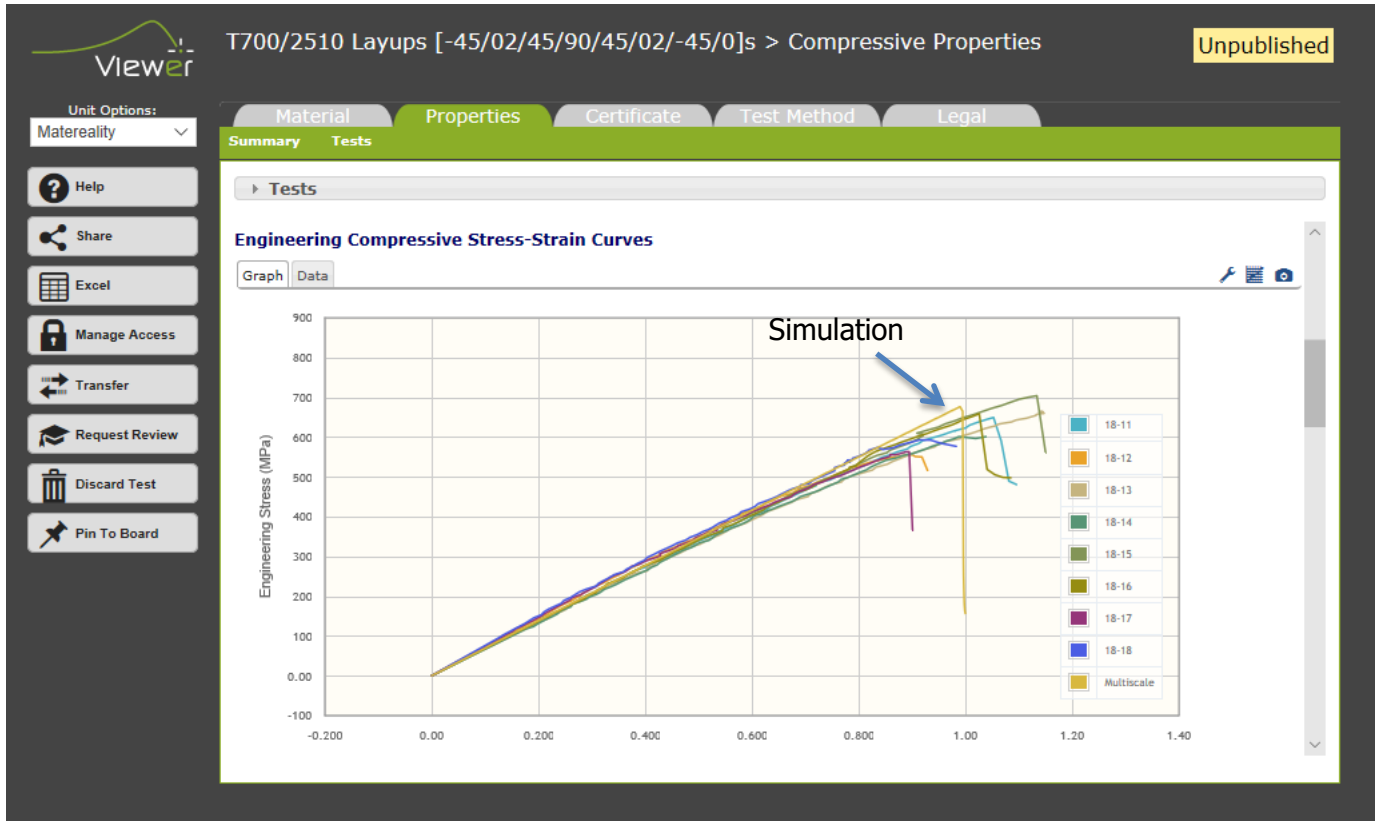
Lobdell, Wollschlager, ATC (2018)

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



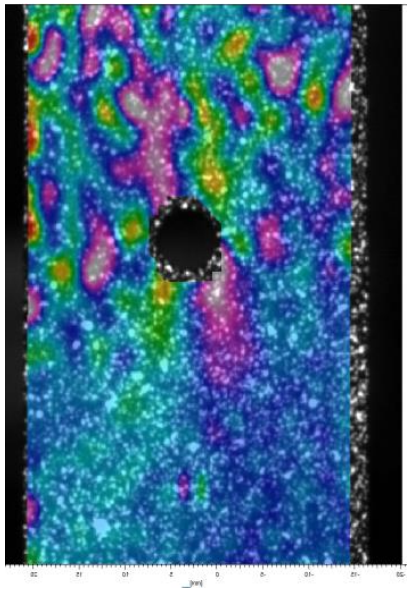
Simulations courtesy: J. Wollschlager, Altair

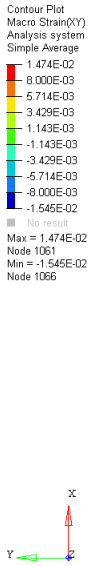
Material Model Validation-2

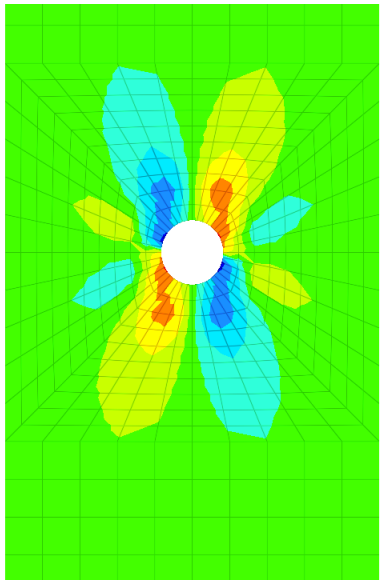
Confirm that the simulation can predict complex case

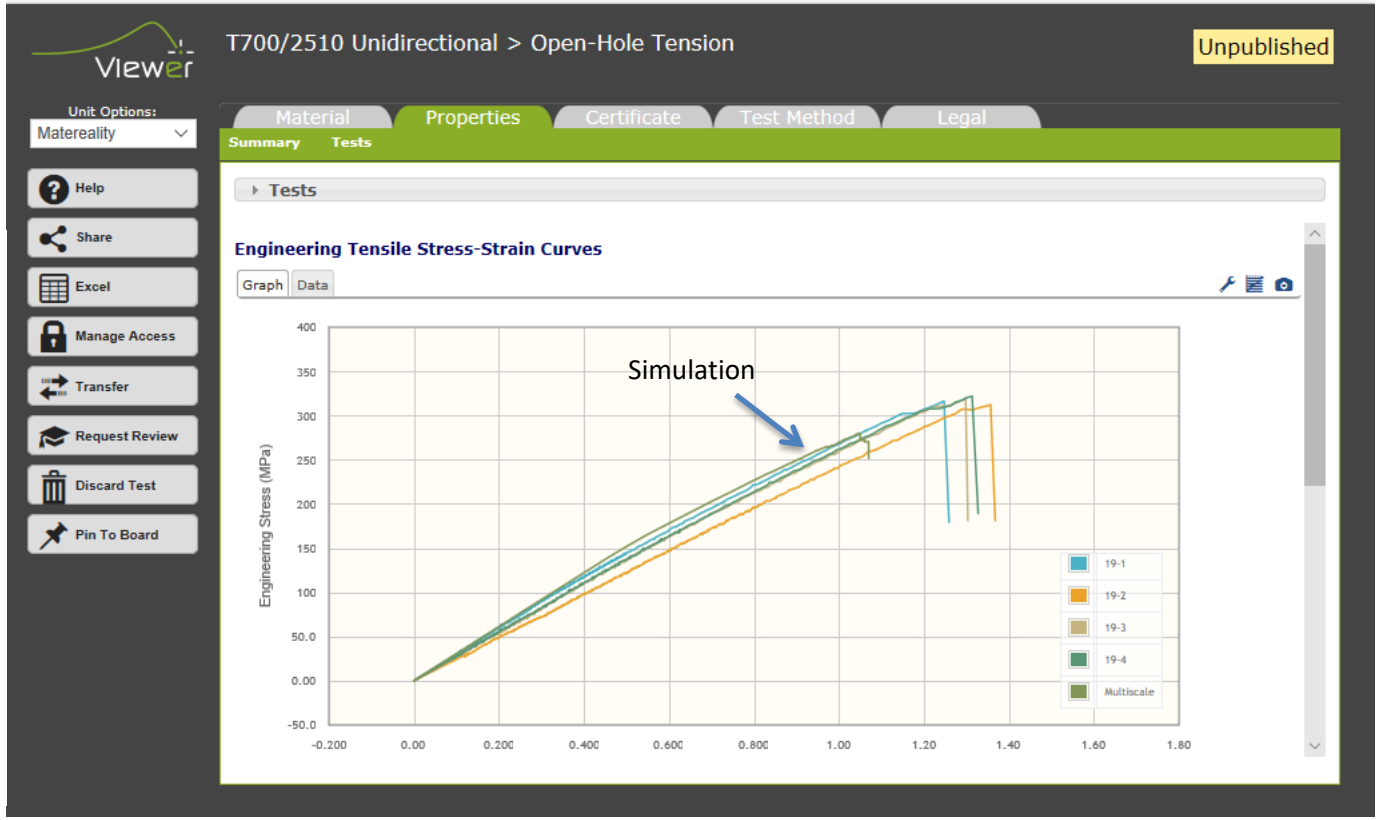
- Complex layup- [-45/02/45/90/45/02/-45/0]s
- Complex test - Open hole tension ASTM D5766

Experimental strains by digital image correlation (DIC)









Simulations courtesy: J. Wollschlager, Altair

Documenting Composite Material Data

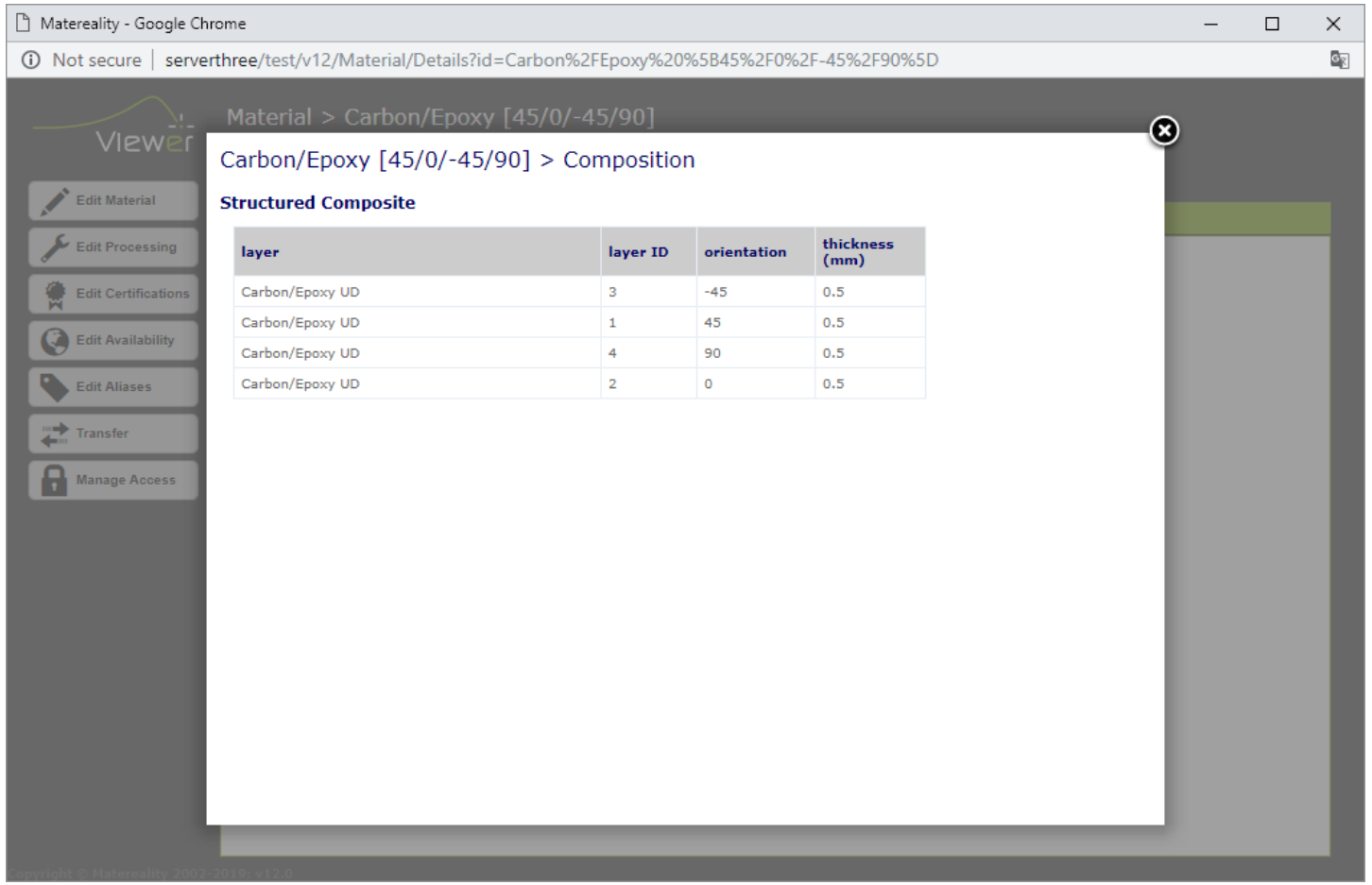
1. Composition (layups)
2. Processing (autoclaving)
3. Properties varying with orientation, temperature, strain rate, other parameters
4. Traceability

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.

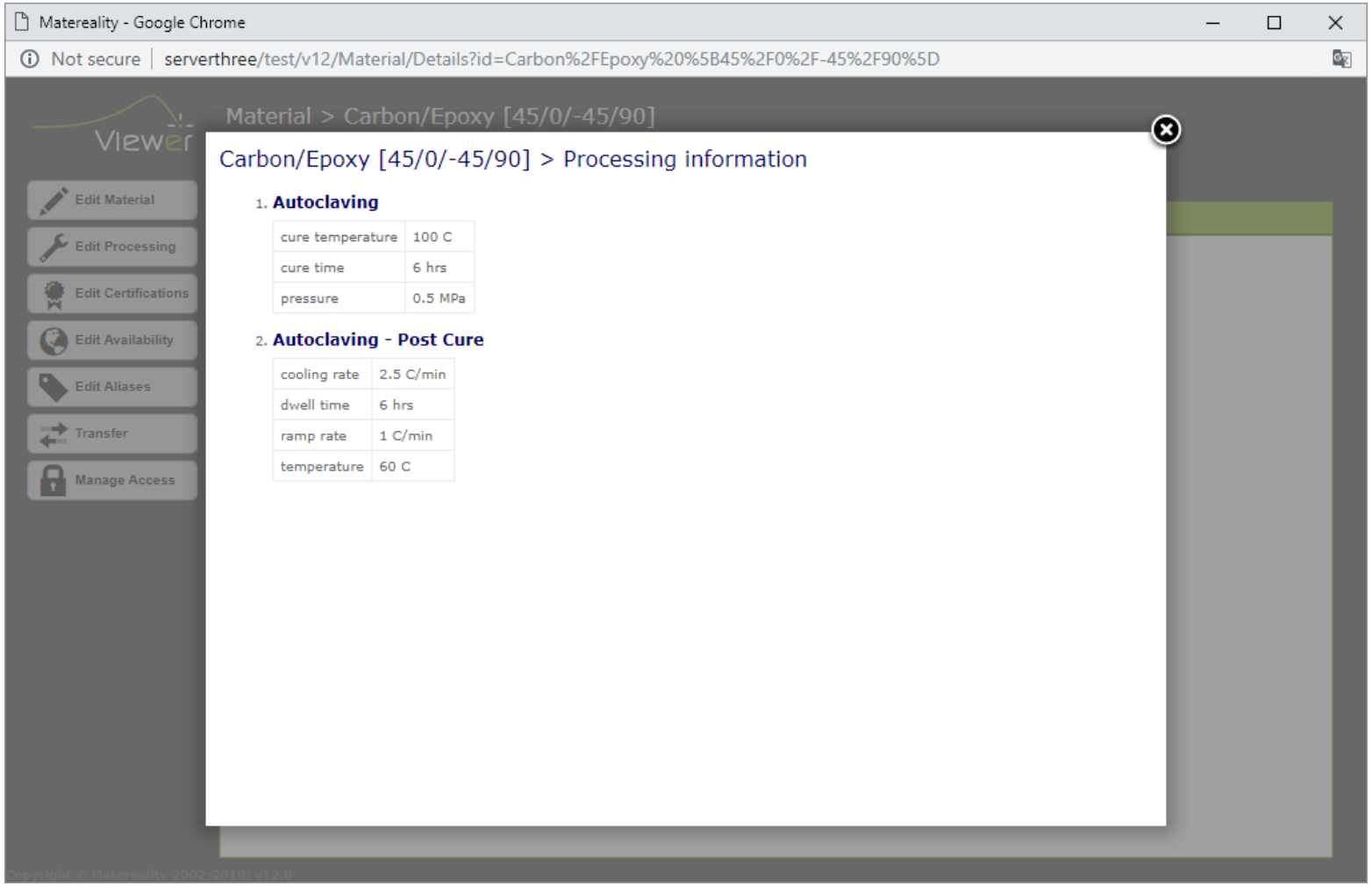


Processing

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

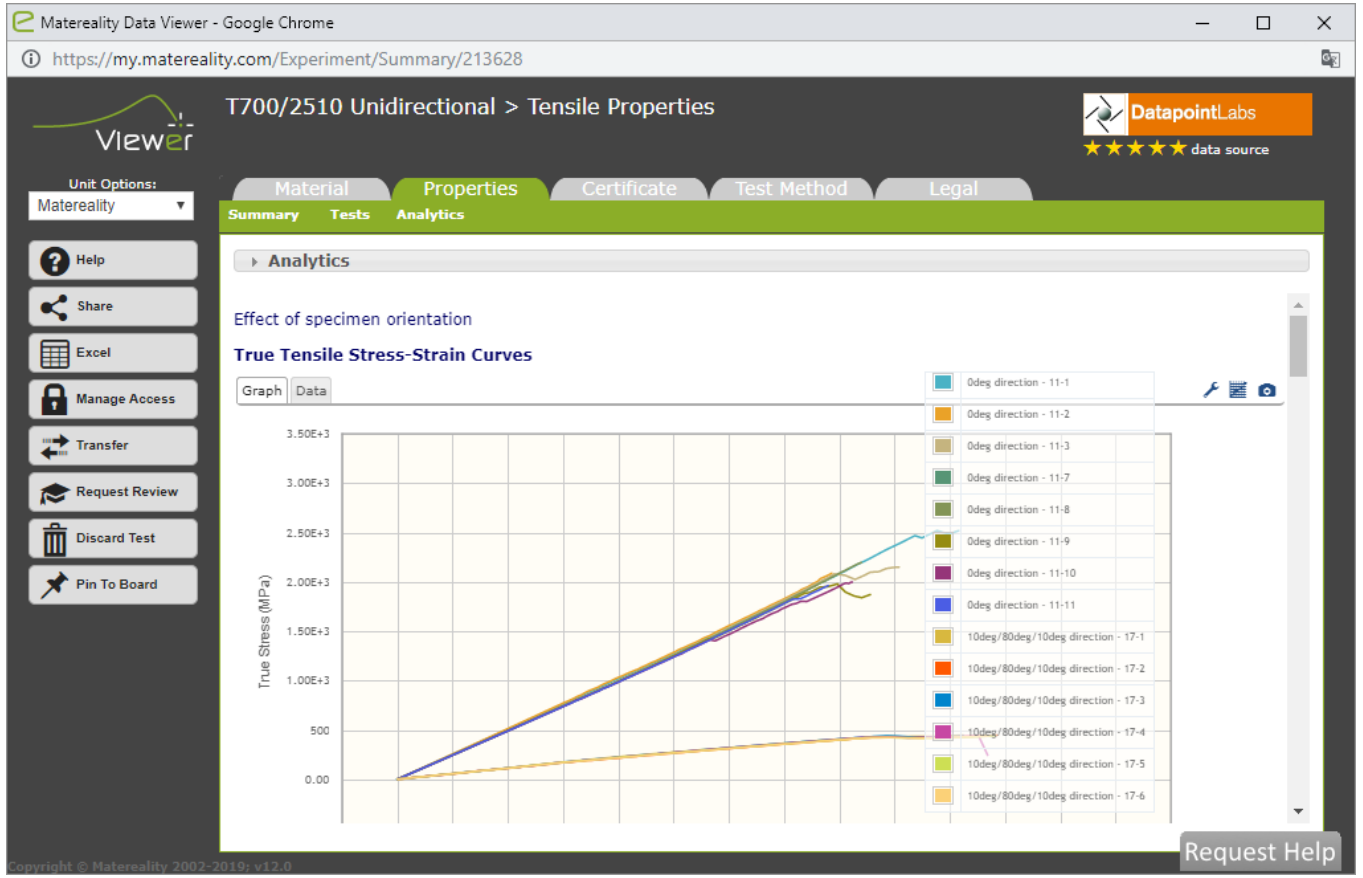


Property data

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

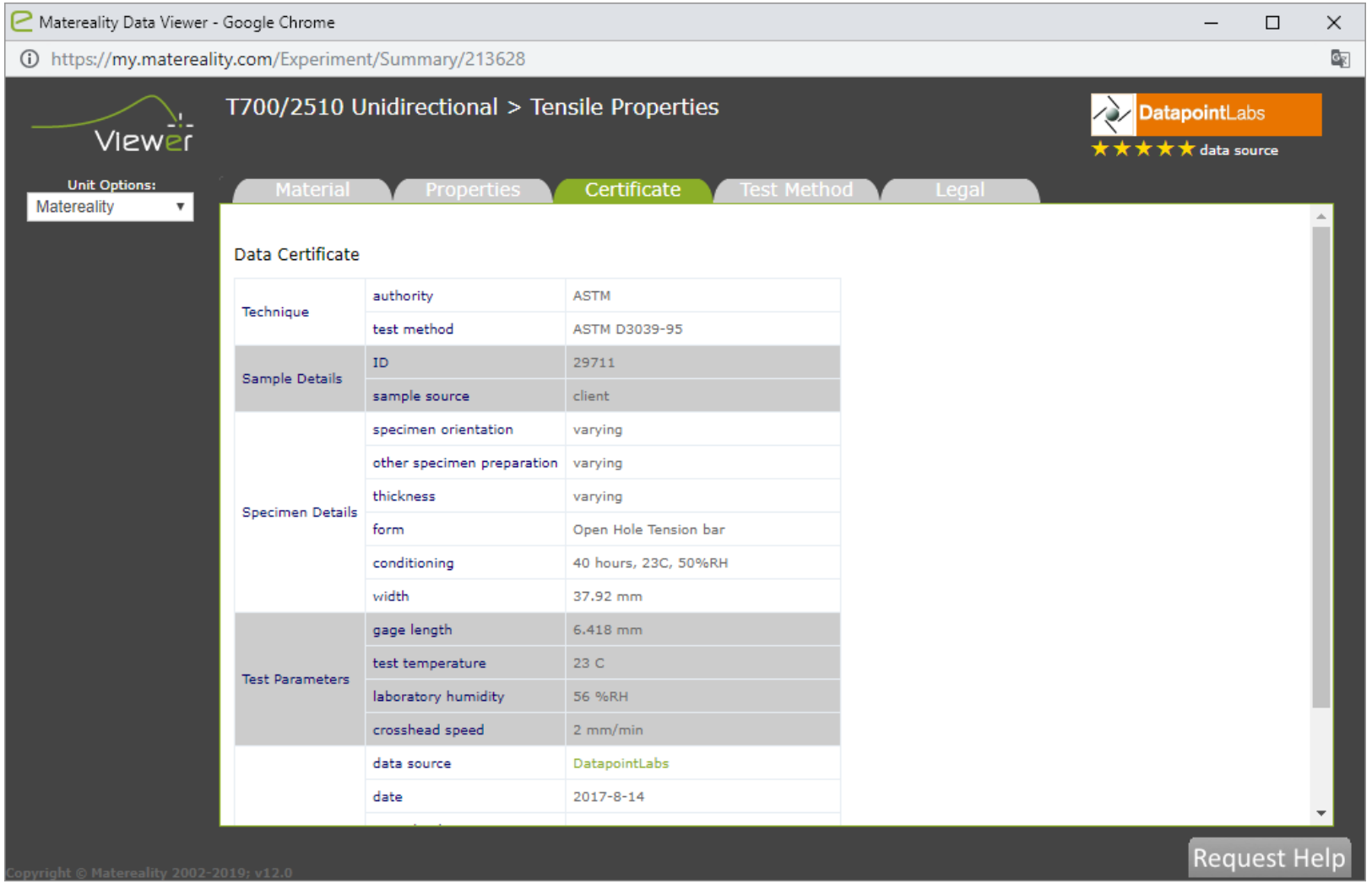


Traceability

Capture details of the physical test

- Sample information
- Test parameters
- Test lab and technician

Matereality Data Certificates satisfy the ISO 17025 data reporting requirement.

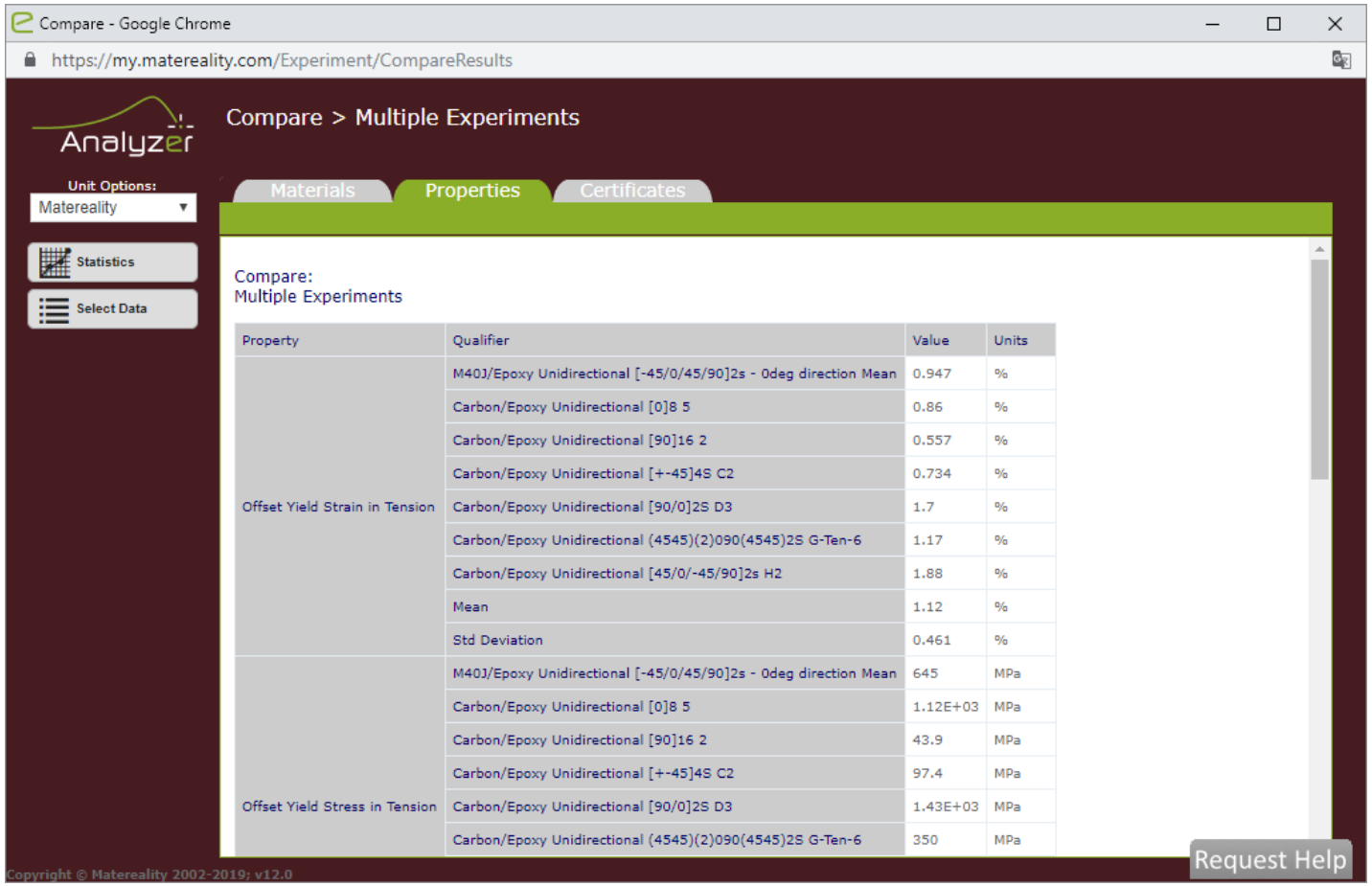


Incorporating Design Allowables

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



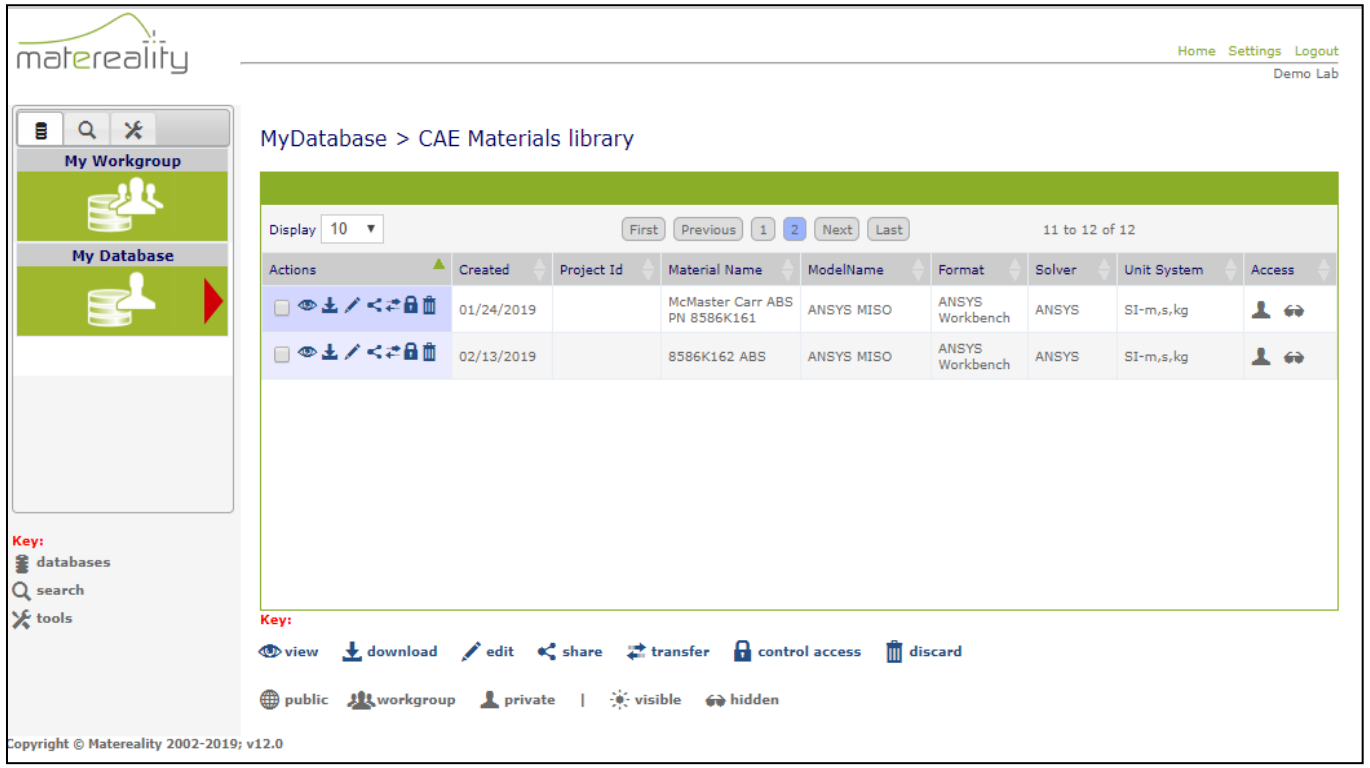
Property	Qualifier	Value	Units
Offset Yield Strain in Tension	M40J/Epoxy Unidirectional [-45/0/45/90]2s - 0deg direction Mean	0.947	%
	Carbon/Epoxy Unidirectional [0]8 5	0.86	%
	Carbon/Epoxy Unidirectional [90]16 2	0.557	%
	Carbon/Epoxy Unidirectional [+-45]4S C2	0.734	%
	Carbon/Epoxy Unidirectional [90/0]2S D3	1.7	%
	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	%
Offset Yield Stress in Tension	M40J/Epoxy Unidirectional [-45/0/45/90]2s - 0deg 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
	Carbon/Epoxy Unidirectional [90/0]2S D3	1.43E+03	MPa
	Carbon/Epoxy Unidirectional (4545)(2)090(4545)2S G-Ten-6	350	MPa

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.

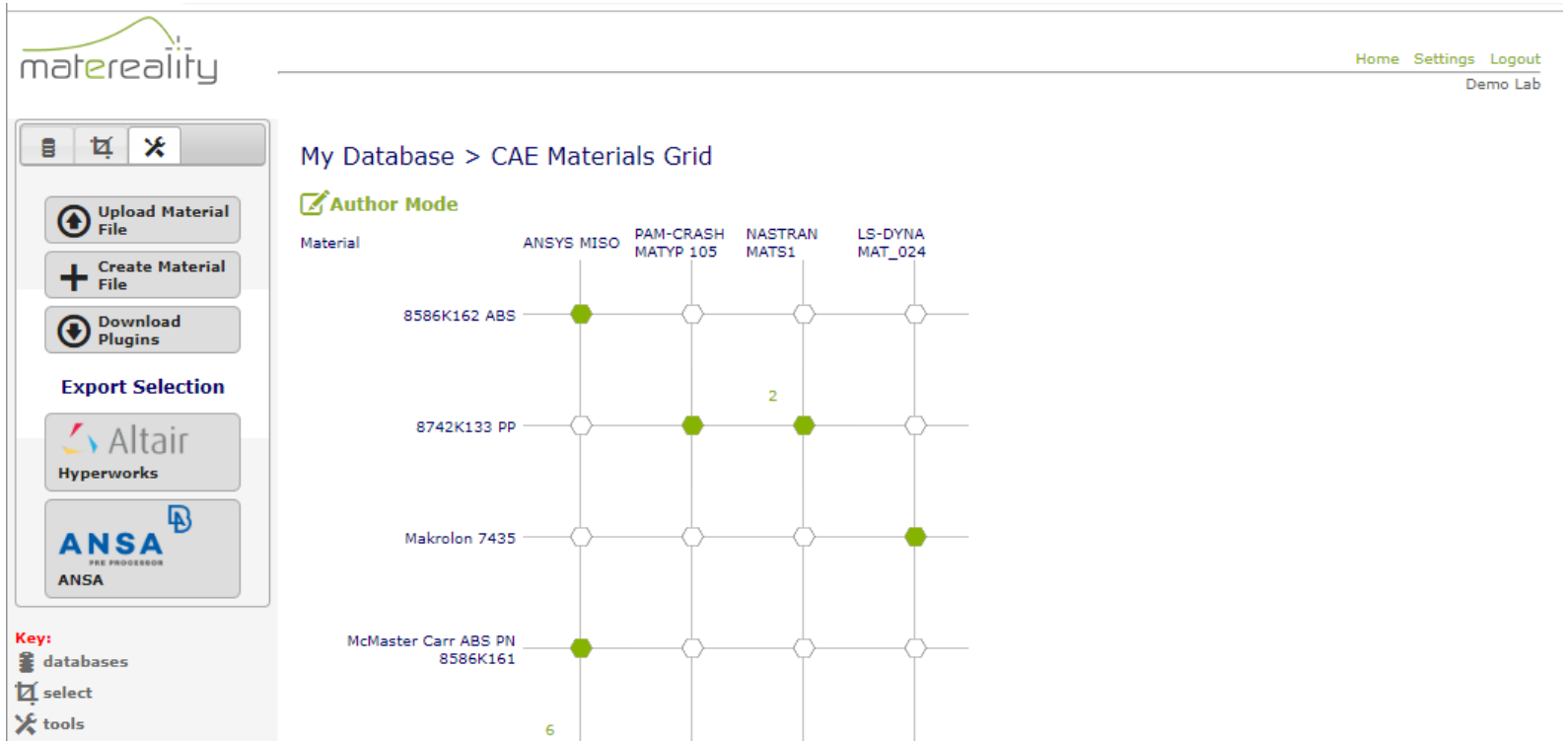


Exporting Material Cards for Simulation

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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