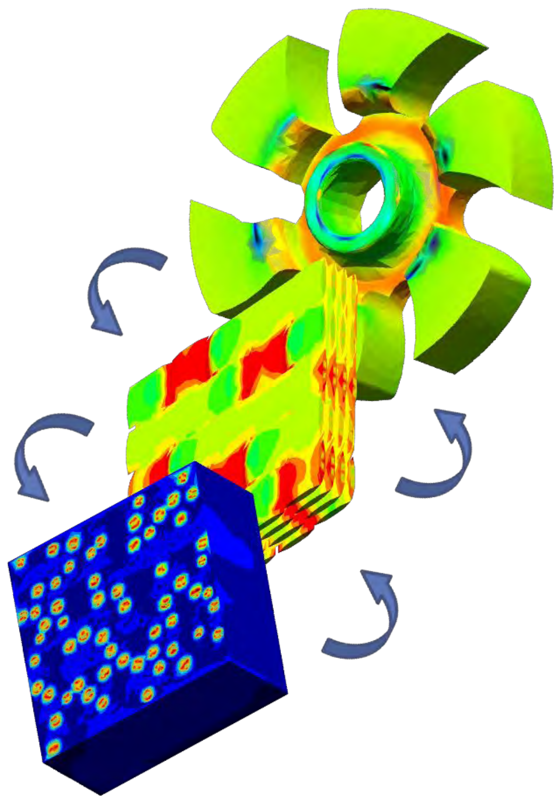
MultiMech 2015 Case Studies

GENERAL FEATURES

- Structural Analysis of Advanced Materials
- Automatic generation of Microstructures
- Finite Element solver
  - Linear and Nonlinear
  - Explicit and Implicit
  - TRUE multiscale™
- Progressive Damage Evolution
- Automatic Crack Initiation and Growth
- Mesh optimization
- 10x more accurate and 6x faster than conventional analysis techniques



MuliMechanics Overview:

MultiMechanics helps companies using advanced materials greatly reduce physical prototyping and testing, by letting them:

- Predict structural failure based on **microstructural design variables**, such as fiber orientation and volume fraction
- Virtually create and test new and existing materials with an unprecedented level of detail and accuracy, for multiple types of composites, including *woven, braided, particulate, continuous and chopped fibers reinforced plastics*
- Zoom into the material microstructure to find out *where, when and why damage initiates*

Multimech is an all-inclusive, Multiscale Finite Element software package for composite structural analysis.

Our unique TRUE Multiscale™ technology extends all the design flexibility and robustness of Finite Element Modeling down to the microstructural level, strongly coupling macro and micro mechanical response.

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Case Study:
Injection Molded - Long Chopped Fiber

See how one client used MultiMech's Virtual Testing, Manufacturing Simulation, and Multiscale Modeling techniques for a full-cycle predictive analysis of a composite part

Objective

A large part manufacturer was having trouble predicting the behavior of their long fiber injection molded parts. They performed robust injection mold simulation but was using a single-scale isotropic material card to simulate part behavior. Their simulation results were consistently predicting 1.5 - 2x higher overall strength than what was experienced in physical testing.

Further, this manufacturer was not able to accurately characterize their fiber and resin properties in situ - having only a general idea of how their materials functioned.

MultiMech's objective was to

1. Reverse Engineer their constituent's properties given a single composite coupon test result
2. Harness their injection mold simulation to get an accurate prediction of fiber orientation and length distributions
3. Run a multiscale analysis to predict the tensile strength of their composite part
4. Perform this multiscale simulation in under 1 hour.

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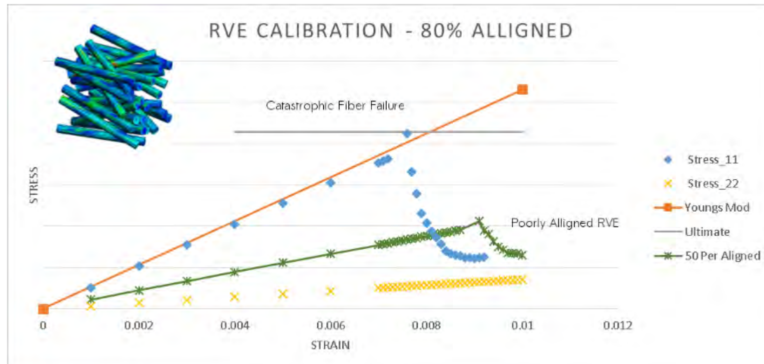
Reverse Engineering Properties

Provided to MultiMech were the material properties for:

- E11 and Ultimate Tensile Strength for an 80% aligned coupon subjected to tensile test (ASTM D3039)
- Approximated Fiber and Resin Mechanical Properties



Using these properties, a reverse engineering study was conducted to find the exact constituent properties, their interactions, and the primary failure mechanism of the composite.

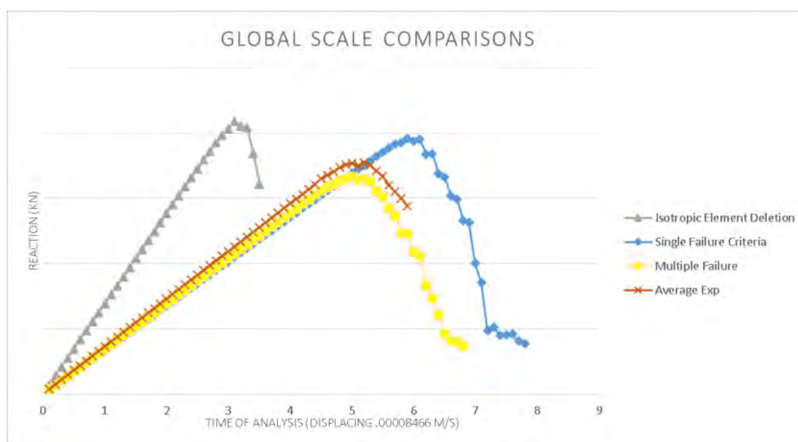
Once reverse engineering was complete, several virtual coupon tests with different fiber alignments and load directions were conducted to demonstrate the variability in composite strength depending on fiber orientation and load path.

Run Stats: 45K Element RVE - Matrix Continuum Damage -Fiber Deletion; One 4GHz core - 50 seconds per step.

Fiber Mapping and Multiscale Analysis

For the analysis of the client's "tension rod" part, the client provided the following data:

- Fiber orientation data and mesh (including jets)
- Fiber length distribution data
- Structural STEP file



Using this data, a structural mesh was generated in MultiMech that balanced the need for refinement in regions of potential failure, with the run-time restrictions set forth by the client. The fiber orientation and length distribution data was automatically mapped onto the new structural mesh and served as the input for the local scale (RVE) mesh generation and orientation.

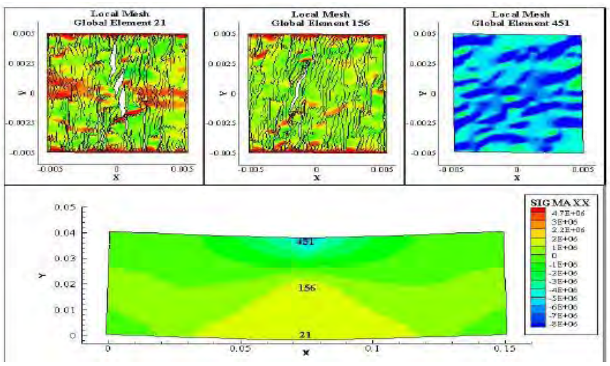
Also a proprietary damage mechanism was used that allowed MultiMech to track microstructure-driven failure, without the overhead of progressive damage modeling. This significantly reduced computation time. The blue plot above are the results of a Multiscale simulation without this proprietary microstructure-driven failure criteria.

The Multiscale results with micro-driven failure were within 4% of the experimental results and over 60% better than client's original, isotropic material assumption.

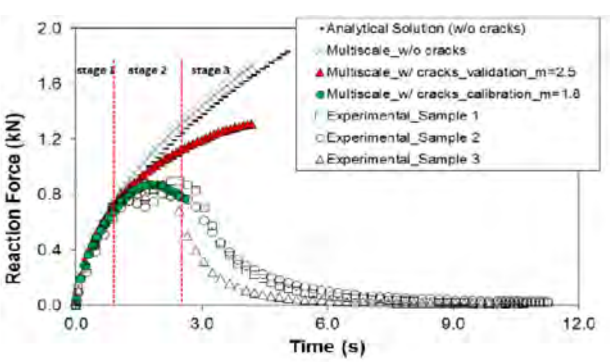
Run Stats: 12K Global Scale Elements; 33K local elements per RVE; 8 cores - 14.4 seconds per step (24 min run-time)

Validation: 3-Point Bending of Particulate Composite

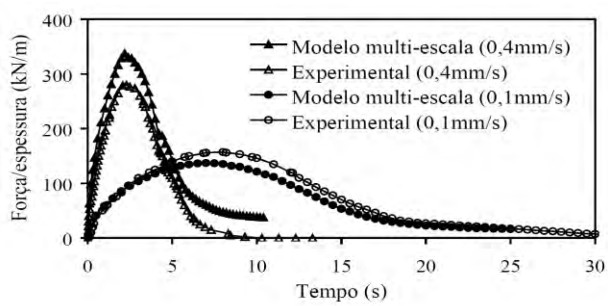
A simply supported beam is subject to a constant loading rate. The bulk material is linear viscoelastic and damage is modeled as explicit cracks automatically inserted at the local scale RVE's.



Schematic of loaded part with progressively damaged local scale RVE's of varying degrees of damage.



Comparisons between experimental data and numerical simulations



Similar results have also been obtained for the so-called Indirect Tension Test, in which a cylindrical specimen is subject to diametral compression. The results are shown above for two different loading rates. Note: this is also a viscoelastic particulate composite.

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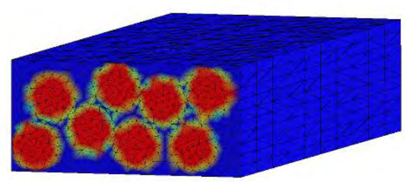
Microstructure Homogenization

A core piece of the MultiMech solution is the ability to efficiently and accurately obtain homogenized properties for a geometrically-realistic finite-element-based material microstructure (often referred to as a Representative Volume Element - RVE)

UD Fiber Micro (Soden, P. (1998) Lamina Properties, Layup Configurations....)

A Common composite microstructure is the unidirectional fiber. MultiMech is able to predict the properties of UD fiber microstructures with an average error of 2.75%

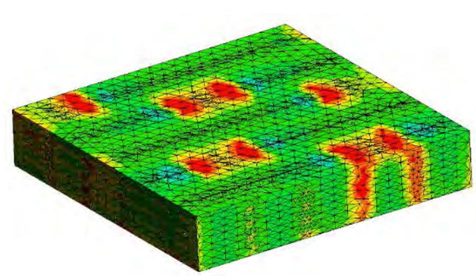
	Experiment	MM	Error Exp
E_1	138000	136223	-1.29%
E_2	11000	9499.31	-13.64%
E_3		9484.44	
Nu_12	0.26	0.253937	-2.33%
Nu_13		0.254444	
Nu_23		0.322812	
G_12	5500	5844.18	6.26%
G_13		5477.6	
G_23		3664.28	
average error			-2.75%



Woven Composite Micro (Daggumati, S (2011) Local strain in a 5-harness satin..)

As 2d and 3d woven composites become mainstream, the ability to compute their orthotropic properties and stress concentrations efficiently will become essential. MultiMech is able to predict the properties of a stacked 2D woven composite 10X better and 6X faster than traditional PBC method.

	Experiment	MM	Error Exp	PBC	Error Exp
E_1	57	55.38	2.84%	56.49	0.89%
E_2		55.28		56.41	
E_3		10.64		10.53	
Nu_12	0.05	0.05	0.00%	0.08	-60.00%
Nu_13		0.42		0.41	
Nu_23		0.42		0.41	
G_12	4.175	4.555	-9.10%	4.28	-2.51%
G_13		3.424		3.048	
G_23		3.423		3.045	
average error			2.09%		20.54%



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