Material Characterization & Qualification

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MCQ

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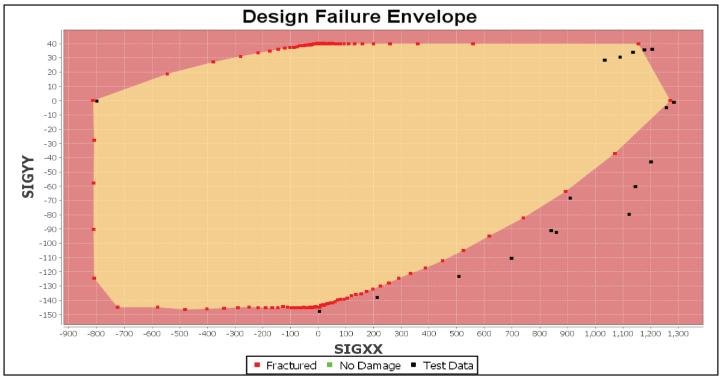
The Industrial Verified Analysis Solution to:

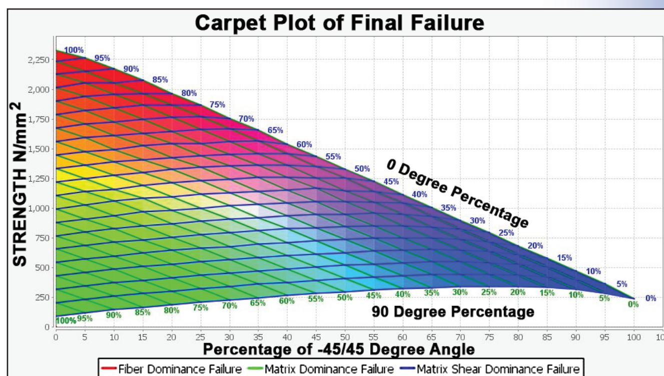
- ***Generate Thermal-Hygral-Mechanical-Electrical Properties of Laminated Composites***
- ***Predict Laminate Strength, Damage Behavior and Failure Mechanisms***
- ***Analyzes PMC/CMC/MMC, 2D/3D Woven Braided Materials***
- ***Produce Material Design Envelopes, Carpet Plots and A- & B-Basis Strength Allowables***
- ***Perform Studies at Micro or Macro Levels and Account for Scatter of Material Properties***
- ***Capture Effects of Manufacturing Defects and Service Environment***

Alpha STAR is pleased to offer our customers and industry leaders the opportunity to participate in a pre-announcement offer of one of our most popular modules in GENOA.

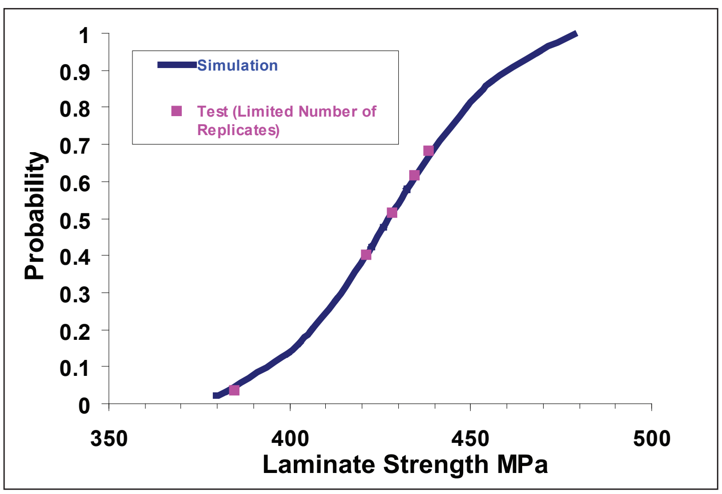
MCQ enables the ultra rapid modeling, design, and analysis of advanced composites for aerospace, automotive, wind turbine, ship building, and infrastructure industries. MCQ uses a unit cell approach for assessing material behavior not requiring finite element modeling. It is applicable to all un-notched laminates where a uniform state of stress persists. MCQ models all types of composite architectures including tape, 2D/3D woven and braided materials using multi-scale physics based micro/macro mechanics formulations. It accounts for "as built" and "as-is" states taking into consideration manufacturing defects and effect of uncertainties in material properties and specimen geometry.



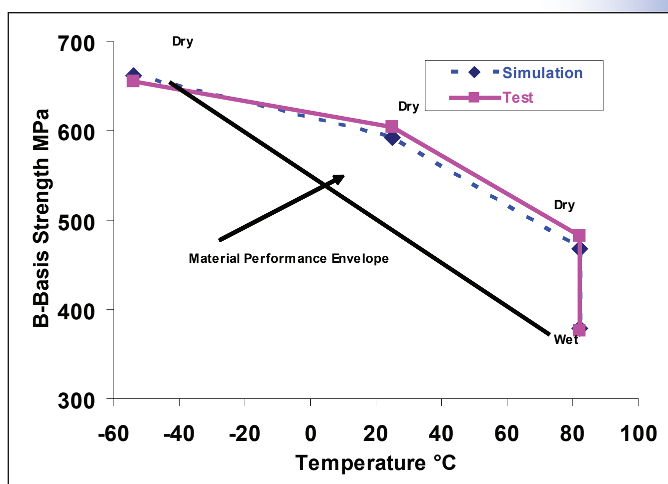
Predicted Design Failure Envelope for E-Glass/LY556 Compared Against Test (Black Dots) Data [7]



Carpet Plot of Laminate Strength as Function of 0, 45, and 90 Degree Ply Percentages (Red = Fiber Failure, Green = Matrix Failure, Blue = Matrix Shear Failure)



Cumulative Distribution Function of Laminate Strength Generated by Simulation Compared to Limited Test data for a Polymer Composites at 82°C with 85% Relative Humidity [1,2]



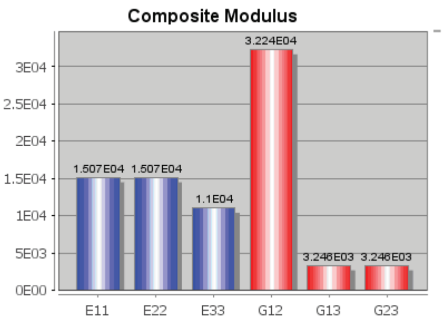
Material Performance Envelope Generated by MCQ [1,2]

Accurate estimation of material properties plays a very important role in delivering a design that meets cost and production schedule requirements. MCQ is ideal for providing quick, simplistic, easy to use, and inexpensive guide to material selection. MCQ comes with a database of properties for glass, carbon, ceramics and other material systems. MCQ delivers accurate stiffness and strength properties as input to your Durability and Damage Tolerance (D&DT) evaluation. The code is designed for use by engineers and scientists who use micro-mechanics type input (fiber/matrix/interphase properties) and those who use macro-mechanics type input (ply properties).

Features of MCQ:

- Laminate properties (thermal-hygral-mechanical-electrical)
- Load limits and damage/failure modes
- "As-built" and "as-is" material states like manufacturing defects and environmental effects
- PMC/CMC/MMC/Hybrid Systems, 2D/3D Architectures, Fiber Metal Laminates, Honeycomb or Foam Cores
- Allowables and carpet plots for test reduction
- Mesh-less unit cell simulation
- Accurate, robust, and user friendly

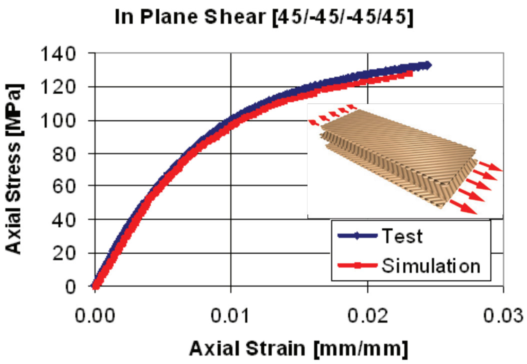
Please turn over to back side for more detailed information of MCQ capabilities.



Layup [0%/45%/90%]	Test [MPa]	MCQ [MPa]	Error [%]
[50/0/50]	1204.56	1117.20	-7.25
[25/50/25]	901.87	865.74	-4.01
[10/80/10]	504.03	504.60	0.11
[50/40/10]	1377.62	1316.20	-4.46

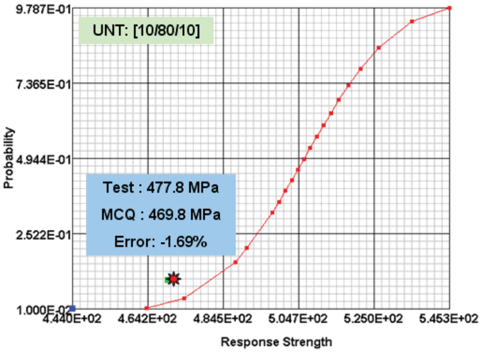
Laminate Analysis

Predict equivalent laminate properties using fiber/matrix or ply properties as input. The properties calculated include laminate strength and stiffness, and electrical and thermal properties as well. [7]



Non-Linear Material Characterization Optimization(MCO)

Reverse engineers effective fiber, matrix, ply non-linear properties (stress strain curves) from ply or from laminate test data, [7]



A- & B- Basis Allowables

Rapid and accurate prediction of A- and B-basis strength allowables for un-notched uniformly stressed coupons. This module provides the option of predicting allowables from a minimal number of test replicates. With a dedicated sensitivity analysis one can determine the influence of manufacturing parameters and material properties on the laminate strength. This helps reduce the scatter and improve the performance of the material. [7]

MCQ

Epoxy (3501-6)

Matrix Material Properties	Symbol	Effective	Units
Young's Modulus	Em	4.41	[GPa]
Poisson's Ratio	vm	0.34	[-]
Tension Strength	SmT	74.29	[MPa]
Compression Strength	SmC	309.6	[MPa]
Shear Strength	SmS	127.7	[MPa]

Fiber (AS4)

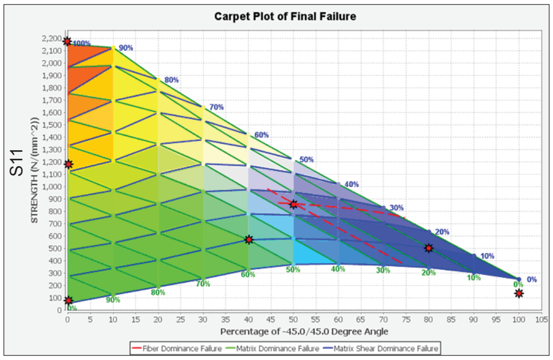
Fiber Material Properties	Symbol	Effective	Units
Longitudinal Young's Modulus	Ef11	215	[GPa]
Transverse Young's Modulus	Ef22	20.76	
Poisson's Ratio	vf12	0.236	
Poisson's Ratio	vf23	0.378	[-]
Shear Modulus	Gf12	126	
Shear Modulus	Gf23	7.53	
Longitudinal Tension Strength	Sf11T	3327	[MPa]
Longitudinal Compression Strength	Sf11C	2355	[MPa]

AS4/3501-6 (Tape)

Loading	Test Stiffness [GPa]	Simulation Stiffness [GPa]	Error [%]	Test Strength [MPa]	Simulation Strength [MPa]	Error [%]
LT	126	126	0	1950	1953.5	0.18
LC	126	126	0	1480	1486.1	0.41
TT	11	11	0	48	48.43	0.9
TC	11	11	0	200	199.84	-0.08
IPS	6.6	6.6	0	79	79.02	0.03

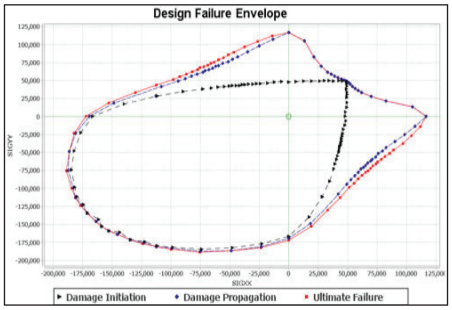
Fiber, Matrix and Lamina Calibration

Reverse engineer effective linear fiber/matrix properties from lamina or laminate test data (strength and stiffness). The effective properties accounts for the thermal residual stresses and interface due to curing process. [1]



Parametric Carpet Plot

Generate multiple carpet plots that show variation in thermo-mechanical properties, including strength, stiffness and thermal expansion, with variation in ply layup distributions. This capability is ideal for use at the beginning of a new program as it provides an accurate and a complete map of the material properties providing alternate design options rapidly and at low cost. [7]



Design Failure Envelope

Predicts design failure envelope for chosen failure criteria for laminates. Strength, strain, and interactive based failure mechanisms are available. Fiber failure under tension/compression including micro-buckling, matrix cracking under tension and compression and delamination (in-plane and out-of-plane) are determined for the ply and the laminate. Several Failure Criteria can be compared for better understanding and comparison against test data.

	E-glass/LY556			S-glass/FM94			AS4/3501-6			IM7/MT45			EGKG/DION 9800 3TEX Weave			T700GC/2510			FML (GLARE 2-3/2-0.2)		
Property	Test [1]	MCQ	% Error	Test [4]	MCQ	% Error	Test [1]	MCQ	% Error	Test [5]	MCQ	% Error	Test [6]	MCQ	% Error	Test [7]	MCQ	% Error	Test [8]	MCQ	% Error
E11 [GPa]	45.60	45.69	0.20	51.22	51.24	0.04	126.00	126.00	0.00	152.90	153.00	0.07	25.00	24.77	-0.92	125.55	124.90	-0.52	64.76	64.76	0
E22 [GPa]	16.20	16.20	0.00	9.80	10.03	2.35	11.00	11.00	0.00	8.18	8.18	0.00	24.75	25.09	1.37	8.41	8.40	-0.06	50.73	50.88	0.295683
G12 [GPa]	5.83	5.83	0.00	3.68	3.77	2.45	6.60	6.60	0.00	3.61	3.61	0.00	3.16	3.24	2.41	4.23	4.23	0.00	-	18.76	-
v12 [-]	0.28	0.28	0.00	0.33	0.33	0.00	0.28	0.28	0.00	0.30	0.30	0.00	0.15	0.11	-26.67	0.31	0.31	0.32	-	0.33	-
XT [MPa]	1280.00	1271.30	-0.68	2298.00	2321.30	1.01	1950.00	1953.50	0.18	2140.16	2155.66	0.72	473.75	462.96	-2.28	2172.44	2177.00	0.21	1102	1102	0
XC [MPa]	800.00	812.80	1.60	1442.00	1493.00	3.54	1480.00	1486.10	0.41	1378.95	1384.34	0.39	-	472.82	-	1449.77	1447.00	-0.19	-	663	-
YT [MPa]	40.00	39.99	-0.02	31.48	32.60	3.56	48.00	48.43	0.90	56.64	54.88	-3.11	454.92	467.06	2.67	49.28	49.28	0.00	309.7	310.4	0.226025
YC [MPa]	145.00	144.90	-0.07	62.29	64.60	3.71	200.00	199.84	-0.08	186.33	186.10	-0.12	-	477.21	-	198.67	200.30	0.82	-	387.3	-
S12 [MPa]	73.00	79.49	8.89	92.00	94.40	2.61	79.00	79.02	0.03	65.82	66.46	0.97	26.90	26.37	-1.97	154.65	156.20	1.00	-	208	-

References

1. Hinton, M.J., Kaddour, A.S. and Soden, P.D., (2004). Predictive capabilities of nineteen failure theories and design methodologies for polymer composite laminates. Part B: Comparison with Experiments. Failure Criteria in Fiber Reinforced Polymer Composites: The World-Wide Failure Exercise, Eds. Hilton, M.J., Kaddour, A.S., and Soden, P.D., Elsevier, Kidlington, Oxford, UK, 1073-1221.
2. Galib Abumeri, Frank Abdi, and Mike Lee, "Verification of Virtual Generation of A- and B-Basis Allowables for Polymer Composites Subject to Various Environmental Conditions", SAMPE 2009 China Conference.
3. DOT/FAA/AR-03/19, Final Report, "Material Qualification and Equivalency for Polymer Matrix Composite Material System: Updated Procedure" Office of Aviation Research, Washington, D.C. 20591, U.S. Department of Transportation Federal Aviation Administration, September, 2003.
4. M. Lee, M. Short, Frank Abdi, and J. Qian., "A Math Based Methodology for Longevity Fatigue Prediction of 3D Woven Fiber Glass Reinforced Vynle-ester Composite". SAE, 2006, Detroit, MI. 06M29-M28 Fatigue.
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6. Talagani, M. R., Garg, M., Gurdal, Z., Frelx, H. de, (2009). Virtual Testing of Glare Coupons Using Progressive Failure Analysis", 50th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Palm Spring, California.
7. G. Abumeri, M. Garg, F. Abdi, A. McCloskey and R. Bohner, "Validation of a Computational Approach for Composite Material Allowables Using Sealed Envelope Predictions for Reduced Testing", Sampe Journal, September/October 2009

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