Micro-Mechanics Based Static/Fatigue Analysis

Challenge

The key challenge is to analytically calibrate both static and fatigue in-situ fiber and matrix properties of the Unidirectional (UD) lamina with high accuracy and in a very short time. The results will then enable the user to predict the elastic and mechanical performance of mixed layups under both static and fatigue conditions. Alpha Stars commercially available material modeling tool MCQ-Composites can be efficiently used to perform such calibrations analytically with high accuracy and shorter turnaround time.

The objective of this case study is to perform static calibration of a laminated tape, based on five ASTM static tests (tension and compression for D3039 and D3410, and a shear test D3518). The shear stress-shear strain curve from a ± 45 specimen loaded in tension (D3518) was used to reverse engineer matrix non-linear stress strain curve. In addition, based on two ASTM cyclic tests, fiber and matrix effective (in-situ) S-N degradation curves of the UD lamina is reverse engineered.

Solution

Classical Laminate Theory (Analytical) and Micro-Mechanics based methodology is employed. The step by step solution process is shown next:

- **Step-1:** Fiber/Matrix/ Ply Calibration
- **Step-2:** Material Non-Linearity Analysis
- **Step-3:** Laminate Mechanics Analysis
- **Step-4:** Constituent Fatigue Life Analysis
- **Step-5:** Progressive Fatigue Life Analysis

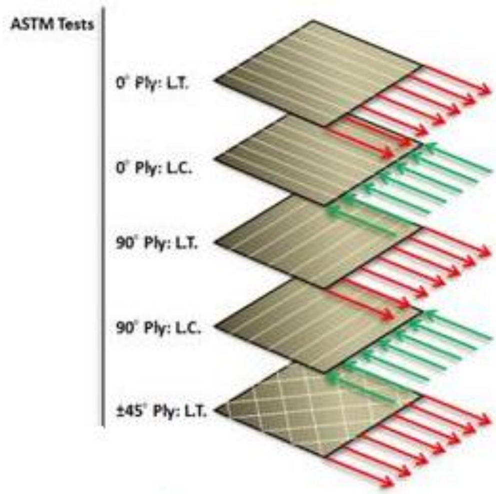
Key Highlights & Benefits
Product: MCQ-Composites
Industry: Aerospace and Automotive
Application: Material Calibration and Validation
Benefits: Rapid assessment of properties, Reduction in testing with cost savings, Strength allowable for reliability, Identification of damage initiation/propagation to failure, Identification of damage/failure modes and Results verified with test data

Results & Conclusion

- Generate fiber and matrix in-situ properties, as well as the matrix non-linear stress-strain curve based on given five ASTM static test results.
- Generate fiber and matrix in-situ S-N degradation curves.

- Predict the elastic and mechanical performance of mixed layups under both static and fatigue loading.

Input	Output



5 ASTM UD laminate static test

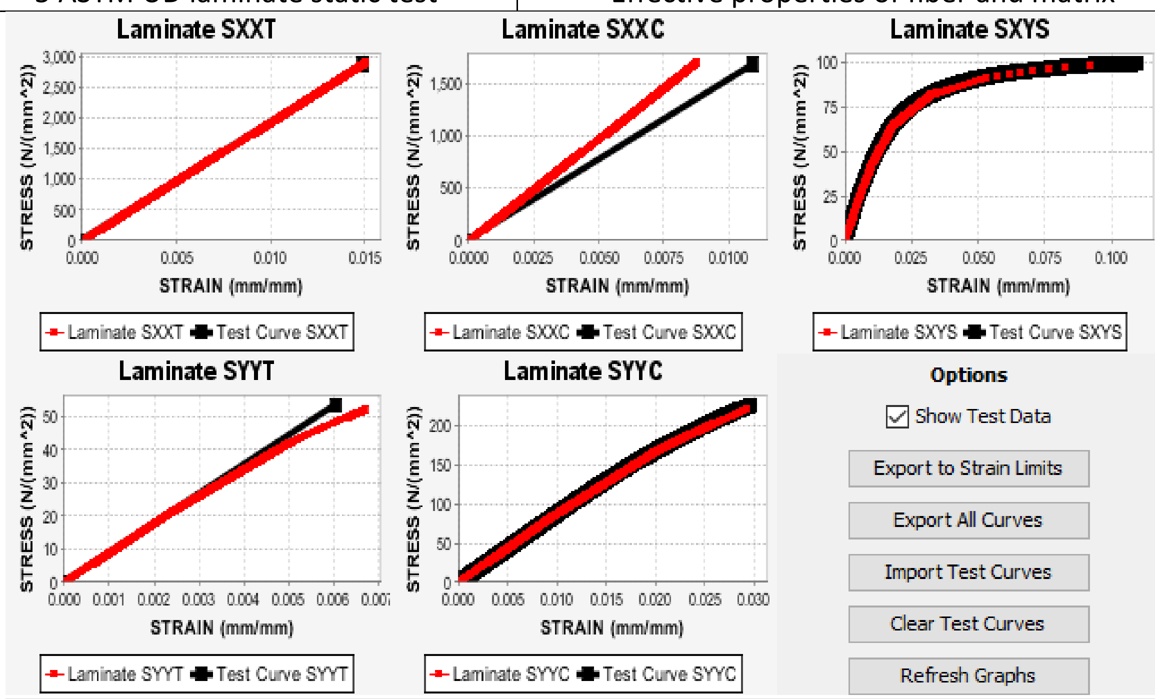
Effective Fiber (IM7) Properties

	Symbol	Units	Effective
Longitudinal Young's Modulus	E_{f11}	[GPa]	277.027
Transverse Young's Modulus	E_{f22}	[GPa]	13.037
Shear Modulus	G_{f12}	[MPa]	11.247
Shear Modulus	G_{f23}	[MPa]	4.698
Poisson's Ratio	ν_{f12}	[-]	0.242
Poisson's Ratio	ν_{f23}	[-]	0.387
Longitudinal Tension Strength	S_{f11T}	[MPa]	4108.442
Longitudinal Compression Strength	S_{f11C}	[MPa]	2274.940

Effective Epoxy (977-3) Properties

	Symbol	Units	Effective
Young's Modulus	E_m	[GPa]	3.438
Poisson's Ratio	ν_m	[-]	0.432
Tension Strength	S_{mT}	[MPa]	81.279
Compression Strength	S_{mC}	[MPa]	344.975
Shear Strength	S_{mS}	[MPa]	154.941

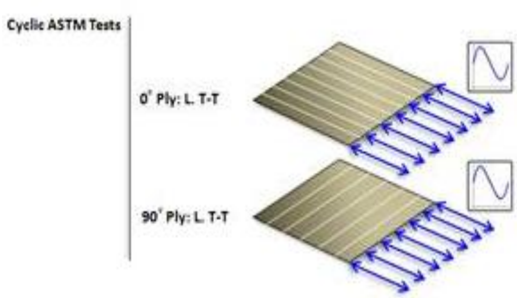
Effective properties of fiber and matrix



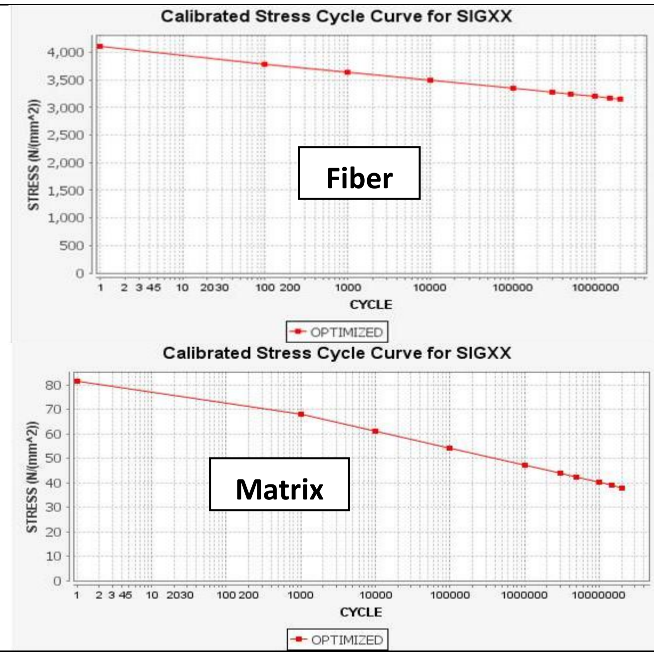
Laminate Mechanics Analysis (MCQ Prediction vs. Test)

Carbon Fiber Composite IM7-9773 — Static Calibration in MCQ-Composites

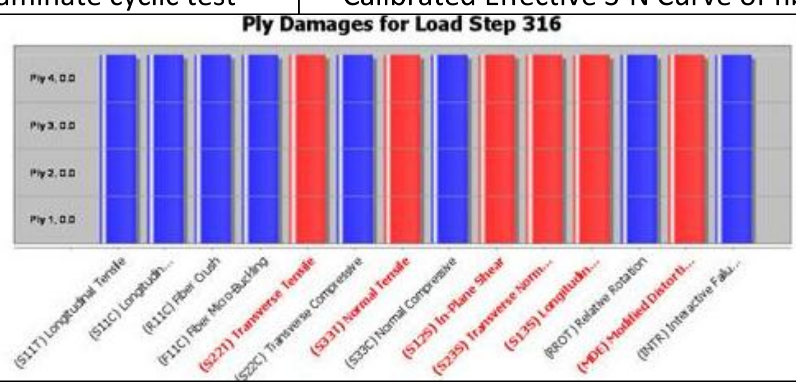
Input	Output



2 ASTM UD laminate cyclic test



Calibrated Effective S-N Curve of fiber and matrix



Through thickness ply damage chart

IM7-9773 — Fatigue Calibration and Progressive Fatigue Life Analysis in MCQ-Composites

Related Publications

1. Damage Tolerant Composite Design Principals for Aircraft Components under Static Service Loading using Multi-Scale Progressive Failure Analysis. Journal of Composite Materials, JCM-16-0118.
2. Damage-tolerant composite design principles for aircraft components under fatigue service loading using multi-scale progressive failure analysis. Journal of Composite Materials 2017.
3. Pressure dependent yield criteria for polymers. Materials Science and Engineering, 13 (1974) 113 –120 © Elsevier Sequoia S.A., Lausanne - Printed in The Netherlands