MCQ Ceramics
Tested and Verified.™

Material Characterization & Qualification – Ceramics

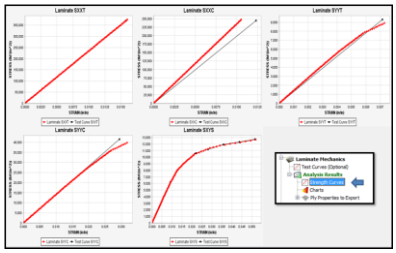
- ***MCQ-Ceramics is a Multi-Scale material modeling, characterization & qualification software that predicts ceramic material performance considering the effect of defects, material scatter and environmental degradation under service load.***
- ***Validation cases available for several classes of Ceramic Matrix Composites:***
  - ***Oxide/Oxide, 2) SiC/SiC-MI, 3) SiC/CAS, 4) SiC/SiC-CVI.***
- ***Easy to use interface and property generation for NASTRAN, ABAQUS, ANSYS***

MCQ-Ceramics enables engineers, designers and material specialists to quickly and accurately predict mechanical properties (stiffness, strength, conductivity) of advanced composite laminates (2-D/3-D) considering environmental degradation effects: (1) effect of defects, voids, fiber waviness (2) micro-crack density, (3) recession, (4) global and local oxidation, and (5) environmental/thermal barrier coating (EBC/TBC). In addition, the non-visual measurement NDE technique such as electrical resistivity (ER), and acoustic emission (AE) is predicted. A building block reverse engineering approach is used to calibrate the "effective" constituent (fiber/matrix) properties. The effective properties are used to validate against the minimum available in-plane ply level ASTM standard test data. It is independent of finite element modeling as it utilizes a unit cell approach. It generates the ABD matrix and engineering constants that are used as material property input file with NASTRAN, ABAQUS, ANSYS and GENOA for comprehensive structural finite element analysis.

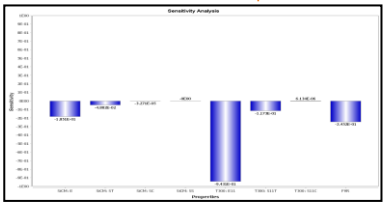
MCQ-Ceramics Highlights

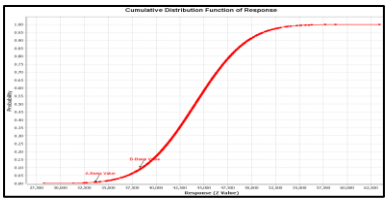
- ✓ **Supports full breadth of 2D/3D composite architectures**
  - Laminated Tape Lay-Up, CVI, MI, EBC/TBC, SiC, Oxide
  - Fiber Architecture (Woven, Triaxial, Harness Satin Weave, Braided,and Stitched)
  - Fiber Coating (InterPhase)
- ✓ **Determines laminate properties such as**
  - Young's Modulus, Poisson's Ratio
  - Strength, Coefficient of Thermal Expansion
  - Electrical & Thermal Conductivity
  - Moisture Diffusivity, Residual Stresses
- ✓ **Determines at the laminate level**
  - Lamina and laminate limit loads, stresses, and strain
  - Damage initiation and propagation to final failure
  - Alternate ply layups to meet design requirements
  - Strength allowable for specific reliability
  - Design failure envelope, fatigue analysis
  - Effects of manufacturing defects
- ✓ **Supports Failure Criteria (In-built and User Defined)**
  - Translaminar (Matrix, Fiber, Ply)
  - Interlaminar/Delamination (Tension, Shear, Relative Rotation)
  - Interactive Strength (Tsai-Wu, Tsai-Hill, Puck, MDE, Hoffman, Hashin)
  - Interactive Strain- Strain Invariant Failure Theory (SIFT)
  - Maximum Stress, Maximum Strain, User Defined
- ✓ **Supports Environmental Degradation**
  - **Micro Crack Density** – Formation of crack density in matrix loaded component reducing stiffness and strength
  - **Matrix Defects** – Void shape, size distribution reducing stiffness and strength, matrix creep, fatigue
  - **Fiber Strength Statistics** – Gradual failure "Rope effect" – Probabilistic Weibull distribution
  - **Interphase Mechanics** – Fiber bridging
  - **Recession** - Material vaporizes at high temperature and loss of mass with sufficient gas velocities
  - **Global Oxidation** – Composite infiltrated with oxygen diffusion, SiC reacts to form SiO2, which eats away fibers.

Match test data using constituent properties

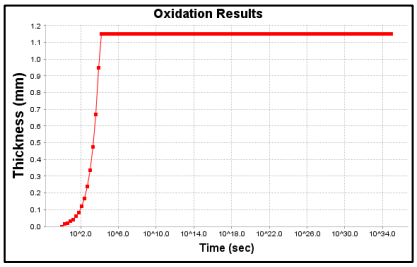


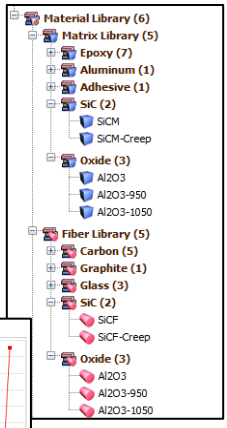
Compute Allowables and Sensitivities



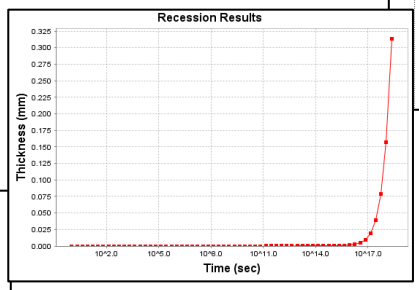


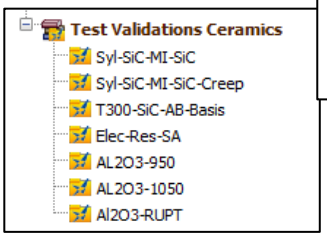
Oxidation





Recession





Includes Test Validation Cases and Material Libraries

- **Discrete Oxidation** – Oxygen/moisture diffuses into surface cracks causing damage and accelerated oxidation

✓ **Supports Service Loading**
- Static (in-plane, out-of-plane, pressure), Fatigue,
- Creep rupture, thermo-mechanical, and strain rate effect

✓ **Includes Test Validations for classes of Ceramic Materials**
- **Oxide/Oxide**: Nextel 610 at 1050 °C, and 950 °C, and Nextel 720 at RT
- **SiC/SiC at RT:** Sylramic/IBN/MI, SiC/SiC CVI, and SiC/CAS
- **SiC/SiC :** SiC-iBN/SiC composite characterization at 1315° C
- **NDE tests***:* SIC/SiC ER, and AE
- **A/B-basis allowable:** Prediction for T300/SiC (0°/90°)

Key Benefits

- Rapid assessment/selection of ceramic composite material layup models to meet design requirements
- Reduce physical test by over 65-70% thus saving significant cost
- Ease of use, results verified with test data for class of materials
- Predicts strength allowable for specific reliability
- Assessment of lamina and laminate limit loads, stresses and strain
- Identification of damage initiation and propagation to final failure & modes of damage/failure

User Friendliness

- Graphic User Interface (GUI) is easy to learn with navigation tutorials and videos. Manages multiple projects, input and output for material characterization
- Easy creation, editing and quick import/export of material properties and laminate layups with commonly used third-party FE Solvers: NASTRAN (.bdf), ABAQUS (.inp), ANSYS (.cdb) and GENOA (.dat) formats

Key Modules

- **Fiber/Matrix/Ply Calibration** Reverse engineer fiber and matrix properties from tested in-plane ply properties. **Material Non-linearity** Predicts effective matrix stress strain curve from in-plane shear ASTM standard test data. The curve lumps the effect of crack density, viscosity, and interphase.
- **Ply Mechanics and Characterization** Compute thermal-electrical-hygral-mechanical ply properties from fiber and matrix properties, void, weave, and waviness information. Compute variation with respect to angle changes.
- **Laminate Mechanics** Predicts laminate level thermal-electrical-hygral-mechanical level material properties using fiber/matrix, ply, or matrix thermal-electrical-hygral-mechanical level material properties as input along with braid cards for fabric, woven or 3D architecture. The analysis relies on output from combined progressive failure analysis, micromechanics and classical laminate theory.
- **Progressive Failure** Performs detailed damage tolerance analysis to ultimately predict the strength, modulus, and laminate and layer-by-layer damage evolution process.
- **Design Failure Envelope** Predicts first ply and final failure envelope for lamina or laminates based on the chosen failure criteria.
- **Parametric Carpet Plots** Provides graphical representation of strength and material properties of laminates containing symmetric and balanced plies varying percentage of three user defined orientations. It helps during laminate layup selection process and ultimately test reduction.
- **A-& B- Basis Allowables**
  Predicts A- and B-basis strength allowables based on material and fabrication uncertainty and scatter from unidirectional ASTM standard tests. Helps in test reduction, material selection process and improve reliability.
- **Manufacturing Defects Mechanics/Characterization**
  Predicts effect of manufacturing defects such as void shapes & size and fiber waviness on matrix or ply level material properties, respectively.
- **Constituent and Progressive Fatigue Life**
  Reverse engineer in-situ stress versus cycles to failure (S-N) curve for the matrix & fiber using in-plane shear, transverse tension, and longitudinal tension fatigue life curves obtained typically from ASTM standard tests or literature. Predicts fatigue life curve for laminates from ply or constituent level fatigue life input.

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More of Alpha STAR's Test Validated products:

MCQ: Composites, Ceramics, Metals, Nano, Chopped

GENOA: PFA, PFDA, UAB, URD, ABS, PCP, PA, Quasi Static Fatigue & Random Fatigue, Harmonic & PSD Fatigue, Fatigue with Fracture Mechanics, PFA_AGING, VCCT, DCZM, Filament Winding, Jobspooler, GENOA_CLOUD