Material Characterization of Advanced Composites

Dr. Hannes Körber

Industry Manager Composites

28. testXpo

16.10.2019
Standard Quasi-Static Testing

Material characterization starts on the ply level.

- Tension
- Tension
- Compression
- In-Plane-Shear (±45°)
- Iosipescu-Shear
- V-Notched Shear
Standard Quasi-Static Testing

The basic in-plane elastic properties of a composite ply are the foundation for material evaluation and design.

$E_1$  longitudinal modulus
$E_2$  transversal modulus
$G_{12}$ in-plane shear modulus
$\nu_{12}$ Poisson ratio

Standard Quasi-Static Testing

The independent strength properties of a composite ply define the cornerstones for failure criteria used in analysis and design.

- **Puck failure envelope**
  for plain stress state

\[ S_L \quad \text{in-plane shear strength} \]

\[ Y_C \quad \text{transverse compressive strength} \]

\[ X_C \quad \text{longitudinal compressive strength} \]

\[ X_T \quad \text{longitudinal tensile strength} \]

\[ Y_T \quad \text{transverse tensile strength} \]
Standard Quasi-Static Testing

Further tests on the laminate level evaluate the influence of holes, fasteners and impact damage. Simple tests are used for quality control.
Open-hole tension and compression strength test generate important design allowables for aerospace structures.

after [Camanho et al. Composites A 43, 2012]
Standard Quasi-Static Testing

Damage tolerance for barely visible impact damage (BVID) is evaluated with the compression after impact (CAI) test.
Standard Quasi-Static Testing

Characterization of interlaminar fracture toughness evaluates the weak-spot of layered composites.

- **Mode I**
  - Normal Crack Opening
  - DCB
  - Double Cantilever Beam

- **Mode II**
  - Shear Crack Extension
  - ENF
  - End Notch Flexure

**Mixed Mode I+II**
Fatigue Testing

Woehler line diagrams express the strength reduction under cyclic loading conditions.

Fatigue tests CFRP
55% fibre volume content
All tests according to ‘cyclic tensile test’ procedure
f=3-10Hz, R 0.1, RT,

[G. Pinter. Montanuniversität Leoben]
ZwickRoell offers a great variety of solutions for fatigue testing of composite materials.

ZwickRoell offers a great variety of solutions for fatigue testing of composite materials.

- **Servohydraulic universal testing machines**
  - up to 2500 kN
  - here: HC25 compact with integrated hydraulic unit

- **LTM electrodynamic testing machine**
  - for fatigue testing up to 10 kN

ISO 13003:2003(E)
Temperature Testing

The mechanical properties of fiber-reinforced polymer matrix composites are strongly temperature dependent.
Temperature Testing

ZwickRoell has developed a modular system for non-ambient testing, covering 21 methods and about 120 test standards.

Testing in large temperature range from -70°C up to 360°C

Testing at ambient temperature
Alignment

Alignment errors strongly effect results for static tests with brittle materials as well as for fatigue and creep testing.

- Misalignments generate peak-strains and lead to apparently lower resistance
Alignment

The intelligent ZwickRoell alignment software (based on testXpert III) guides the alignment process in a perfect way.

The Alignment software

- **guides** the operator during the measuring procedure
- **controls** the testing machine
- **measures** the alignment error
- **supports** the operator aligning the grips via the alignment device
- **records** the alignment measuring results according to ASTM standards
Polymer composites are strain rate dependent materials.

- Relevant strain rates for dynamic automotive and aerospace load scenarios
  - Automotive: quasi-static \( \leq \dot{\varepsilon} \leq \approx 500 \) s\(^{-1}\)
  - Aeronautical: quasi-static \( \leq \dot{\varepsilon} \leq \approx 1000 \) s\(^{-1}\) (and higher)

[Nemat Nasser, ASM Handbook Vol. 8, 2000]
Polymer composites are strain rate dependent materials.

In-plane shear stress-strain response of UD carbon-fiber-reinforced polymer

ZwickRoell offers a wide range of test machines for evaluation of the velocity-dependent material response of composites.
ZwickRoell offers a comprehensive range of standardized grips, fixtures and solutions to achieve reliable test results for composites.