A178

	Testing
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Introduction[edit | edit source]

This page provides an overview of the typical tests performed to obtain the properties of and characterize a composite material. It introduces and links to the equipment found in a test lab including analytical equipment such as a DSC, DMA, TMA, TGA, FTIR, Rheometer, etc. and mechanical testing equipment such as load frames and fixtures. Testing steps are support activities within the factory. That is, they are not directly involved in the processing of a composite part, but support those activities that are directly involved.

See also Foundational method documents in Foundational Knowledge on how to perform tests to determine different material properties and the AIM event webinar: Composite materials engineering webinar session 12 - Testing.

Background[edit | edit source]

ASTM D4762 provides an extensive list of the standards that govern various types of testing for polymer matrix composite materials. However, a small set of specific material properties are required for analysis when designing composite parts. The properties of interest are:

- Tensile strength, modulus, and Poisson's ratio (see Tensile Testing - M117)
- Compressive strength, and modulus
- Shear strength, and modulus

Watch this AIM event webinar to learn more about these properties and how they are used: Parameters for Structural Analysis of Composites.

Some secondary tests may also be performed as part of material characterization and/or design activities. These properties are usually used for material comparison/screening or quality control purposes, as they are not directly input into standard composite analysis.

- Flexural strength and modulus
- Short beam shear
- Glass transition temperature (see Glass transition temperature (Tg) - A210)

Application[edit | edit source]

For all types of tests, the method of specimen preparation is extremely important. Divergence from the specimen dimensions required by the ASTM standards introduces the potential for inappropriate specimen failure modes and variability in the results. Appropriate preparation methods must be used to ensure that the specimens meet the required tolerances and have not been damaged by the machining process. Adhering to the test standard also allows for direct comparison to other results obtained under those specifications, perhaps from a completely different laboratory.

Refer to the following list for brief description of the mechanical properties measured in the tests:

- E_i^+ : Tensile modulus
- E_i^- : Compressive modulus
- E_f : Flexural stiffness
- G_i : Shear modulus
- ν_{ij} : Poisson's ratio
- S_i^+ : Tensile strength
- S_i^- : Compressive strength
- S_f : Flexural strength

Tensile Strength and Modulus[edit | edit source]

This test is performed to determine the in-plane tensile properties of composite materials. Extensometers, strain gauges, and/or DIC methods are commonly used to take strain measurements for modulus and Poisson’s ratio calculations. Depending on the type of reinforcement in the composite, the specimens may either be rectangular strips or dog-bone shaped. Tensile properties are typically fibre-dominated. For more information on how to carry out this test, see Tensile Testing - M117.

Test	Properties Measured	Specimen Type	Description/Advantages	Disadvantages	Comments
ASTM D3039	E_i^+, ν_{ij}, S_i^+	Rectangular	Suitable for random, discontinuous, and highly oriented reinforcements. Use extensometers or strain gauges for strain measurements.	Tabbing may be required. Tabs must be parallel and edges perpendicular with the gage.	Preferred for most use cases. G10 glass fibre laminate is commonly used for the tabs. Bondline thickness typically between 0.5 to 1.2 mm.
ASTM D5083	E_i^+, ν_{ij}, S_i^+	Rectangular	Technically equivalent to ISO 527-4. No tabbing required. Use extensometers for strain measurements.	Only suitable for plastics and low-modulus composites	Straight-sided alternative so ASTM D638.
ASTM D638	E_i^+, ν_{ij}, S_i^+	Dog-bone	Test specimens easy to prepare. Technically equivalent to ISO 527-1. Use extensometers for strain measurements.	Should not be used for composites with highly oriented reinforcements	Also not recommended for high modulus composites.

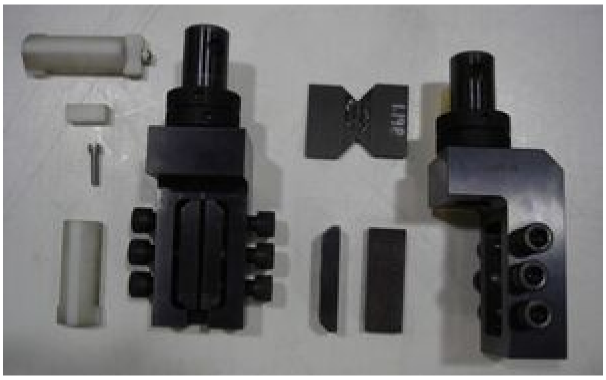
Compressive Strength and Modulus[edit | edit source]

This testing is performed to determine the in-plane compressive properties of composite materials. Strain gauges are used to take strain measurements for calculating Young's modulus in compression and Poisson's ratio. The test uses a rectangular specimen. Compression properties are resin-dominated.

Test	Properties Measured	Specimen Type	Description/Advantages	Disadvantages	Comments
ASTM D6641	E_i^-, ν_{ij}, S_i^-	Rectangular	Specimens may be tabbed or untabbed. Specimens are loaded by a combination of end and shear loading.	Composites containing more than 50% 0° plies must be tabbed. Limited to composites that are balanced and symmetric and contain at least one 0° ply.	Most common method due to ease of use and simplicity. Suitable for continuous fibre composites. AKA Combined Loading Compression (CLC)
ASTM D3410	E_i^-, ν_{ij}, S_i^-	Rectangular	Shear loading - Typically produces the most repeatable results.	Second most common method. The fixture is expensive and cumbersome to use. AKA Illinois Institute of Technology Research Institute (IITRI). Requires perfectly square ends on the specimens as it is end-loaded.	Widely accepted in the industry.
ASTM D695	E_i^-, ν_{ij}, S_i^-	Rectangular	The test is required to show equivalence to a test done 20-30 years ago (i.e., replacing an aircraft part that was developed with test data from ASTM D695 in the 70s). Good for very thin specimens.	The test is not common today.	Originally came from the plastic industry.

Shear Strength and Modulus[edit | edit source]

This testing is performed to determine the in-plane shear properties of composite materials. The testing is performed on a load frame, and uses strain gauges to take strain measurements for modulus calculations. The test uses a rectangular specimen with centrally located v-notches.



ASTM D7078 V-Notched Rail shear test fixture.

Test	Properties Measured	Specimen Type	Description/Advantages	Disadvantages	Comments
ASTM D7078	$$G_i$$	Rectangular with v-notches	Provides shear strength and modulus if strain gauges are used. Generally does not require tabs.	Specimens can be difficult to machine. Results are less susceptible to how square the edges are since the specimen is held in shear. Specimen is larger compared to Iosipescu test. Biaxial strain gauges required to obtain modulus data.	Recommended when shear modulus is required. Produce pure uniform shear stress
ASTM D5379	$$G_i$$	Iosipescu shear	Provides shear strength and modulus if strain gauges are used. Generally does not require tabs.	Specimen is loaded on it's edges so the edges must be square, therefore preparation is important.	Recommended when shear modulus is required. Produces pure uniform shear stress
ASTM D3518	$$G_i$$	+-45 Tension shear	The specimen is similar to D3039.	More historic than anything. Does not produce pure uniform shear stress.	Used for non-technical reasons (fixture availability) or for quality control.
ASTM D2344	$$G_i$$	Short beam shear	Interlaminar shear compared to the other in-plane tests.	Does not produce pure uniform shear stress.	Recommended for quality control/comparative analysis.

Flexural Strength and Modulus[edit | edit source]

This testing is performed to determine the flexural strength and modulus properties of composite materials. The test results can be compared with the composite analysis results to provide an assessment of the accuracy of the model. The testing is performed on a load frame, and uses a deflectometer to take deflection measurements for modulus calculations. The test uses a rectangular specimen.

Test	Properties Measured	Specimen Type	Description/Advantages	Disadvantages	Comments
ASTM D7264	E_f, S_f	Rectangular	3 point and 4 point bending. 4 point is preferred as it reduces shear stress in the loading region but requires a higher test load. Specimens are easy to prepare and test. Suitable for random, discontinuous, and continuous reinforcements.	Loading nose/supports can create stress concentrations. Results are affected by specimen geometry, support span, and loading rate.	
ASTM D790	E_f, S_f	Rectangular	Specimens easy to prepare and test. 3 point bend condition.	Loading nose/supports can create stress concentrations. Results are affected by specimen geometry, support span, and loading rate.	Support span of 16:1 (depth to thickness) commonly used for plastics. Support span of 32:1 commonly used for high modulus composites. Often used for quality control purposes.

Glass Transition Temperature[edit | edit source]

This test is performed to determine the glass transition temperature of a material. The glass transition temperature is used, among others, to define the service temperature of the composite part. The test can be performed on three different pieces of equipment, as outlined below.

Test	Properties Measured	Specimen Type	Description/Advantages	Disadvantages	Comments

ASTM D7028	Rectangular	Dynamic Mechanical Analysis (DMA) method for determining Tg using a 3 point bend condition. One of the major fibre directions must be parallel to the length of the specimen. Specimens are larger than for the other two Tg tests. Tg is based on mechanical response of specimen over the desired temperature range. See Dynamic Mechanical Analyzer (DMA) - A344 for more information.	Specialized equipment required (DMA). Results are sensitive to test parameters and moisture content of specimen.	Meant for composites with continuous, oriented, high modulus reinforcements. This method is usually preferred for determining the Tg of a composite for quality control methods.
ASTM E1356	Rectangular	Thermomechanical Analysis (TMA) method for determining Tg by measuring the change in dimensions over a temperature range that includes the Tg. The slopes of the probe displacement before and after the Tg are used to extrapolate the transition. See Thermogravimetric Analyzer (TGA) - A329 for more information]]	TMA probe can sink into the material when it is above its Tg. This will affect the measurements. Care must be taken that the probe does not get stuck in the sample.	Meant for amorphous materials or partially crystalline materials.

ASTM D3418	less than 20 mg	Differential Scanning Calorimetry (DSC) method for determination of transition temperatures and enthalpies of fusion and crystallization of polymers. The normal operating temperature range is from the cryogenic region to 600°C. Certain equipment allows the temperature range to be extended. See A192 for more information]]	Interpreting DSC results requires expertise. Factors such as heating rate, sample mass, and calibration can influence the DSC measurements	Meant for a wide range of materials.

For more information on the common methods of destructive and non-destructive testing and how to navigate through the myriad options, see Composite materials engineering webinar session 12 - Testing - A131.

Explore this area further

- Testing - A178
  - Dynamic Mechanical Analyzer (DMA) - A344
  - Thermogravimetric Analyzer (TGA) - A329
  - Thermomechanical Analyzer (TMA) - A353
  - Rheometer - A357

Related pages

Page type	Links
Introduction to Composites Articles	
Foundational Knowledge Articles	• Conduction - A118 • Convection - A106 • Glass transition temperature (Tg) - A210 • Heat of reaction - A114 • Specific heat capacity - A117 • Thermal conductivity - A116 • Thermal diffusivity - A143 • Viscosity (resin) - A203
Foundational Knowledge Method Documents	• How to measure gel time - M101 • How to measure reinforcement content (and corresponding matrix content) - M109
Foundational Knowledge Worked Examples	
Systems Knowledge Articles	
Systems Knowledge Method Documents	
Systems Knowledge Worked Examples	

Systems Catalogue Articles	
Systems Catalogue Objects – Material	
Systems Catalogue Objects – Shape	
Systems Catalogue Objects – Tooling and consumables	
Systems Catalogue Objects – Equipment	• Rheometer - A357
Practice Documents	• Practice for developing a thermal transformation process step - P105
Case Studies	• Troubleshooting of room temperature processes for large recreational and industrial parts - C100
Perspectives Articles	• Case Study: Optimizing a Press Moulding Process - A324 • Composites Process Simulation: A Review of the State of the Art for Product Development - A283 • Dr. Anoush Poursartip's cdmHUB global composites expert webinar - A136 • Fabric Forming: how it affects design and processing, and how simulation can address this - A310 • Interview with Prof. Kevin Potter - A134 • Simulation models for rapid liquid composite molding - A333.0

About **Help**

Engineered materials (designed to have specific properties) made from two or more constituent materials with different physical or chemical properties. The constituents remain separate and distinct on a macroscopic level within the finished structure.

Differential Scanning Calorimetry (DSC).

Application and Impact Mobilization Events (AIM).

The continuous material phase that binds the reinforcement together, maintains shape, transfers load, protects the reinforcement from environment and damage, and provides the composite support in compression.

Desirable characteristics:

- Moisture/chemical resistance
- Low density
- Processability

For polymer matrix composites (PMCs), resin refers to the matrix; the continuous material phase that binds the reinforcement together, maintains shape, and transfers load. Resins are divided into two main groups: thermosets and thermoplastics.

The glass transition temperature (T_g) is the temperature region where the polymer transitions from a hard, glassy material to a soft, rubbery material. It is one of the most important properties of any amorphous polymer.

Literally "without structure", randomly coiled molecular polymer chains.

Periodic 3-D, repeating array of molecules.