Ensuring Compliance with ASTM STANDARDS for Mechanical Testing of Plastics and Composites

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To reduce weight and increase fuel economy, aerospace and automotive designers are increasingly using lightweight plastics and new composite materials such as carbon fiber reinforced plastics (CFRPs).

Composite materials offer high strength with reduced weight, making them ideal for high-performance components for a wide range of applications.

Evaluating the Performance of Composite Materials

Thorough mechanical characterization of new plastics and composites is essential to ensure ***effective modeling*** and the ***safe adoption*** of these new materials in final products.

ASTM standardized test methods for plastics and CFRPs are widely used to evaluate these new materials. This eBook describes the use of Shimadzu's AGX Series Universal Test Machines to evaluate plastics and CFRPs according to several ASTM methods.

CFRP ASTM Test Methods

The performance of CFRPs depends on the fiber strength, the filling ratio of the carbon fibers in the resin and the orientation of the carbon fibers. For these reasons, CFPRs exhibit highly anisotropic mechanical behavior. Specialized ASTM standard test methods have been ***developed to determine composite strength under different loading orientations***.

Shimadzu's AGX Series Universal Test Machines, ASTM-compliant test jigs and Trapezium X Series software provide an excellent testing platform to evaluate composites. Shimadzu's TRView non-contact digital extensometer allows video capture of tests and subsequent analysis using digital image correlation (DIC) techniques to determine strain distributions.

V-Notched Beam Testing Method

(ASTM D5379)

ASTM D5379 is a V-notched beam testing method ***used to determine the in-plane shear properties*** of composite materials. This test method applies an asymmetrical four-point compression load to a sample with V notches, which enables the application of only shear stress on the evaluation area. This method is ideal for testing a variety of CFRP laminate materials, including unidirectional, orthogonally laminated, and discontinuous fiber materials.

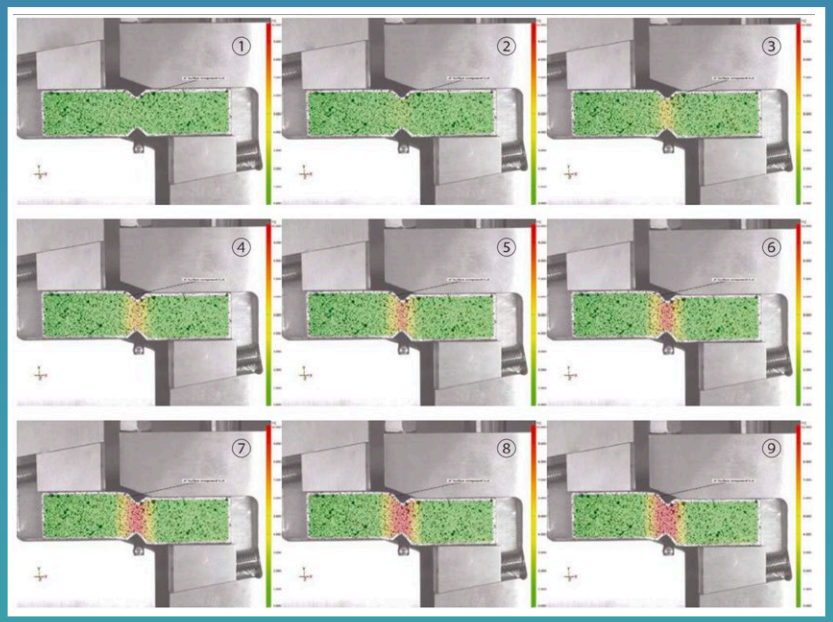
Results from a typical ASTM D5379 test are shown in Table 1. To obtain these measurements, an AGX Series Universal Test Machine, Trapezium X Series software and an ASTM-compliant test jig were used. The AGX Series provides multiple input channels for strain gauges and other analog devices.

Strain gauges were attached between the top and bottom V notches to measure strain in -45° and +45° directions (the center of the evaluation area). The mean of the outputs obtained from the strain gauges was calculated, confirming that shear strain was being applied symmetrically on the front and rear of the specimen.

Table 1: Test Results

Specimen	Shear Modulus (GPa)	Shear Strength (MPa)
Test 1	4.62	136.0
Test 2	4.63	133.0
Test 3	4.50	131.0
Mean	4.58	133.0

Shear Strain Distribution



Specimen After Testing

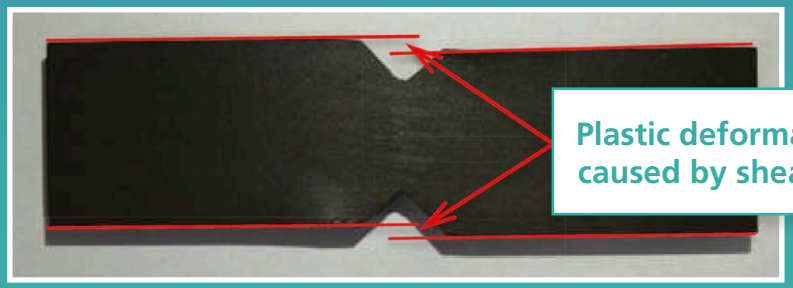


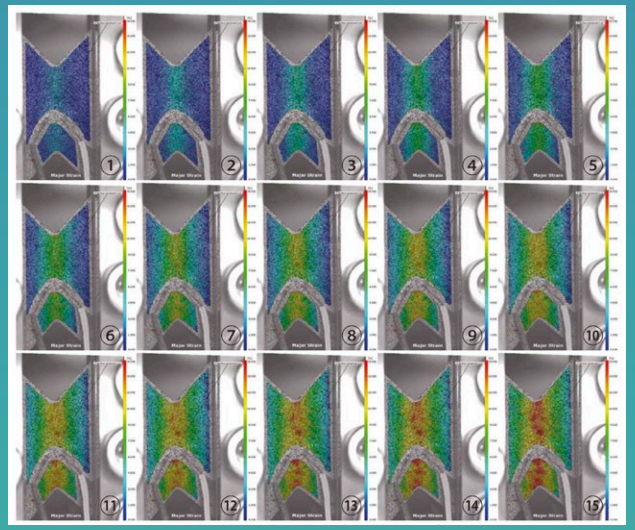
Table 2: Test Conditions

Testing Machine	AGX Series
Load Cell	50 kN
Test Jig	ASTM D7078 jig
Software	TRAPEZIUM X Series (Single)
Test Speed	2 mm/min

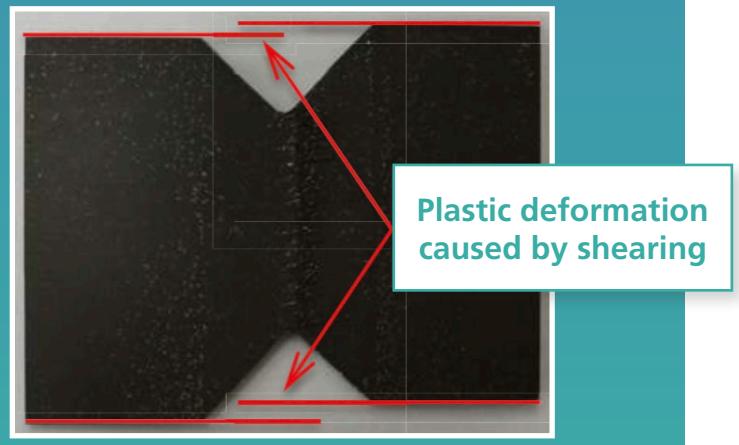
Table 3: Test Results

Specimen	Shear Modulus (GPa)	Shear Strength (MPa)
Test 1	4.63	121.72
Test 2	4.55	120.00
Test 3	4.58	120.05
Mean	4.59	120.60

Shear Strain Distribution



Specimen After Testing



V-Notched Rail Shear Testing Method
(ASTM D7078)

ASTM D7078 is a V-notched rail shear testing method that is widely ***used to determine the in-plane shear characteristics*** of composite materials. This method uses a sample without holes with a large gauge section and can accommodate CFRPs with discontinuous fibers.

Shear strain can be calculated using the AGX Series, TRAPEZIUM X Series software and an ASTM D7078 test jig. For this test, two strain gauges were attached at the midpoint between the V notches in order to measure strain in -45° and +45° directions. The equipment configuration is shown in Table 2. Table 3 shows that the test results are highly reproducible.

Open-Hole Compression Test
(ASTM D6484)

CFRPs offer ***a number of benefits, including specific strength and high rigidity***. However, they lose a substantial amount of their strength when a cutout is made. ASTM D6484 is an open-hole compression (OHC) testing method that uses a sample with a 6 mm (0.25 inch) diameter circular hole cut in its center.

ASTM D6468 has two loading methods: Method A and Method B. In Method B the sample is compressed using compression plates located on the ends of the sample and test fixture.

A typical ASTM D6484 test sample is shown in Figure 1. ASTM D6484 Method B test results using a Shimadzu AGX Series Test Machine and TRViewX video extensometer are shown in Table 4. The stress-displacement curves are shown in Figure 2.

Figure 3 shows DIC strain distributions around the hole in the specimen. Strain accumulated at the vertical sides of the open hole (regions 1 and 3), and strain appeared along the axis of compression from those points. The final break occurred at the vertical sides of the hole.

Figure 1: Specimen

Table 4: Test Results

Specimen Name	Open-Hole Compressive Strength (MPa)
1st	278.2
2nd	273.0
Mean	275.6

Figure 2: Stress-Displacement Curves for Compression Test

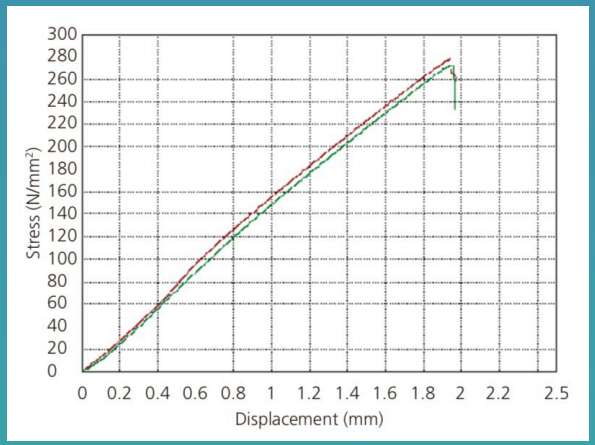
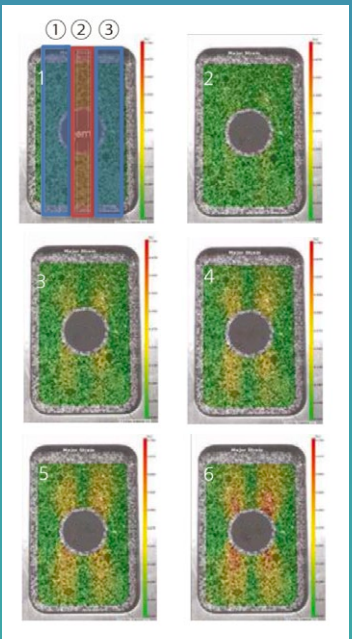


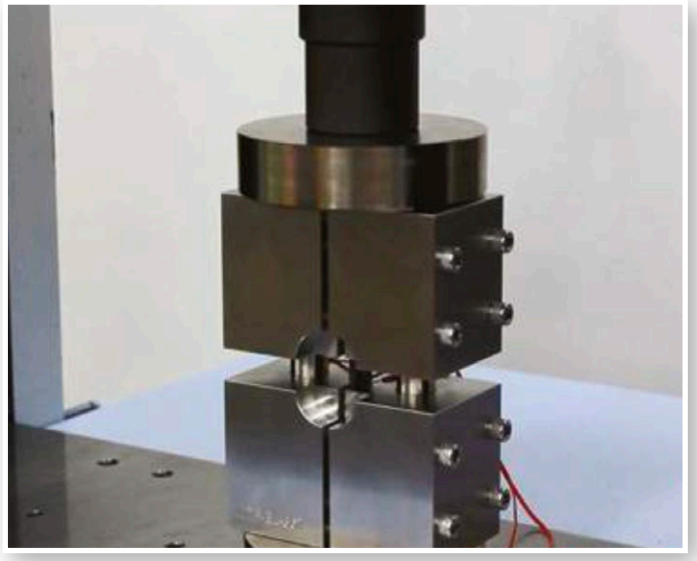
Figure 3: DIC Analysis Results



Combined Loading Compression Test
(ASTM D6641)

ASTM D6641 combined loading compression (CLC) test can be used to simultaneously evaluate compressive strength and elastic modulus. ASTM D6641 may be performed with a simple jig structure and untabbed specimens.

The images on the right show the test jig and a typical sample. Strain gauges are attached to the front and rear of the specimens to confirm alignment. Samples mounted in the test jig assembly are compressed using compression plates.



Typical test results obtained using a Shimadzu AGX Series Universal Test Machine and CLC test fixture are shown in Table 5.

Table 5: Test Results

	Compressive Strength (MPa)	Elastic Modulus (GPa)
1st	629.9	71.4
2nd	651.4	74.3
Mean	640.7	72.9

Tensile Testing Methods
(ASTM 3039, ASTM D638)

ASTM 3039 defines procedures for the tensile testing of polymer composite samples. Rectangular test specimens (25 mm wide x 100 mm long) are typically used. Tabs may be bonded to the sample ends to assist in gripping.

ASTM D638 specifies methods for ***testing the tensile strength of plastics and calculating their mechanical properties***. This test method uses dumbbell-shaped specimens with either a 25 mm or 50 mm gauge length.

ASTM D638 requires a test force accuracy that meets ASTM E4 Class 1—accuracy within ±1% of the indicated test force. All of Shimadzu's test frames and load cells meet the test force accuracy requirements for ASTM D638.

For ASTM D638, Shimadzu offers a range of extensometer options including strain gauge extensometers and the TRViewX non-contact digital video extensometer.

Flexural Testing Methods:

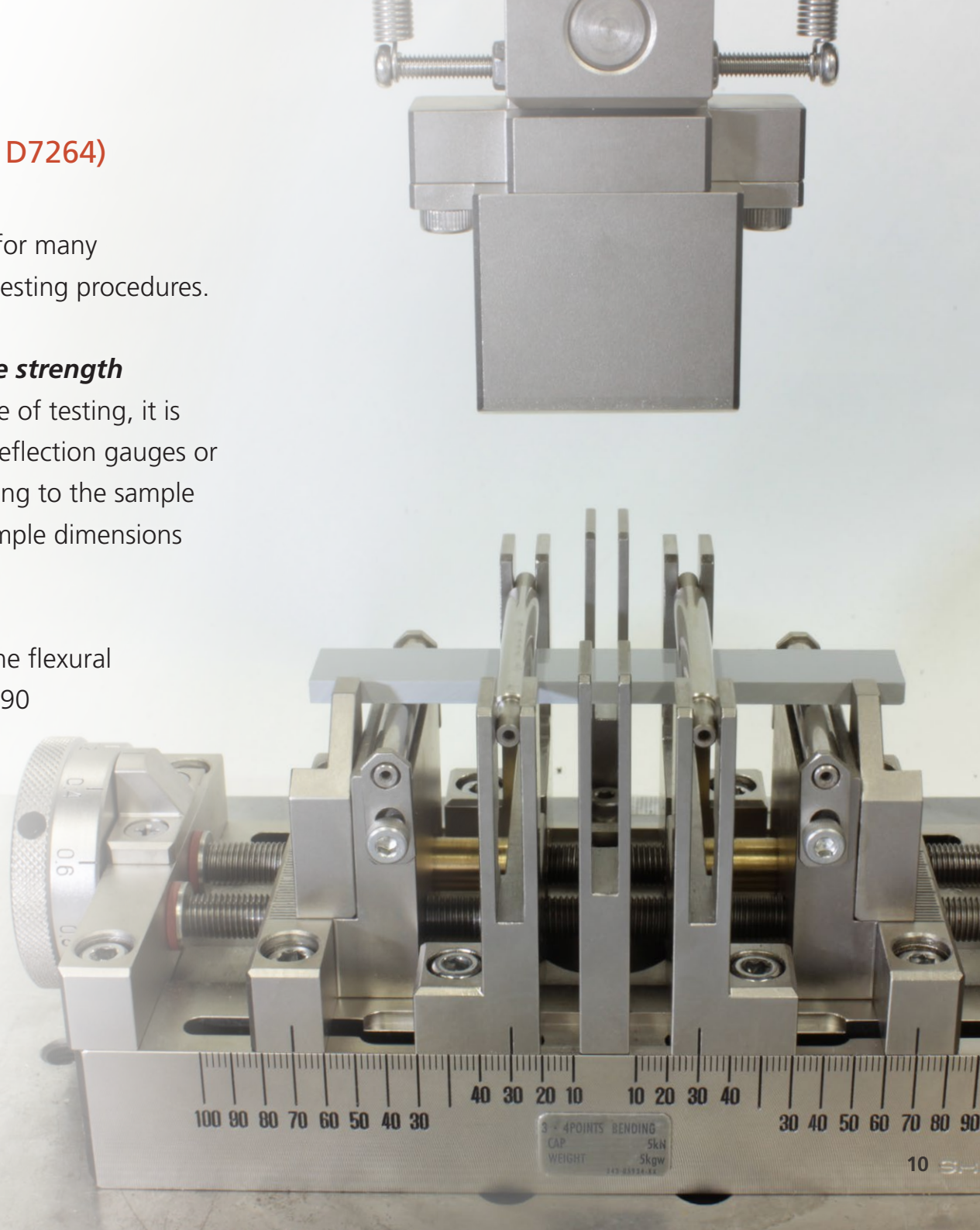
(ASTM D790, ASTM D2344, ASTM D6272, ASTM D7264)

The flexural or bending properties of plastics are important for many applications. Various ASTM standards describe appropriate testing procedures.

Three- or four-point bending testing is used to ***measure the strength properties of comparatively rigid materials***. For this type of testing, it is recommended to directly measure the sample strain using deflection gauges or other strain gauges. The fulcrum span is determined according to the sample thickness. It is therefore important to know the range of sample dimensions before selecting the test jig.

ASTM D790 is a common testing method for determining the flexural properties of reinforced and unreinforced plastics. ASTM D790 requires a testing force accuracy within ±1% of the indicated test force, as specified by ASTM E4 Class 1. All of Shimadzu's testing frames and load cells comply with the accuracy requirements of ASTM D790.

In this testing method, a deflectometer is used to measure flexural displacements. Shimadzu offers deflectometers that meet the testing requirements of ASTM D790. They can be easily integrated into the AGX Series test frames.



Testing Solutions for ASTM Standards

Shimadzu offers a comprehensive line of test frames, grips and extensometers that meet or exceed the requirements of important ASTM testing standards. From compositional analysis to mechanical testing to inspection evaluations, we have the quality instruments you need to ensure ongoing success.

To learn more about how Shimadzu can support your materials testing needs, visit

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