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Application Data Sheet

No. 34

Autograph Precision Universal Testing Machine

Material Testing & Inspection

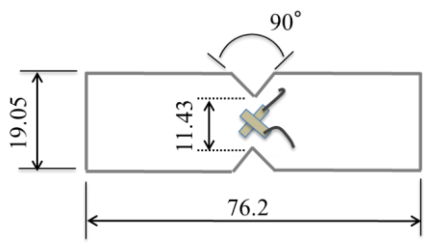
V-Notched Beam Testing (Iosipescu) of CFRP

Standard No. ASTM D5379

■ Introduction

Carbon fiber reinforced plastics (CFRP) that employ thermoplastic resins with excellent workability and formability, and a higher specific strength compared to conventional materials, is being investigated for applications in industrial goods where strength and durability are sought after characteristics. Differing from conventional homogeneous materials, composite CFRP materials are anisotropic, and demonstrate tension, compression, bending, in-plane shear, out-of-plane shear, or a combination of these properties in a complex fracture behavior dependent on the principle axis and direction of the stress applied. Recently, with the use of computer aided engineering (CAE) becoming widespread in industry, the number of prototypes has been reduced and the cost of new product development decreased. However, because information about various material characteristic values is needed in order to increase the precision of predictions about material performance of the designed products, test methods that can evaluate for each type of failure behavior are sought for the evaluation of CFRP.

This article describes an example test performed using the V-notched beam testing method (Iosipescu method, ASTM D5379), which is used widely in the field of composite materials as a method of testing in-plane shear. This test method applies an asymmetrical four-point compression load to a specimen with V-notches, which enables the application of only shear stress to the evaluation area. Furthermore, configuration of the specimen and jig is relatively simple, and this test method can be used with various CFRP laminate materials, including unidirectional materials, orthogonally laminated materials, and materials with discontinuous fibers.



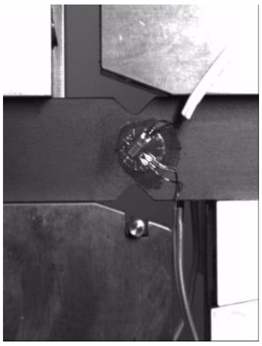


Fig. 1: The Shape of specimen

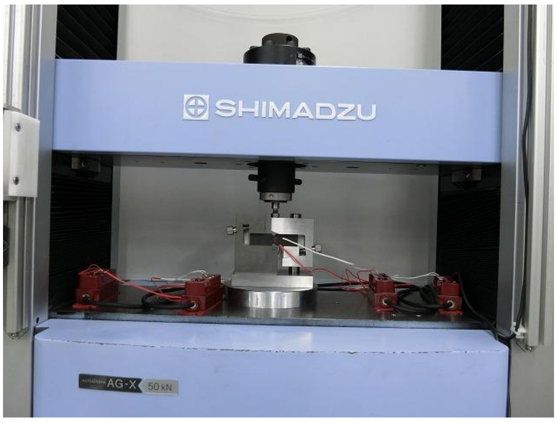
$$\gamma = |\varepsilon_{+45}| + |\varepsilon_{-45}| \quad \text{(eq.1)}$$

γ = Shear strain
ε_{+45} = Strain in +45° direction
ε_{-45} = Strain in -45° direction

■ Measurement and Jigs

Information on ASTM D5379-specified specimens is shown in Fig. 1. The specimen is an orthogonally laminated material formed from Toray T800S prepreg in $[0/90]_{5s}$ alignment and cured in an autoclave. Two-axis strain gauges are attached in the middle between the top and bottom machined V-notches (center location), so they could measure strain in -45° and +45° directions. When the data obtained from these two strain gauges is placed into equation 1, we can calculate the shear strain, which is a characteristic value essential for evaluating the shear elastic modulus of a material. For this test, the strain gauges are placed on both the front and rear sides of the specimen. Outputs are obtained from the front and rear strain gauges where using the mean of these outputs allows for an accurate understanding of shear strain, captures the effect of torsion on the specimen that can occur during testing, and is also necessary in allowing us to confirm whether shear strain is being applied symmetrically at the front and rear sides of the specimen.

A photograph of the testing system used is shown in Fig. 2. For this test, an observation system that uses the DIC system can also be attached to this testing system. The images for observation are captured via the DIC system in synchrony with the stress and strain gauge outputs obtained from the specimen by the test machine. This allows for easy evaluation of the process of CFRP fracture by comparing various characteristic values, although the evaluation was difficult to perform by conventional test measurement systems alone. Because strain distribution was to be performed in this test using digital image correlation (DIC) analysis based on the images captured by DIC system, spray paint was used to create a random pattern on the surface of the specimen prior to testing.



(a) Standard System

(b) DIC System (Optional)

Fig. 2: Testing Apparatus

■ Measurement Results in Standard System

Each of the material characteristic values measured during this testing is shown in Table 2. In addition, a photograph of the specimen after testing is shown in Fig. 4, a shear stress-strain curve calculated based on data obtained from the strain gauges is shown in Fig. 5, Shear stress-shear strain curve is shown in Fig. 6, and a Shear stress-testing machine stroke curve is shown in Fig. 7. All the results for each shear characteristic value we measured were highly reproducible. The shear strain-time curve also shows that outputs from the strain gauges on the front and rear of the specimen were similar, and the shear strain applied to the specimen was good in terms of symmetry.

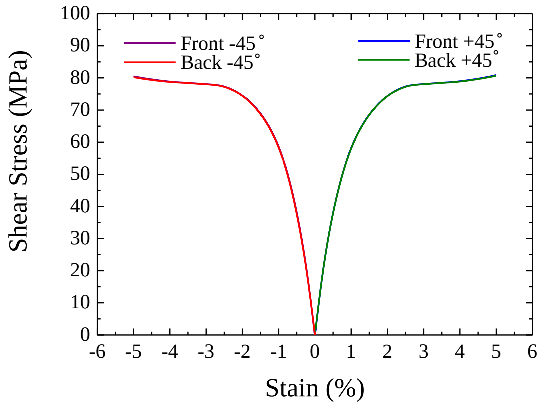


Fig. 5: Shear Stress-Strain Curve

Table 2: Test Results

	Shear Elastic Modulus (GPa)	Shear Stress (MPa)
Test 1	4.62	136.0
Test 2	4.63	133.0
Test 3	4.50	131.0
Average	4.58	133.0

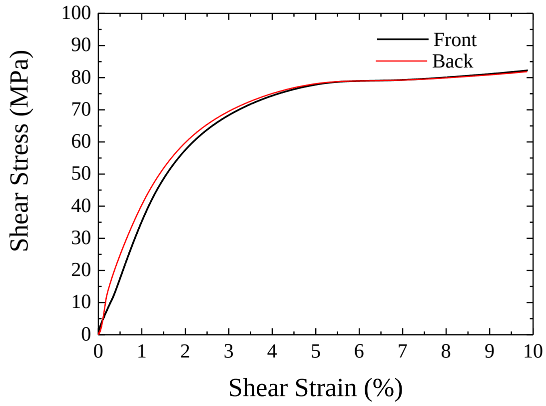


Fig. 6: Shear Stress-Shear Strain Curve

Fig. 4: Test Specimen After Testing

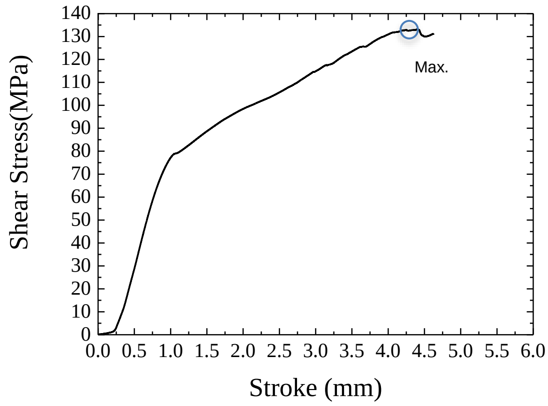


Fig. 7: Shear Stress-Stroke Curve

■ Measurement Results in the DIC System (Optional)

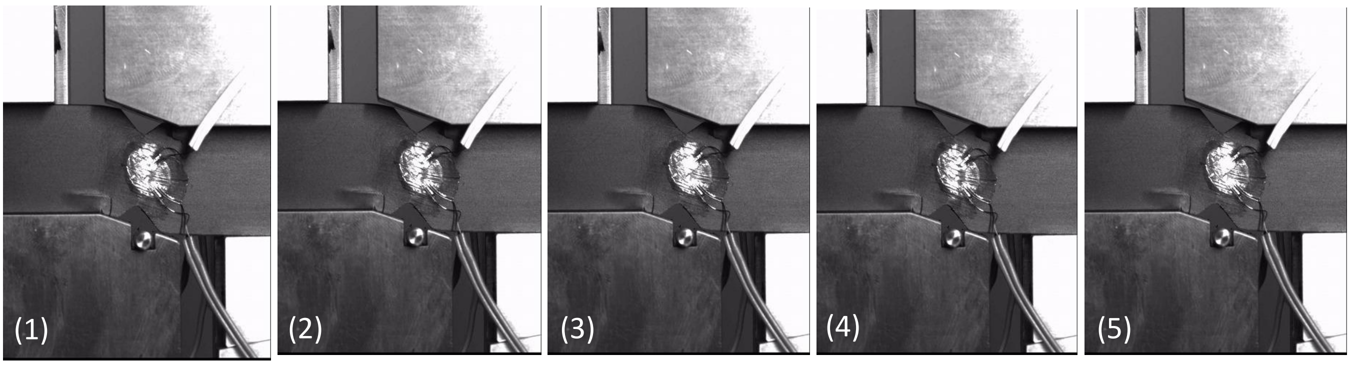


Fig. 8: View of Test Specimen Fracture (The point at which test specimen fracture occurs is shown in images captured over a 10-second period at 2-second intervals.)

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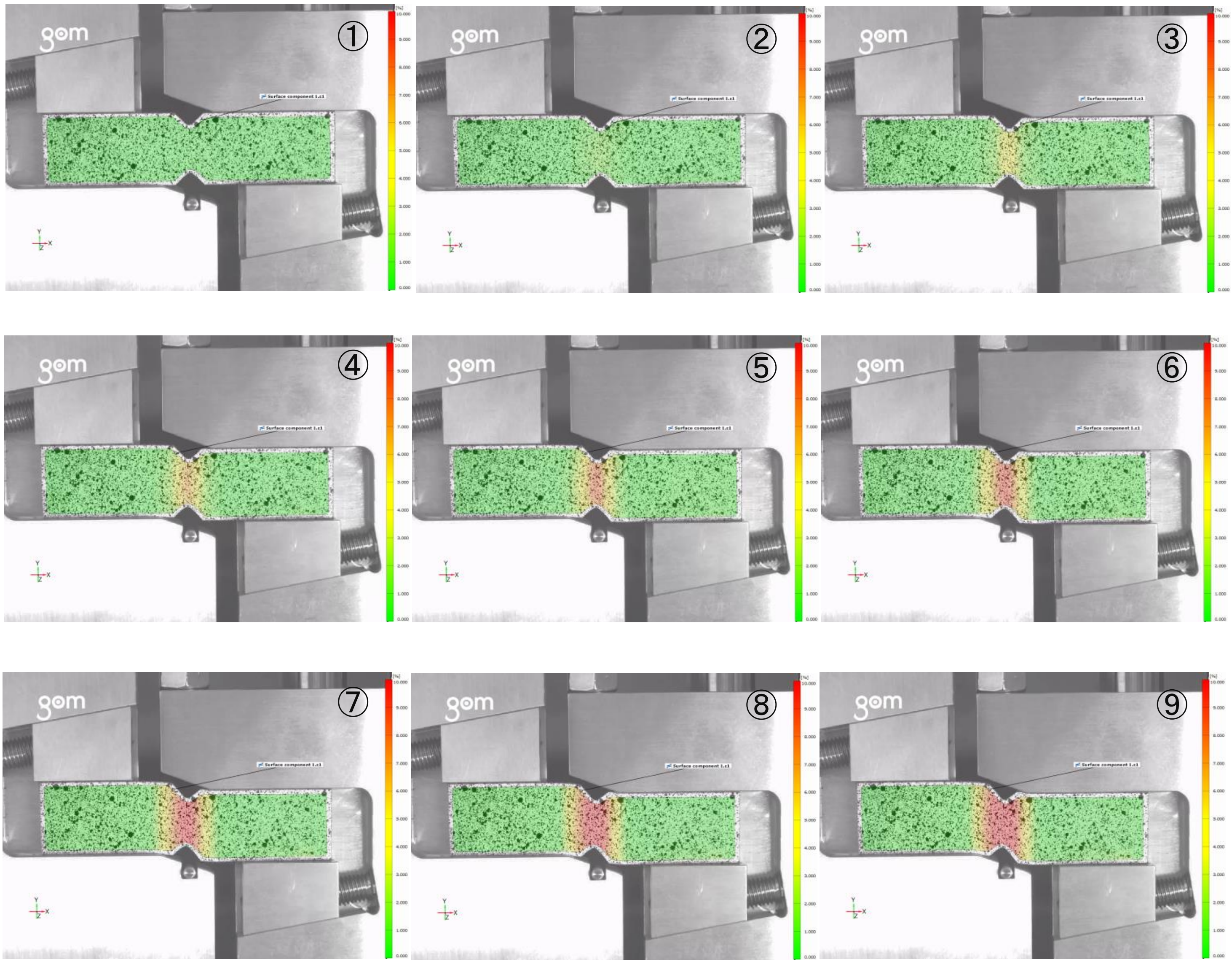

Fig. 9: Strain Distribution (DIC analysis images)

Images captured immediately prior to specimen fracture are shown in Fig. 8 (2-second intervals).

Images of strain distribution obtained by DIC analysis are shown in Fig. 9. The warmth of the colors shown on the specimen correlates with the quantity of strain occurring in those locations. Low strain locations appear as dark colors (black, blue, etc.) and high strain locations appear as bright colors (orange, red, etc.). We can see that as the test proceeds strain is focused locally between the V-notches.

■ Summary

This testing system allowed us to perform V-notched beam testing (ASTM D) with good results. The inclusion of the non-contact extensometer to this system allowed us not only to evaluate basic characteristic values such as shear elastic modulus and strength, but also gave us reference data that demonstrated the mechanism of fracture of CFRP, and showed strain analysis is possible through DIC analysis and visual observation of specimen fracture.

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V-Notched Rail Shear Testing System (Standard)

Testing Machine: AG-Xplus
Load Cell: 50 kN
Test Jig: V-notched rail shear testing jigs
Extensometer: Strain gauge
Software: TRAPEZIUM X (Single)

AG-Xplus Floor-Type Precision Universal Testing Machine

- A high-precision load cell is adopted. (The high-precision type is class 0.5; the standard-precision type is class 1.)
  Accuracy is guaranteed over a wide range, from 1/1000 to 1/1 of the load cell capacity. This supports highly reliable test evaluations.
- Crosshead speed range
  Tests can be performed over a wide range from 0.0005 mm/min to 1,000 mm/min.
- High-speed sampling
  Ultrafast sampling, as fast as 0.2 msec. Sudden changes in test force, such as when brittle materials fracture, can be assessed.
- TRAPEZIUMX X operational software
  The software offers a variety of convenient and user-friendly features. It is designed for intuitive operation.
- Smart controller
  Real-time test force and position data is readily confirmed, and the manual dial can be used for fine adjustments to jig positioning.
- Optional Test Devices
  A variety of tests can be accommodated by switching between an abundance of jigs in the lineup.

DIC System (Optional)

Testing Machine: AG-Xplus
Load Cell: 50 kN
Test Jig: V-notched rail shear testing jigs
Extensometer: Strain gauge
DIC system ARAMIS (GOM mbH)
Software: TRAPEZIUM X (Single)

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