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Application News

No.i251A

Material Testing System

Shear Test of Composite Material (V-Notched Rail Shear)

Introduction

Carbon fiber reinforced plastic (CFRP) do not oxidize or rust and have a higher specific strength and stiffness than existing materials. Applications of CFRP are being investigated, with a focus on applications as industrial products that require strength and durability. Compared to existing homogeneous materials, composite materials like CFRP are anisotropic, and display complex failure behaviors as a result of tension, compression, bending, in-plane shear, out-of-plane shear, or a combination of these stresses arising from loading in the principal-axis direction. In recent years, use of CAE analysis in industry has become widespread since it can reduce numbers of prototypes and reduce the cost of new product development. Because values for each of the stress properties stated above are needed to increase precision when predicting product characteristics during product design, there is a strong demand for test methods able to evaluate pure failure behaviors in CFRP.

There are various tests methods for evaluating composite materials. Of these methods, two commonly used in-plane shear test methods to test in the direction of fibers in fiber reinforced composite materials and to test textile laminated materials are the Iosipescu method (ASTM D5379) that applies an asymmetrical four-point bending load to a specimen cut with notches, and method (ISO 14129) that applies a ±45° tensile load on laminated materials. We used the V-notched rail shear method (ASTM D7078) that can be used to test in-plane shear. Because this method uses a large gauge area on the specimen, it can accommodate specimens without holes and CRFP laminate materials that have discontinuous fibers.

Measurement System

The equipment configuration is shown in Table 1. Information on the specimen prescribed by ASTM D7078 is shown in Fig. 1. The specimen is a $[0/90]_{10s}$ orthogonally laminated material made from Toray T800S prepreg that was molded in an autoclave. The specimen has a 31-mm evaluation area (see Fig. 1), and two-axis strain gauges attached at the mid-point between the V-notches (center of evaluation area) that are able to measure strain in –45° and +45° directions. Shear strain can be calculated by inserting the strain values obtained from these two strain gauges into equation (1). Shear strain is a property needed to evaluate the shear modulus.

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

γ : Shear strain
ε_{+45} : Strain at +45°
ε_{-45} : Strain at –45°

In this test, strain gauges were attached on both the front and rear of the specimen. Calculating the mean of outputs obtained from strain gauges on both sides allows for more accurate measurement of the shear strain in the specimen, and confirms whether shear strain is being applied symmetrically on the front and rear of the specimen.

Table 1 Test Conditions

Testing Machine	: AG-50kNX plus
Load Cell	: 50 kN
Test Jig	: ASTM D7078 jig
Software	: TRAPEZIUM X (Single)
Test Speed	: 2 mm/min

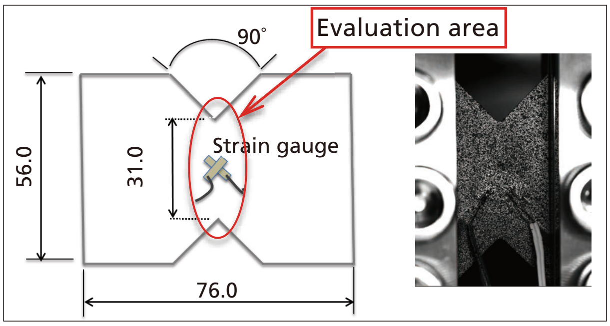

Fig. 1 Shape of Specimen

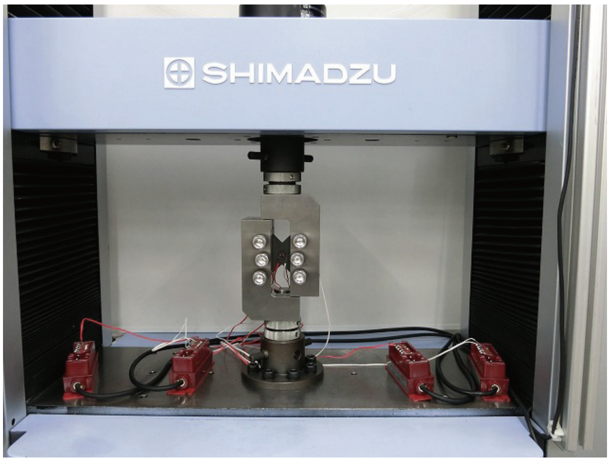

Fig. 2 Testing Apparatus

Fig. 3 Imaging Apparatus

The testing and imaging apparatus are shown in Fig. 2 and Fig. 3. Images captured using a TRViewX (Shimadzu Digital Video Extensometer) were gathered simultaneous to values obtained from the strain gauge outputs and specimen stress obtained by the testing apparatus. This made it easy to compare and evaluate images of the CFRP failure process against each specimen property values, something that was difficult to perform only with previous testing systems. Strain distribution can also be evaluated using digital image correlation (DIC, ARAMIS, GOMmbH) analysis of the images captured by TRViewX. To perform DIC analysis, paint must be sprayed on the specimen surface to create a random pattern on the front surface of the specimen.

Analytical Results

Each specimen property value obtained from this test is shown in Table 2. A photograph of the specimen after testing is shown in Fig. 4, a shear stress-normal strain curve is shown in Fig. 5 (strain values obtained from strain gauges), a shear stress-shear strain curve is shown in Fig. 6 (shear strain calculated from Equation (1)), and a shear stress-stroke curve is shown in Fig. 7. Table 2 shows that the results obtained for each shear property were highly reproducible. Fig. 5 and Fig. 6 show that the same strain values were obtained from the front and rear strain gauges, and highly symmetrical shear strain was applied to the specimen.

Table 2 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

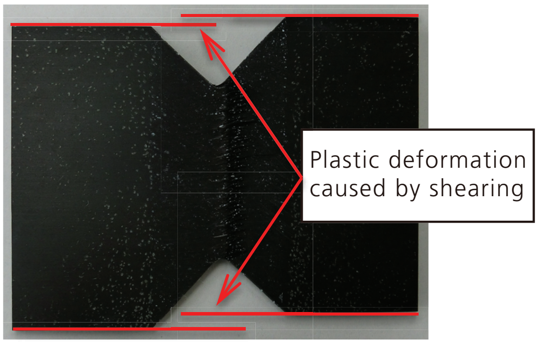

Fig. 4 Specimen After Testing

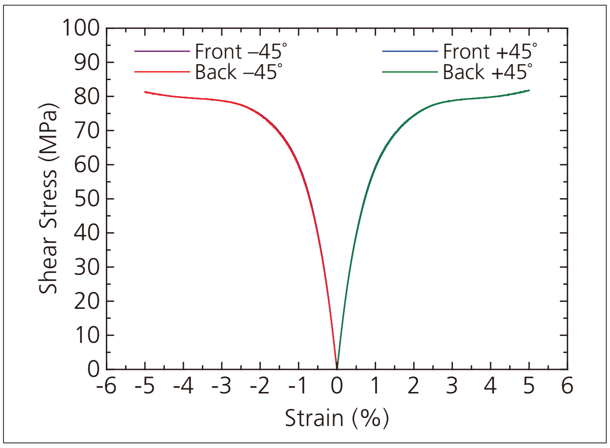

Fig. 5 Shear Stress-Normal Strain Curve

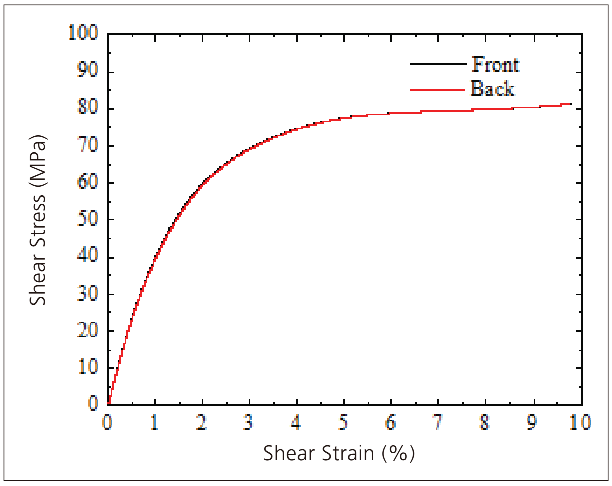

Fig. 6 Shear Stress-Shear Strain Curve

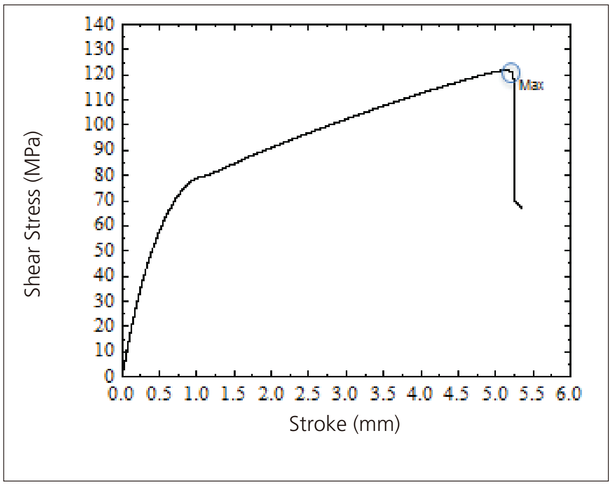

Fig. 7 Shear Stress-Stroke Curve

Failure of the specimen is shown in Fig. 8. A crack that appears close to the upper notch quickly propagates down toward the bottom notch during a simultaneous decrease in test force. Images of the shear strain distribution obtained by DIC analysis are shown in Fig. 9. The amount of strain occurring in the specimen is shown in terms of color, with low strain areas in cooler colors (black and blue) and high strain areas in warmer colors (orange and red). The images show that as the test progresses strain accumulates and is localized between the V-notches.

Fig. 8 Specimen Failure Process (images show the point at which the specimen fails)

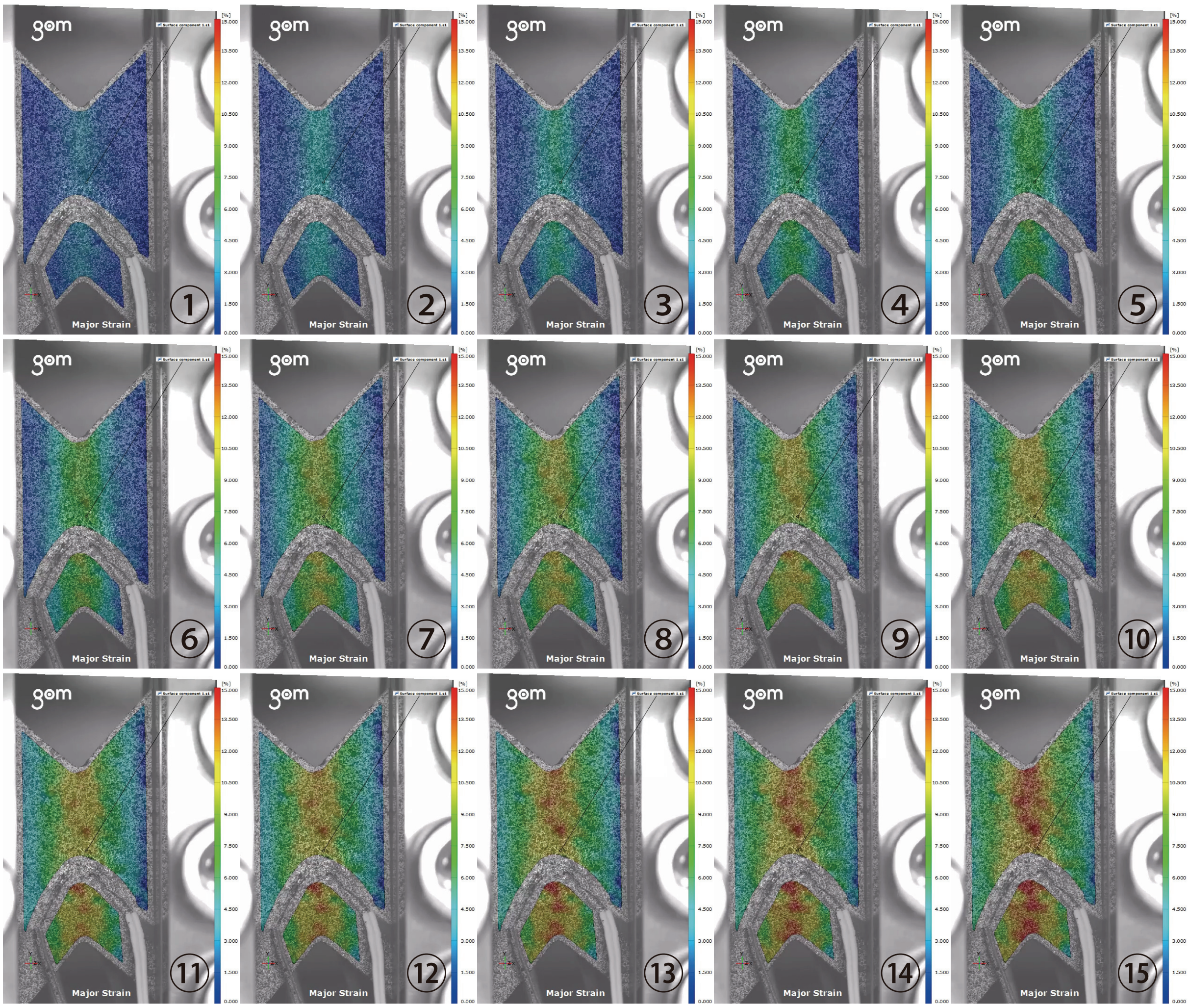

Fig. 9 Shear Strain Distribution (DIC analysis images)

Conclusion

We used this test system to successfully implement the V-notched rail shear method (ASTM D7078). In addition to evaluating the basic properties of shear modulus and shear strength, integrating a Digital Video Extensometer into the test system enabled us to capture reference data that can be used to elucidate the mechanism of failure of CFRP, allowing strain analysis to be performed in terms of specimen failure mode and DIC analysis.

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