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Application News

No. V025

HPV-X2 High-Speed Video Camera HITS-T10 High-Speed Impact Testing Machine

3D-DIC Analysis in Interlaminar Shear Impact Test of Composite Materials

Composite materials feature higher specific strength and specific stiffness than metal materials. For this reason, yearly increasing amounts of composite materials are used in passenger and various transport aircraft in order to improve fuel efficiency through weight reduction. However, since the superior properties of composite laminated materials are limited to the fiber direction and layers are adhered only using matrix resin, these materials are very low in strength. If the strength between layers is low and an external load is applied, delamination will easily occur and cause a reduction in compressive strength. Therefore, evaluation of interlaminar properties is important when evaluating composite laminated materials. Furthermore, since these materials may be subject to impact loads when used in transport aircraft, it is also important to determine the impact properties in addition to static properties.

In this research, strain distributions resulting from interlaminar shear impact test, which employed the short-beam method based on JIS-K7057, were visualized as an evaluation of interlaminar properties. Strain distribution was visualized using two HPV-X2 high-speed video cameras and 3D digital image correlation (DIC) analysis.

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* DIC analysis
This technique compares a random pattern on the sample surface before and after sample deformation to determine the amount of pattern movement. The random pattern used here was applied directly onto the specimen using a black marker pen.

Measurement System

Interlaminar shear impact test was performed using the HITS-T10 high-speed impact testing machine and the fracture process was observed using two HPV-X2 high-speed video cameras. Capturing video from two directions enables three-dimensional strain measurement and allows high accuracy strain measurement that takes out-of-plane deformations into account. Fig. 1 shows the picture of the test and Fig. 2 shows the test fixture with the specimen. Table 1 lists the system configuration. The video captured by the HPV-X2 cameras is analyzed using the VIC-3D DIC software to determine the strain distribution. Since VIC-3D can control the HPV-X2 cameras, calibration and analysis can be performed easily with no need for separate PCs for analysis and HPV-X2 control.

Table 1 Testing System

High-speed video camera	:	Two HPV-X2 high-speed video cameras
Testing system	:	HITS-T10 high-speed impact testing machine
Test fixture	:	Short-beam test fixture
Illumination	:	Stroboscope
DIC software	:	VIC-3D

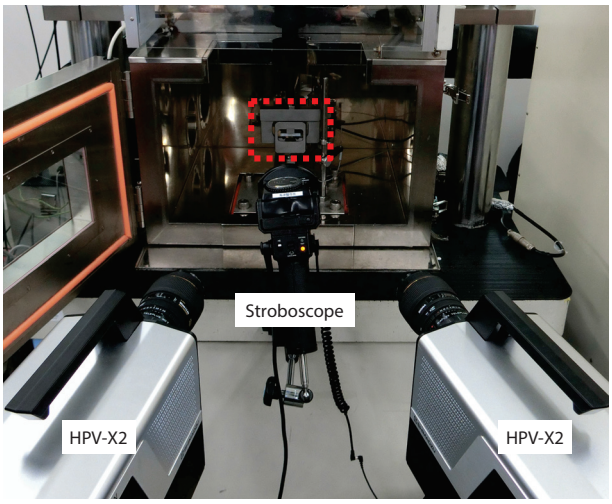

Fig. 1 Picture of the Test

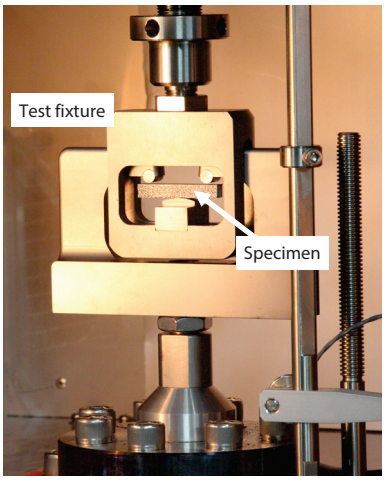

Fig. 2 Test Fixture with Specimen Mounted

Test Conditions

A GFRP unidirectional laminate was used as the specimen. Table 2 lists the details of the specimen. Table 3 lists the test conditions.

Table 2 Measurement Conditions

Specimen	:	GFRP unidirectional laminate
Specimen dimensions [in]	:	0.25 × 0.25 × 1.75

Table 3 Test Conditions

Test speed	:	10 m/s
Recording speed	:	670 kfps
Support span	:	1.2 in.
Test fixture dimensions	:	Indenter radius: 1 in., support radius: 0.25 in.

Measurement Results

Fig. 3 shows the DIC analysis results of shear strain up to immediately before fracture. Immediately after starting the test, shear strain is concentrated directly below the supports, as shown in Fig. 3 (1). Next, shear strain occurs symmetrically from the supports to the indenter, and immediately before fracture, shear strain is distributed on the entire specimen. Fig. 4 shows delamination. In Fig.4 (2), delamination is occurring from the left side of the specimen. Delamination progresses from there and also occurs from the right side as shown in (4). Fig. 5 shows the DIC analysis results in sync with Fig. 4. Fig. 5 shows that delamination occurs from the positions where shear strain was concentrated. Performing DIC analysis also enables determination of the delamination positions, which were difficult to discern in Fig 4.

Conclusion

In this research, we performed 3D-DIC analysis to measure the shear strain in interlaminar shear impact test of a GFRP unidirectional laminate using two HPV-X2 cameras. Performing 3D-DIC analysis allowed us to confirm the increase in shear strain during testing and the strain distribution when delamination occurred. The HPV-X2 is well-suited to observation of the fracture process in impact test such as that presented here, and proves useful in evaluating impact properties.

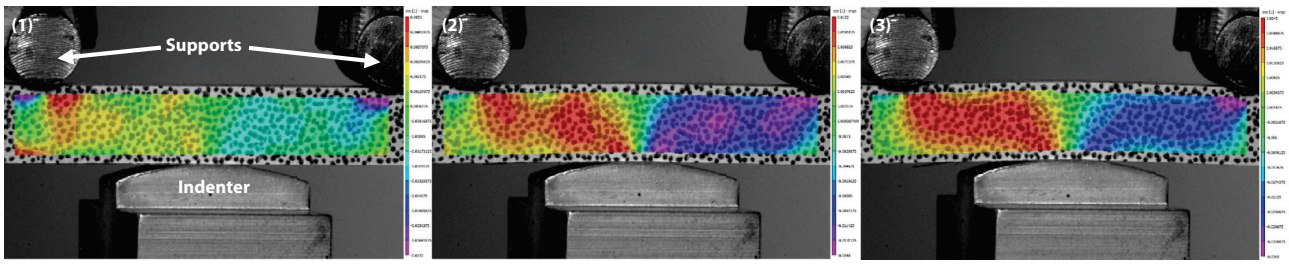

Fig. 3 DIC Analysis Results of Shear Strain up to Immediately Before Fracture (time between images: 27 µs)

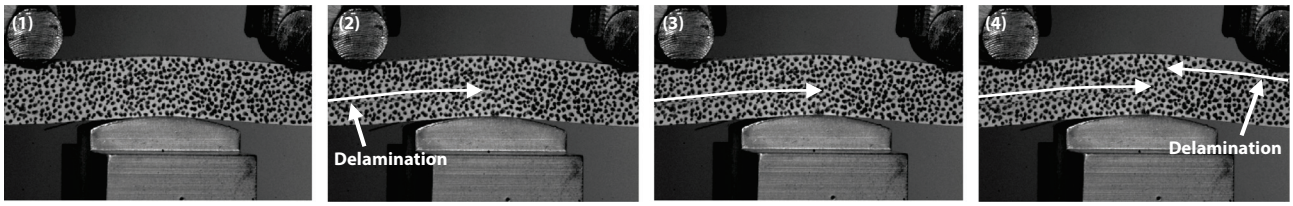

Fig. 4 Progress of Delamination (time between images: 6 µs, white arrows indicate delamination positions)

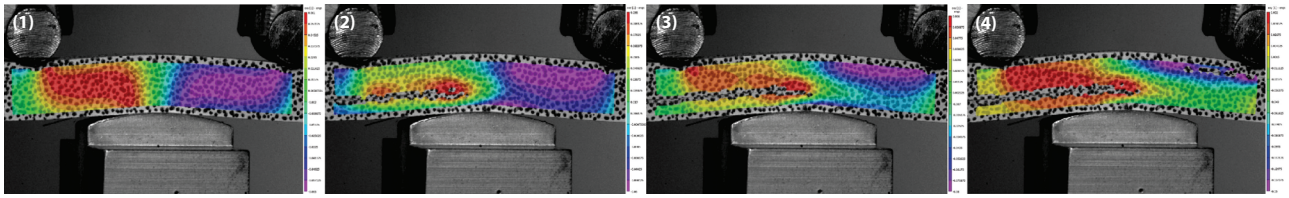

Fig. 5 DIC Analysis of Delamination (DIC analysis results of Fig. 4)

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