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Application News

No.V19

High-Speed Video Camera

Observing the Failure of Open-Hole CFRP specimens in Tensile Tests

-Synchronized Imaging Using Two High-Speed Video Cameras-

Introduction

Offering superior specific strength, even compared to other composite materials, carbon fiber reinforced plastic (CFRP) is used in aircraft and some transport vehicles for the purpose of saving fuel through weight reduction. Composite materials have excellent mechanical properties. However, a general feature of composite materials is that their strength decreases markedly when they are notched. CFRP is no exception, so tests of notched specimens are important. In this case, testing is performed using specimens notched with a circular hole at the center. In this experiment, tensile tests were performed using CFRP specimens (laminate method $[45/0/-45/90]_{2s}$) with a total length of 150 mm, a width of 36 mm, and a thickness of 2.5 mm, prepared with a 6 mm circular hole at the center. The failure process of the CFRP specimens was observed during the tensile tests. In particular, it is important to confirm the failure process of weak regions, such as the periphery of circular holes, for CFRP development and to confirm the validity of CAE analysis. However, since the failure of CFRP is a brittle phenomenon, where failure occurs instantaneously, it cannot be confirmed with the naked eye. For this reason, high-speed video cameras are used to observe the failure. In this experiment, synchronized images were obtained at the front and the side of the specimens using two HPV-X2 high-speed video cameras.

Measurement System

In this experiment, the AG-Xplus precision universal testing machine and two HPV-X2 high-speed video cameras were used. Table 1 shows the instruments used. To observe the specimen failure in a tensile test, a trigger signal synchronized to the failure must be transmitted to the high-speed video cameras. The failure starts on the periphery of the circular hole. Accordingly, aluminum foil was affixed to the periphery of the circular hole using adhesive, as shown in Fig. 1, so that conduction would be lost when the specimen fails. The failure was observed using this timing to trigger the cameras.

Table 1 Testing Equipment

High-Speed Camera	: HPV-X2 ×2
Lens	: 105 mm Micro lens ×2
Illumination	: Metal halide lump ×2
Testing Machine	: AG-Xplus
Load Cell	: 100 kN
Grips	: 100 kN Non-shift wedge-type grips
Grip Teeth	: Trapezoidal file teeth for composite mater
Software	: TRAPEZIUM X (Single)

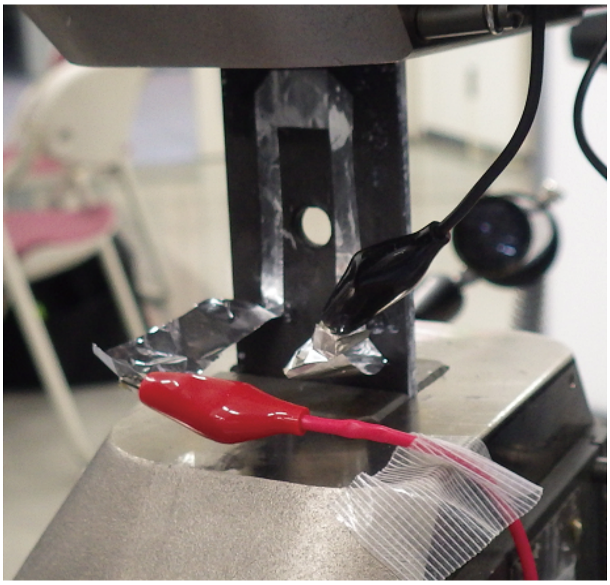

Fig. 1 Aluminum foil Trigger

Measurement Results

Table 2 shows the measurement conditions, and Fig. 2 shows the test configuration. As shown in Fig. 2, the failure of the specimen was recorded from the front by camera (1) and from the side by camera (2). Fig. 3 shows the test results from the AG-Xplus. Failure begins where the test force suddenly drops in Fig. 3. Fig. 4 shows the specimen failure observed from the front, and Fig. 5 from the side. Image (2) in Fig. 4 shows that the failure starts on the left side of the circular hole. In image (3), a crack also appears on the right side of the circular hole. Subsequently, cracks progressed in an orientation of 45 degrees, the orientation of the fibers in the outer layer. Further, as the test progressed, multiple cracks were confirmed, as in images (7) and (8). In the observations from the side, no failure was confirmed at the time the failure started, and was only initially confirmed in image (5). This is likely because the cracks started at the periphery of the circular hole reached the side of the specimen in image (5). Subsequently, failure was confirmed in multiple layers, except for the 0-degree layer, in image (6). Further, in image (7), failure was confirmed in the 0-degree layer, after which the failure progressed toward the outersurface. The final condition of the specimen is shown in Figs. 6 and 7.

Table 2 Measurement Conditions

Test Speed	: 5 mm/min
Frame Rate	: 1M frames/sec
	2M frames/sec

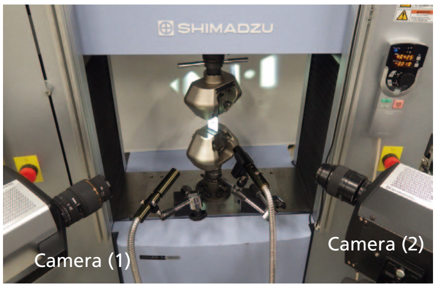

Fig. 2 Test Configuration

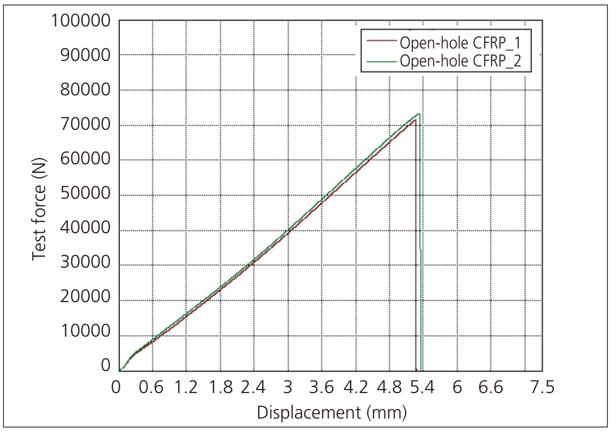

Fig. 3 Test Results

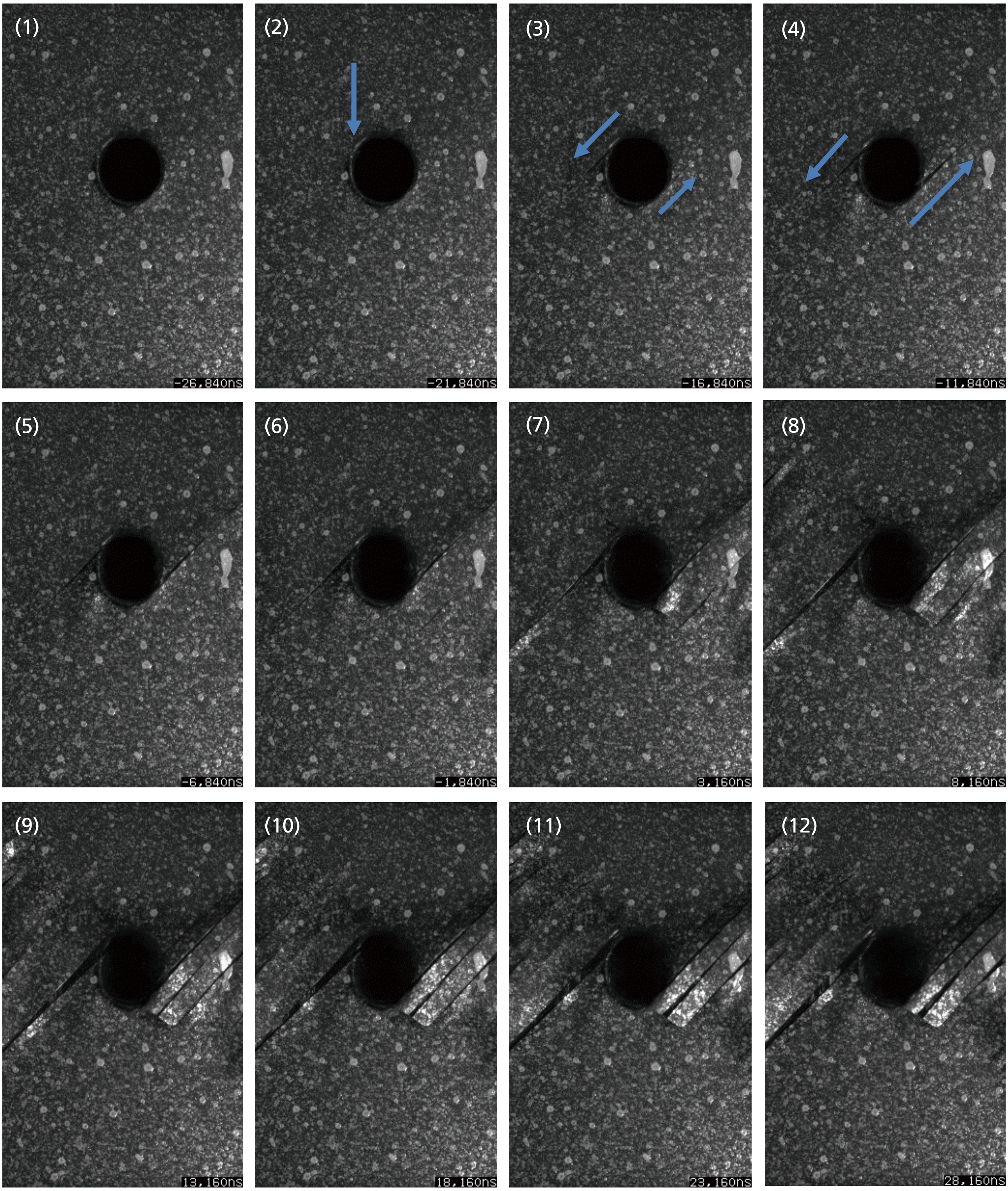

Fig. 4 Images from Camera (1) (5 µs between images)

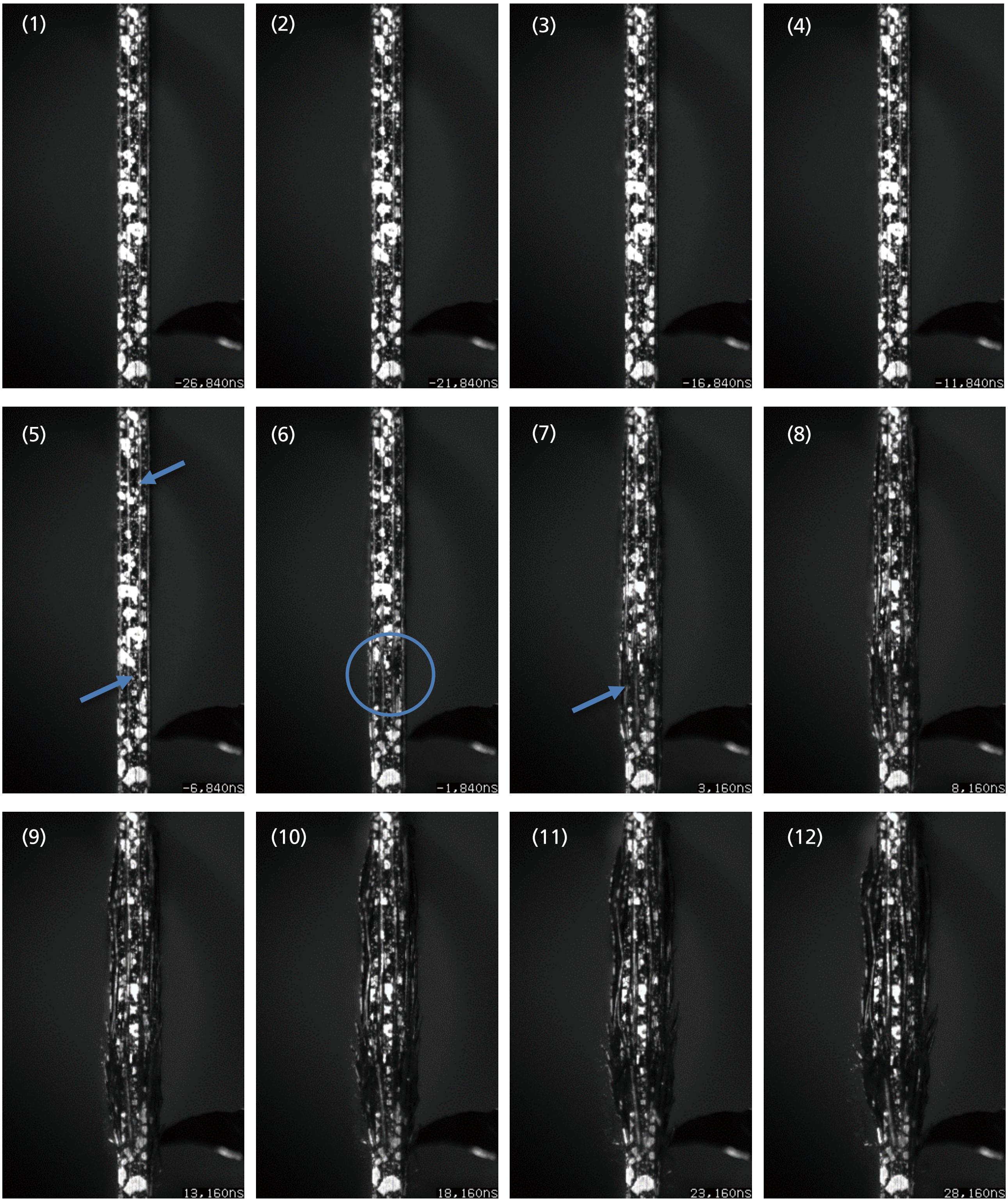

Fig. 5 Images from Camera (2) (5 µs between images)

Fig. 6 Specimen After Failure (front)

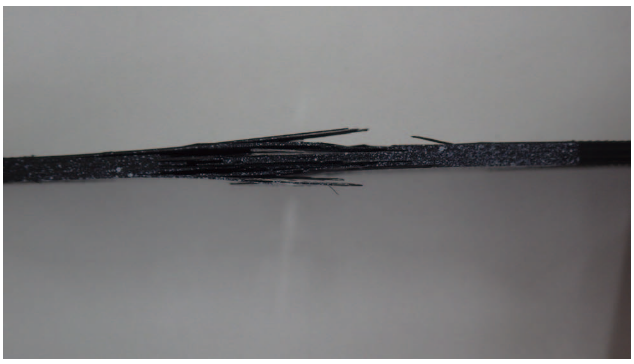

Fig. 7 Specimen After Failure (side)

Conclusion

The conventional HPV-X does not have a synchronization function, and so is incapable of recording from two directions. Also, the sensitivity of the HPV-X is insufficient, so it cannot record at imaging speeds of 500,000 fps or faster. The HPV-X2 is equipped with a synchronization function, and features improved sensitivity, so this instrument is capable of synchronized recordings at 2 Mfps, as in this case. As a result, failures can be observed in tensile tests of materials like CFRP that fails at high speeds.

Generally, failure observations are often recorded from the front of the specimen. However, adding recording from the side enables confirming the failure process that cannot be observed just from the front. In particular, with CFRP materials with different fiber orientations for each lamination layer, where failure progresses in different manner for each layer, as shown in this article, the failure process can be observed in more detail by recording from two directions.

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