

Gigacycle 3-Point Bending Fatigue Test of CFRP Using Ultrasonic Fatigue Testing System

Fumiaki Yano, Tsubasa Yamamoto

User Benefits

- ◆ Use of the ultrasonic fatigue testing system enables fatigue testing at 20 kHz, making it possible to complete a fatigue test of 10^9 cycles in about 14 hours.
- ◆ A simple 3-point bending test of CFRP is possible using the ultrasonic fatigue testing system.
- ◆ The condition of test pieces vibrating at 20 kHz can be observed with a high-speed video camera.

Introduction

Carbon fiber reinforced plastic (CFRP) is known as a material with high specific strength/specific stiffness and is used in various industries, such as the transportation sector. In order to use CFRP as a structural material, from the viewpoint of long-term reliability and durability, it is necessary to evaluate fatigue, as fatigue is the main cause of structural failure. Although a 10^9 cycle fatigue test requires several months with conventional fatigue testing machines, Shimadzu USF-2000A ultrasonic fatigue testing system allows fatigue testing at a frequency of 20 kHz, making it possible to complete a 10^9 cycle fatigue test in about 14 hours. Thus, use of the USF-2000A is an effective means of assessing long-term reliability and durability.

This article introduces an example of a 3-point bending ultrasonic fatigue test of CFRP using the USF-2000A.

Measurement System

Fig. 1 shows the appearance of the measurement system. The test was conducted using a 3-point bending indenter and a prototype of a 3-point bending jig for ultrasonic fatigue testing, based on the average stress loading mechanism of the USF-2000A. The test specimen prepared for the test was a CFRP specimen with dimensions of length 40 mm × width 7 mm × thickness 3.5 mm. Since resonance of the specimen at 20 kHz is required in ultrasonic fatigue testing, it is necessary to set a span that will resonate at 20 kHz. In this experiment, the test was conducted with the span set at 16.5 mm. Table 1 summarizes the instrument configuration.

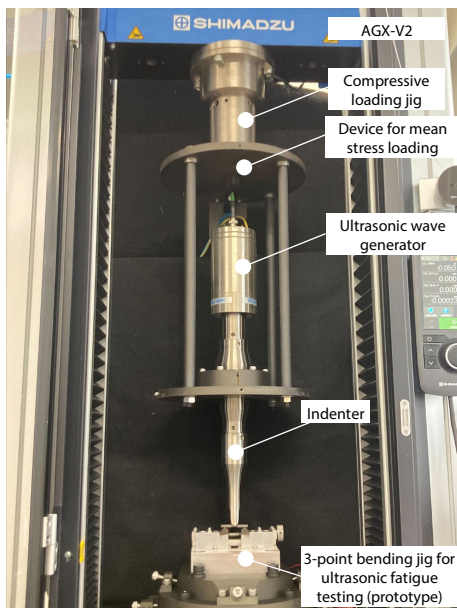


Fig. 1 Condition of Test

Table 1 Instrument Configuration

Ultrasonic fatigue testing system	: USF-2000A
Precision universal testing machine	: AGX-V2
Test jigs	: Device for mean stress loading Compressive loading jig Indenter (R5) 3-point bending jig for ultrasonic fatigue testing (support R2)
Software	: Super Sonic
High-speed video camera	: HPV-X2
Radiation thermometer	: FT-H10 (KEYENCE)

Observation of Specimen during Test

Before starting the actual ultrasonic fatigue test, the behavior of the specimen during the test was recorded with an HPV-X2 high-speed video camera. Fig. 2 shows the condition of high-speed recording. A random pattern for DIC analysis was applied to the specimen, and the framerate for high-speed recording was set to 1 Mfps. Fig. 3 shows an example of an image captured in high-speed recording.

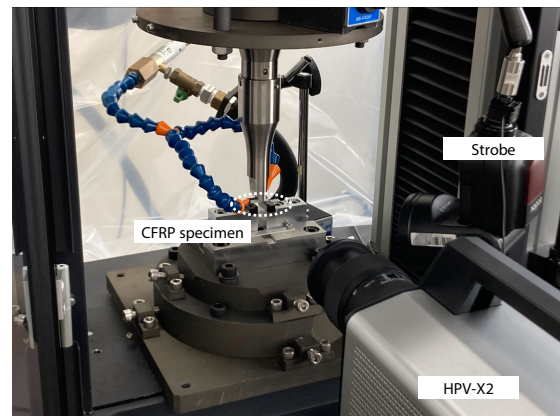


Fig. 2 Condition of High-Speed Recording

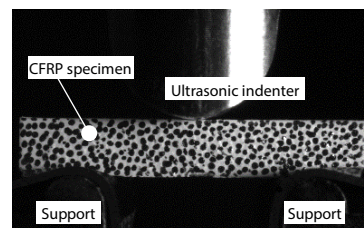


Fig. 3 Example of Image Captured by High-Speed Recording

Fig. 4 shows an example of the DIC analysis results. The graph in Fig. 4 shows the displacement in the test axial direction at a point directly under the ultrasonic indenter. Satisfactory loading was confirmed by the sine wave directly under the indenter.

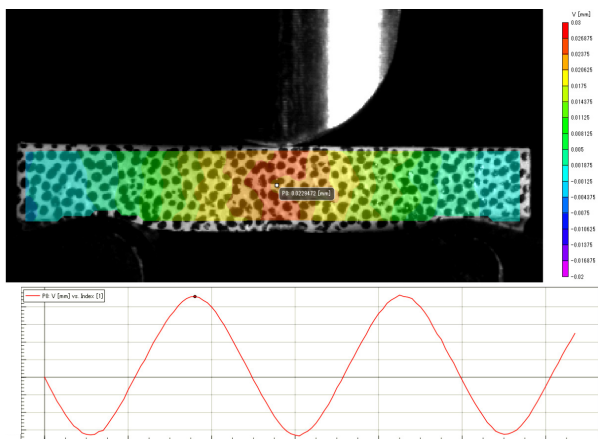


Fig. 4 Example of Results of DIC Analysis

■ Results of Static 3-Point Bending Test

Fig. 5 shows the results of the static 3-point bending test. The maximum test force in this measurement was 3479 N.

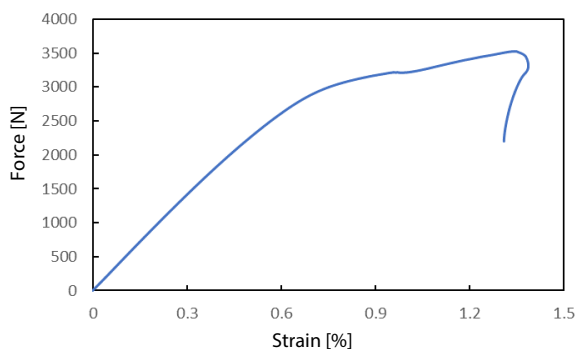


Fig. 5 Force-Strain Diagram

■ Results of 3-Point Bending Ultrasonic Fatigue Test

Fig. 6 shows the condition of the 3-point bending ultrasonic fatigue test. To avoid heat generation in the test specimens, cooling by an air cooler and intermittent operation in which oscillation was cyclically started and stopped were used. The surface temperature of the specimens was checked using a radiation thermometer. Table 2 shows the test conditions. The loaded test force in the ultrasonic fatigue test was equivalent to 65 % to 85 % of the maximum test force in the static 3-point bending test. Measurements were also carried out using a conventional fatigue testing machine under the condition of a large test force, which resulted in a smaller number of cycles to fracture. Fig. 7 shows those results and the results of a 3-point bending fatigue test using the USF-2000A. The results of the conventional fatigue tester and the USF-2000A were approximately in agreement, suggesting the effectiveness of the USF-2000A.

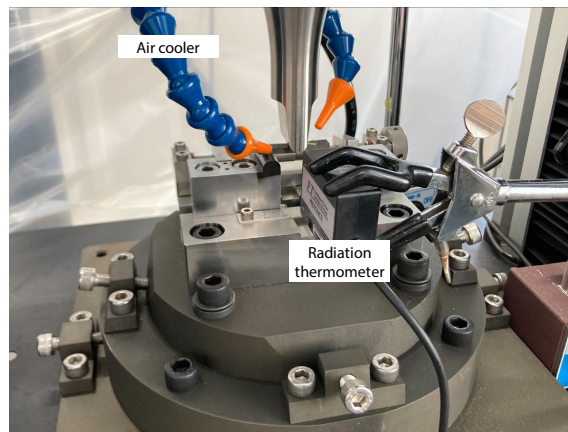


Fig. 6 3-Point Bending Ultrasonic Fatigue Test

Table 2 Conditions of Fatigue Test

Loading condition	: 65 % - 85 % of static bending strength
Stress ratio	: 0.7
Frequency	: 20 kHz
Maximum number of cycles	: 1×10^9

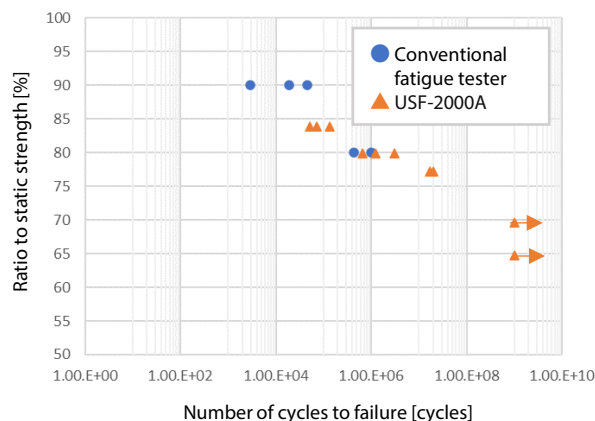


Fig. 7 S-N Diagram

■ Conclusion

A 3-point bending ultrasonic fatigue test was conducted using the USF-2000A ultrasonic fatigue testing system. The measurement results were approximately in agreement with the results of a conventional fatigue test, suggesting the possibility that the USF-2000A can be used in 3-point bending fatigue tests of CFRP. The time required for fatigue testing can be substantially shortened by using this system.

HPV is a trademark of Shimadzu Corporation or its affiliated companies in Japan and/or other countries.

› Please fill out the survey

Related Products

Some products may be updated to newer models.



› **USF-2000A**
Ultrasonic Fatigue Testing System



› **Hyper Vision HPV-X2**
High-Speed Video Camera

Related Solutions

› **Engineering
Materials**

› **FRP**

› **Price Inquiry**

› **Product Inquiry**

› **Technical Service /
Support Inquiry**

› **Other Inquiry**