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Application News

Tabletop Dynamic and Fatigue Testing System Servopulser™ EHF-L Series
High-Temperature Fatigue Testing Machine with Scanning Electron Microscope
SEM Servopulser

Three-Point Bending Fatigue Tests of Carbon Fiber Reinforced Plastic Using the SEM Servopulser

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User Benefits

- The SEM Servopulser can perform three-point bending fatigue tests of carbon fiber reinforced plastic.
- The SEM Servopulser can also be used to observe fatigue cracks.
- High-accuracy dynamic control can be achieved with the Servo Controller 4830.

Introduction

Carbon fiber reinforced plastic (CFRP) has high specific strength and stiffness and is widely used in various industrial fields, including transport vehicles. In order to ascertain its long-term reliability and durability as a structural material, it is necessary to evaluate it for fatigue, one of the main causes of structural failure. However, since CFRP is composed of two types of materials, carbon fibers and matrix resin, it exhibits complex behaviors in failure, such as matrix cracking, inter-layer delamination, and fiber rupture.

This article describes bending fatigue tests that used the Servopulser EHF-L tabletop dynamic and fatigue testing system. The extension of cracks during the fatigue tests was observed using the SEM Servopulser, a high-temperature fatigue testing machine with a scanning electron microscope.

Test Specimen Information and Measurement System

The test specimen information is shown in Table 1. The EHF-L and the SEM Servopulser were used in the tests. The test equipment configuration is shown in Table 2. First, the CFRP test specimen S-N curve was created using the EHF-L. Then, the fatigue testing conditions were set on the SEM Servopulser based on the S-N curve obtained, and the cracking process was observed.

Table 1 Test Specimen Information

Test Specimen:	CFRP
Lamination Method:	(0/90)/(45/-45) alternate lamination
Dimensions:	Length 36 × width 5 × thickness 3 mm

Table 2 Equipment Configuration

Testing Machine:	EHF-L, SEM Servopulser
Load Cell:	10 kN
Test Jig:	Three-point bending test jig
Control Device:	Servo Controller 4830
Software:	Windows software for 4830

Static Three-Point Bending Test Results

To set the conditions in the fatigue tests, static three-point bending tests were performed. The test conditions are shown in Table 3, and the stress-displacement curves are shown in Fig. 1. The mean value of the flexural strength in the static three-point bending tests was 628 MPa (standard deviation 50.6 and coefficient of variation 8.1). The loading conditions in the fatigue tests were based on this value. The test setup is shown in Fig. 2.

Table 3 Test Conditions

Test Speed:	1 mm/min
Number of Tests:	n = 4
Distance between Supports:	30 mm
Indenter/Support Point:	R2
Apparatus Used:	EHF-L

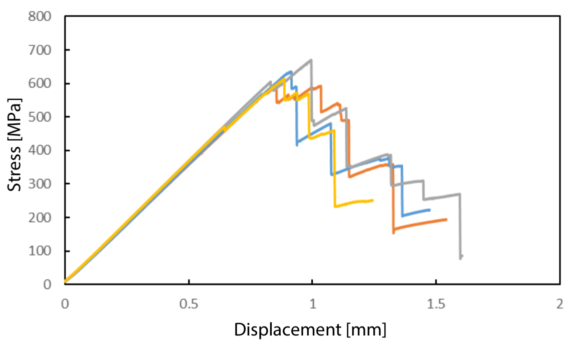

Fig. 1 Stress - Displacement Curves

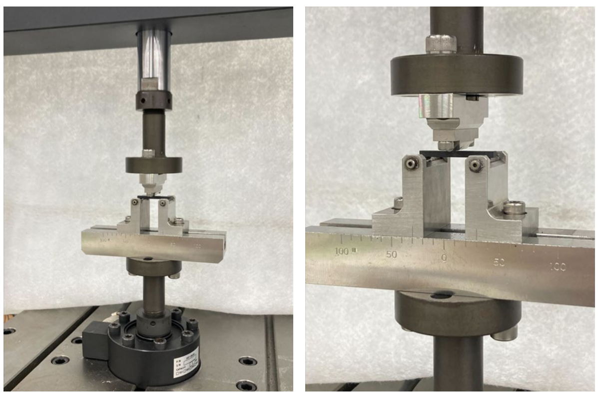

Fig. 2 Test Setup

■ Three-Point Bending Fatigue Test Results

The loading conditions in the three-point fatigue tests were 60 to 85 % of the static three-point flexural strength. The test conditions are shown in Table 4, and the S-N curves are shown in Fig. 3.

Table 4 Three-Point Bending Fatigue Test Conditions

Maximum Loading Stress:	377, 409, 440, 472, 503, 535 [MPa] (60 to 85 % of the static flexural strength)
Stress Ratio:	0.1
Frequency:	20 Hz
Number of Tests:	n = 2
Distance between Supports:	30 mm
Indenter/Support Point:	R2
Apparatus Used:	EHF-L

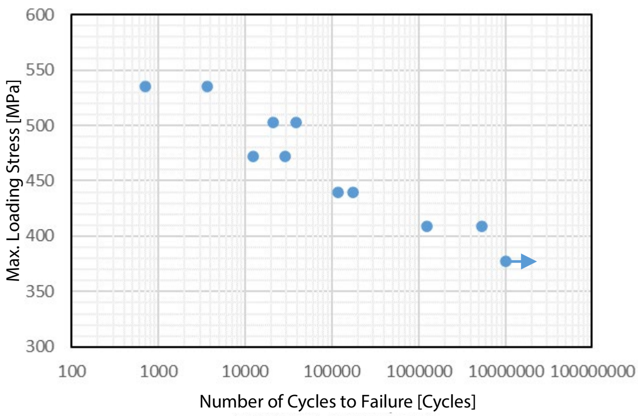

Fig. 3 S-N Curve

Note: Each blue point is one fatigue test result. The point with an arrow indicates that even at the prescribed number of cycles (10 million) the specimen did not fail

■ Observations Using the SEM Servopulser

The SEM Servopulser combines a scanning electron microscope (SEM) with a fatigue testing machine (Servopulser). This enables the extension of cracks to be observed in detail during tests. From the S-N curve in Fig. 3, observations using the SEM Servopulser were performed up to a maximum loading stress of 535 MPa. Fig. 4 shows a photograph of the test specimen and test jig. To make the test specimen more easily observed using the SEM, the test specimen was coated with gold in advance. Fig. 5 shows images observed using the SEM Servopulser. Fig. 5 (1) shows the test specimen directly below the indenter before the test. Fig. 5 (2) to (4) show the test specimen close to the indenter when the number of cycles was 719. The SEM magnification ratio was 30, 50, and 100, respectively. From Fig. 5 (2) to (4), compression failure, including the rupture of fibers, was observed on the left side of the indenter. Fig. 5 (5) and (6) show the test specimen when the number of cycles was 5500 with a magnification ratio of 13 and 100, respectively. From Fig. 5 (5), it can be seen that cracking occurred not only on the indenter side but also on the opposite side. In Fig. 5 (6), a new matrix crack that was not observed in Fig. 5 (4) was observed, so it is clear that the damage had progressed.

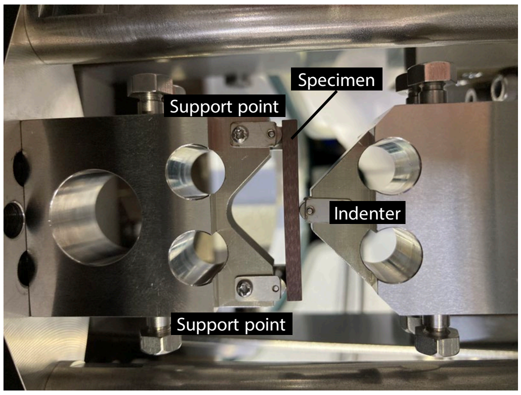

Fig. 4 Test Specimen and Test Jig

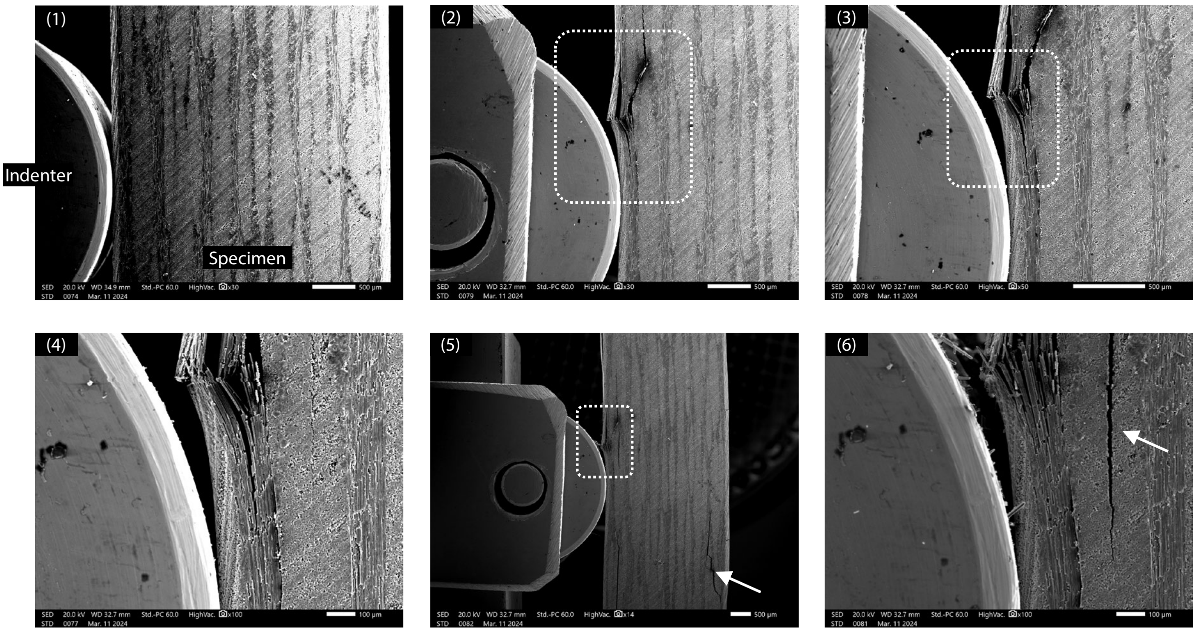

Fig. 5 Examples of Observations Using the SEM Servopulser

(1) Before the test (2) 719 cycles, magnification ×30 (3) 719 cycles, magnification ×50
(4) 719 cycles, magnification ×100 (5) 5,500 cycles, magnification ×13 (6) 5,500 cycles, magnification ×100

■ Conclusion

Bending fatigue tests were performed on CFRP using a fatigue testing system, and the resulting S-N curve was compiled. Then the conditions were set on the SEM Servopulser based on the S-N curve obtained, and damage to the test specimen was observed during the test. By changing the magnification on the SEM, it was possible to observe the damage location on the test specimen in detail. As the test progressed, it was possible to clearly observe how the damage progressed. In this way, the SEM Servopulser demonstrated it can assist in evaluating the fatigue properties of composite materials, such as CFRP.

Related Applications

1. Three-Point Bending Fatigue Test and Crack Observation of Cracked Specimens Using SEM Servopulser
   Application News No. 01-00794
2. Three-Point Bending Fatigue Tests of Welded Material Using the SEM Servopulser
   Application News No. 01-00792

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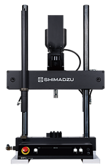

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