Excellence in Science

Dynamic and Fatigue Testing Machines Servopulser EHF-L Series
Servopulser with Scanning Electron Microscope

Application News

Three-Point Bending Fatigue Test and Crack Observation of Cracked Specimens Using SEM Servopulser

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User Benefits

- SEM Servopulser allows for real-time observation of microscopic fracture occurring during the test.
- The Servo Controller 4830 enables high-precision dynamic control.

■ Introduction

Material fracture arises from both macroscopic defects originating from specific damage points and microscopic defects such as inclusions or crystal lattice transitions. By analyzing the cracks that propagate from these defects in detail, it becomes possible to predict the fatigue life of the material and improve the durability and safety of products and components. A Scanning Electron Microscope (SEM) is useful for observing damage and cracks on a material's surface at high resolution. In material fatigue evaluation, a strength test is conducted, but in the past, damage and cracks were observed after the tests, and it was not possible to observe crack propagation at the microscopic level during the tests.

In this paper, an SEM Servopulser (Fig. 1) was used, which combines a Scanning Electron Microscope (SEM) and an electric-hydraulic fatigue testing system (Servopulser). By using the SEM Servopulser, it is possible to observe microscopic fracture on the surface of the specimen in real time. In this test, a three-point bending fatigue test was conducted on a metal specimen with a notch in the center using the SEM Servopulser, allowing real-time observation of crack propagation.

Fig. 1 Servopulser with Scanning Electron Microscope

■ Measurement System

In the fatigue test, the SEM Servopulser and dynamic and fatigue testing machines, Servopulser EHF-L Series (Fig. 2), were used. The testing equipment used in this test is shown in Table 1. A view of the test is also shown in Fig. 3.

The test specimen was made of stainless steel (L36 × W4 × t2.5 mm) and had a notch with a depth of 0.5 mm at the center along the length (Fig. 4).

Table 1 Test Equipment

Fatigue Testing Machine	: SEM Servopulser Servopulser EHF-LV020k1A
Load Cell	: 10 kN
Actuator Stroke	: ±10 mm (SEM Servopulser) ±25 mm (EHF)
Distance between Supports	: 30 mm
Support Roller and Punch Radius	: 2 mm
Software	: Windows Software for 4830 Fatigue and Endurance Testing

Fig. 2 Dynamic and Fatigue Testing Machine Servopulser EHF-L

(a)

(b)

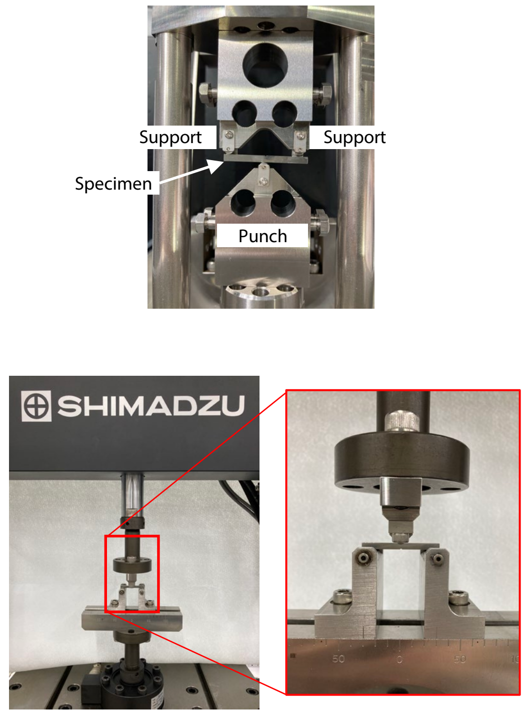

Fig. 3 View of the Test (a) SEM Servopulser (b) EHF-L

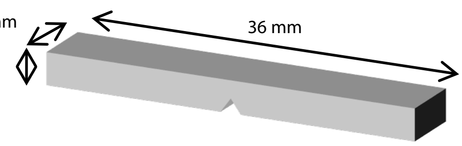

Fig. 4 Specimen Dimensions

■ Results of the Static Three-Point Bending Test

Before the fatigue evaluation, a static three-point bending test was conducted using the EHF-L, and the maximum test force was measured (test speed: 5 mm/min). The test force-stroke diagram is shown in Fig. 5. From the static test results, the maximum test force was calculated to be 1138 N (standard deviation: 1 N).

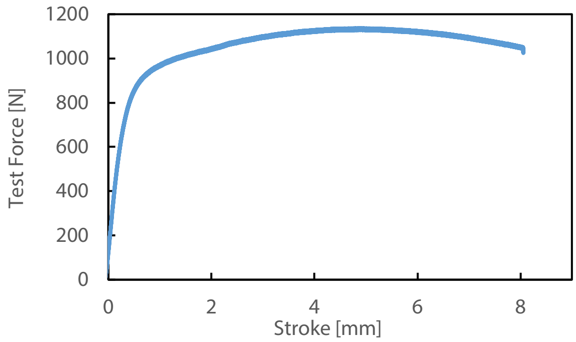

Fig. 5 Test Force – Stroke Diagram

■ Results of the Fatigue Three-Point Bending Test

The maximum load test force for the fatigue test was set based on the maximum test force measured during the static test. The conditions are shown in Table 2 along with other parameters. The number of cycles to failure at each condition was obtained from two test specimens, and the resulting maximum load test force versus number of cycles to failure diagram is shown in Fig. 6.

Table 2 Conditions for the Fatigue Test

Maximum Load Test Force	:	638, 558, 479, 439, 419, 405 N
Stress Ratio	:	0.1
Frequency	:	20 Hz

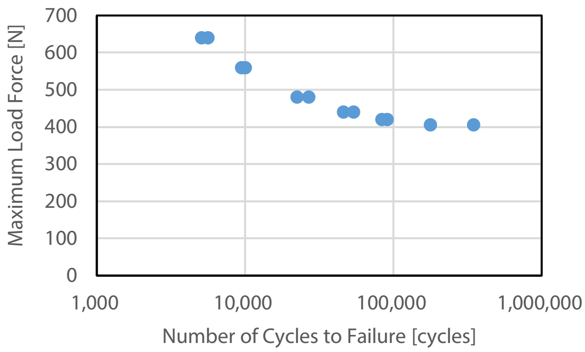

Fig. 6 The Relationship between the Maximum Load Test Force and the Number of Cycles to Failure

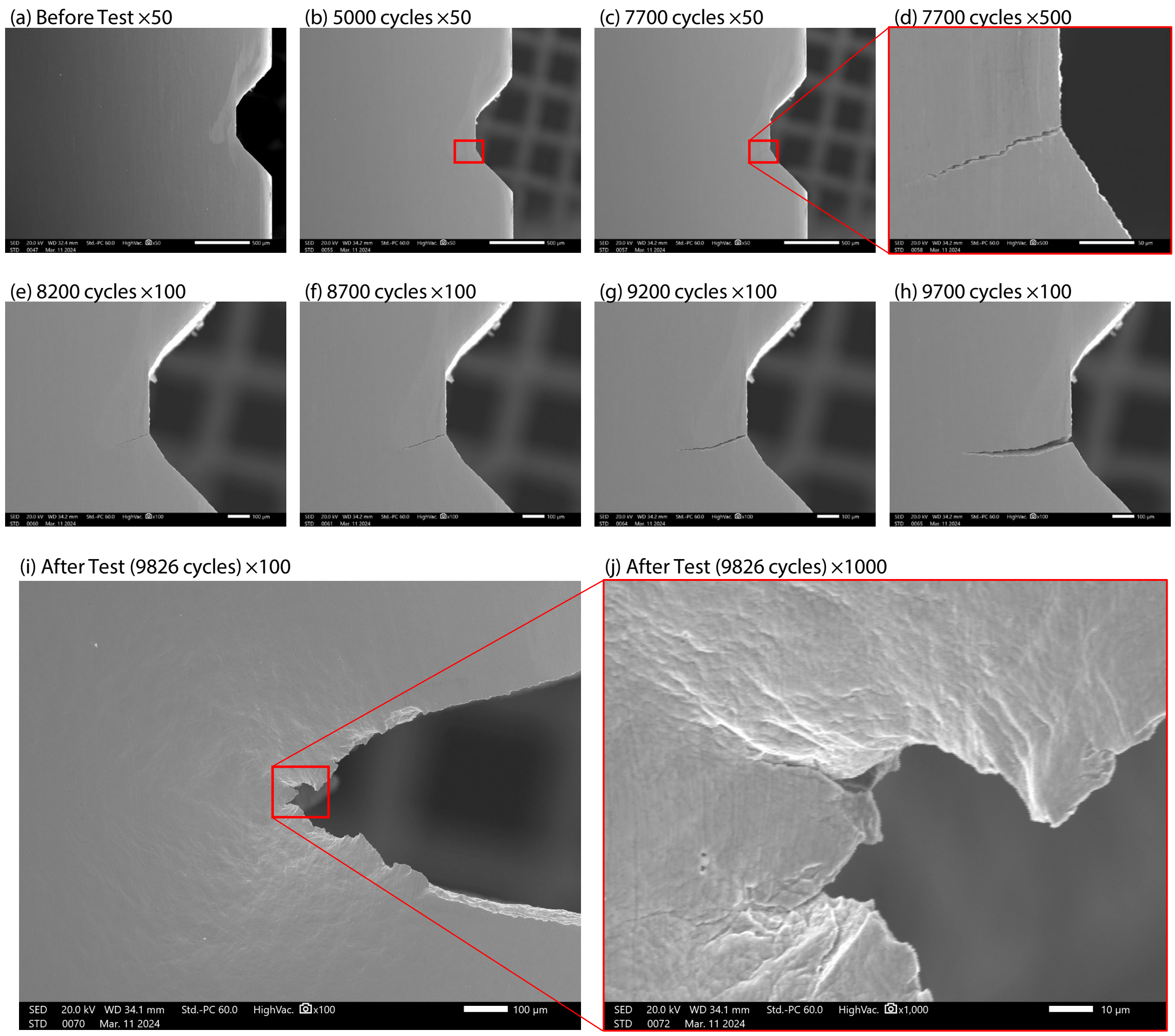

Fig. 7 Secondary Electron Images

The secondary electron images of the crack during the test are shown in Fig. 7. After the test started in Fig. 7(a), a small crack in the red box was confirmed for the first time at the 5000th cycle in (b). The crack could be clearly observed from the 7700th cycle shown in Fig. 7(c), and it was found that the crack, with a length of about 120 µm, was generated from the image at a magnification of 500× in (d). As shown in Fig. 7(e) to (h), the crack continued to grow with the number of cycles, and the crack length was about 400 µm at the 9700th cycle just before failure. The tip of the crack that failed at the 9826th cycle was Fig. 7(i), and it had opened significantly from the pre-crack region up to (h). Fig. 7(j) shows the tip of (i) observed at a magnification of 1000×. From the images above, it was confirmed that the crack growth during the test could be observed using the SEM Servopulser.

■ Conclusion

In this paper, fatigue property evaluation of cracked specimens and crack observation during the test was conducted using the Servopulser with scanning electron microscope and the dynamic and fatigue test machine Servopulser EHF-L.

Initially, a static three-point bending test was conducted, and the maximum test force was measured. Based on the results, the maximum load test force for the fatigue test was set, and the maximum load test force versus number of cycles to failure diagram was obtained. Simultaneously, secondary electron images were obtained during the test using the SEM Servopulser, and the generation and growth of the crack were observed.

Using the measurement system introduced in this paper, material strength testing is possible, and furthermore, it is possible to observe microscopic fractures on the specimen's surface in real time during the test.

Related Applications

1. Three-Point Bending Fatigue Tests of Welded Material Using the SEM Servopulser
   Application News No. 01-00792-EN
2. Three-Point Bending Fatigue Tests of Carbon Fiber Reinforced Plastic Using the SEM Servopulser
   Application News No. 01-00793-EN

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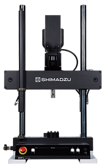

EHF-L Series

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