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Ultrasonic Fatigue Testing Machines USF-2000A

Application News

Ultrasonic Fatigue Test for Hourglass-shaped Metal Test Specimens with Parallel Sections

Tsubasa Yamamoto and Fumiaki Yano

User Benefits

- The ultrasonic fatigue tester is capable of testing at a repetition rate of 20 kHz and can complete tests with 10^9 cycles (1 billion cycles) in only about 14 hours.
- It is possible to test hourglass-shaped test specimens with parallel sections specified in the Chinese National Standard GB/T 43896 "Metallic materials-Very high cycle fatigue-Ultrasonic fatigue test method."

■ Introduction

Fatigue is a fracture phenomenon caused by repeated loads, even within the elastic region. It is said that about 70 % of structural fracture phenomena are caused by metal fatigue. For most structural steels, there is a fatigue limit where fatigue failure does not occur even after repeated loading if the stress is less than a certain value, and the number of cycles is about 10^6 to 10^7. However, in high-strength steels such as chromium molybdenum steel, it is known that fatigue failure occurs in the ultra-high cycle range of 10^8 to 10^9 cycles, exceeding 10^7 cycles, due to inclusions in the material. Therefore, the standard of 10^7 repetitions as the maximum number of repetitions used in general fatigue tests is not sufficient, and fatigue tests with more than 10^9 cycles are required. On the other hand, a fatigue test with more than 10^9 cycles would take more than 3 years at a 10 Hz load. The ultrasonic fatigue tester used in this study is capable of testing at 20 kHz and can complete tests with 10^9 cycles in about 14 hours, making it ideal for measuring ultra-high cycle fatigue.

In previous reports[1,2], we conducted tests on standard hourglass specimens. In November 2024, the National Standard GB/T 43896 of the People's Republic of China (Metallic materials- Very high cycle fatigue-Ultrasonic fatigue test method) was issued, so Shimadzu has added a new dimension calculation function for hourglass-shaped specimens with parallel sections to its USF-2000A dedicated software, Super Sonic.

In this paper, we introduce an example of measurement of an hourglass-shaped specimen with a parallel section in compliance with GB/T 43896 using SNCM439, a type of structural steel.

■ Instruments

The USF-2000A was used in this test. Table 1 shows the testing equipment and Fig. 1 shows the test setup. In the ultrasonic fatigue test, a longitudinal wave vibration generated by a piezo actuator causes the specimen to resonate, and stresses are applied to the specimen. The cyclic stress is not measured using a load cell, but is calculated based on the displacement of specimen's end face. In this test, an eddy current displacement meter was used to measure the displacement of the end face.

In the ultrasonic fatigue test, internal heat generation occurs due to the high repetition rate. According to GB/T 43896, the surface temperature of the high-stress part of specimen is measured, and the specimen temperature during the test is required to be within room temperature +10 °C. In order to suppress the temperature rise of the specimen, an air cooler was employed to blow cooling air onto the heated region, and intermittent operation was performed as described below.

Table 1 Instrument Configuration

Testing Machine	: USF-2000A
Thermometer	: Radiation thermometer
Displacement Gauge	: Eddy current displacement meter
Software	: Super Sonic

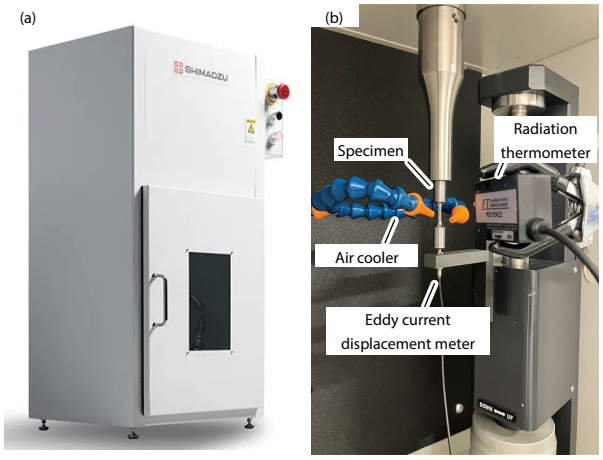

Fig. 1 (a) View of the USF-2000A, (b) View of the Test

■ Test Sample

An hourglass-shaped specimen with a parallel section is a specimen with a parallel part in the center. The shape of the specimen used in this test is shown in Fig. 2. Since the cross section of the parallel part is constant and the stress during the test is uniform, it is suitable for testing materials with obvious defects such as inclusions.

GB/T 43896 recommends that the test is conducted at a resonant frequency of 20 ± 0.5 kHz. The resonant frequency varies with the length of the specimen, and the longer the specimen, the lower the resonant frequency. This time, 3 types of specimens with different lengths of specimen shoulders were produced based on the dimension calculation function. Then, the resonant frequency of each specimen was measured, and by clarifying the relationship between the length of the specimen shoulders and the resonant frequency, the size of specimen that resonates at 20 kHz was determined. Fig. 3 shows the relationship between the resonant frequency and the length L of the specimen shoulders. Based on Fig. 3, this test was performed with the length of the specimen shoulders set to 16.4 mm.

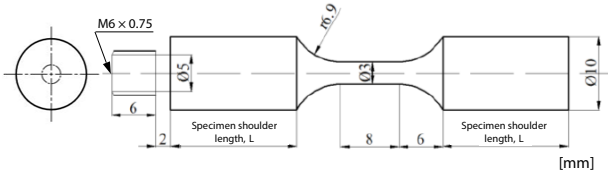

Fig. 2 Hourglass-Shaped Specimen with Parallel Section

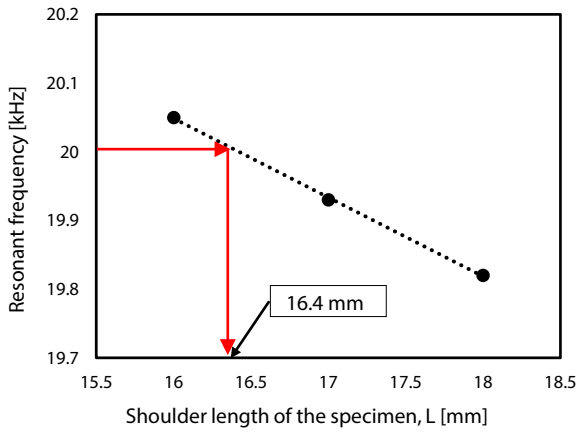

Fig. 3 Relationship between Resonance Frequency and Shoulder Length of Hourglass-Shaped Specimen with Parallel Section

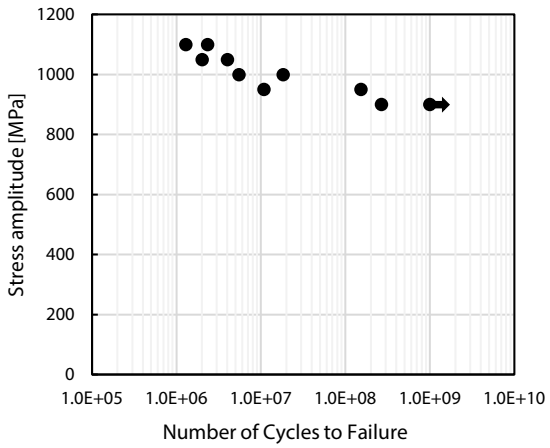

Fig. 4 S-N Diagram of SCNM439

■ Test Conditions

Table 2 shows the test conditions. In these tests, the maximum applied stress was set to level 5. In addition, intermittent operation was performed in which oscillation time and stop time were alternately repeated in order to prevent heating of the specimens. The conditions of intermittent operation were determined by measuring the temperature of the specimen surface with a radiation thermometer. Table 3 shows the conditions of intermittent operation.

Table 2 Test Conditions

Specimen	:	SNCM439
Stress Amplitude	:	1100, 1050, 1000, 950, 900 MPa (Total 5 conditions)
Maximum Cycles	:	1×10^9
Number of Specimens	:	N = 2
Stress Ratio	:	-1.0
Frequency	:	20 kHz

Table 3 Intermittent Operation Conditions

Stress amplitude [MPa]	Oscillation time [ms]	Non-oscillation time [ms]
1100	110	1200
1050	110	1000
1000	150	600
950	200	550
900	200	500

■ Test Results

The test results are shown in Fig. 4. The SNCM439 material tested this time was heat-treated to increase its strength. From the S-N diagram, fatigue failure was confirmed at 10^7 to 10^8 cycles under the condition of maximum applied stress of 950 MPa or more. In addition, the maximum number of cycles was set at 10^9 cycles, and in the test at 900 MPa, it was confirmed that the tests on samples were completed without failure up to the maximum number of cycles.

■ Conclusion

In these tests, ultrasonic fatigue tests were conducted on SNCM439 hourglass-shaped specimens with a parallel section in accordance with the Chinese National Standard GB/T 43896, “Metallic materials-Very high cycle fatigue-Ultrasonic fatigue test method,” and S-N diagrams were obtained.

<References>

1) Ultrasonic Fatigue Testing of Metal Materials, Application News No. i258

2) Detection of Inclusions in Metal Materials Using an Ultrasonic Fatigue Testing System, Application News No. i259

3) GB/T 43896-2024
Metallic materials-Very high cycle fatigue-Ultrasonic fatigue test method

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