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Application News

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USF-2000A Ultrasonic Fatigue Testing System

Ultrasonic Fatigue Testing of Metal Materials

Generally it is known that with most structural metal materials the fatigue strength lowers until a load is applied 10^6 times, and from 10^7 times onward the fatigue limit is reached, at which no fatigue fracture will occur. However, it is also revealed that with high-strength metal materials that are hardened or surface treated, internal inclusions become an origin of a fatigue fracture and cause a fracture even at 10^8 to 10^9 cycles. On the other hand, recently, the functionality and endurance required for industrial products are becoming stringent, and according to this trend, metal materials forming industrial products must also meet rigorous requirements. Therefore, conventional testing with a maximum of 10^7 loading cycles is now insufficient, and a fatigue test exceeding 10^9 cycles has become required. However, such a fatigue test will take considerable time. For example, a test with 10^9 cycles at a frequency of 10 Hz theoretically requires about 3.2 years. The ultrasonic fatigue testing system used for this experiment enables testing at a frequency of 20 kHz, achieving a test with 10^9 cycles in about 14 hours. Therefore, this testing system is a very effective measurement system for fatigue tests exceeding 10^9 cycles.

In this experiment, we used two kinds of metal specimens, SNCM439 and A6063, for testing according to WES 1112: 2017 (Ultrasonic fatigue testing method for metal materials) stipulated by the Japan Welding Engineering Society. The results are introduced in this article.

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Measurement System

We used the USF-2000A ultrasonic fatigue testing system, for measurement. For the measurement principle, please refer to our catalog of this system (Dynamic/Fatigue Testing Systems). Table 1 gives the testing system configuration and Fig. 1 shows the picture of the test. In WES 1112: 2017, it is stipulated that the surface temperature of a high stress portion on the specimen must be measured to determine the conditions to keep the temperature at 30 °C or less and that the use of a radiation thermometer is recommended. When room temperature exceeds 30 °C, the upper limit must be "room temperature + 5 °C. In addition, forced air cooling is recommended to cool the specimen with air of 10 °C or less.

Table 1 Testing System

Testing system	: USF-2000A Ultrasonic Fatigue Testing System
Thermometer	: Radiation thermometer
Displacement meter	: Eddy current displacement sensor

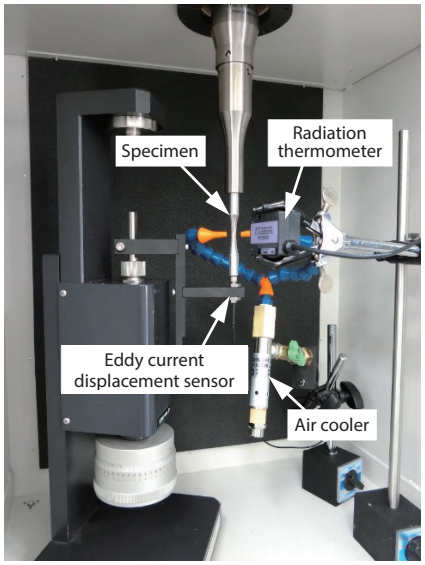

Fig. 1 Picture of the Test

Preparation of Specimens

The ultrasonic fatigue testing system resonates a specimen at 20 kHz to generate stress on the specimen. Regarding the frequency, WES 1112: 2017 describes that, since a frequency lower than 15 kHz in the zone of audibility may cause a noise problem and a high frequency higher than 30 kHz may present difficulties in designing specimens that can resonate, testing in a frequency of 20 ± 1 kHz is recommended. To fulfill this requirement, specimens that can resonate at 20 kHz must be prepared. We prepared three specimens having different lengths in the parallel portions (L in Fig. 2) and calculated respective resonant frequencies, from which a specimen size at 20 kHz was obtained through linear interpolation. As an example, the drawing of the SNCM439 specimen is shown in Fig. 2, and the relation between the resonant frequency and the parallel portion length is shown in Fig. 3.

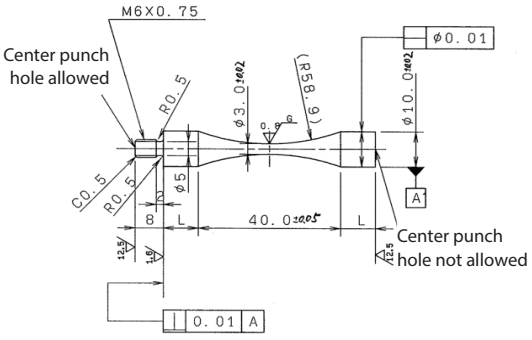

Fig. 2 SNCM439 Specimen Drawing

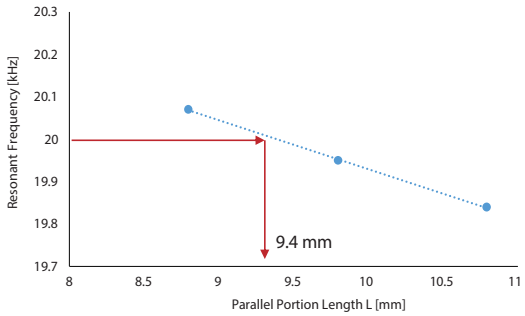

Fig. 3 Relation between Resonant Frequency and Parallel Portion Length with SNCM439

Test Conditions

The test conditions are listed in Table 2. Testing was performed on two kinds of metal specimens by setting six levels of stress amplitude as indicated in Table 2. To prevent heat generation on the specimens, in addition to forced air cooling, intermittent operation was performed by repeatedly alternating oscillation and non-oscillation. WES 1112: 2017 states that intermittent operation may be performed since the influence of intermittent operation on the test is negligible. Table 3 lists the conditions of intermittent operation.

Table 2 Test Conditions

Specimen	:	SNCM439, A6063 T5
Stress amplitude	:	SNCM439 1100, 1050, 1000, 950, 900, 850 MPa A6063 120, 110, 100, 90, 80, 70 MPa
Maximum cycles	:	1×10^{10}
Number of specimens	:	n = 2
Stress ratio	:	-1
Frequency	:	20 kHz

Table 3 Intermittent Operation Conditions

Specimen	Stress amplitude [MPa]	Oscillation time [ms]	Non-oscillation time [ms]
SNCM439	1100	200	500
	950 to 1050	300	500
	850 to 900	300	200
A6063	120	200	500
	110	300	500
	70 to 100	300	100

Test Results

The test results of SNCM439 are shown in Fig. 4 and those of A6063 are shown in Fig. 5. The SNCM439 and A6063 specimens used in the testing were tempered at a low temperature and T5 heat treated, respectively, to have a high strength. These specimens exhibited a fatigue fracture at 10^8 to 10^9 cycles under the condition where the stress amplitude was small. When the stress amplitude is large, the variation in the number of cycles to failure is small; when the stress amplitude is small, this variation is large. This suggests that when the stress amplitude is high a fracture occurs from the surface of the specimen and when the stress amplitude is low a fracture originating from internal inclusions occurs and the size of inclusions affects the progress of the fracture.

Conclusion

In this experiment, we performed ultrasonic fatigue testing of two kinds of metal materials. Both materials exhibited a fatigue fracture at 10^8 to 10^9 cycles. Therefore, in cases where higher endurance is required, testing need to be repeated for over 10^7 cycles. The ultrasonic fatigue testing system used for this experiment enables fatigue tests at 20 kHz, which is suitable for testing exceeding 10^7 cycles.

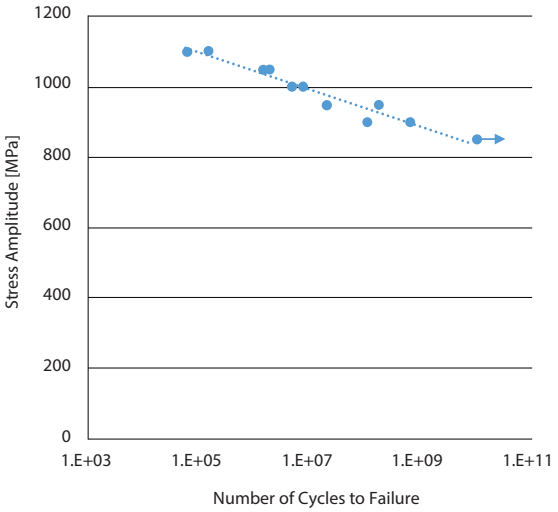

Fig. 4 S-N Diagram with SNCM439

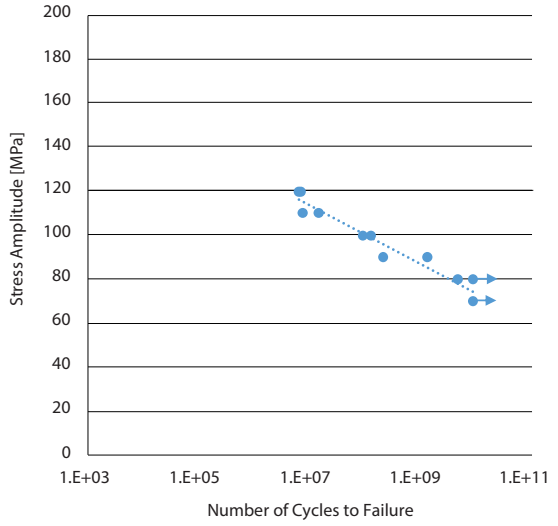

Fig. 5 S-N Diagram with A6063

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