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Application News

No.V21

High-Speed Video Camera

Observation of Bending Fatigue Testing of Metal Plate at Ultrasonic Frequency

Introduction

Fatigue failure refers to the fracture of a component due to repeated load cycles, which can occur using a force much smaller than the static fracture strength. Also, because fatigue-related failure occurs suddenly, there are cases where this has led to serious accidents involving ships and aircraft. Therefore, knowledge of the fatigue properties of materials used in products is very important. However, determination of fatigue characteristics typically requires time-consuming testing using 10^7 repetitions (as per JIS Z2273, General Rules for Fatigue Testing of Metals), which at 10 Hz, takes about 12 days to complete. Also, due to enhancements in equipment efficiency and speed, there are now requests for fatigue evaluation with more than 10^7 repetitions. In response to this, an ultrasonic testing machine capable of 20 kHz ultrasonic fatigue testing is now in use. However, due to the very rapid vibration that is generated during measurement with this instrument, visual confirmation of the movement and deformation of the specimen is not possible. Therefore, a high-speed video camera was used to observe the movement of a metal plate vibrating while conducting a 20 kHz bending fatigue test. Previously, gaining an understanding of the overall movement of the test specimen required incremental repositioning of a displacement gauge, but with the high-speed video camera, it is possible to evaluate the movement of the specimen in a single observation process. Further, the possibility of determining the amount of movement of the specimen from captured images was also demonstrated.

Measurement System

The USF-2000 Ultrasonic Fatigue Testing System and the HPV-X2 high-speed video camera were used for this experiment. Table 1 lists all the instrumentation that was used. Shooting during the test can be conducted at any desired timing. Fig. 1 shows a photograph of the test specimen. For the bending vibration, the vibration modes shown in Fig. 2 are available, with a test specimen dimensioned to resonate for each vibration mode. Here, a test specimen was prepared to provide a second-order bending mode.

Table 1 Imaging Equipment

High-speed video camera	: HPV-X2
Microscope	: Z16 APO
Lighting	: Strobe
Testing apparatus	: USF-2000

Table 2 Measurement Conditions

Measurement speed	: 2 million frames/sec
Test frequency	: 20 kHz
Test specimen size	: 10.0 × 3.020 × 0.406 mm

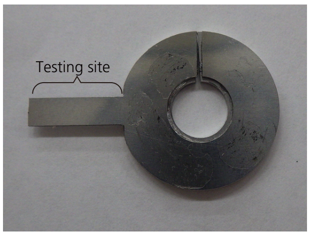

Fig. 1 Specimen

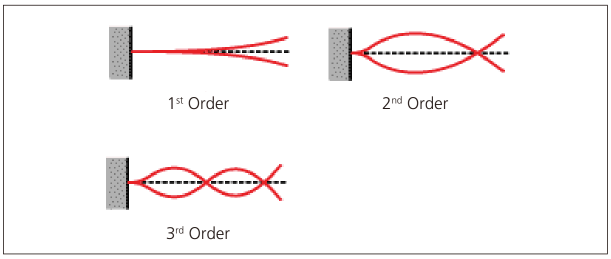

Fig. 2 Bending Mode Examples

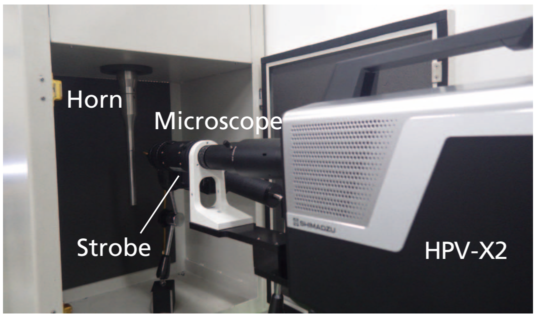

Fig. 3 Overview of Test

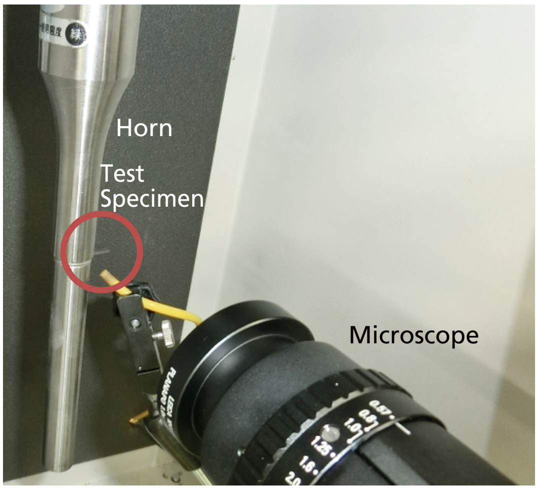

Fig. 4 Periphery of Specimen

Measurement Results

Fig. 3 shows an overview of the test setup, and Fig. 4 shows a close-up view of the vicinity of the specimen. The vibration generated by the actuator is amplified by the horn, causing the specimen to vibrate. Table 2 shows the measurement conditions. To obtain image data at more than 100 frames per cycle, the shooting speed must be set to two million frames/sec. Fig. 5 shows a series of captured images. The blue line traversing the images in Fig. 5 is situated at the center of the specimen in image (1). The central portion of the specimen is shifted in the downward direction as the images proceed from (1) to (3). Then, the center portion of the specimen shifts in the upward direction, reaching a maximum at image (9). From image (9), the specimen center descends once again, returning at image (11) to the same position as in image (1). From the above, the vibration cycle of the specimen was determined to be 20 kHz. Also, from Fig. 5, the specimen tip does not move very much, although it can be seen that the specimen is in a second-order bending mode due to movement of the test specimen center. Applying image processing software to the captured images permits determination of the range of movement of the test specimen. Here, we determined the amount of movement of the central part of the specimen. Fig. 6 shows the relationship between time and the amount of movement of the specimen center. Also, from Fig. 6, the amplitude in the bending test is determined to be about 80 µm, and the vibration frequency is determined to be 20 kHz.

Conclusion

Fatigue testing of a target component conducted using the ultrasonic frequency was documented using the HPV-X2, and the movement characteristics of the test specimens were confirmed. The HPV-X2 proved to be effective in capturing the high-speed movement generated during the test, and installation of a microscope permitted visual documentation of these minute movements. Aside from this confirmation of movement in the specimen during the test, the actual degree of movement in the test specimen can be determined from the captured images. The USF-2000 calculates the stress amplitude from the amplitude of vibration, thereby permitting the determination of the stress load on the test specimen from the images. Thus, the HPV-X2 can effectively serve in the very important fatigue testing process during product development.

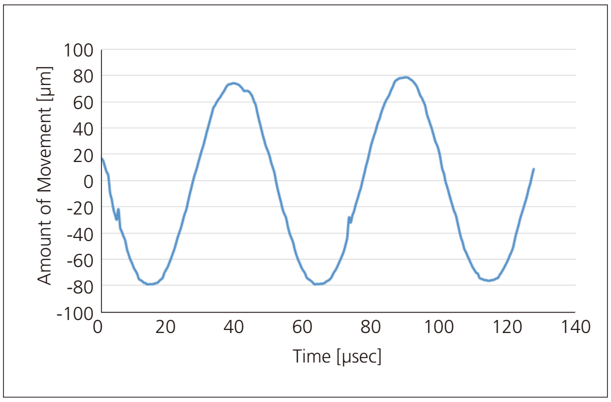

Fig. 6 Amount of Movement of Specimen

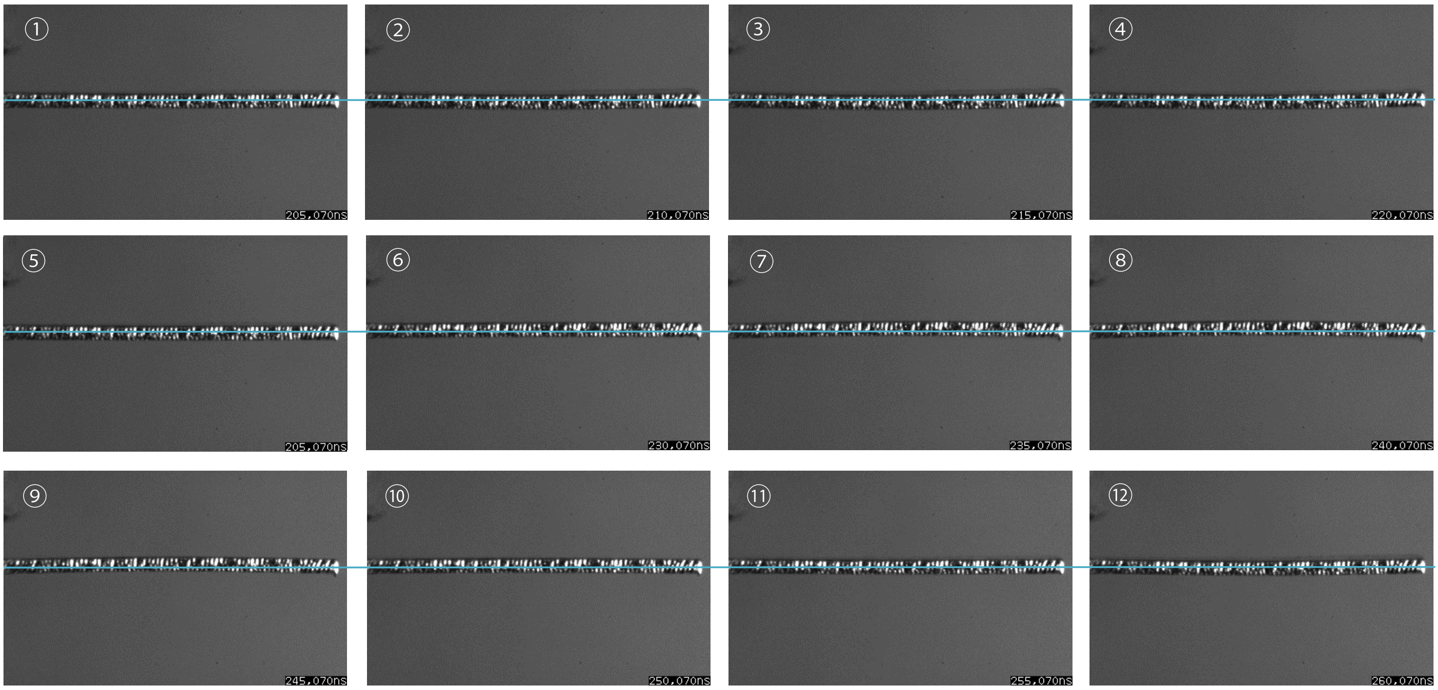

Fig. 5 High-Speed Images (Imaging interval: 5 µsec)

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