RELATIONSHIP BETWEEN TEMPERATURE PROPERTY AND LOADING FREQUENCY OF ROTATING BENDING FATIGUE TESTING MACHINE OF CANTILEVER TYPE

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RELATIONSHIP BETWEEN TEMPERATURE PROPERTY AND LOADING FREQUENCY OF ROTATING BENDING FATIGUE TESTING MACHINE OF CANTILEVER TYPE

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ABSTRACT

Fatigue property in gigacycle regime is focused as an important subject in recent years. In such a long-life region, a tremendous long period is required to perform the tests. To overcome this difficulty, a part of authors has been developing the new rotating bending fatigue testing machine, which enables to reduce the test period and cost drastically. It was confirmed that the fatigue test dates are consistent with many experimental results obtained by hydraulic tension and compression fatigue testing machines and the rotating bending fatigue test machines of both-handed type known as Ono type. Although it prefers to reduce the fatigue test period as short as possible, the maximum frequency of a rotating bending fatigue test is limited by the standards because of the possibility of local temperature rise in specimen caused by the cyclic plastic work and the heat transfer from fatigue testing machine. Such local temperature rise might affect the fatigue property. However, the appropriate loading frequency limit is unclear because of the difficulty of the temperature measurement in the fracture portion of a specimen precisely during the rotating bending fatigue test. An in-situ temperature measuring technique is proposed to measure the temperature at the fracture portion of the specimen in real time during the fatigue testing, and the validity to determine the loading frequency of a rotating bending fatigue testing machine is discussed in this study.

KEYWORDS

Maximum loading frequency, Cantilever type rotating bending fatigue testing machine, Temperature measuring, Fracture portion, In-site temperature measuring technique

INTRODUCTION

The fatigue property in gigacycle regime is focused as an important subject in recent years. For example, it will take too much time to obtain P-S-N curves or S-N curves especially in the regime of very high cycle. In order to shorten the test period, some works have been tried by applying the ultrasonic fatigue test system. In such an ultrasonic fatigue testing, local temperature rise inside the specimen increases so significantly that appropriate temperature control systems are required [2-4]. In addition, the loading frequency is quite higher than the in-service condition of the machines and structures.

Therefore, the high speed fatigue testing machines with mechanical loading system should be developed. In order to shorten the testing period, a part of authors developed a multiplex rotating bending fatigue machine [8-9]. Such a fatigue testing machine can perform the fatigue test on multiple specimens under different load magnitude simultaneously at an appropriate loading frequency without local temperature increase inside the specimen which might affect the fatigue property and the fracture mechanism. Such a kind of multiplex fatigue testing machine is adopted more and more widely, because the testing condition is quite same with testing performed by the conventional testing machine and the testing result is compatible with the data base of fatigue property which is obtained by the conventional testing machines and usually referred in fatigue testing and safety design of mechanical products [5-6].

On the other hand, many standards for the fatigue tests restrict the loading frequency. For example, Japan Industrial standards JIS Z 2274 for the rotating bending fatigue test is specified in a range of 1000 to 5000 rpm [10]. To obtain effective experimental data, the loading frequency should be limited into a reasonable range, although fatigue testing machine can work very well at a higher frequency. It is considered the local temperature increasing inside the specimen caused by the plastic work during cyclic loading in fatigue test is one of reasons to set a limit of loading frequency. However, the appropriate loading frequency limit is unclear because of the difficulty of the temperature measurement near a fracture portion of a specimen precisely during the rotating bending fatigue test.

In this paper, an in-situ temperature measuring technique is proposed to measure the temperature at the fracture portion of the specimen in real time during the fatigue testing, and the validity of limit loading frequency in the rotating bending fatigue testing machine is discussed.

DUAL-SPINDLE FATIGUE TESTING MACHINE

In this research, a duplex rotating bend fatigue testing machine developed by a part of authors was applied to perform the fatigue tests. This fatigue testing machine has two spindles and two specimens can be installed at both ends of each spindle. Both spindles are driven by an electric motor. Thus, 4 specimens can be tested simultaneously at a given speed under a given rotating bending load. A photograph (front view) of such a fatigue testing machine is indicated in Fig.1 and a specimen mounted in the chucking parts is shown in Fig.2.

Fig.1: Dual-spindle rotating bending fatigue machine YRB300L (front view)

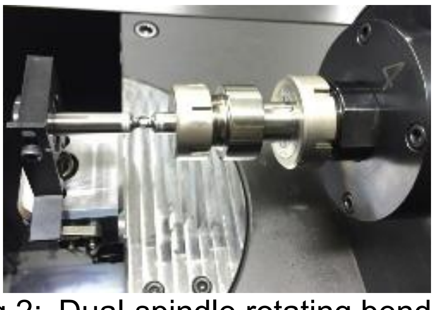

Fig.2: Dual-spindle rotating bending fatigue machine YRB300L (chucking parts and specimen)

IN-SITU TEMPERATURE MEASURING TECHNIQUE

A wireless temperature monitoring system developed by the authors as indicated in Fig.3 [7]. Amplifier, A/D converter, micro-controller, and transmitter are encapsulated in a tool holder. The analog signal produced by the thermocouple is converted to a digital signal and wirelessly and continuously transmitted to a PC through a receiver connected to PC. The temperature history is recorded and monitored on PC in real time. An exchangeable adapter as shown in Fig.4 is adopted to mount such the wireless temperature monitoring tool into the fatigue testing machine.

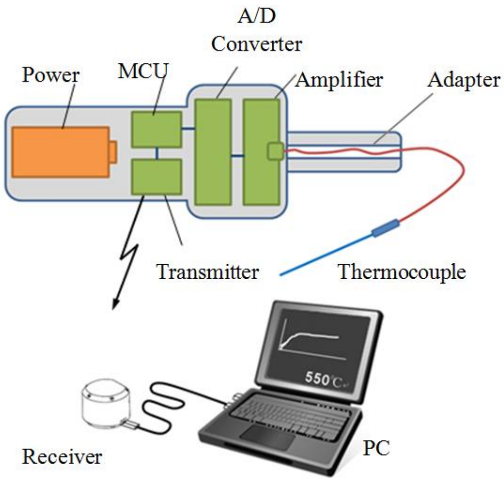

Fig.3: Construction of the wireless temperature monitoring system

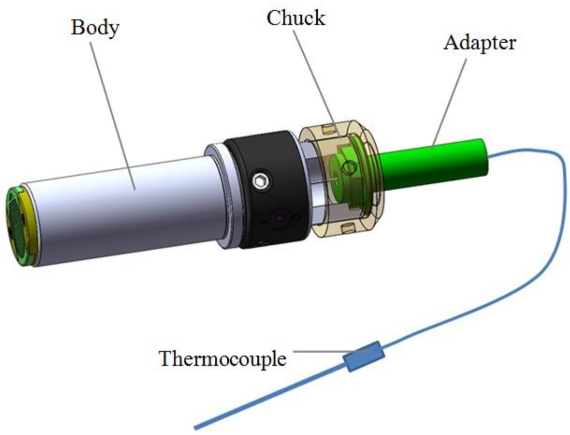

Fig.4: Appearance of the wireless temperature monitoring tool

TEMPERATURE MEASURING METHOD NEAR THE MINIMUM CROSS SECTION OF SPECIMEN

In order to measure the temperature near the minimum cross section of specimen, the developed temperature monitoring system is installed on the other spindle opposite side of the specimen as indicated in Fig.5. A bearing unit is adopted to support the end of temperature monitoring tool to suppress the vibration during the spindle rotating at a high speed. As shown in Fig. 6, a hole with diameter of 0.5mm is prepared at one side of the specimen. A thermocouple (JIS C1605-95, Class 2, K type) is inserted to the center of specimen through the prepared hole and the thermocouple is connected to the temperature monitoring tool through the hollow spindle as indicated in Fig.5.

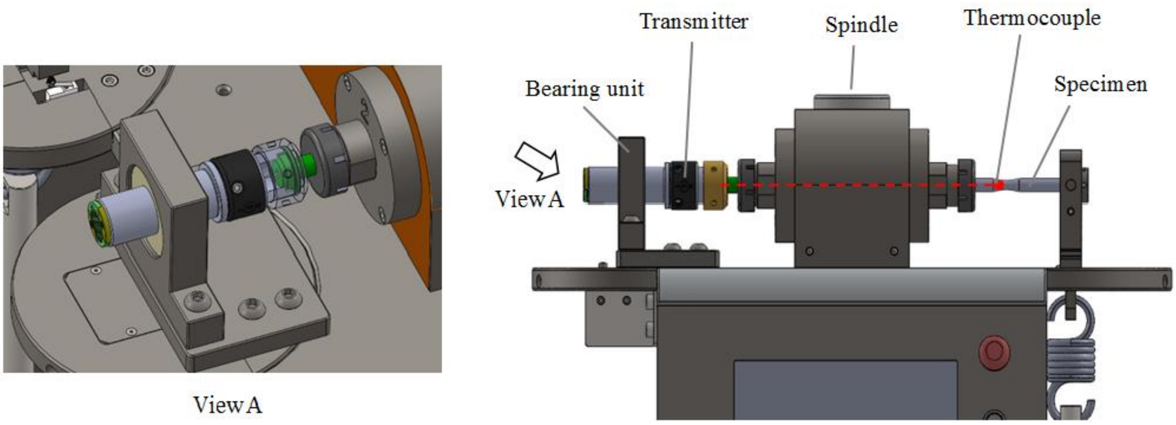

Fig.5: Construction of the wireless temperature measuring system

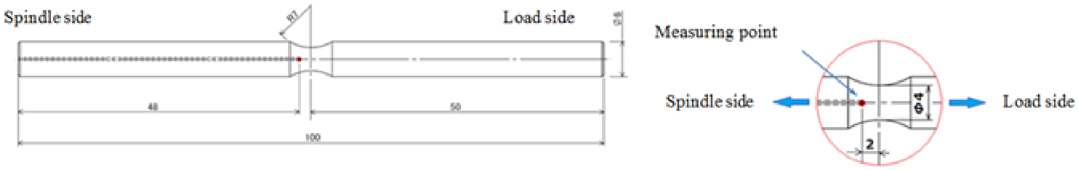

Fig.6: Specimen for temperature monitoring

TEMPERATURE MEASUREMENT RESULTS

The testing conditions are listed in Table 1. Materials used in this study are A6005C (also named as A6N01 in Japan)-T5 aluminum alloy and anti-flammable magnesium alloy AZX611-F. Fatigue specimens were machined into the shape and dimensions indicated in Fig.6. The temperature near the minimum cross section of a specimen was measured during a fatigue test by developed monitoring system as indicated in Fig.5. The stress amplitude loaded on the specimen is 15MPa.

Rotating speed / Material	3000 rpm	5000 rpm	6000 rpm
A6005C	Condition1	Condition3	Condition5
AZX611	Condition2	Condition4	Condition6

Table1: Test conditions

The temperature measured results are shown in Figs.7 and 8. At each rotation speed, the temperature near the minimum cross section of the specimen rose gradually and tended to converge to a constant value for both material. Furthermore, there is a tendency that the amount of temperature increase is large according to the loading speed is higher. However, the maximum temperature increase during the tests is less than 20 degree Celsius for each specimen as shown in Fig.7 and Fig.8. Thus, it was confirmed that the temperature increase during the fatigue tests is not too high to affect the fatigue testing result. Also, same tendencies were confirmed under different load levels such as 80MPa and 148MPa introduced by the authors in the past research [1].

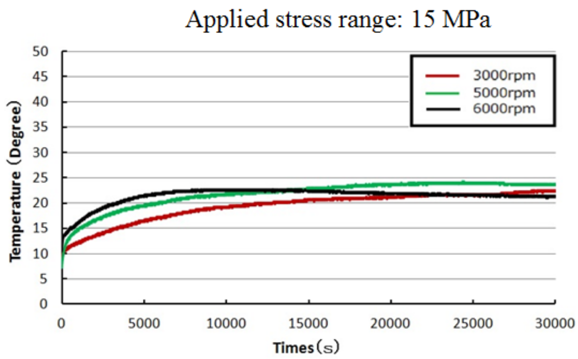

Fig.7: Results of temperature monitoring (material: A6005C-T5)

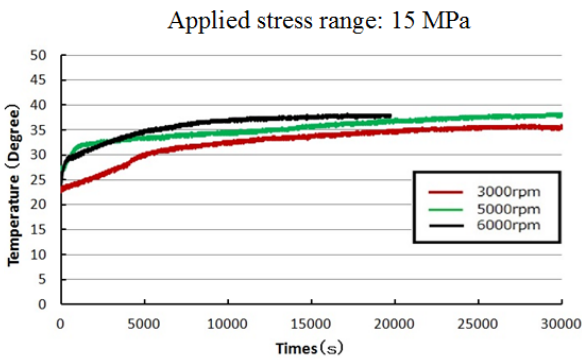

Fig.8: Results of temperature monitoring (material: AZX611-F)

FATIGUE TESTING RESULT UNDER OVER TESTING SPEED LIMIT

Maximum loading frequency is limited below 5000rpm as indicated in the Japanese Industry Standard (JISZ 2274) [10]. Usually the maximum loading frequency is set as nearly 3000rpm [5-6]. In order to investigate the possibility of the enhancement of maximum loading frequency, fatigue test results between the loading frequency 6000 rpm and 3000rpm was compared.
It is confirmed that there is no clear gap between the experimental results as indicated in Fig.10. The scatter of fatigue life is in an acceptable range. Referring to the temperature monitoring result indicated in before section, we know that there is no clear temperature increase between them. Thus, it is rational to enhance the maximum loading frequency to 6000rpm for collecting the fatigue data more efficiently.
If the maximum loading frequency is enhanced from 3000rpm to 6000rpm, the fatigue testing period can be shortened to about 120 days in a case of fatigue test in a gigacyle regime.

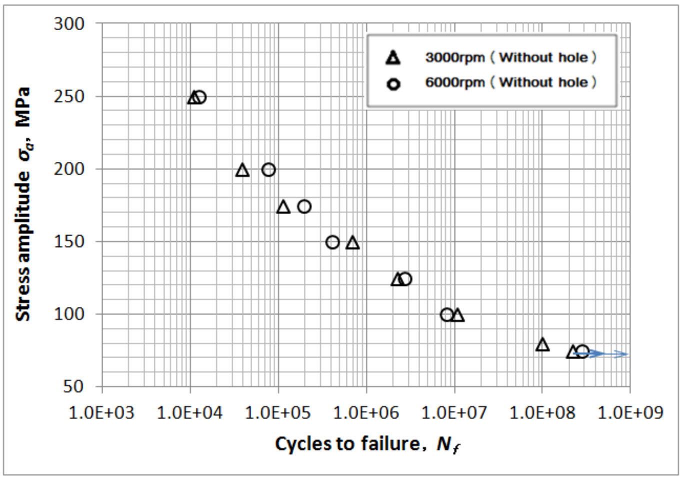

Fig.10: Influence of rotating speed on fatigue test results

CONCLUSIONS

A wireless temperature monitoring system is developed to measure the temperature at the fracture portion of the specimen in real time during the fatigue testing, and the validity to enhance the loading frequency is discussed. Main conclusions obtained in this study are summarized as follows.

(1) The temperature increase in vicinity of fracture section of specimen is compared at a loading frequency of 3000rpm which is in the range provided by Japanese Industry Standard (JISZ 2274) and 6000rpm which is over the maximum limit of the loading frequency (5000rpm) provided in JISZ 2274. Although the temperature increase is a little higher at a loading frequency of 6000rpm, there is no clear effect on the fatigue life.
(2) It is rational to enhance the testing frequency of cantilever rotating bending fatigue test to 6000rpm which is over the limit value of 5000rpm provided in JISZ 2274 for collecting the fatigue data more efficiently.
(3) The developed wireless temperature monitoring system can be used to measure the temperature of fracture section in a real time during fatigue testing. Thus, it is an effective system to evaluate the loading frequency limit of cantilever rotating bending fatigue test.

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