

# Development and Several Additional Performances of Dual-Spindle Rotating Bending Fatigue Testing Machine GIGA QUAD

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**Abstract** In order to investigate the fatigue characteristics of metallic materials experimentally, a long period of time is required to get sufficient number of S-N data. In recent years, in order to overcome this difficulty, multi-type rotating bending fatigue testing machine whose name is GIGA QUAD have been developed by Yamamoto Metal Technos Co., Ltd., in which four specimens can be tested simultaneously. In this time, some additional new functions have been developed as follows;

(1) 'high and low temperature environmental testing unit' whose target temperature is in a range of 600°C and -150deg.C, (2) 'fracture alarm unit', and (3) '2-step variable loading unit'.

By combining these new functions with the machine of GIGA QUAD, one can perform the fatigue tests efficiently corresponding to the respective requirements for researchers in both of academic and industrial sectors.

**Keywords** High temperature environmental testing unit, Low temperature environmental testing unit, Fracture alarm unit, 2-step variable loading unit, multi-type rotating bending fatigue testing machine

## 1. Introduction

One of difficulties in fatigue tests for structural materials is to take a long time to perform the fatigue test. Fatigue tests are usually conducted toward the loading cycles of  $N=10^7$ , but the fatigue property in gigacycle regime is also focused as an important subject in recent years[1]-[8]. In such a long life region, a tremendous long period is required to perform fatigue tests. If the fatigue test is performed at the loading frequency of 50Hz, it takes more than 200 days to reach  $10^9$  cycles of the load application. It means that it takes very long term for us to obtain one S-N curve.

In addition, since the fatigue life of any metallic material has a distinct scatter, sufficient number of specimens should be tested to obtain the reliable fatigue property. An example of such fatigue test data for a bearing steel in very high cycle regime are shown in Figure 1 as an S-N diagram[5]. Type I indicates the conventional bearing steel, whereas Type II indicates the high purity bearing steel.

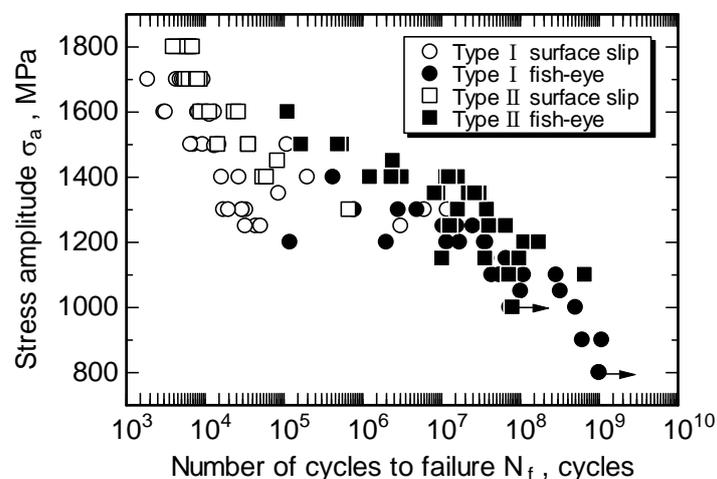


Figure 1. Typical example of fatigue test data for bearing steel in very high cycle regime

Open marks indicate the data in the surface initiated fracture, while solid marks give those data in the interior inclusion initiated fracture. In order to complete a series of fatigue tests to obtain all the data in Fig.1, it takes several years for one kind of metallic material. This circumstance introduces a serious difficulty to every researcher in the area of “*Metal Fatigue*” from technological and economical backgrounds.

If the high loading frequency such as ultrasonic fatigue test was accepted to save the testing time, temperature raising of the specimen due to the internal friction would take place and some cooling system or intermittent loading system should be furnished to examine the original fatigue property[9-12]. Thus, the acceleration fatigue test by ultrasonic technology would cause new difficult subjects as the fatigue testing method to obtain the fatigue property at the usual frequency.

In order to overcome these difficulties, authors have developed special types of fatigue testing machines in rotating bending, in which four specimens can be tested simultaneously[13,14]. Thus a series of fatigue tests even in gigacycle regime can be carried out within a reasonable time period. Based on this advantageous performance, the name of “GIGA QUAD” was accepted for this new machine. By using this machine of GIGA QUAD, fatigue tests can be performed much quickly comparing with the conventional testing machines, even if it is used with various environment options. Accordingly, this machine is useful to file up a number of fatigue test data in gigacycle regime for various kinds of metallic materials, and such databases can provide the fundamental design data for mechanical structures in the wide variety of the engineering application.

## 2. DUAL-SPINDLE ROTATING BENDING FATIGUE TESTING MACHINE

This machine has two spindles and two specimens can be mounted at both ends of each spindle as indicated in Fig.2 and Fig.3. Each spindle is driven by an electric motor via a V belt and the number of revolution is counted by means of photo-sensor. Thus, this machine can perform fatigue tests for 4 specimens simultaneously. In order to apply the testing load, the corresponding weight is suspended through a helical spring attached to the outer bearing block. The rotating speed of the spindle, that is, the testing speed is 3,150rpm (52.5Hz)

GIGA QUAD has two types of ‘YRB200’ and ‘YRB200L’ according to the loading capacity (Maximum load). The maximum load of YRB200 is 20kg, whereas the load of YRB200L is 80kg.

Table 1. Specification of the Device

	YRB200	YRB200L
Motor	0.2kw-4P	0.4kw-4p
Capacitance	380V	380V
Collet Chuck	φ2.5~13	φ2.5~20
Max Load	20kg x 4	80kg x 4
Spindle Speed	3,150rpm	3,150rpm
Weight	140kg	170kg
Size	470x400x1050	800x660x1100
Spindle Number	2	2



Figure 2. GIGA QUAD YRB200



Figure 3. GIGA QUAD YRB200L

Hourglass type of specimen as shown in Fig.4 is accepted as a formal test piece. Diameter of the critical section ' $\phi\beta$ ' is designed as to give the reasonable stress level for the each material, while the diameter of the specimen grip ' $\phi\gamma$ ' may be decided by user freely. Collet chucks with different diameters such as 6mm, 8mm and 10mm are prepared in advance. Among them, the user can choose the most preferable collet chuck depending on the individual circumstance for the testing material.

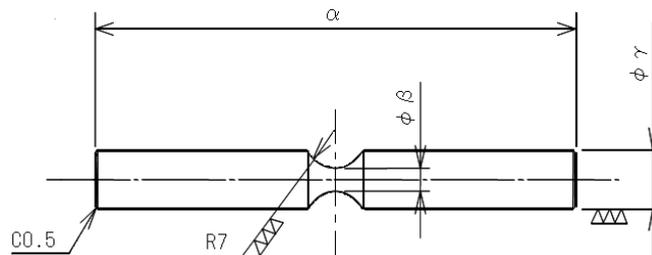


Figure 4. The shape and dimensions of the specimen

### 3. Support for environmental testing

#### 3.1. High temperature environmental testing unit

In order to perform the rotating bending fatigue test at high temperature, a special chamber and a

temperature controlling system have been developed.

By using such an unit, one can carry out the fatigue test within a temperature range of room temperature (RT) to 600deg.C. Accuracy of the temperature controlling is within  $\pm 2$ deg.C. As fatigue test data are distinctly affected by the testing temperature, it is important to perform the fatigue tests at the accurate temperature. In such a case, this unit is useful to obtain the correct S-N property of the material at the definite temperature.

#### Specification

Temperature controlling range: room temperature to 600deg.C

Size of control panel box: 170mm x 220mm x 280mm

Specimen type : our standard specimen ( $\phi 10$ )

Power: AC100V 1set

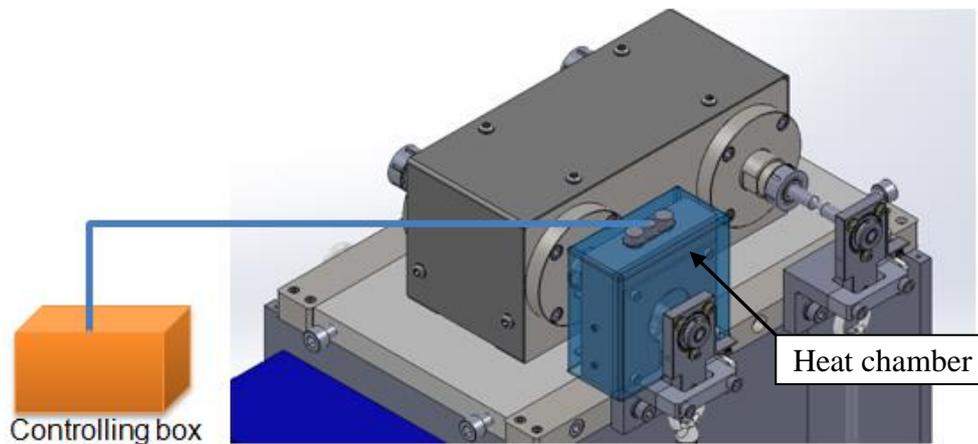


Figure 5. High temperature environmental testing unit

### 3.2. Low temperature environmental testing unit

A special unit to spray liquid nitrogen into the chamber has been developed to conduct the rotating bending fatigue test at low temperature environment.

By using this unit, one can carry out the fatigue test within the temperature range of RT to -100deg.C with the accuracy of  $\pm 5$ deg.C.

#### Specification

Temperature controlling range : -100 deg.C to room temperature

Size of control panel box : 170mm x 220mm x 280mm

Specimen type : our standard specimen ( $\phi 10$ )

### 3.3. 2-step variable loading unit

A special loading unit has been developed to perform the rotating bending fatigue test under the condition of 2-step variable loading. Stress applied to the specimen is provided by suspending the appropriate weight in the structure of the machine. In this unit, 2-step loading is applied by lifting a part of weight with air cylinder periodically in testing. By setting any value of the weight and the lifting period, one can perform fatigue tests in a wide variety of the testing environments close to real machines in the practical use.

### 3.4. Fracture alarm unit

A fracture alarm unit which can detect fracture of specimen and inform the fracture to researchers via e-mail has been developed. In the case of fatigue test to obtain the S-N property, the test is repeatedly conducted by using a lot of specimens. In some cases, stress is changed with a definite time span in order to simulate the actual service loading. Since the fatigue life of each specimen has a distinct scatter, it is impossible to know the fatigue life exactly before the fatigue test. Due to this difficulty, every researcher has to come to the testing machine to confirm whether the specimen has failed or not.

If the person does not notice the fracture of the specimen, he/she wastes much time to find the fatigue failure even though the number of cycles to failure is recorded. In order to prevent such a time consumption, this unit was originally developed here.

Adopting this unit, the researcher can get the prompt information on the failure immediately after the specimen has failed. Thus, the next fatigue test can be started soon and the above time consumption can be effectively solved. In addition to this advantage, researchers' mental stress to check the fatigue failure can be also reduced.

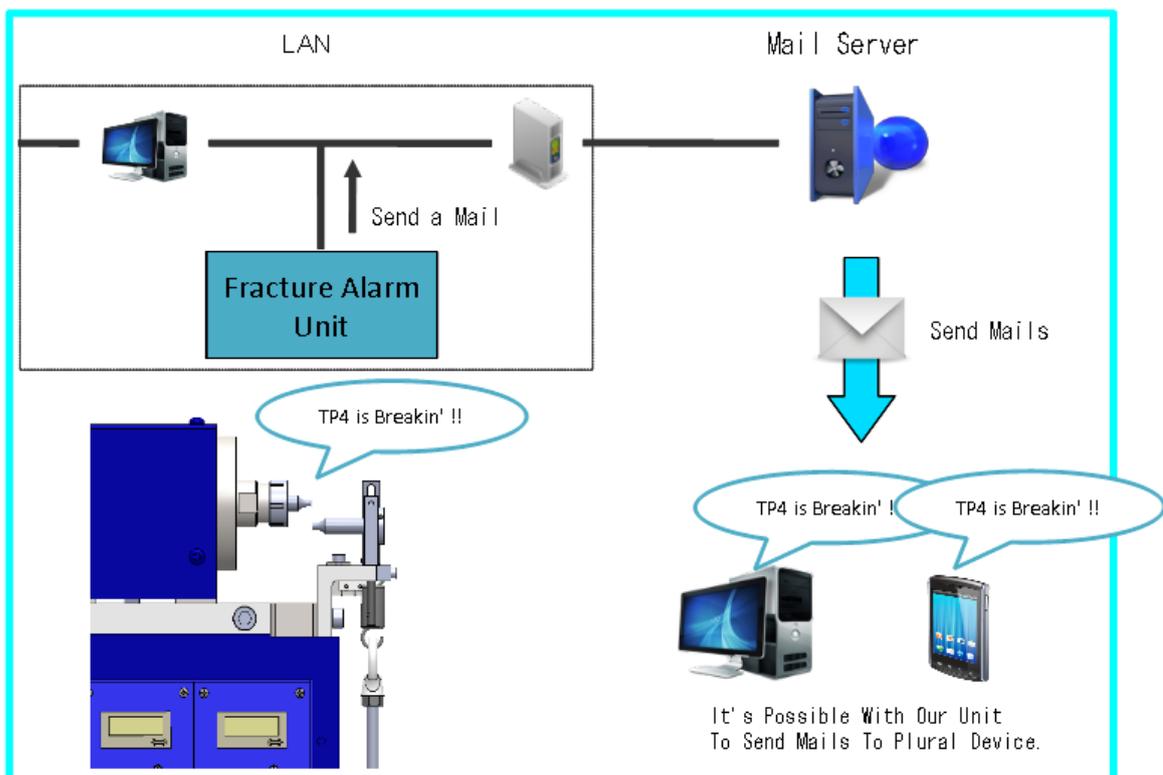


Figure 7. Fracture alarm unit

## 4. CONCLUDING REMARKS

Conventional fatigue tests take a long time more than 200 days to reach  $N=10^9$ , and a number of fatigue test data are required as the fundamental data in the mechanical design. In order to solve such difficulties, the high performance fatigue testing machine in rotating bending “GIGA QUAD” has been developed in this work.

Based on a lot of experimental results, the fundamental performance of this testing machine was

confirmed. Actually these machines are already being used at many laboratories in universities and industries. Thus, conventional customers and new customers have informed that this testing machine is successfully used to obtain a number of fatigue data within a reasonable short period.

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