DEVELOPMENT AND FUNDAMENTAL PERFORMANCE OF DUAL-SPINDLE ROTATING BENDING FATIGUE TESTING MACHINE WITH SPECIAL DEVICE PROVIDING CORROSIVE ENVIRONMENTS

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ABSTRACT

Conventional fatigue tests are conducted by setting the run-out number of loading cycles to N=10^7, but the fatigue property in gigacycle regime is also focused as an important subject in recent years[1]. In such a long life region, a tremendous long period is required to perform fatigue tests. Thus, it is very difficult to conduct fatigue tests for many specimens by means of usual types of fatigue testing machines. In order to overcome this difficulty, special types of fatigue testing machines have been developed under rotating bending in which four specimens can be tested simultaneously. By using this testing machine, fatigue tests were carried out efficiently, and it contributes to make fatigue databases in gigacycle regime.

KEYWORDS

Fatigue testing machine, Dual-spindle rotating bending, Collet chuck, Gigacycle fatigue, GIGA QUAD, Environmental fatigue test, Salt water

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] 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 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 order to overcome this difficulty, authors have developed special types of fatigue testing machines in rotating bending, in which four specimens can be tested simultaneously. Thus a series of fatigue tests even in gigacycle regime can be carried out within a reasonable period. Based on this advantageous performance, the name of “GIGA QUAD” was accepted for this new machine. By using GIGA QUAD, fatigue tests can be performed much quickly comparing with the conventional testing machines. 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.

DUAL-SPINDLE ROTATING BENDING FATIGUE TESTING MACHINE

Outline

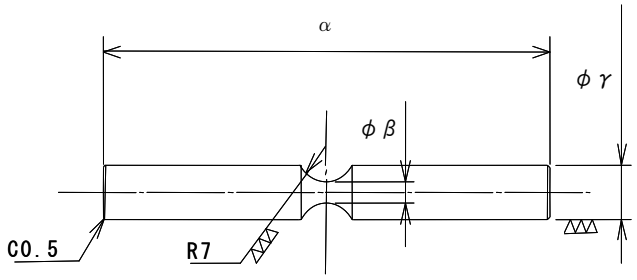
This machine has two spindles and two specimens can be mounted at both ends of each spindle as indicated in Fig.1. Each spindle is driven by an electric motor via a V belt and the number of revolution is counted by means of photo-sensor. Thus, this machine can perform fatigue tests for 4 specimens simultaneously. In order to apply the testing load, the corresponding weight is suspended through a helical spring attached to the outer block as indicated in Fig.1. The rotating speed of the spindle, that is, the testing speed is 3150rpm (52.5Hz).

YRB200 YRB200L

Fig.1: Dual-spindle rotating bending fatigue testing machine (GIGA QUAD)

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. Therefore, the user can choose the appropriate type based on the respective requirements.

Hourglass type of specimen as shown in Fig.2 is accepted as a formal test piece. Diameter of the critical section '$\varphi\beta$' is designed as to give the reasonable stress level for the each material, while the diameter of the specimen grip 'φγ' 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.



α : Length of the specimen
φβ : Diameter of the critical section
φγ : Diameter of the specimen grip

Fig.2: Shape and dimensions of the specimen

Four main advantages

The present fatigue testing machine of GIGA QUAD has four main advantages. They are High Efficiency, Easy Operation, Clear Observation of fracture surface and Support for environmental testing. Each of these advantages is further explained as follows;

1. High efficiency

This machine is convenient to get a number of fatigue test data very quickly, because four specimens can be tested simultaneously. In order to obtain one S-N curve, four specimens can be tested at different stress levels by giving different weights for the respective specimens. Thus, S-N property of a definite material can be obtained within the reasonable short period. In comparison with the conventional machine, the testing time required to perform a series of fatigue tests to clarify an S-N property is simply shortened into 1/4 of the conventional machine. From this point of view, the present machine of GIGA QUAD has a significant performance of the high efficiency.

2. Easy operation

In this testing machine, the specimen can be easily fixed and removed as indicated in Fig.3. As mentioned above, different diameters of 6mm, 8mm and 10mm are prepared as the inner diameter of the collet chucks. Thus, the user can choose the most convenient size of the collet chuck. Eccentricity at the outer end of the specimen after chucking was kept within $\pm 20\mu m$. Such a small eccentricity is fundamentally important to perform the fatigue tests in rotating bending. If the eccentricity becomes large, problems of vibration and noise take place in the fatigue tests and, therefore, some extent of error is included in the applied stress. According to preliminary experiments, no effect of the eccentricity was found for fatigue test data to obtain the S-N property, if the eccentricity is kept within $\pm 30\mu m$. This is the reason why the eccentricity of this testing machine was restricted within the small value of $\pm 20\mu m$ expecting some extent of margin.

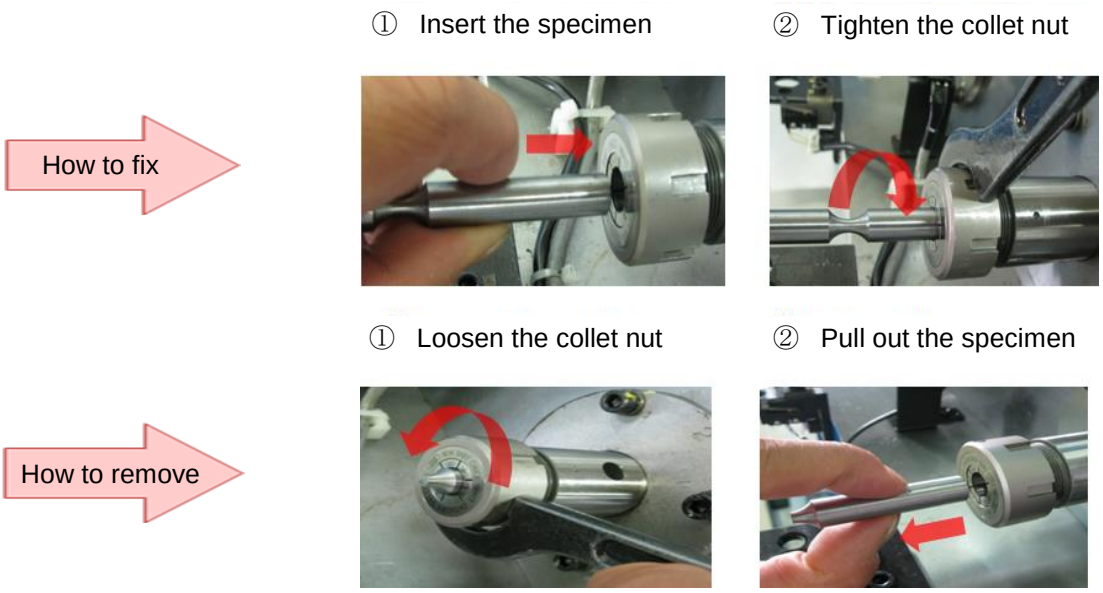


Fig.3: Simple procedure to fix and remove the specimen

3. Clear observation of fracture surface

Usually, it is important to observe the fracture surface of failed specimen by several kinds of microscopes such as SEM and SIM. Thus, when the specimen failed during the fatigue test, the failed specimen should be supported steadily so as to keep the fracture surface undamaged. In order to satisfy this requirement, outer half of the failed specimen is supported by the special jig at the instance of the fatigue fracture as shown in Fig.4. This is an advantageous point in cantilever type of rotating bending. When the failed specimen falls down on the jig, the bottom of the bearing block pushes a micro-switch to interrupt the counting of the revolution. In this way, the number of stress cycles, that is, the fatigue life can be recorded on the magnetic counter.

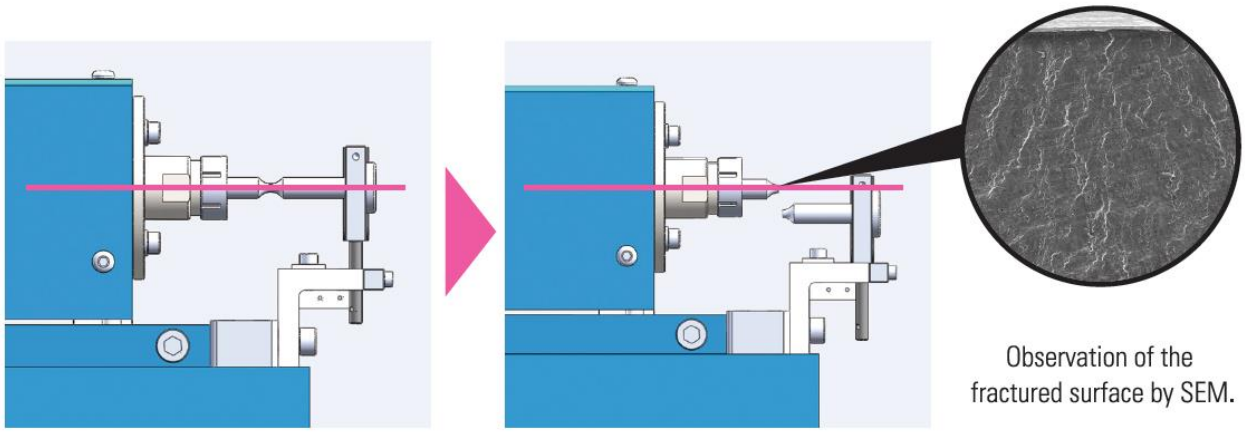


Fig.4: Image before/after the fatigue fracture

4. Support for environmental testing

Various kinds of mechanical structures have to be used in corrosive environments. In the mechanical design of such products, fatigue test data in the corresponding environment should be obtained as the fundamental design data. The present testing machine can be applied to perform fatigue tests in such cases.

As indicated in Fig.5, a special chamber can be attached around the individual specimen. Corrosive solution is pooled in a tank inside the top space of the stand, and the tank is connected to the chamber by a polymer tube. Of course, the solution feeding rate can be given at any level by using the adjuster mounted on the front surface of the stand. In this manner, the corrosive solution is dropped onto the critical portion of the specimen at the definite rate.

Special technique was introduced in this additional facility in order to avoid the corrosive damage of the fatigue testing machine itself. From this point of view, a little negative pressure was always given inside the corrosive chamber so that the corrosive solution and its fine splashes do not leek out from the chamber. This corrosive chamber can be installed depending on the requirement by the customer. Figure 5 indicates an example of such testing machine with a couple of corrosive chambers. Same kind of corrosive environment can be given in both chambers, and different corrosive environments can be also given in the respective chambers.

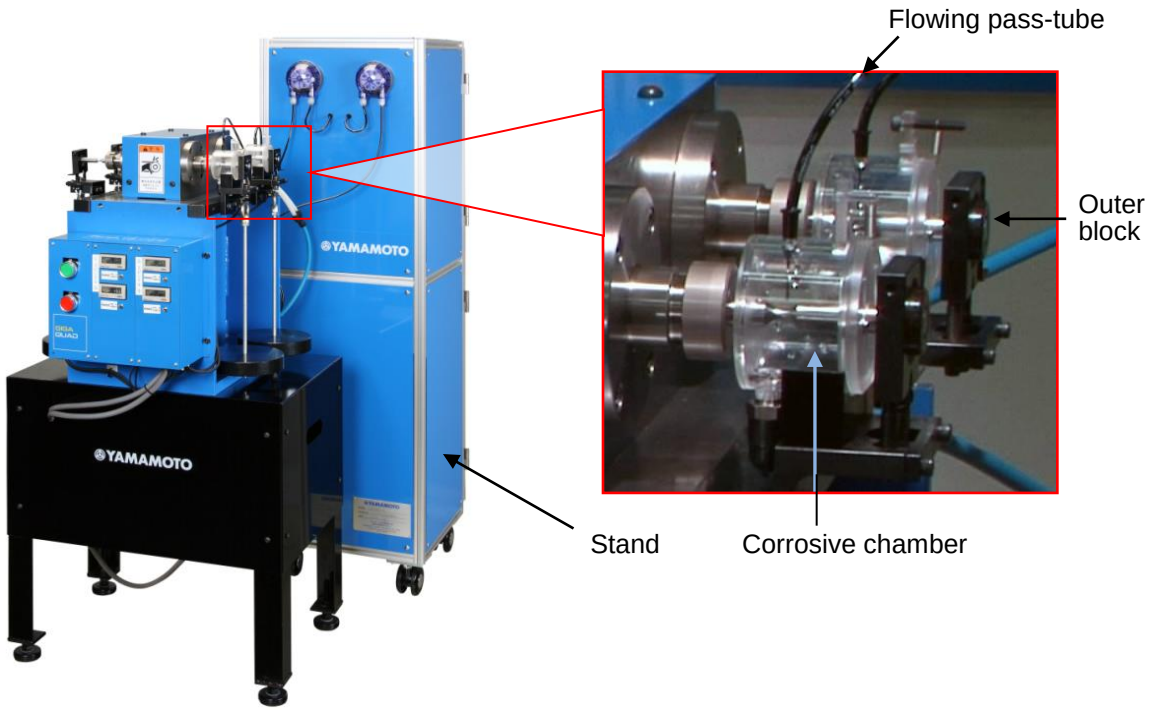


Fig.5: Photograph of fatigue testing machine combined with the corrosive chamber

Figure 6 indicates the schematics of the corrosion fatigue testing machine. Corrosive solution is stored in the tank inside the stand, and the solution is pumped up by the tube pump. Thus, the corrosive solution can be dropped down onto the specimen. Dropping rate of the corrosive solution can be adjusted by an electric controller attached on the front

surface of the stand. The dropped solution is sucked in the drainage tank provided a little negative pressure (weak vacuum) which is operated by using compressed air.

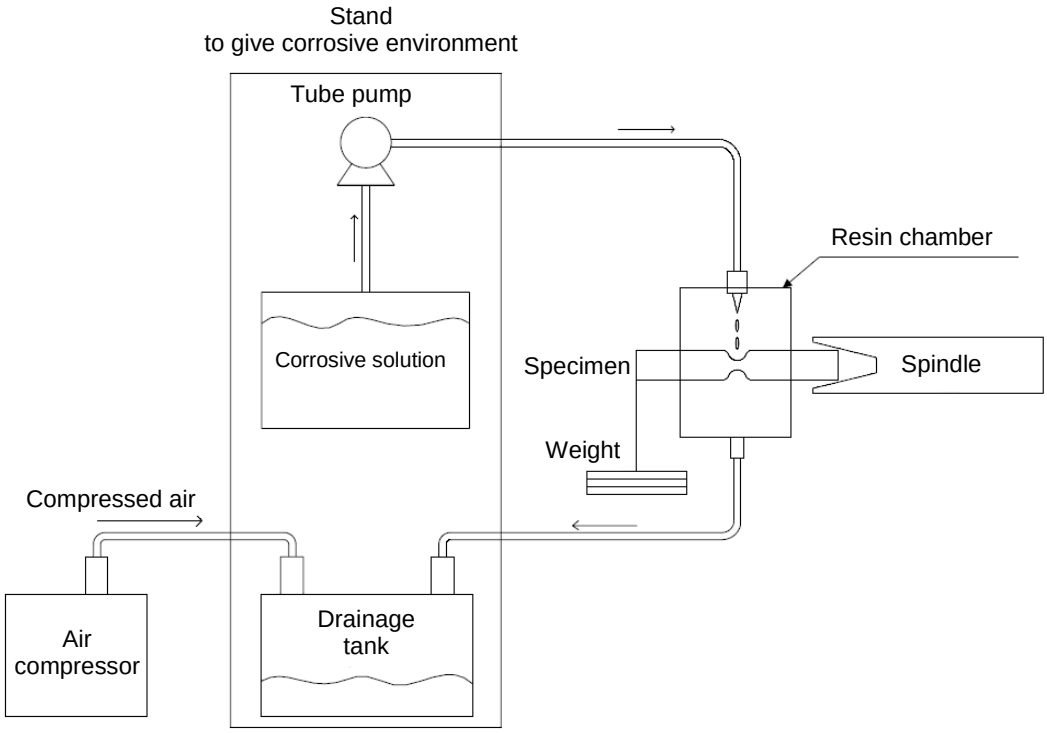


Fig.6: Schematics of corrosion fatigue testing machine

CONCLUDING REMARKS

Conventional fatigue tests take a long time such as 200days 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, every customer informed that this testing machine is successfully used to obtain a number of fatigue data within a reasonable short period.

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