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

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ABSTRACT: Recently, particular attention has been paying to the fatigue property of metallic materials in the very high cycle regime and in corrosive environments from viewpoints to ensure the long term durability of mechanical structures and to realize the low-carbon sustainable society. 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. 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. In such a long life region, a tremendous long period is required to perform fatigue tests. In this study, a new type of dual-spindle rotating bending fatigue testing machine was developed in order to overcome these difficulties. By using this machine, one can perform the fatigue tests for four specimens simultaneously in rotating bending in the corrosive environment of 3% salt water. In this new type of machine, dual spindles are driven by an electric motor via V-belt and special technique was introduced in this additional facility in order to avoid the corrosive damage of the fatigue testing machine itself.

Keywords: gigacycle regime, corrosive environment, fatigue test, rotating bending, GIGA QUAD

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]-[3]. 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.

If the high loading frequency such as ultrasonic fatigue test was accepted, temperature raising of the specimen due to the internal friction would take place and some cooling system should be furnished to examine the original fatigue property[4,5]. 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. 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 even if it is used with the corrosive environment option. 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.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. The rotating speed of the spindle, that is, the testing speed is 3150rpm (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

Model	YRB200 / YRB200L
Motor	0.2kw-4P / 0.4kw-4p
Capacitance	380V
Collet Chuck	ϕ2.5～13 / ϕ2.5～20
Max Load	20kg x 4 / 80kg x 4
Spindle Speed	3150rpm
Weight	140kg / 170kg
Size	470x400x1050 / 800x660x1100
Belt	V Belt M
Spindle Number	2
Bearing (Spindle)	Angular Contact Ball Bearing

Fig. 1: GIGA QUAD YRB200

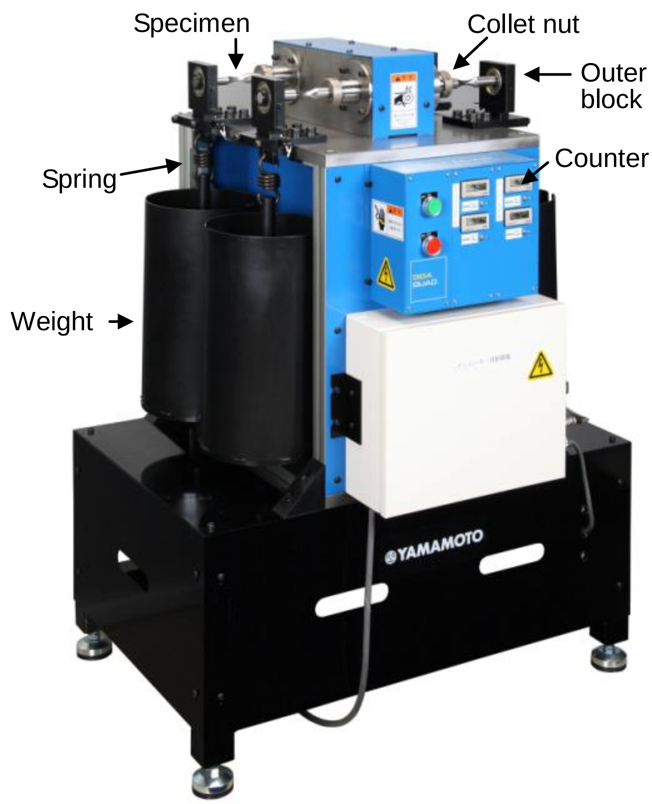

Fig. 2: GIGA QUAD YRB200L

Hourglass type of specimen as shown in Fig.2 is accepted as a formal test piece. Diameter of the critical section ‘ϕβ’ 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.

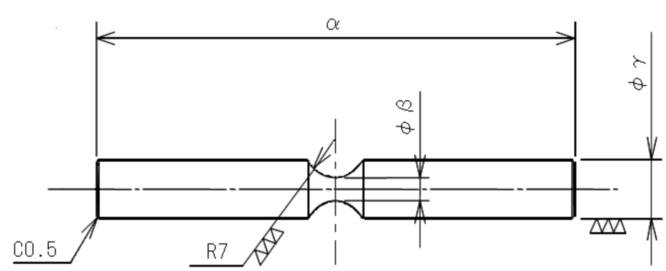

Fig. 3: The shape and dimensions of the specimen

3. FOUR MAIN ADVANTAGES

3.1. 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. From this point of view, the present machine of GIGA QUAD has a significant performance of the high efficiency.

3.2. Easy operation

In this testing machine, the specimen can be easily fixed and removed as indicated in Fig.4. 1 and 2 in Fig.4 show how to fix the specimen, and 3 and 4 show how to remove the specimen. 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.

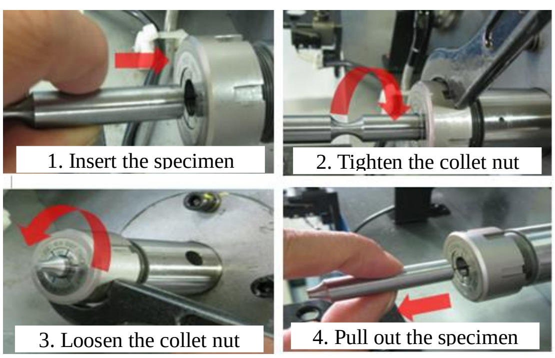

Fig. 4: Simple procedure to fix and remove the specimen

3.3. Precise eccentricity

Eccentricity at the outer end of the specimen after chucking was kept within ±20μm. Such a small eccentricity is fundamentally very 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 ±30μm. This is the reason why the eccentricity of this testing machine was restricted within the small value of expecting some extent of margin.

3.4. 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. GIGA QUAD can be applied to perform fatigue tests in such cases. As indicated in Fig.5 and 6, a special chamber can be attached around the individual specimen.

Corrosive solution is pooled in a tank inside the top space of the stand as indicated in Fig.5, and the tank is connected to the chamber by a polymer tube as indicated in Fig.6. 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. Fig.6 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

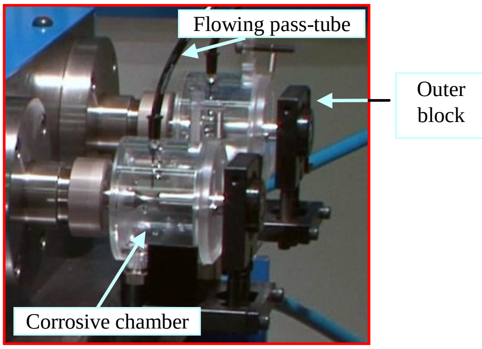

Fig. 6: Corrosive chamber

Corrosive solution is pooled in a tank inside the top space of the stand as indicated in Fig.5, and the tank is connected to the chamber by a polymer tube as indicated in Fig.6. 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. Fig.6 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.7 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.

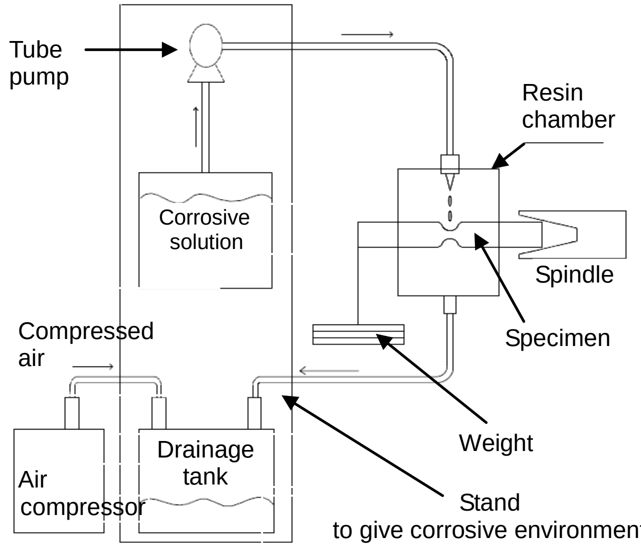

Fig. 7: Schematics of corrosion fatigue testing machine

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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