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Development of Strength Test System for Structure under Large Uniform Surface Load

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Abstract. Large uniform load on plane widely exists in the structural design of ship equipment. In order to verify the reasonability of equipment structural design, a test system of structural strength is needed to make structural test. To this end, a strength test system is developed. In this test system, a concentrated load, which is equal to actual uniform surface load that acts on the equipment, is imposed on the loading part by Hydraulic Loading Method. Then, the concentrated load is turned into several concentrated loads uniformly distributed in loaded area of the equipment structure. Stress measurement system is applied to make a tracking measurement of the series of points in the equipment structure. The test data is professionally recorded with a real-time analysis. In order to verify the feasibility of the test system, a complete test platform for a ship equipment structure is designed, furtherly a contrastive analysis has been undertaken between the outcome of the test system and the one of finite element simulation, and it turns out that the application of the test system is feasible.

1 Introduction

Large uniform load on plane widely exists in the structural design of ship equipment, as which is well-known that it very complicated. In order to verify the reasonability of equipment structural design, making a test on the structural strength of a new equipment model is usually necessary. R. S. Dow (1996) puts large scale FRP structure into test to confirm the reasonability of marine structure design. Some researchers have developed a new inflatable/rigidizable hexapod structure testbed for shape and vibration control of large structures in space (O. Adetona et al. 2002). H. Jiao (2015) gives structural model test study of lightweight girder of bridge crane. W. Choi, H. B. Park, C. D. Kong (2014) have studied advanced propeller blade for next generation turboprop aircraft, discussed its static structural design and test.

In structural strength test, loading methods such as Gravity Loading Method (GLM), Hydraulic Loading Method (HLM), Mechanical Loading Method (MLM) and Pneumatic Loading Method (PLM) are usually used. Z. Li (2004), X. Cheng (1990) and S. J. Harrison (2004) explore all of the above-mentioned loading methods respectively. Z. Fang and J. Yu (2003) makes a further discussion of HLM method, and put forward determination of the parameters in the servo-hydraulic structure testing system. Airbag design is one of the key technology of PLM, design method of uniform loading system using Airbags in structure strength test is brought out in S. Chen, Z. Yang and B. Li (2012).

The GLM method can be easily achieved. Materials for load can be obtained from local sources, but loading weight on the structure surface is time-consuming. In HLM method, comparatively, high load can be easily obtained. Loading is not only high efficient but also safe, so that it deserves an extensive use. The loading system of MLM is the simplest, however, it has a flaw that the materials for high load can be hardly to be obtained. Loading in PLM method which can be loaded vertically on the sample's surface, the advantage of this loading method is stable, and the disadvantage is that the loaded surface is invisible. According to the above comprehensive analysis, it is supposed that HLM method is more suitable for the structural strength test of ship equipment with large uniform load on plane.

2 The HLM method

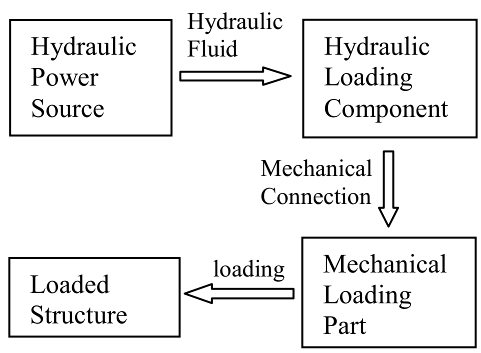

Figure 1. Loading sketch of HLM method

The HLM method is widely used in structure test. Figure 1 gives loading sketch of HLM method. In this method, there must be a Hydraulic Power Source. The Hydraulic Power Source presses hydraulic fluid into hydraulic loading component. Then, according to the mechanical loading part which connect to the hydraulic loading component, the structure is loaded.

In HLM method, the load is always concentrated load. When applied to structure test, the Mechanical Loading Part may need adaptive modification.

3 Test System

3.1 Equivalents from actual uniform load

Some concentrated loads take the place of the uniform load, which load on plane, as expressed in formula. (1). The alternative rule is shown as follows:

(1) the sum of all the concentrated loads is equal to the uniform load;

(2) the point of composition of the concentrated loads coincide with the point of composition of the uniform load;

(3) every concentrated load must be equal to each other, and point of the concentrated loads must be uniform distributed.

$$\begin{cases} P = S \cdot p \\ \sum_{i=1}^{N} P_{\mathrm{i}} = P \\ \sum_{i=1}^{N} P_{\mathrm{i}} L_i = P L \\ P_1 \approx P_2 \approx P_3 \approx \cdots P_N \end{cases} \quad (i = 1, 2, 3 \cdots N) \tag{1}$$

Where P is concentrated load, S is plane area, p is uniform load, Pi is the concentrated load which act on point i, L is distance between acting point of P and the centre of rotation, Li is distance between acting point of Pi and the centre of rotation.

3.2 Theory of loading

As shown in Figure 2, concentrated load is acted on Rigid Loaded Plane. The concentrated load is equal to the uniform load which act on Tested Structure Plane. The acting point of the concentrated load and the uniform load coincide. There are elastomers between the Rigid Loaded Plane and the Tested Structure Plane. The elastomers are uniformly distributed throughout the Tested Structure Plane. In testing, the elastomer cannot be crushed, and the material of elastomer must be chosen to meet the testing requirement. When being tested, the concentrated load acts on the elastomers uniformly by the Rigid Loaded Plane. Because that every elastomer has identical size and performance, the load transmitted by the elastomer itself is unanimous. In this way, concentrated loads which act on the Tested Structure Plane are got, and they are uniformly distributed.

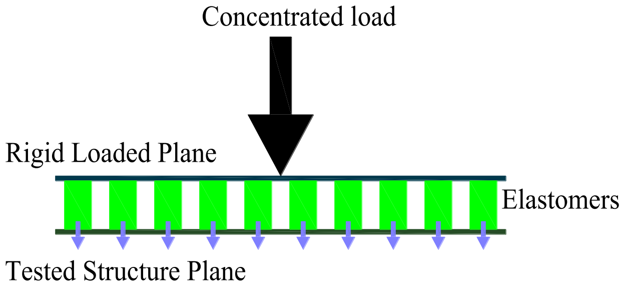

Figure 2. Sketch of loading

3.3 Composition of test system

The test system is comprised of hydraulic loading device, loading part, tested structure and test bed, and system of stress measurement as shown in Figure 3. The hydraulic loading device consists of a hydraulic power source and some hydraulic loading components. Concentrated load is supplied by this device, and tested structure would be under normal loading. Maximum load supplied by this device must be able to fulfil test requirement. The loading part has a plane structure at its end. There are many elastomers on this plane structure, and the elastomers are uniformly distributed. The plane structure of loading part and the tested structure plane have the same shape. In testing, tested structure must be fastened stably to test bed.

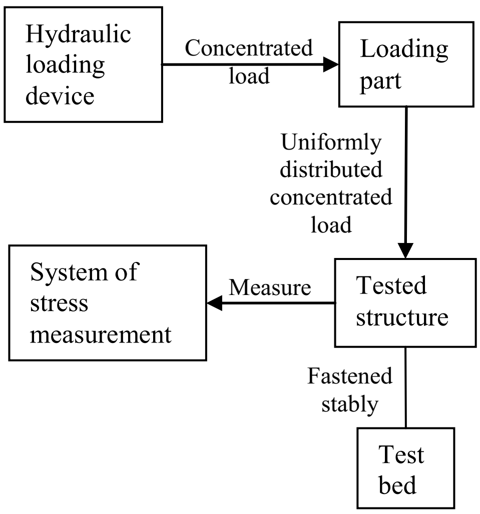

Figure 3. Constitution of the test system

3.4 Record and process of test data

There is a special system of stress measurement, which is used to record the test data and process the test data constantly.

4 Feasibility of the Test System

Plane structure as shown in Figure 4 is common in ship equipment. What we will discuss is that the application of the preceding test system to validate the feasibility of design of the plane structure.

4.1 Test platform

Figure 4. One plane loaded structure

Figure 5. Plane structure of the loading part and the elastomers

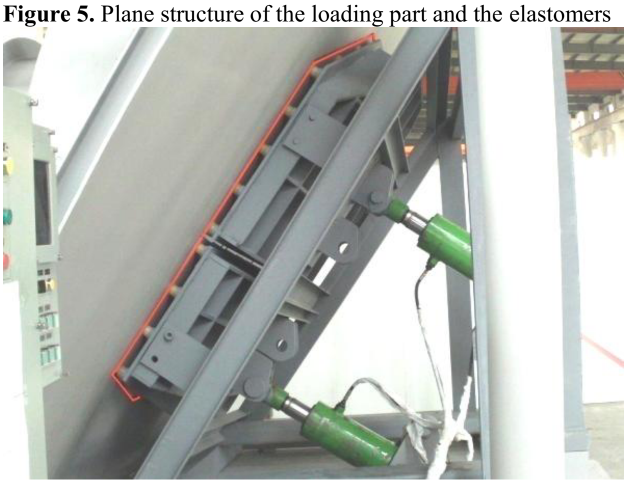

Figure 6. Loading condition of the plane loaded structure

A test platform is designed for the plane loaded structure as shown in Figure 5. In this test platform, hydraulic cylinder is the hydraulic loading component, and it is in charge of hydraulic loading. Structure of the loading part is specially designed for greater stiffness. Plane structure of the loading part and the loaded structure plane have the same shape. Also, there are many elastomers on this plane structure of the loading part, and the elastomers are uniformly distributed, as shown in Figure 5. An instrument of static strain gauge is used to measure the strains of the plane loaded structure while loaded, and then the strains are converted to stresses. When testing, the loading condition of the plane loaded structure can be seen in Figure 6. In Figure 7, the special system of stress measurement is shown.

Figure 7. Special system of stress measurement

4.2 Analysis of test result

The plane loaded structure is fastened stably while testing. The 40%, 60%, 80% and 100% designing load tests are respectively completed, and every test is repeatedly carried out. In order to validate the reliability of the test result, finite element method is used to simulate the structural static stress of the plane loaded structure.
Comparison of the result between the test and the simulation is conducted. Results of comparison of five points among them are shown in Figure 8- Figure 12.

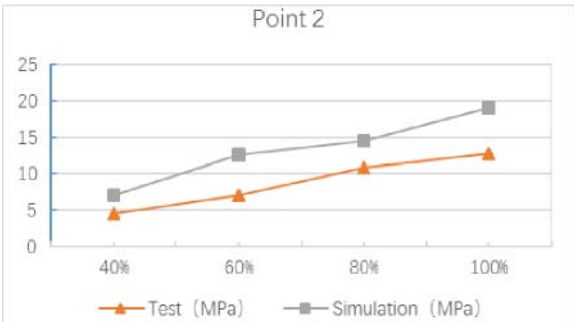

Figure 8. Data comparison of experiment and simulation at point 1

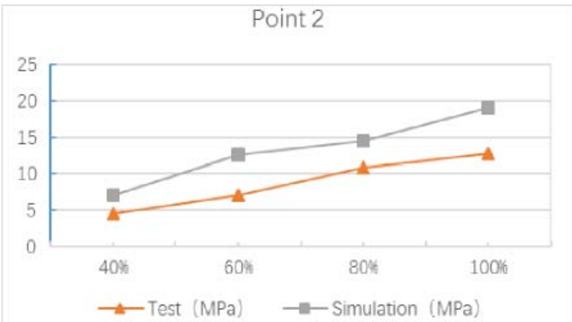

Figure 9. Data comparison of experiment and simulation at point 2

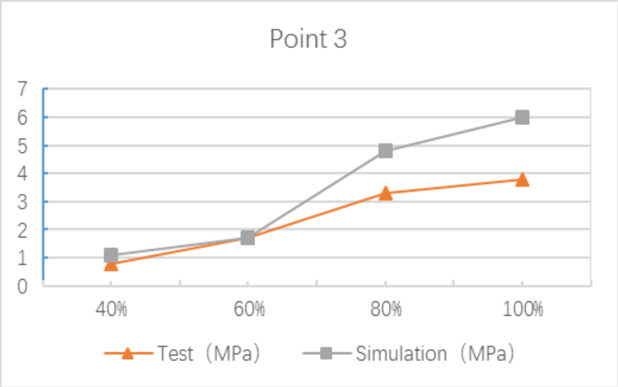

Figure 10. Data comparison of experiment and simulation at point 3

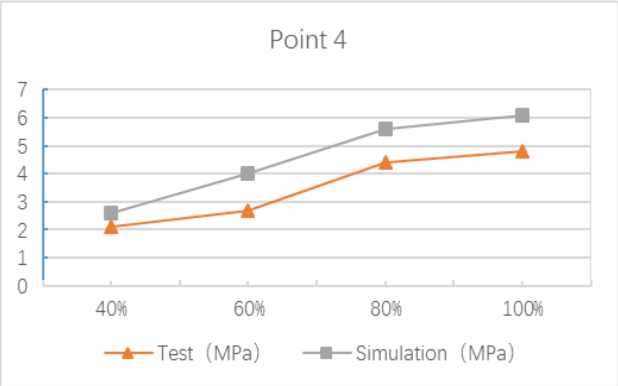

Figure 11. Data comparison of experiment and simulation at point 4

Whether the test or the simulation, the stress of the points increases with the increase of loading force from the figures, and this is accord with the actual situation. Comparison shows that the test results fit the finite element simulation very well, and maximum stress point of test and simulation coincide in Figure 12. Thus, we can say that this test platform can be used to accurately measure stress of the plane loaded structure which is common in ship device.

Because that the test platform can be used to accurately measure stress of the plane loaded structure which is common in ship device, it is shown that the strength test system for structure under large uniform surface load is feasible.

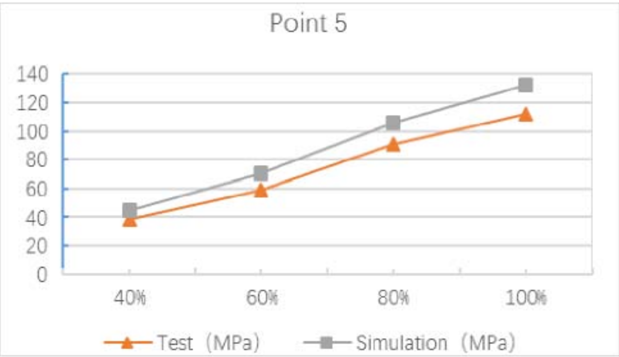

Figure 12. Data comparison of experiment and simulation at point 5

5 Conclusion

Hydraulic Loading Method is used to load on Rigid Loaded Plane. What it is loading is concentrated load, which is equal to the uniform load. Then, the concentrated load is turned into many concentrated loads which are uniformly distributed by loading part. Stresses of many points of device are measured through system of stress measurement, and the measured data is record and processed.

In order to validate feasibility of the test system, a test platform is designed for one plane loaded structure which common in ship device. Then data from test platform is compared with that of simulation. Results of comparison show that the strength testing system for structure under large uniform surface load is feasible.

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