Design of static test loading device for flexible large deformation structure

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Abstract. The static test of flexible large deformation structure simulates the stress state in service through the loading device. However, when the static loading device is applied to the static test of a large deformation structure, there are problems such as the deviation of loading direction and the difficulty in adjusting the loading direction. In view of the above problems, a loading device for the static test of flexible large deformation structure is designed. By setting force sensors and displacement measurement modules in each loading direction, the device can monitor the force and direction of the loading point in real-time, and correct the loading direction of the step-by-step loading combined with the adjustment of the slider, so as to solve the deviation of the loading direction in the static test of large deformation structure by the traditional loading method. The loading device is successfully applied to the static test of a landing gear for unmanned aerial vehicle. The test results show that the device has good loading integrity, small load error, accurate loading direction, and can be applied to multi-size landing gear structures.

Keywords: Flexible large deformation structures; static testing; real-time force monitoring; multi-size structural testing; loading device design.

1. Introduction

Flexible large deformation structure has the characteristics of high elasticity and high strength, which can play the role of cushioning and damping, and is widely used in the bearing structure of mechanical equipment. Due to the harsh service conditions and large mutation loads of such structures, a series of strict test verification and assessment is needed in the development process [1]. Taking the UAV landing gear as an example, the landing gear structure is the key bearing structure of UAV in the process of take-off, ground gliding and landing. In the development process of the landing gear, it is necessary to assess the anti-overload and bearing capacity of the UAV landing gear under different conditions. Therefore, it is necessary to carry out a special mechanical test assessment, so as to effectively verify whether the UAV landing gear meets the service requirements under various predetermined conditions [2]. The static test of the landing gear structure is one of the important test items, and the verification of the static test is also the key link in the development of the landing gear. At present, the loading methods of static load test mainly include the counterweight loading method, mechanical action loading method, and hydraulic action loading method. The counterweight loading method [3] is mainly suitable for small loading, especially for small loading in the gravity direction. However, for the landing gear, which is a large deformation structure, the step-by-step loading of static load test has the disadvantages of complex operation and difficulty in implementation, especially for the loading in non-gravity direction, special transfer mechanism needs to be designed. At the same time, it is difficult to adjust the loading direction in a non-gravity direction for large deformation structures. Mechanical action loading method [4] and hydraulic action loading method [5,6], the loading principle is different, the loading method is similar in the actual test, but when the two loading methods are applied to the static test of large deformation landing gear structure multi-dimensional force step by step loading, there is a deviation of the loading direction caused by structural deformation, and the two loading methods also have the problem of real-time adjustment of the loading direction in the process of step by step loading, which will lead to a serious deviation of the actual load and the theoretical load[7]. Mechanical action loading method and hydraulic action loading method are usually suitable for large load loading, which is used for large deformation structure static test loading, and there are shortcomings of complex loading system, large cost, and limited space[8]. In generally, the current loading equipment suffers from low efficiency, difficulty in following force and displacement changes, and significant loading errors.

In view of the shortcomings of the traditional loading method in the static test loading of large deformation structures, a static test loading device for flexible large deformation structures was designed based visually guided follow-up method, which mainly solves the problem that it is difficult to realize the multi-dimensional force step by step accurate and coordinated loading of flexible large deformation structures in the static load test.

2. Technical Scheme

The static test loading device of a flexible large deformation structure is a nonstandard structure composed of various modules. It can not only correct the loading direction step by step, but also be suitable for large deformation structures with various sizes. The composition structure is shown in Fig.1.

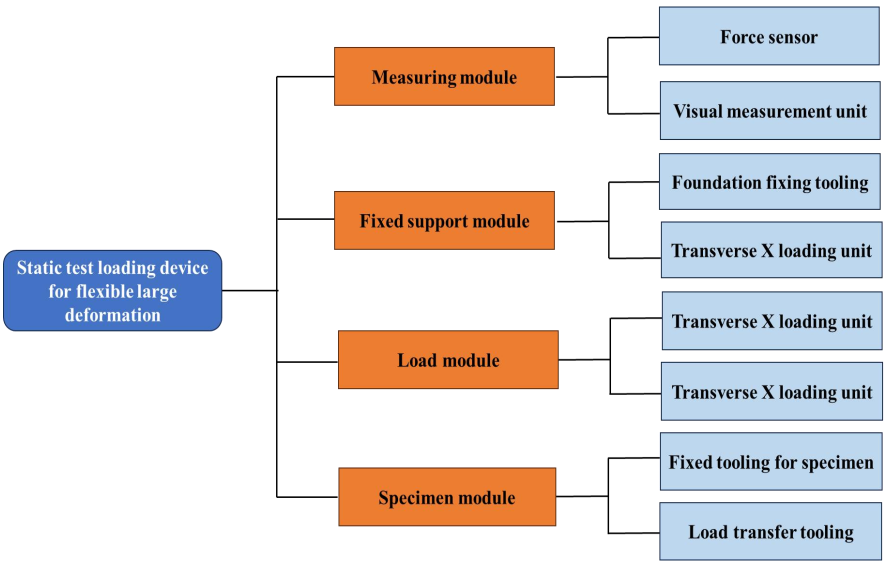


Fig. 1 Structure diagram of the loading device

The static test loading device of flexible large deformation structure is shown in Fig.2. The fixed support module provides the basic installation platform and the fixed installation interface of the specimen. The fixed tooling of the test piece in the specimen module is used to realize the connection between different test pieces and the test foundation installation platform to simulate the real load conditions. Then, the transfer tooling is used to realize the connection between the loading boundary of the test piece and the test loading module. After that, the load is applied through the loading module. The loading unit can be used independently or cooperatively.

The real-time load measurement of the loading point is synchronously carried out by the force sensor, and the real-time axial displacement measurement of the two loading points of the test piece is realized by the visual measurement unit during the multi-dimensional force step-by-step loading process. According to the feedback results of the real-time load and the axial displacement of the loading point, the real-time adjustment of the load size is realized by using the tightening or loosening of the loading screw nuts, and the real-time adjustment of the loading direction with the change of the loading level is realized by adjusting the slider in the corresponding loading unit, so as to finally realize the multi-dimensional force progressive coordinated loading of the static test of flexible large deformation structures with different sizes. This technical scheme can not only ensure the accurate loading direction, but also be applicable to the static test loading of large deformation structures with various sizes.

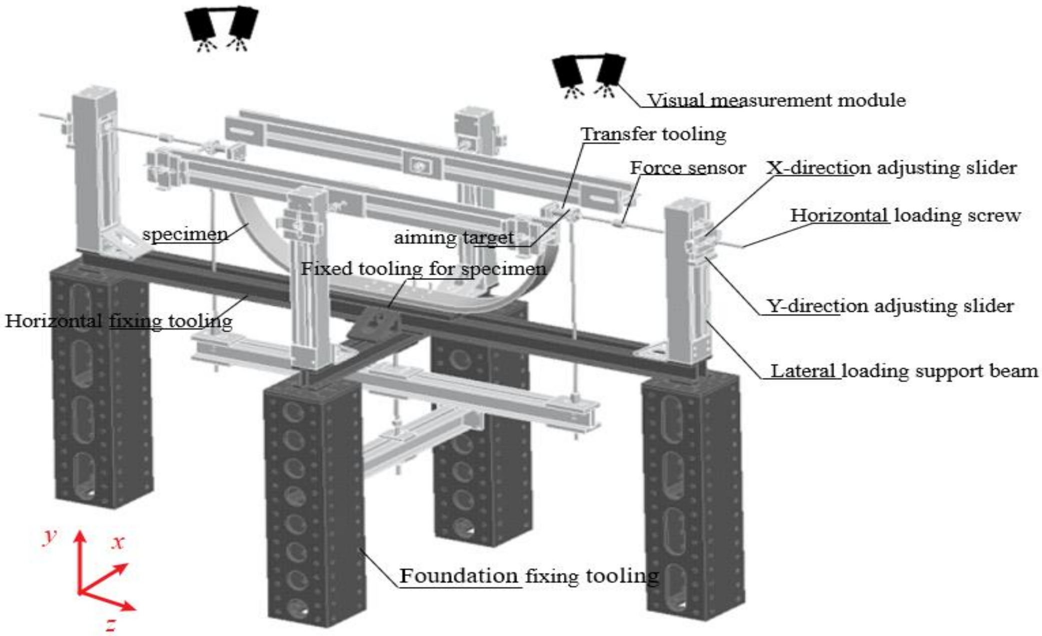


Fig. 2 Diagram of loading device for flexible large deformation structure

3. Test Procedure

The static test loading device of flexible large deformation structure can effectively realize the multi-dimensional force step by step coordinated loading of flexible large deformation structure with different sizes. The specific operation process is shown in Fig.3.

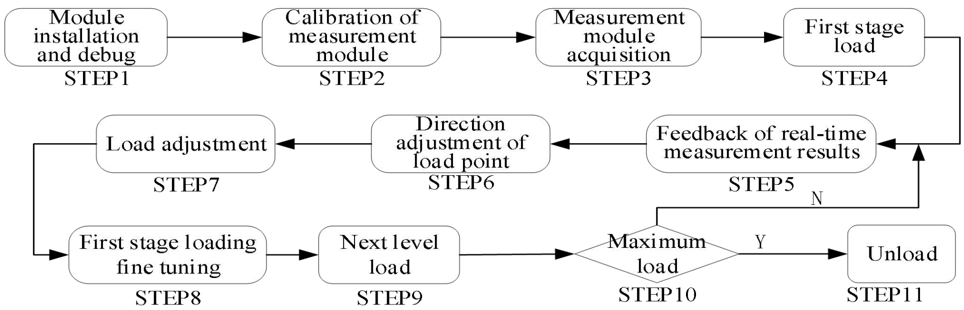


Fig. 3 Test flow diagram

In the system debugging stage, the horizontal loading screw and loading beam are adjusted to the level, and then the adjustment slider is leveling. During the loading process, the real-time load measurement results of force sensors in each direction of the load measurement unit will deviate from the theoretical load value of the first load. According to the deviation between the real-time load measurement value of the force sensor and the theoretical load value of the load, the load in X, Y, and Z directions is adjusted by tightening or loosening the outermost nut of the lateral load screw. According to the real-time measurement results of the loading direction of the loading point target in the experimental coordinate system by the visual measurement module, the slider is adjusted to realize the correction of the lateral loading direction. To carry out other load conditions loading, need to wait for unloading, repeat steps 5 ~ 13, completing different load tests.

4. Application Case

According to the above loading method and technical scheme, the loading system is built and applied to the static test of the main landing bracket of the UAV. The test is shown in Fig.4. The maximum theoretical load in the x, y, z direction is 500N, 1000N, -400N respectively. According to the static test standard, the load is graded to ensure the stability of the loading process. The load is divided into10 load levels, the first six stages are loading, and the last four stages are unloading. The theoretical loading curve is shown in Fig.5(a). The static test of UAV landing gear is carried out according to the test process described in Section 3.

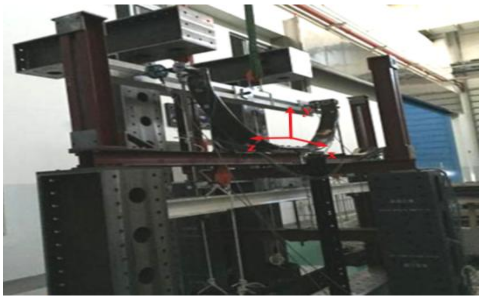
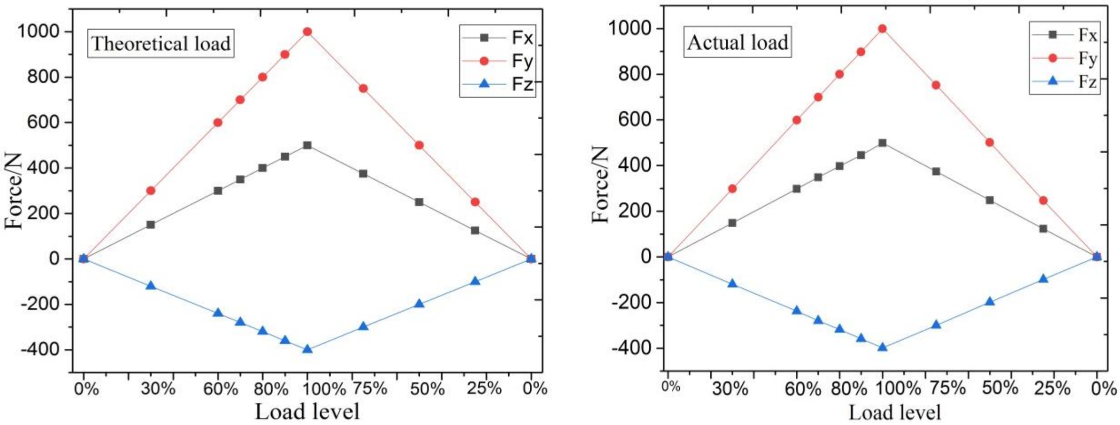


Fig. 4 Application case



(a) theoretical load (b) actual load

Fig. 5 Loading curve of static test

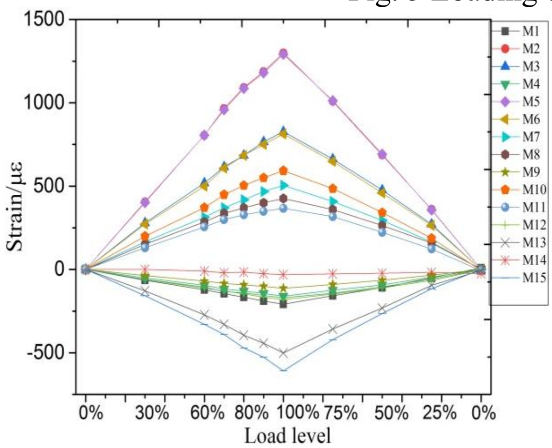


Fig. 6 strain-load curve of UAV landing gear

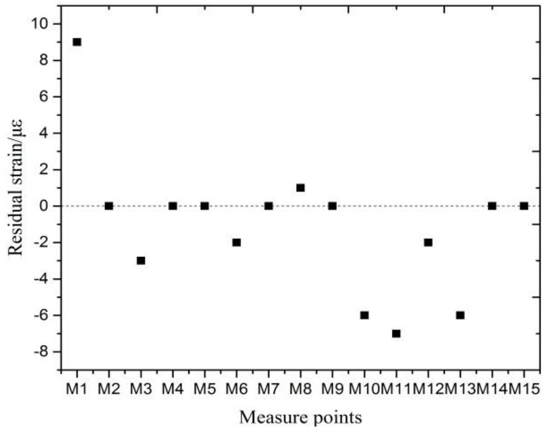


Fig. 7 Residual strain distribution map

The comparison of Fig.5 shows that there is a small error between the actual load and the theoretical load, and the load error of the maximum load value is only 1.2 %. Compared with the theoretical load curve, the actual load curve has the same loading trend and good linearity, indicating that the loading method has high accuracy. Fig.6 shows the strain-load level curve of 16 measuring points of the UAV landing gear. The strain curve of 16 measuring points is consistent with the trend of the loading curve on the whole. With the loading and unloading process, it increases first and then decreases, indicating that the step-by-step loading integrity is good, which also means that the loading direction is accurate under step loading. Fig.7 gives the residual strain distribution map of different measuring point (M1-M15). From the figure, the strain value of the landing gear after unloading is less than 10 με, and the strain value returns to zero well, which reflects the reasonable design of the loading device, and there is no external deformation in the loading process.

5. Conclusion

Aiming at the problems of step-by-step loading direction deviation and direction adjustment difficulty of traditional loading device in the static test of flexible large deformation structure, a loading device suitable for static test of large deformation structure is designed in this paper. The device realizes the position and direction correction of the loading point in the step-by-step loading process of a large deformation structure by combining measurement module and slider adjustment, and the loading method is applied to the static test of a UAV landing gear. The test results show that the loading device is stable step by step, the loading error is small, and the loading direction is accurate. It is also verified that the loading device is suitable for multi-dimensional force coordinated loading of static test of flexible large deformation structures, and the modular design is also suitable for flexible large deformation structures with different sizes. The significance of these findings lies in their ability to improve the accuracy and reliability of static testing for large deformation structures, especially in aerospace. Enhanced loading accuracy and direction control enable more precise validation of structural performance, leading to safer and more efficient designs. Future research could enhance the device's precision and explore its use in dynamic testing. Integrating advanced sensors and automated controls could further increase its effectiveness in structural testing.

Acknowledgments

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