Test Equipment for Flap Support with Controllable Deformation Adjustment

Sanyuan Li[1,*], Xianmin Chen[1], Yunzhao Gong[1], Shanshan Li[1] and Meng Dong[2]

[1]National Key Laboratory of Strength and Structural Integrity, Aircraft Strength Research Institute of China, Xi'an 710065, China
[2]Shanghai Aircraft Design and Research Institute, Shanghai 201210, China
*Corresponding author's e-mail: lsynuaa@126.com

Abstract. The deformation of the aircraft wing makes the support boundary condition of the flap change. In the function and reliability test of the flap, it is necessary to accurately simulate the supporting of the wing to the flap. In the current engineering test, the boundary of the flap is generally fixed in the 1g flight state, which cannot accurately simulate the deformation of the aircraft wing. In this paper, a novel test equipment with multiple position-adjustable joints is designed for dynamically simulating the deformation support boundary of aircraft flaps, and has been applied in a flap test.

Keywords: flap test, deformation support boundary, dynamic simulation method

1 Introduction

The trailing edge flap is an important part of the aircraft's high-lift system and is installed on the rear beam of the wing. During the take-off and landing of the aircraft, the flaps are unfolded to increase the area and camber of the wing, thereby providing enough lift and drag for the aircraft. The flap is a key structure with high-reliability requirements. In the development process of the flap, it is necessary to verify its motion principle and reliability by tests. Because structural deformation is one of the main factors affecting the motion function of the mechanism, it is necessary to accurately simulate the deformation of the flap when performing the function and reliability test of the flap mechanism. The wing supporting the flap will undergo complex deformation during the aircraft's flight. The deformation of the wing is an important part of the deformation of the flap structure. However, it is difficult to simulate the deformation of the wing in the flap function and reliability tests.

At present, there are two types of flap specimen support methods [1]. One type of support method is to use a wing or a wing dummy with 1 g deformation to support the flap, which can accurately simulate the support boundary of the flap. However, it cannot accurately simulate the deformation of the wing during the whole flight of the aircraft and costs much more. The other type of support method is to use a fixed supporting device to support the flap, which cannot accurately simulate the support boundary of the wing, but the test design is simple and costs less. To improve the test simulation accuracy of the flap support boundary and reduce the test cost, engineers have improved the second type of support method. In the flap test, the support method in [2-5] can be adjusted, which cannot still meet the requirements of the deformation boundary simulation during the whole take-off and landing process. Jandaurek and Johst [6] and Li [7] proposed a deformation-based flap support scheme, which provides the possibility for the dynamic simulation of the flap deformation boundary. However, it has not been verified by experiments and cannot solve the dynamic simulation problem. Currently, there is no experimental equipment that can accurately simulate the support boundary of the flap. Therefore, in this paper, a dynamic simulation support method for the flap deformation boundary is proposed to solve the above problems, and a set of flap support equipment has been designed and applied.

2 Flap Specimen and its Support Boundaries

The studied flap specimen is composed of a flap dummy, two flap motion mechanisms, three limiting mechanisms, etc (as shown in Figure 1). These five mechanisms are installed on the rear beam of the aircraft wing.

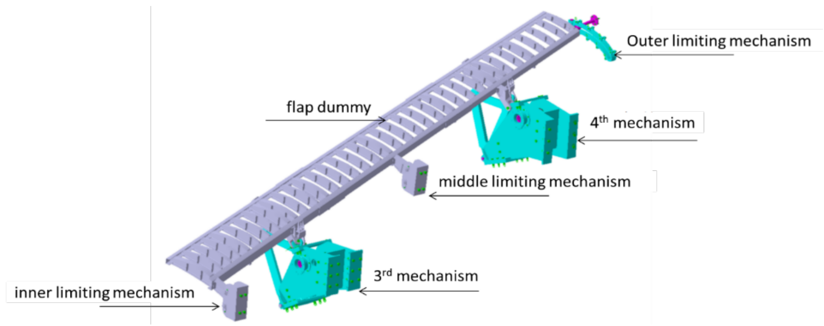

Fig. 1. Flap specimen.

During the flight of the aircraft, the wing bending and torsion deformations take place, so that the installation positions of the flap mechanisms and the transmission devices on the rear beam of the wing are displaced, as shown in Figure 2. Throughout the entire process of flap function and reliability test, it is necessary to simulate the displacement change of the support points.

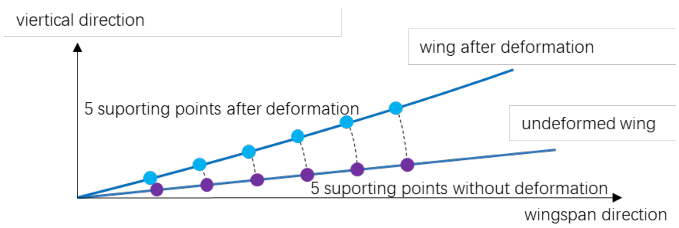

Fig. 2. Aircraft wing deformation diagram.

It can be seen from Figure 3 that the displacement track of a single flap support point is a curve. It has the largest displacement component in the vertical direction of the flap, the smaller displacement component in the wingspan direction, and the smallest displacement component in the heading direction. We can obtain the displacements of the flap support points by simulation or experiment.

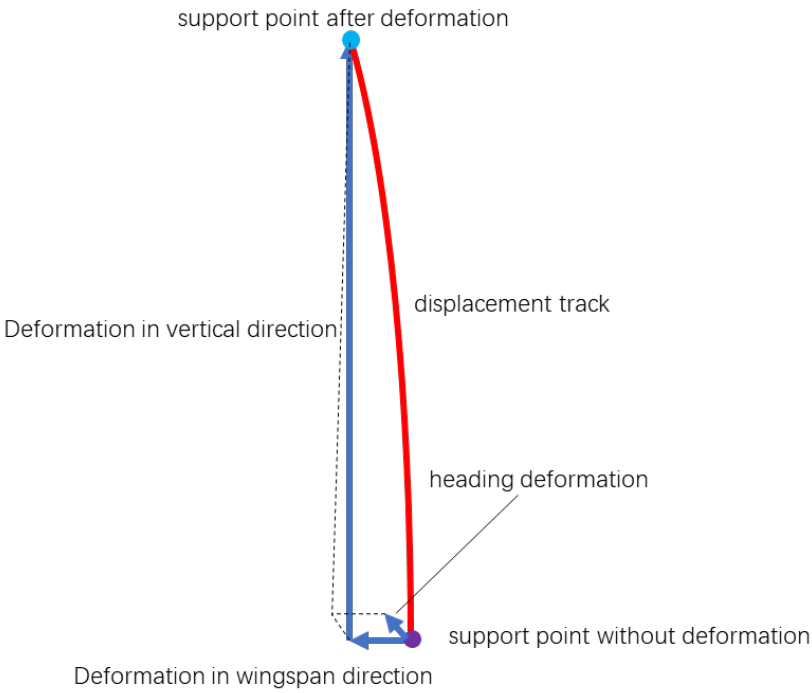

Fig. 3. Displacement track of flap support point.

3 Principle and Composition of the Flap Support Equipment

3.1 Principle of the Flap Support Equipment

The curve displacement track of one flap support point is approximately treated as a straight line, as shown in Figure 4. Firstly, the displacement of the flap joint in the heading direction is ignored. Then the maximum displacement in the vertical and the smaller wingspan displacement of the support joint are synthesized into a vector starting from the initial installation position of the flap joint. Finally, we can obtain the simplified displacements of the flap support joints with the deformation size and direction.

The displacements of the flap support joints at different deflection angles can be calculated and simplified by the above method. Then, according to the order of the test cases and flap deflection angles, the support points' motion rate of each flap support joint can be calculated. Finally, the displacements and motion rates are compiled into the boundary simulation test spectrum. In the test process, the displacements of all flap support points are coordinated and controlled by the test spectrum, and the dynamic simulation of the deformation boundary of the flap can be realized.

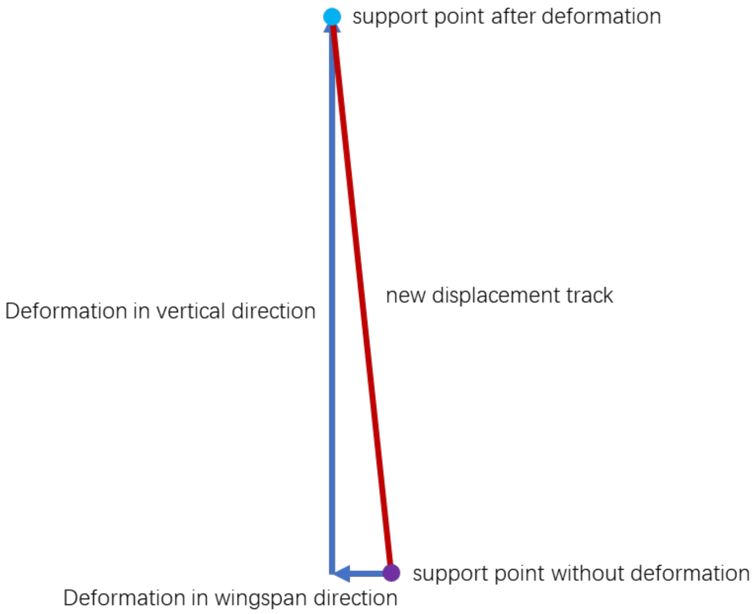

Fig. 4. The simplified displacement of one flap support point.

For the two support points on a flap, the deformation boundary is simplified by the aforementioned method. The results of the simplification are presented in Table 1. It can be seen from the table that the simplified errors are all below 3%.

Table 1. Simplified results of two support points on a flap.

	Original displacement (mm)				Simplified displacement (mm)				Error [e]
	X[a]	Y[b]	Z[c]	Vector [d]	X	Y	Z	Vector	(%)
Point 1	2.94	131.00	12.80	132.00	0	131.00	12.80	131.62	0.29
Point 2	4.20	340.00	35.00	342.00	0	340.00	35.00	341.80	0.06

[a] X, displacement in heading direction.
[b] Y, displacement in vertical direction.
[c] Z, displacement in wingspan direction.
[d] Vector, synthesis of X, Y and Z.
[e] Error, the relative error between the simplified vector and the original vector.

3.2 Composition of the Flap Support Equipment

To achieve a high-precision simulation of the deformation boundary of the flap, this paper designs an adjustable support device for one point as shown in Figure 5. It is mainly composed of a joint installation slider, linear guide, screw, worm gear, and servo motor. The two sides of the joint installation slider are sleeved on the cylindrical linear guide rail, and the middle part is connected with the screw. When the servo motor drives the screw to rotate through the worm gear, the joint installation slider can move linearly along the linear guide rail to simulate the linear displacement of a single flap support joint.

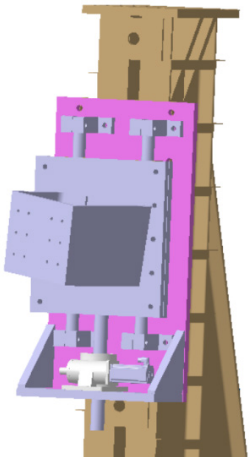

Fig. 5. Support device for one point.

The flap support equipment with controllable deformation adjustment is designed, which has five sets of the above support device installed on five support columns to support the flap specimen as shown in Figure 6. The dynamic and accurate simulation of the support boundary of the flap is realized by coordinating the motion of these joints through the test control system.

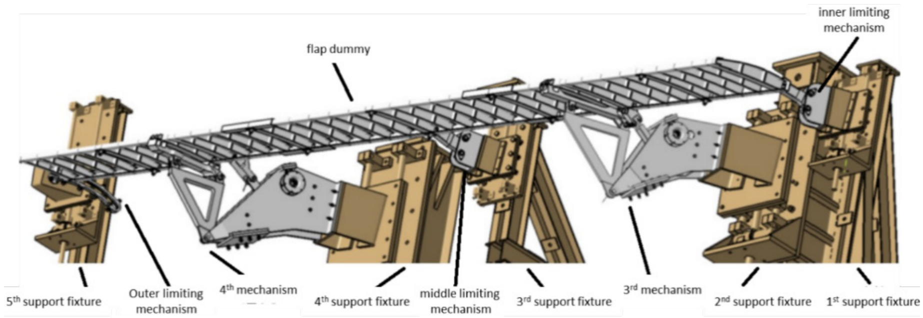

Fig. 6. Support equipment of the flap specimen.

The support equipment designed in this paper has been applied in a flap function test as shown in Figure 7. During the test, the deformation of the flap support boundary can be dynamically adjusted by the control system to meet the test requirements.

Fig. 7. Application in the flap function test.

4 Conclusion

The flap support equipment and method can simulate dynamically the changing support boundary caused by wing deformation during the whole aircraft take-off and landing process. It can significantly improve the accuracy of boundary simulation in tests, fully reflect the influence of wing deformation on the movement function and performance of flaps, and make the experimental results more realistic and reliable. The accuracy of the simulation boundary of the flap is improved and determined by the proportion of heading deformation ignored. Moreover, its cost becomes much lower. So far, this method and equipment have been applied in a flap development test. It can also be extended to simulate the deformation support boundary of other structures, such as landing gear.

References

1. LI Sanyuan, CHEN Xianmin, PANG Baocai. Research on Self-adaptable Loading Technology for Trailing Edge Flap [J]. Engineering & Test, 2020, 60(4):41-43, 56 (in Chinese).
2. PANG Baocai, DONG Dengke, GONG Yunzhao, et al. Study on tracking loading method of locomotory wing for flap and slat [J]. Mechanical Science and Technology for Aerospace Engineering, 2014, 33(10):1590-1593 (in Chinese).
3. Zhang Tuo, Zhang Yuan, Ren Peng, et al. Application of movable airfoil function test based on swing arm follow-up loading technology [J]. Science Technology and Engineering, 2021, 21(17):7363-7368 (in Chinese).

4. Zhang Tuo, Zhang Yuan, Yang Zhaolin, et al. Research and application of moving airfoil follow-up loading technology based on simulated trajectory [J]. Science Technology and Engineering, 2019, 19(18):324-328 (in Chinese).
5. ZHANG T, SONG PF, YIN W, et al. Follow-up loading technology for lift structure with spatial complex movement [J]. Acta Aeronautica et Astronautica Sinica, 2022, 43(6):526044 (in Chinese).
6. K. Jandaurek, M. Johst. Development trends and innovations in aerospace system testing using the example of high-lift [C]. Grapevine: 55th AIAA Aerospace Sciences Meeting, 2017.
7. Aixian Li. A High Lift Test System Based on Wing Deformation [C]. Journal of Physics: Conference Series: 2658 (2023) 012043.