The analysis of aircraft fuel system ground test simulation turntable's structure

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Abstract. The aircraft fuel system simulation as an important part of aircraft design is a complex systems engineering, it is one of the experimental project to ensure the success of aircraft design. The test verifies the aircraft fuel system's correct and reasonable of design and calculation and verify that the fuel system function and reliability. The aircraft fuel system ground test turntable's frame is a key component in the test, its structural design and analysis is complex and important. Through the intensity and modal analysis of fuel system ground simulation turntable by finite element analysis software Abaqus obtain the turntable's stress and strain characteristics in the horizontal position and vertical position. And then calculate the dynamic characteristics of the turntable's six modes of natural frequencies and get the displacement images of the turntable. It provided an important theoretical basis for fuel system ground simulation turntable's optimal development and design.

Introduction

In new aircraft's design, system simulation test as an important component of the aircraft design work is a complex system engineering. Ground simulation test system can verify the correctness and accuracy of the design, and can solve some problems that the theoretically difficult to solve[1-2]. Fuel system ground simulation turntable is the key equipment in the aircraft fuel system ground simulation test, the test tank installed in the inside frame, by turning the inside and outside frames to simulate the change of the angle of flue level in the flight[3]. It is a moment of inertia of the hundreds of thousands kg.m^2 low-speed big load equipment. Ground simulation test of the aircraft fuel system is one of the project must do to ensure the first flight is successful. The test verifies the aircraft fuel system design, calculation of the correct and reasonable and verify that the fuel system function and reliability[4]. The fuel system ground test simulation turntable structure shown in Figure 1.
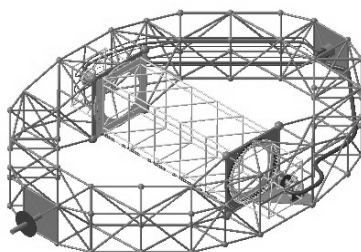

Figure 1, the fuel system ground test simulation turntable

The parameters of the turntable

The size of the turntable: 17.6m × 10.8m × 2.8m, the use of tube of Q345D, connected by spherical joints. The outside frame of rod 326, which with Φ76mmx4mm cross-section of 272, Φ83mmx5mm cross-section of 48, Φ102mmx7mm cross-section of 4, Φ402mmx16mm cross-section of 2. Rotating frame rotation angle range: -90 ° ~ +90 °, speed: 0 ~ ± 20 °/s, the

maximum angular acceleration: 10 °/s². The test bench of the maximum load of 15t, the overall structural strength is not less than four times safety factor.

Strength Analysis

Gravity load. Within the transmission device of the inner frame and within the working load conjunctive 15t, taking four times safety factor, which is 60t calculation quality. Therefore, the inside frame pass 600kN load to the outside frame which through both ends of the transmission device. in horizontal position, each end passing 300kN, in the Abaqus model, this 300kN load concentrated force in the form role outside frame of support plus stiffened plate 8 nodes, each node by the 37.5kN of concentration. In vertical position, loads mainly effect on the button of the turntable, each node is 75kN force, the direction is vertical downward.

Torque equivalent load. The connection between the inside and outside frame is slewing bearing, the maximum torque which the hydraulic motor pass to the inner frame is 90KN.m, then reaction to the outer frame, the equivalent of eight nodes in a radius of approximately 1000mm in the outside frame, each node have 11.25kN of concentration.

Moment of inertia. The frame around the X axis to accelerate the rotation, the moment of inertia would have a maximum angular acceleration of 10 °/s². Turntable along the X direction's rotational inertia is 52330kg.m². So the inertial torque:

$$M = J \times \beta = 5.233 \times 10^4 kg.m^2 \times 0.1745 rad/s^2 = 9.13 \times 10^3 N \cdot m \qquad (1)$$

The moment of inertia add: in the center of turntable set an RP-1 point, then all the rods of the frame couple with the RP-1 point. Put (1) torque load at this point equivalent to the turntable's moment of inertia.

Deformation analysis of the time within the framework to pass outside the framework of the load to take the actual size of 150kN calculation, in the horizontal position, each side to pass 75kN. Abaqus model, 75kN load concentration in the form of role outside the framework of the eight nodes, each node by 9.375kN of concentration. In vertical position 150KN force acting on the bottom of the bottom eight nodes, respectively, by 18.75kN of concentration.
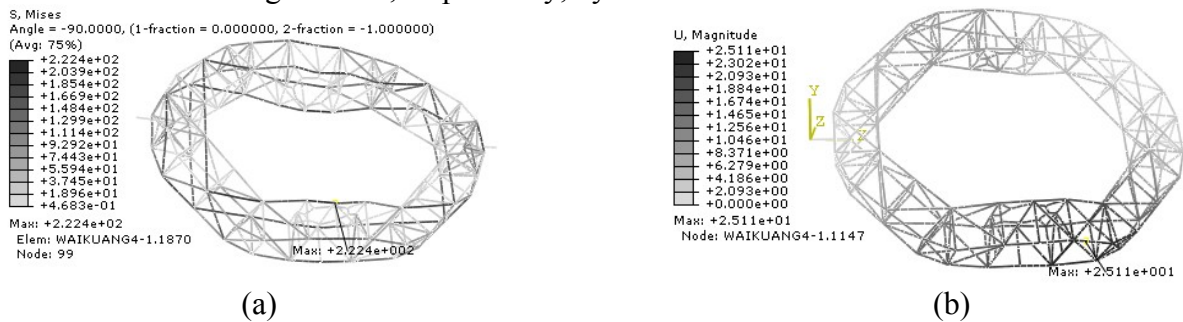

(a)   (b)

Figure 6, a) turntable's stress cloud in horizontal position b) turntable's deformation cloud in horizontal position

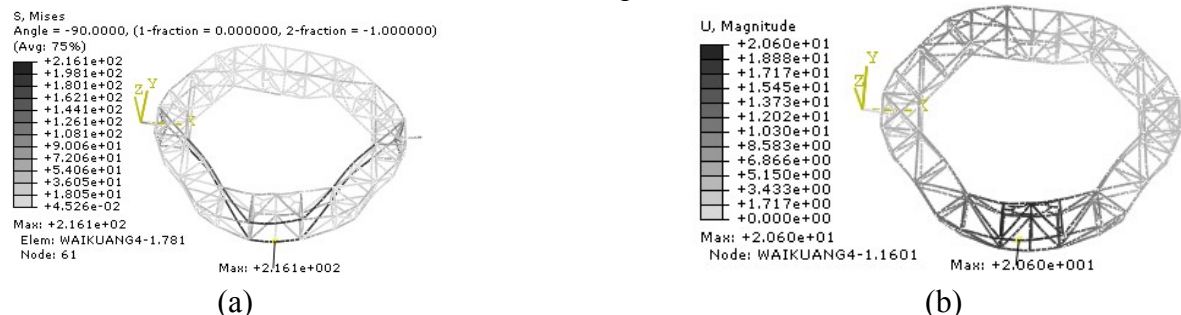(a)   (b)

Figure 7 a) turntable's stress cloud in vertical position b) turntable's deformation cloud in vertical position

Abaqus solving turntable diagram of stress and deformation in Figure6, Figure7 shows. From the stress diagram can be seen that the central bar of the turntable framework subject to the maximum stress, maximum value 222.4MP less than 230MP the allowable stress, followed by some oblique

bar. We can increase the turntable strength by increasing the cross-section of these rods. In the deformation diagram, Because of the inertia moment of action, leading to both sides of turntable's deformation asymmetric, and due to the inner frame on the outer frame rotating torque, resulting in each lateral deformation in the center of asymmetric turntable. The maximum deformation is 2.511cm, which meet the requirements.

The modal analysis

Modal analysis of the system mainly research in the undamped state vibration characteristics, mainly for the system's own natural vibration frequency and vibration mode.

Abaqus offers the Lanczos and the subspace iteration eigenvalue extraction methods. The Lanczos method is generally faster when a large number of eigenmodes is required for a system with many degrees of freedom. The subspace iteration method may be faster when only a few (less than 20) eigenmodes are needed[5]. In this analysis, we use the subspace iteration eigenvalue solver and solving for the first six eigenvalues. Table 1 lists the turntable frame the first 6 natural frequency and mode shape characteristics and there are first 6 modal diagrams as it show in Figure 9.
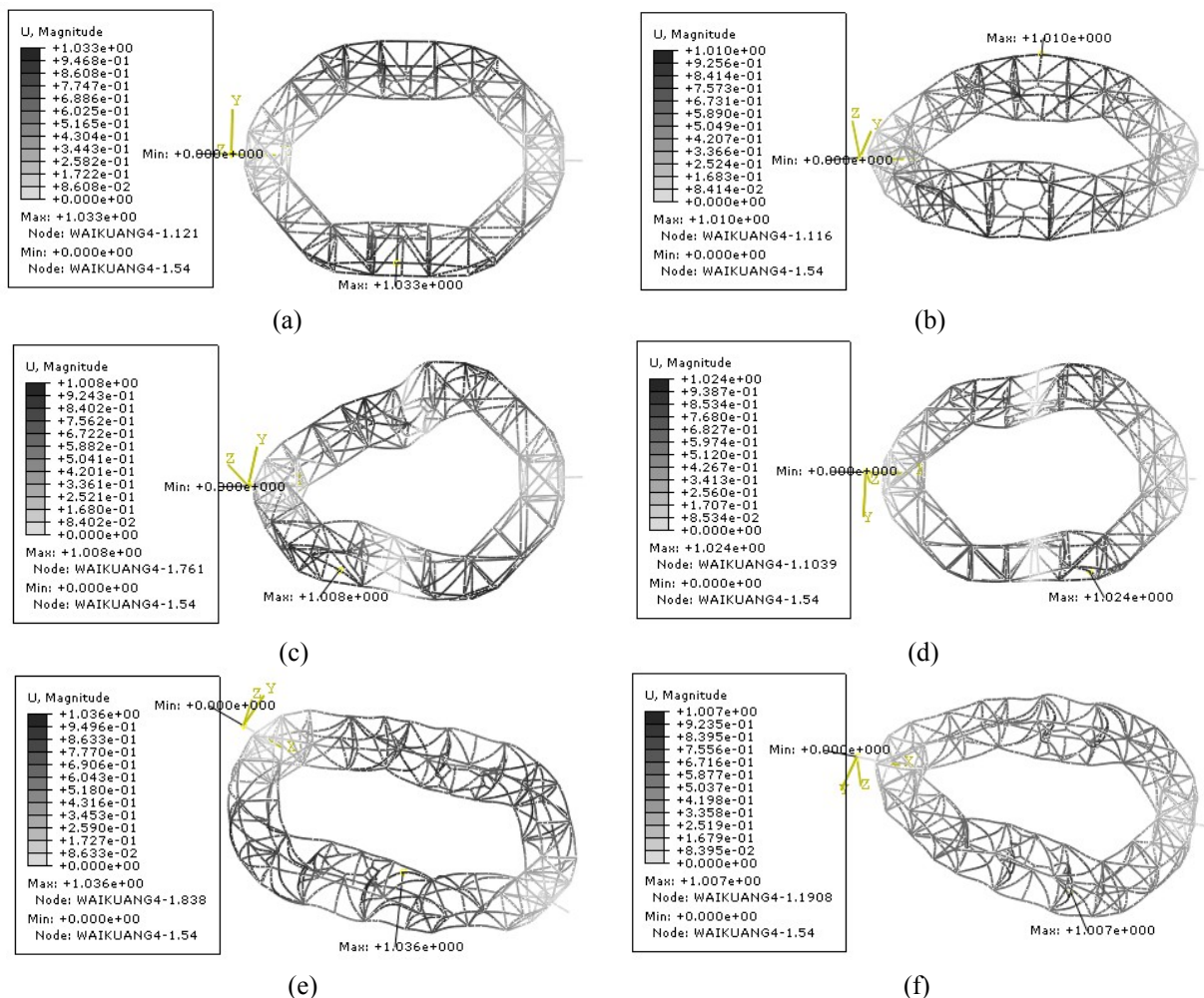
(a)

(b)

(c)

(d)

(e)

(f)

Figure 8, a)turntable's first vibration mode diagram b) turntable's second vibration mode diagram c) turntable's third vibration mode diagram d) turntable's fourth vibration mode diagram e)turntable's fifth vibration mode diagram f) turntable's sixth vibration mode diagram

Table 1 turntable frame before order natural frequency and vibration characteristics

Order	Natural frequency /Hz	Modal features
1	1.6335	The frame on both sides along the X positive direction distortion
2	10.381	The frame on both sides along the Z positive direction bending

3	13.295	The frame on both sides along the Z direction wave deformation
4	16.945	The frame on both sides along the Z direction wave deformation
5	21.791	Each sides of frame along the positive and negative directions of the X bending
6	23.498	The frame on both sides along the X positive direction bending

Turntable frame excitation frequency of 0.056 Hz, and it are far away from the natural frequency of the turntable, so the turntable don't occur resonance.

Conclusion

1) We can see the static solution results of fuel system ground test simulation turntable, the stress are less than 230 MPa, which is less than the turntable material allowable stress.

2) We can see from the turntable frame modal analysis results, the turntable frame in case of no-load, vibration mode for bending along a certain direction and wave bending, the maximum amplitude of the frequency of 21.791 Hz, the amplitude of1.036mm. The maximum amplitude in the turntable's middle position.

3) Although the transfer structure to meet the static and modal design requirements, but the static analysis of the results shows that the turntable frame some of the rod low structural strength, by increasing The cross-section of these rods to increase its strength.

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