Structure design and Strength check of the Re-import section of a continuous transonic wind tunnel

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Abstract. In order to accelerate the development of large transport aircraft, it is important to build a continuous transonic wind tunnel. The re-import section, acted as a key part of the wind tunnel, plays an important role in maintaining the stability and balance of the wind tunnel. On this account, the structure design and strength check of the re-import section is investigated. Firstly, the 3-D model of re-import section is established based on NX software. Secondly, the layout of stiffeners is optimized to solve the bearing problem of components. Finally, the strength check of the re-import section is carried out based on ABAQUS software to validate the effectiveness of the designed structure.

1. Introduction
At present, there are five continuous transonic wind tunnels with 5m magnitude in the world, including four in the United States and one in Europe [1], while the largest transonic wind tunnel in China is the 2.4m ejector transonic wind tunnel which is built by China aerodynamic research and development center in 1997. The wind tunnel investigated in this paper is the first 5 meter continuous transonic wind tunnel in China that can effectively make up for the such shortcomings of the existing transonic wind tunnel as small size and weak comprehensive simulation test capability. The 5 meter continuous transonic wind tunnel plays a key role in the accurate simulation of aircraft shape, aeroelastic evaluation, integrated body / propulsion design and the exploration of transonic flow mechanism and promotes the innovation and development of aerospace industry [2].

Acted as a key part of the wind tunnel, the re-import section is used to re-enter the air flow extracted from the test section into the main return channel of the wind tunnel to maintain the stability and balance of the running state of the wind tunnel. According to the previous design experience of transonic wind tunnel, the re-inlet is similar to the open collector, and the air flow is disordered, even couple with the regulator structure, which threatens the normal operation of the wind tunnel [3]. Moreover, due to the large size of the 5m wind tunnel, the maximum size of the re-import section is more than 20 meters, thus the design requirements for stiffness and strength are more stringent. On this account, the structural design and strength check of the re-import section is investigated in this paper.

2. The structure of re-import [4-7]
2.1. Structure composition
The re-import section is a double-layer structure, mainly including the blocking plate, pressure chamber, rectangular diffusion section, square to round diffusion section, conical diffusion section, adjusting plate as shown in Fig.1. The adjusting plate, as shown in Fig.2, is located at both sides of the
square to round diffusion section, two of which are distributed on one side and driven by the screw elevator. There are two inlets in the pressure chamber, one is located above the chamber, through which the air flows into the main channel, and the other is located on the side of the chamber, through which the compressor anti surge bypass air flows into the main channel.

![Figure 1. The structure of re-import section.](image)

![Figure 2. The location of adjusting plate.](image)

2.2. Design of key components

2.2.1. Design of blocking plate. The blocking plate, as shown in Fig.3, with the diameter of 21 m, separates the re-introduction chamber from the test chamber. Due to the large diameter of the blocking plate, the maximum pressure difference between the two sides is about 0.15 MPa, and the blind force borne by the blocking plate is about 5200 t. In order to strengthen the rigidity and strength of the blocking plate, the optimized design scheme is as follows.

1. The blocking plate is reinforced by transverse / longitudinal rib plate and wing plate. A ring-shaped rib is designed near the pressure chamber. The ring-shaped rib plate is uniformly distributed between the ring-shaped rib and the pressure shell. The thickness of the blocking plate is 40 mm, the height of the rib plate is 1000 mm, and the thickness of the plate is 30 mm.

2. The transverse / longitudinal rib plate of the blocking plate are welded with the inner rectangular diffusion section, and the rib plate of the rectangular diffusion section are aligned with that of the blocking plate to better transfer the force. The three-dimensional structure of the plug plate is shown in Fig. 3.
2.2.2. Design of pressure chamber. The pressure chamber, as shown in Fig.4, with the maximum pressure difference of 0.15 MPa, is welded with blocking plate and bellows. The upper of the pressure chamber is the air inlet of the test section, and the side is the air inlet of the anti surge pipeline. The pressure chamber is supported by three groups of bidirectional sliding supports. The key to the design of the chamber is to bear the blind force of the blocking plate, the additional load of the internal section and the pressure difference. Thus the rib, as shown in Fig.5, is used to transfer the blind plate force to the bearing shell and finally to the three groups of supports. Additionally, a crevice with 30mm is reserved between the shell and the inner conical diffusion section to compensate for the different thermal expansion deformation.
2.2.3. Design of adjusting plate. The adjusting plate, as shown in Fig.6, includes adjusting plate structure body, locking device, locking auxiliary device, universal wheel, etc. The locking device is driven by screw elevator. The locking device adopts the form of one pulling two, and the locking auxiliary device adopts the form of one pulling one. The rubber is arranged in the end of the locking auxiliary device to increase the friction force with the bottom plate of the inlet (i.e. the locking force), and the universal wheel is acted as an auxiliary support.

3. Strength check [8-9]

3.1. Modeling
To simplify the calculation, the sheet model is used to calculate the re-import section, and the local chamfer and threading hole are ignored. The calculation model is shown in Fig.7.

3.2. Boundary condition
The model is imported in ABAQUS software. The material of bear shell uses Q345R and that of other parts use Q355B. Additionally, the boundary condition contains the following constraints. In detail, the connecting end face of pressure chamber is fixed, the flange end face of isolation door is freedom, the connecting end face of bellows is freedom and the supports bottom is set as constraining Z direction and rotation around x, y, z direction.

3.3. Calculation condition
According to the actual work condition, the pressurization condition and negative pressure condition are mainly considered in the calculation.

In pressurization condition, the pressure difference of blocking plate is 250kPa, while in negative pressure condition the pressure difference of blocking plate is 4kPa.
3.4. Calculated results

3.4.1. Pressurization condition. The calculation results are shown in Fig.8 and Fig.9, from which we can find that the stress concentration occurs at the opening and the maximum stress is 188.8 MPa. The reasons maybe come from two aspects. One is the wall thickness is not taken into account in the calculation, the other is not chamfering at rib plate welding. Totally, the overall stress level is not more than 80MPa, which meets the material stress requirements and the maximum displacement is 5.1 mm, which is mainly reflected in the outward expansion of the housing and meets the requirements.

![Figure 8. Cloud chart of stress in pressurization condition.](image1)

![Figure 9. Cloud chart of displacement in pressurization condition.](image2)

3.4.2. Negative pressure condition. The calculation results are shown in Fig.10 and Fig.11, from which we can find that the stress concentration occurs at the opening and the maximum stress is 106.8 MPa. While the overall stress level is not more than 80MPa, which meets the material stress requirements and the maximum displacement is 2.7 mm, which is mainly reflected in the inward contraction of the housing and meets the requirements.
4. Conclusions
(1) Structure of re-import section is designed and the layout of stiffeners is optimized to solve the bearing problem of components.
(2) The strength check is carried out using ABAQUS software and the obtained results show that the overall stress level meets the requirements, which indicates the design of re-import section is reasonable.

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