Research on Dynamics Stiffness of Honeycomb Sandwich Structure Door

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Abstract. During the emergency opening of the aircraft door in the air, the door must experience a complex and harsh mechanical environment. In order to ensure the high reliability of the door, it must have sufficient dynamic stiffness. When using finite element software for static engineering analysis, the calculation results often have large deviations due to improper simplification of the motion links in the structure. Aiming at the characteristics of the honeycomb sandwich structure of a class of civil aircraft doors, a combination of topology optimization and dynamic analysis was adopted to take into account the door load and the door opening speed. The results of dynamic calculation show that when the door is opened in the air, the bending deformation during cruise is in compliance with the requirements, and the structural rigidity meets the functional requirements. The research results have important effects on the design and optimization of the stiffness performance of honeycomb sandwich doors.

1. Introduction
The composite honeycomb sandwich structure has a large bending stiffness and a light weight, and is widely used in the aircraft structure [1-4]. The structural height of the small structural height door can bring obvious weight reduction effects with a full height honeycomb sandwich structure. In order to comprehensively consider the stiffness of the honeycomb sandwich structural door in cruise state under pneumatic [5,6] load and mechanism rod load, this paper gives a feasible stiffness design method by reasonable selection indicators. The goals of optimizing power paths, reducing structural weight and improving response speed have been achieved by combining topology optimization and multi-body dynamics analysis. The results of the research have an important role in the design and optimization of the aircraft door stiffness performance.

2. Topological optimization of honeycomb sandwich structure

2.1 Main parameters of honeycomb sandwich structure
Design targets are concentrated in the optimal stiffness. As the stiffness increases, the parts materials will be increased, which often introduces weight increase. A topological optimization method is used in order to balance stiffness and weight.

In order to investigate the bending deformation of the aircraft door in the flight process, the honeycomb clipboard is considered as an overall body. The parameters of the honeycomb sandwich structure are shown in Figure 1.
2.2 Material, load and boundary conditions

The inside and outside skin is 2024-T42 aluminum alloy, and the honeycomb core uses 5052 aluminum alloy honeycomb core. The tie rod material is 15-5PH steel. The pneumatic load is 2.7 MPa allocated load, which acts on the inside skin of the door. The first, second and third degree of freedom in the upper end of the mechanism rod have been constrained.

Topology optimization initial settings are as follows: The door is located in the initial position and is subject to the above pneumatic load. The design constraint is: The gap between drive mechanism and door meet technical requirements, and the deformation of the front end of the door does not exceed 4 mm. Optimization goals: Minimal weight. The weight of the whole door is minimal. Material distribution requirements when optimized: Avoid interferometry, such as door structures and mechanical rod, and door and body link holder. Cancel the material with a smaller load.

2.3 Topology optimization process

Topology optimization is divided into two processes: one is to remove material, and the other is designing parts according to the remaining material. The door material that affects the loads transfer significantly has been obtained through software calculations after constraint conditions, load, and goals were set. Then the door structure can be checked whether the deformation targets are met.

After the multi-wheel iteration, the most efficient material can be performed. The process of removing the material is shown in Figure 2.
design of the part itself should be considered for the manufacturing process and the mechanical properties of the parts. The door structure is shown in figure 3 based on the topology optimization results.

![Figure 3 the door structure model](image)

### 3. Dynamics analysis

After topology optimization, the anti-bending and anti-twisting ability and the motion response speed of the door are analyzed by multi-body dynamics analysis method. Dynamic analysis load conditions are as follows: Gravity acceleration is -1.24g to 3.24g; mechanism rod preloading force is 800N to 2200N. The multi-body dynamics model of the door and drive system is shown in figure 4.

![Figure 4 Multi-body dynamics model](image)

When the mechanism rod preloading force is 800N, the dynamics analysis results are shown in Table 1. When the mechanism rod preloading force is 2200N, the dynamics analysis results are shown in Table 2.

#### Table 1 Min clearance under 800N preload

| number | Gravity acceleration /g | The door rotation angle/° | Minimum gap between door and drive system/mm |
|--------|--------------------------|---------------------------|---------------------------------------------|
| 1      | 0                        | 29.9                      | 40.4                                        |
| 2      | 1                        | 31.8                      | 37.4                                        |
| 3      | 1.24                     | 29.5                      | 37.8                                        |
| 4      | 3.24                     | 30.9                      | 46.0                                        |

#### Table 2 Min clearance under 2200N preload

| number | Gravity acceleration /g | The door rotation angle/° | Minimum gap between door and drive system/mm |
|--------|--------------------------|---------------------------|---------------------------------------------|
| 1      | 0                        | 31.3                      | 34.7                                        |
| 2      | 1                        | 33.0                      | 36.4                                        |
| 3      | 1.24                     | 31.1                      | 32.2                                        |
| 4      | 3.24                     | 26.4                      | 31.6                                        |

According to calculation results from tables above, when the mechanism rod preloading force is 800N, minimum gap between door and drive system is 37.4mm under four gravity acceleration conditions. When the mechanism rod preloading force is 2200N, minimum gap between door and drive system is 31.6mm under four gravity acceleration conditions. During the opening process of the door,
the gaps between the door and the drive system is sufficient to ensure that the door can be smoothly opened without Collision and friction phenomena. The anti-bending and anti-twisting stiffness of the door matches the speed of the drive system.

4. Conclusions
In this paper, a combination of topology optimization and dynamic analysis was adopted to take into account the door load and the door opening speed. The results of dynamic calculation show that when the door is opened in the air, the bending deformation during cruise is in compliance with the requirements, and the structural rigidity meets the functional requirements. This issue is a kind of typical large acceleration and fast response mechanism design. The ideas and methods in solving this problem have good reference significance, especially in consideration of the characteristics of the project's tight design time.

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