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Design and Analysis of An Antenna Cabin

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Abstract. As a new method of application usage of cabin, the experience design combines with finite element simulation during the development process is effective. This method can quickly determine the rationality of the design and effectively shorten the development cycle. According to the layout features of a certain type of antenna cabin, the stiffness of the roof structure was enhanced, so that the local stiffness was improved, but the total stiffness declined after the cabin raised. The antenna produces periodic dynamic load when working, the natural frequency of the cabin should avoid antenna working frequency in order to avoid resonance. The natural frequency of the cabin was analyzed by finite element method, according to the typical condition. The structure of the cabin was simplified when the finite element modeling. The results show that the natural frequency of the cabin avoids antenna working frequency, and the rationality of structural design was verified.

1. Introduction

With the progress and development of science and technology in our country, the cabin, as a carrier of equipment, is widely used in communication, measurement and control, command, security and other fields [1]. Whether military or civilian, the cabin has good maneuverability, rapid response deployment capability has been developed vigorously, and the application field has been expanding. The design idea of the cabin has gradually shifted from traditional empirical design to simulation design. Using the simulation results to guide the structure design can reduce the design risk, reduce the cost and shorten the cycle [2~4].

An antenna cabin is mainly equipped with automatic elevating mechanism, turntable and antenna. When the cabin is working, the antenna rotates uniformly on the turntable. The shelter should be able to rotate in different types of antennas without damage or failure, which means that the dynamic characteristics of the cabin are required. Therefore, the finite element analysis method is used in the design of the automatic elevate cabin structure. The simulation analysis of the dynamic characteristics verifies the rationality of the structure design and shortens the development cycle.

2. Structural design of an antenna cabin

2.1. Basic survey of an antenna cabin

The dimensions of an antenna cabin (length * width * height): 3000mm * 2200 mm * 2000 mm. The overall shape of the cabin is shown in Figure 1. The cabin is equipped with diesel generators, cabinets and other equipment. The cabin layout is shown in Figure 2. In order to meet the installation and heat dissipation requirements of diesel generators, hatch doors and shutters are installed at the corresponding positions of adjacent cabin panels, and the boarding doors, ventilation windows and

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transfer orifices are designed according to the needs. Antenna turntable and antenna are installed on the roof of the cabin. There are three kinds of antennas, one of which is selected according to the requirements of use. The weight and working speed of the top antenna are shown in Table 1.

Figure 1. Sketch chart of the contour of the cabin.

Figure 2. Drawing of interior layout of the cabin.

Figure 3. Diagrammatic sketch of operative mode of the cabin elevated state

Table 1. Weight and working speed of antenna on the top of the cabin

Device name	Weight（kg）	Working speed（r/s）
1#Antenna	150	1/12
2# Antenna	25	0.5
3# Antenna	1	2

The working state of the cabin can be divided into two kinds: one is that when the cabin is parked on the ground, the top antenna rotates uniformly, the other is that the automatic elevating mechanism elevates the cabin, the bottom of the cabin is 300 mm away from the ground, and the top antenna rotates uniformly. Figure 3 gives a schematic diagram of the working state of the shelter elevation.

2.2. Structural design of the cabin

The antenna cabin uses the existing mature structure design and technology, adopts the skeleton large plate structure, and the cabin body is mainly composed of large plate, cast steel corner parts and edge wrapping. The large plate is a composite sandwich structure consisting of skeleton, filler and skin. In order to improve the stiffness of the cabin, the top, bottom and sides of the g cabin are welded with steel profiles, while the rest of the large plate skeleton is welded with aluminum profiles. Polyurethane foam is used as filler, aluminum alloy material is used inside and outside skin, and a temperature isolation layer is set between the skin and the skeleton to increase the thermal insulation performance. The skeleton, skin, filler and insulation layer are bonded together by glue. In order to ensure the continuity of the structure and improve the overall performance, edge-wrapped joints are used to reinforce the joints of cabin panels. Silica gel is used to seal the edge and the deck to ensure the overall tightness of the cabin. Cast steel corner parts are installed at 8 corners of the cabin, which are mainly used for elevating the cabin and connecting and fixing the cabin and the truck.

In order to meet the noise requirement, separate oil engine compartments are specially designed at the installation site of diesel generators. Separate compartments are formed by splicing the separators, which can increase the thermal resistance between the diesel generators and the main compartment, and have the function of heat insulation. At the same time, the separators also play the role of sound insulation and noise reduction, which can effectively prevent the transmission of noise from diesel generators to the main compartment. In order to improve the reliability of equipment installation, buried iron is installed at the equipment installation site of the cabin board, and the equipment is fixed directly on the cabin body by screw. Air-conditioning bracket is welded with steel profiles. The bracket is hung on the cabin board to facilitate the installation and maintenance of air-conditioning.

The top turret and antenna of the automatic elevator are of large mass and relatively small mounting surface. When the cabin is elevated, the local loads are large. At the same time, the cabin structure is prone to local modes in this position. Therefore, the installation of the turret needs to be strengthened. In order to improve the bending stiffness, the 80*40*2 rectangular steel tube is welded at the skeleton of the corresponding position of the roof, and the structure of the installation area of the turntable is strengthened. Angular braces are set at the joint of the steel tube and the side plate, and the restraint stiffness of the steel tube root is increased. The integral skeleton structure of the cabin is shown in Figure 4, and the section structure of the reinforced area is shown in Figure 5.

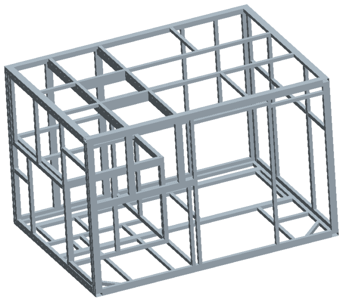

Figure 4. Skeleton of the antenna cabin

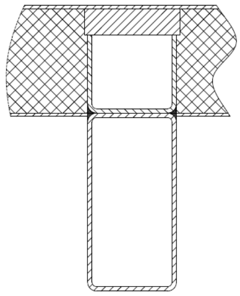

Figure 5. Section of reinforced area

3. Finite element analysis of the cabin

The dynamic load generated by the uniform rotation of the antenna on the top of the cabin directly acts on the top of the cabin. The ability of the cabin to bear the dynamic load depends on the dynamic characteristics of the cabin structure. The natural frequencies and modes of the cabin can be obtained by modal analysis of the cabin. On the basis of the modal analysis results, the response analysis of the cabin under various dynamic loads can be further carried out. The low-order frequency of the structure is easier to couple with external excitation than the high-order frequency, and the influence of the low-order mode is more serious than that of the high-order mode. Therefore, in the dynamic analysis of structures, the weighting coefficients of low-order modes are much higher than those of high-order modes, so the dynamic characteristics of structures are basically determined by low-order modes[5-6].

The natural frequencies of the cabin should avoid the working frequencies of the three antennas and avoid resonance. The structure of the antenna cabin is very complex, and the natural frequencies of the cabin can’t be obtained by theoretical calculation. The natural frequencies of the cabin can be obtained by finite element analysis method, which can be used as the basis for structural design.

3.1. Establishment of finite element model

In order to simplify the calculation and improve the calculation efficiency, the following simplifications and assumptions are made for the structure of the cabin when the finite element model is established[7].

- The joints of shelter panels are treated as rigid joints and simplified into continuous structures;
- Neglecting the reinforcement effect of the envelope and insulation layer on the whole structure;
- The influence of small openings on the stiffness of the cabin structure is not considered;
- The local reinforcement of the corner on the top corner of the cabin is neglected;
- The increasing effect of iron embedding on the cabin is neglected;
- The reinforcement of door frame, orifice frame and window frame to cabin is neglected;
- The large-mass equipment in the cabin is simplified to the mass element, ignoring the reinforcement effect of the equipment structure on the cabin;
- To distribute the weight of the remaining small-mass equipment in the cabin on the bottom of the cabin;
- Simplify the automatic elevating mechanism, neglect the supporting plate and flange structure of the local strengthening of the automatic elevating mechanism, only consider the stiffness of the main beam, establish the finite element model of the automatic elevating mechanism with the beam

element, and set the section of the beam element according to the section of the main beam;

- According to the actual use, the restraint between the automatic elevating mechanism and the cabin releases the degree of freedom of rotation along the altitude direction.

3.2. Material parameters
The mechanical properties of the materials used in the shelter structure are shown in Table 2.

Table 2. Mechanical Properties of the Cabin Structural Materials

Material name	Modulus of elasticity（MPa）	Poisson ratio	Density（kg/m^3）
Steel Q235	210000	0.28	7.8×10^3
Aluminium alloy 5052	71000	0.3	2.7×10^3
Polyurethane foam	13	0.17	60

3.3. Analysis and boundary conditions
There are six working states in the antenna cabin. The overall stiffness of the cabin is weaker than that of the cabin directly placed on the ground. Therefore, the natural frequencies of the whole cabin with different antenna configurations are mainly analyzed in the finite element analysis. The mass of antenna 2 and antenna 3 is close to each other, and the weight change of antenna 2 and antenna 3 has little influence on the natural frequencies of the cabin as a whole, which can be neglected. Therefore, only two kinds of working conditions can be analyzed. The first condition is that the cabin rises 300 mm and the antenna 1 works. The second condition is that the cabin rises 300 mm and the antenna 2 works. Fixed support constraints are applied to the roots of the automatic elevating mechanism in the model. The finite element model of the cabin skeleton is shown in Figure 6 and the overall finite element model of the cabin is shown in Figure 7.

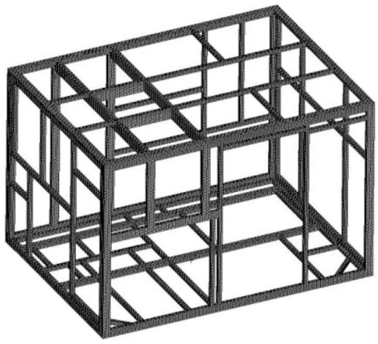
Figure 6. Finite element model of the cabin skeleton

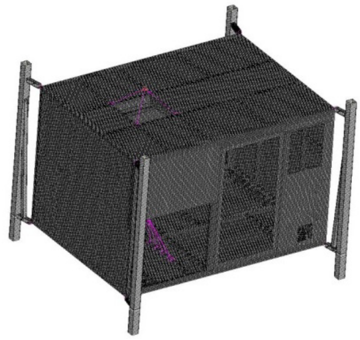
Figure 7. Finite element model of the cabin

4. Calculation results
The above model is solved and the vibration modes of the cabin under two working conditions are calculated. The vibration modes of the cabin under working condition 1are given in Figure 8-10.

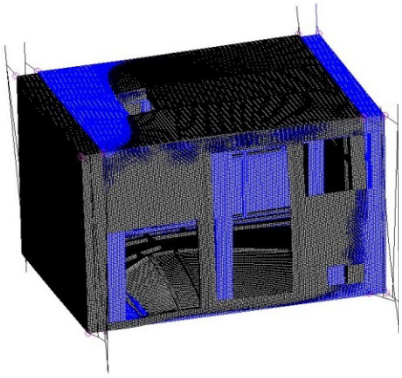

Figure 8. First order vibration mode of the cabin under working condition 1

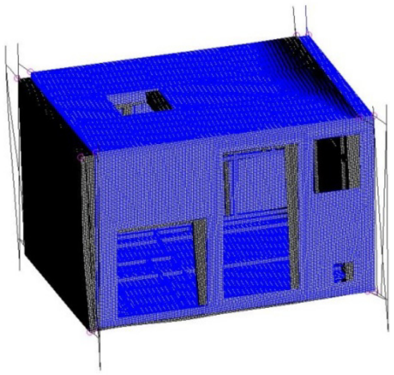

Figure 9. Second order vibration mode of the cabin under working condition 1

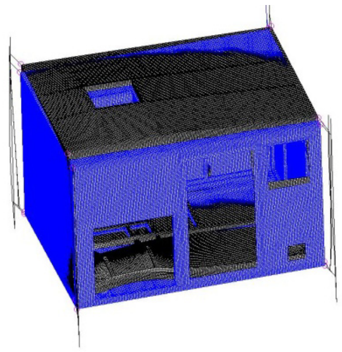

Figure 10. Third order vibration mode of the cabin under working condition 1

The results show that the natural frequencies of the first and second order are close to each other, and the trend of the first and third order modes is consistent. The first and second modes are mainly the bending vibration of the automatic elevating mechanism, and the third modes are mainly the bending vibration of the roof and bottom of the shelter. The natural frequencies of the cabin under both conditions are shown in Table 3.

Table 3. Calculation results of natural frequencies of the cabin

Natural frequency	Working condition 1	Working condition 2	Working frequency of 1#Antenna	Working frequency of 2#Antenna	Working frequency of 3#Antenna
First order	9.58Hz	9.72Hz			
Second order	13.89Hz	14.30Hz	0.08Hz	0.5Hz	2Hz
Third order	15.63Hz	15.91Hz			

5. Conclusion

After the above analysis, the natural frequencies of the cabin in the two working modes have avoided the working frequencies of the three antennas, and are much higher than the working frequencies of the antenna, which can avoid resonance. The vibration form of the cabin is mainly bending. At the same time, there is no local vibration in the analysis process. This shows that the design of the structure of the cabin is reasonable. At the same time, it shows that the finite element analysis method is introduced into the design process of the cabin structure, which improves the design efficiency and shortens the development cycle.

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