Dynamics Simulation Analysis and Enhancement of Phased Array Antenna Plate

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Abstract. Phased array antennas have been widely used in military and civilian electronic fields as equipment for transmitting and receiving electromagnetic waves. The flatness of the antenna array is mainly ensured by the rigidity of the antenna frame. Therefore, the structural design of the planar array antenna mainly lies in the structural design of the antenna frame. Given the planarity requirements of the antenna array, how to properly design the structure of the antenna frame becomes a difficult problem facing the structural designer. In this paper, static stiffness and strength analysis are performed using finite element method (FEM) when the antenna is slipping. By establishing finite element model of the antenna, the platforms and the leatheroid ground, the laws of dynamic stress and deformation are researched. Analyse the reasons of structure breakage when it slips, and advance the method of enhancing the stiffness and strength, offer a theoretical basis of structure design.

Keywords: Finite Element Method, Dynamics Simulation, Phased Array Antenna

1. Introduction
As a equipment of sending and receiving electromagnetic waves, phased array antenna is widly used in the military and civilian field. The framework of the antenna is the most important during structure design, and how to design framework reasonable is a problem to structure design staff. [1, 2]

Although ground model experiments and tests are currently being performed, there is still a considerable gap compared with developed countries. Research by Domestic Aviation Sector Research Institute in the field of anti-shock design of electronic equipment is still very backward, mainly relying on experience. Due to the lack of practical engineering application experience, some key parts are hesitant to optimize the structure.

The antenna board is mainly composed of an electrical board, an active mounting board, and a frame. The active mounting board is composed of a surface aluminum plate and a honeycomb material in the middle. It carries a variety of stand-alone electronic devices. It is made of high-strength plates, and the connection between the plates is achieved by welding. This is mainly to improve the overall stiffness of the antenna so that the entire structure is good in rigidity, lightweight and high strength.
2. Model establishment
It is an extremely important task to establish an accurate and reliable structural finite element calculation model, which is directly related to the correctness of the calculation results. However, the actual engineering problems are often very complicated, and it is impossible to build a finite element model that is completely consistent with the physical model. Therefore, the necessary simplification must be performed in the process of establishing the finite element calculation model, otherwise, our work will be difficult. Go on, even run aground. Generally speaking, the error caused by this calculation model to simulate engineering problems is much larger than the calculation error of the finite element method itself. In this sense, the accuracy of structural finite element method analysis results depends on the accuracy of the computational model. Therefore, the following two basic requirements are required for the established finite element model. [3, 4]

2.1 The calculation model must be sufficiently accurate
The simplified model should reflect the actual situation of the structure. The accuracy here is mainly reflected in three aspects, that is, to ensure the consistency of shape and structure, to maintain the consistency of boundary conditions, constraints, and the consistency of loads and actual working conditions. Only the simplification made under this premise is meaningful, and the final result can reflect the actual situation.

2.2 The calculation model must have good economics
The economy here is mainly reflected in the modeling workload and the computing overhead of the computer. In theory, it is most accurate to analyze and calculate the actual model without any simplification, but it is not feasible in the operation process. From the perspective of doubling the workload, it is difficult in actual work. achieve.

For the overall consideration of meshing the model, because the frame is a foundation of the antenna structure, its mesh needs to be divided first. The model of the electrical board does not affect the accuracy of the analysis results, ignores some small holes on the board, and combines the divided small boards into a whole. Before dividing the finite element mesh of the mounting plate, first, divide the entire surface of the mounting plate into several small rectangular blocks, and then mesh the small rectangular blocks. The quality of the resulting mesh will be very good. Both the active mounting board and the electrical board are assembled on the antenna frame, and the number of connection holes is large. Considering that the rigidity of each board and the frame is good, the shell unit is directly connected. In the beginning, the antenna board leaned on the debugging platform horizontally. The part in contact with the debugging platform was the electrical board of the antenna board, and the debugging platform was fixed on the artificial leather floor.

Figure 1 Three-dimensional model of the antenna board
3. Finite element dynamics simulation of antenna plate slipping process

3.1 Simulation results of finite element dynamics of electrical board[5, 6]

According to the observation of the results, the stress of the electrical board reaches a peak of about 5ms after the collision, so pay attention to the results at this moment. The stress-strain cloud diagram and corresponding graph of the electrical board at about 5ms are listed below.

![Stress cloud of the electrical board](image1)

Figure 3.1 Stress cloud of the electrical board

![Strain cloud of the electrical board](image2)

Figure 3.2 Strain cloud of the electrical board
Figure 3.3 Stress curve diagram of the electrical board

It can be seen from the stress-strain cloud diagram of the electrical board that the stress and strain at the edges of the electrical board is relatively large, which is mainly because the edge part is the main force part at the time of the collision, which causes its deformation to be greater than elsewhere. In general, the stress value of the electrical board is not very large, and the maximum stress value can be seen from the stress curve diagram at about 25Mpa.

3.2 Frame finite element dynamics simulation results
Through observation, it can be seen that the peak stress appears about 3ms after the collision. From the stress curve of the frame, it can be concluded that the maximum stress of the frame is about 200Mpa, which is much larger than the stress value of the electrical board. This is mainly because the frame serves as the entire antenna board. The main load-bearing member of the steel, because of its greater stiffness. The stress on one side of the frame is relatively large, which is mainly due to the side leaning on the debugging platform at the beginning. When the antenna plate slips, the speed on that side will be very large. It causes a great impact and forms a large stress so that the stress value on one side is much larger than the other side.

3.3 Simulation results of finite element dynamics of electrical board
Through observation, it can be seen that the peak stress appears about 5ms after the collision. From the stress curve of the mounting plate, it can be concluded that the maximum stress value of the mounting plate is about 2Mpa, which is far lower than the peak stress of the frame, and it is also more The peak stress is low, which is mainly because the stiffness of the mounting plate is lower than that of the other two parts. Besides, the active mounting plate does not directly collide with the ground like the electrical board, so the active mounting plate appears. The peak stress is lower than in the other two parts.

3.4 Analysis of Finite Element Dynamics Simulation of Antenna Plate
From the allowable stress of the materials of the various components of the antenna board, it is known that the allowable stress of the material of the active mounting board is above 200Mpa, and the allowable stress of the piezoelectric material is also above 200Mpa, and the material of the frame is carbon fiber. The stress is above 1000Mpa, and the peak stress of each component of the antenna board during the slipping process obtained from the simulation analysis shows that these peak stresses are far lower than the allowable stresses of the materials of the corresponding components of the antenna board, so from In terms of strength, the strength of the antenna board is undoubtedly satisfactory.

It can also be seen from the strain cloud diagrams and corresponding strain curves of the antenna board that during the collision of the antenna board, the strain of the frame and the electrical board are small, while the strain of the mounting board is very large, reaching 0.016, which indicates that The rigidity of the mounting plate is not ideal and needs to be further strengthened.

4. Antenna board stiffness and strength enhancement measures
It can be known from the above analysis that, for a phased array antenna, the strength of the antenna plate under normal operating conditions is undoubtedly in line with requirements. However, if the antenna board slips during installation and commissioning, that is, under the condition of impact load, under such harsh conditions, the strength of the antenna board may not meet the requirements, which requires the antenna board to be Strengthened. Besides, for phased array antennas, in addition to requiring the antenna plate to have sufficient strength, it also needs to have sufficient rigidity to reduce deformation and ensure the flatness of the array surface. Therefore, the stiffness design of the antenna board is also very important.

To strengthen the rigidity and strength of the antenna board, we can consider it from two aspects: overall layout and local structure. For the overall layout, you can start with the active installation board and the electrical board as far as possible without division or less division, and set the position and number of the fulcrum of the front frame properly. Therefore, the improvement of the antenna board structure will undoubtedly be improved from the local structure.

4.1 Frame rigidity and strength enhancement measures
The main function of the frame of the antenna board is to install and fix the line source and ensure the accuracy of the array under load. Therefore, improving the rigidity and strength of the frame is of great significance for the design of the antenna board. To improve the overall rigidity of the antenna, the following measures can be taken.

4.1.1 Try to form a closed structure and fill it with lightweight foam or honeycomb material

4.1.2 Beams with high bending and torsional stiffness are used.
The stiffness of the beam is proportional to the product of the modulus of elasticity and moment of inertia (or torsional moment of inertia) of the material used and has nothing to do with the strength of the material. Therefore, a material with a high elastic modulus should be selected in the stiffness design instead of High-strength material. After the material is determined, the beam stiffness is determined by the bending (torsion) moment of inertia. The most ideal cross-sectional shape is to obtain the maximum bending (torsion) moment of inertia with the least material. When the cross-sectional area is the same, the profile size of the section should be increased instead of the wall thickness to increase the moment of inertia, and the structural material should be arranged as far away from the neutral axis of the section as possible. For the cross-sectional shape of the torsion beam, try to choose a hollow closed cross-section, of which the circular cross-section is preferred, followed by the box cross-section. If the beam is subjected to both bending and torsional loads, a square or nearly square box section with better comprehensive performance should be selected. Hollow cross-section beams such as Y-section and composite box-section beams, beams with polyline webs, I-beams (or I-sections with double flange plates) have good torsional properties. To give full play to the material
properties, composite beams of different materials can be used. For example, the flange plate with higher strength uses higher strength materials, and the web uses lower strength materials, and the welds are arranged on the neutral axis as much as possible. Depending on the load distribution, a variable cross-section design can also be used.

4.1.3 Use ribs reasonably.
The ribbed plate can improve the overall stiffness and local stiffness of the beam. Through it, it can effectively transmit the load and make the load distribution uniform; it can convert the load of the vertical plate wall into tensile, compression or bending deformation in the plane of the ribbed plate, thereby reducing the wall thickness of the main body Thin; ribs prevent distortion of beam section. The function of the ribs is not dependent on the number, but on the correct configuration, and the thickness is generally about 60% of the body wall. In open box beams, the vertical stiffness is best with parallel bars, followed by diagonal bars, and transverse bars are ineffective; torsional stiffness is best with diagonal bars, followed by transverse bars, and longitudinal bars are not effective big.

4.2 Stiffness and strength enhancement measures for active mounting boards and electrical boards
To improve the rigidity and strength of the antenna board, in addition to strengthening the rigidity and strength of the frame, the rigidity and strength of the active mounting board and the electrical board can also be enhanced to increase the rigidity and strength of the antenna board. To improve the rigidity and strength of the active mounting board and the electrical board, the holes for mounting electronic components on the board can be reasonably arranged on the structure while ensuring the electrical performance requirements. Also, the purpose of improving the rigidity and strength can be achieved by rationally designing the structure of the honeycomb panel used to form the electrical board and the mounting board.

4.3 Other measures to strengthen stiffness and strength
In addition to strengthening the rigidity and strength of the antenna plate from the structural aspect, it can also start from the application of new materials and advanced processing and manufacturing technologies. For example, the use of new materials with greater specific stiffness and specific strength to replace the original materials can well solve the main contradiction between stiffness, strength, and quality, and by using more advanced processing methods to improve the antenna board the surface quality of each component can achieve the purpose of improving its stiffness and strength.

5. Conclusion
The antenna plate is one of the basic components of a phased array antenna, and it is also a very complicated component. For the components mounted on the antenna to function properly, the antenna structure should have sufficient strength and appropriate stiffness. It is almost impossible for the antenna to slip under normal use, but during transportation, installation, and debugging, it is inevitable that the antenna plate will slip due to the negligence of staff or an irresistible accident. Damage the precious precision instruments installed on the antenna board, and then affect the normal use of the antenna. For how to analyze the stiffness and strength of the antenna plate when it slips, it is impossible to obtain an accurate solution of the stress and strain of the antenna plate by classical mechanical methods. However, if a lot of experiments are performed, it will consume a lot of manpower and material resources, and the experiment will be subject to many Constraints on objective conditions. Practice has proved that the finite element method is an effective numerical calculation method. The use of the finite element method can well analyze the stiffness and strength of the antenna plate during the slipping process.

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