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Analysis and Optimization of Antenna Reflective Surface Structure Deformation

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Abstract: This research aims at the problem of insufficient antenna accuracy caused by the self-weight. Taking the 10-meter diameter reflector antenna as example, we firstly analyze the structural characteristics of the antenna, model it by finite element method and analyzes its deformation, and optimize and improve the backframe structure according to its deformation law by mainly improving the connection and structure of its beam and radiation beam. hen changes the skin to carbon fiber material to reduce the self-weight of the antenna, and compares the original antenna (aluminium alloy for the skin) and the optimized and improved reflective surface deformation. This paper can provide a certain reference for the structural optimization design of medium and large reflective surface antennas, and also provide research ideas for the simulation of deformation caused by the self-weight of the antenna.

1. Introduction

The reflector antenna is mainly composed of the antenna reflective surface, the back frame and the feeder [1-3], because of its simple structure, easy design and superior performance, and has the advantages of wide working frequency band and high working accuracy, which are widely used in satellite communications, microwave communication and radar remote sensing [4-6]. With the country's vigorous investment in the field of space in recent years, the demand for large-diameter, high-precision and high-frequency band reflector antennas is increasing, and the higher the requirements for reflector electrical performance. The shape and surface accuracy of the antenna is the main factor affecting its electrical performance, which is mainly affected by the antenna's self-weight, thermal radiation, and wind charge, including random errors, dimensional errors and other factors [7,8]. As the diameter of the reflective surface increases, the self-weight of the reflective surface itself increases, and at the same time, in order to provide sufficient support, the structure of the back frame becomes more and more complex, and the self-weight is also getting larger and larger. The large aperture of the reflective surface leads to an increase in its self-weight, and the greater the deformation caused by the self-weight of the reflector surface, which seriously reduces the accuracy and affects the electrical performance of the antenna [9-11].

2. Establishment of Three-Dimensional Model of Antenna and Optimization of Back Frame Structure

This project takes the 10-meter caliber reflective surface antenna as the research object(Figure 1).Firstly we model the reflector antenna, mainly including the reflector surface, back frame and base of the antenna; Secondly, analyze the gravity deformation of the antenna reflector surface and backframe and the optimized and improved backframe; Finally, the surface and the back frame are analyzed with different materials, and the influence of different materials and the back frame structure on the deformation of the antenna reflective surface is compared [12].

For example, Table 1 is the main material parameters used in this section, mainly for the reflective surface using aluminum alloy, the back frame using structural steel, and the core layer using aluminum alloy. Divided the grid, the grid size is 30mm, and set the boundary conditions, and the constraints are fully constrained for the bottom ring of the back frame.

Because the model is a surface model, there are too many solids, the meshing time is too long during the analysis of the antenna reflector, and the machine performance and calculation amount are too large in the calculation process, so we only selects a quarter of the antenna model (Figure 2) as the analysis object. It can be seen from Figure 2 that the pitching large tooth arc and antenna counterweight of the backframe structure are concentrated in the central area of the antenna, which will cause the large reflective surface antenna to appear deformed in the boat, and its deformation is not uniform enough, affecting the shape and surface accuracy of the antenna.

Table 1: This article uses the main parameters of the material

Name/Property	Density(kg m^-3)	coefficient of thermal expansion (C^-1)	coefficient of thermal conductivity (W m^-1 C^-1)
Aluminum alloy	2770	1.2E-05	144
Structural steel	7850	2.3E-05	60.5

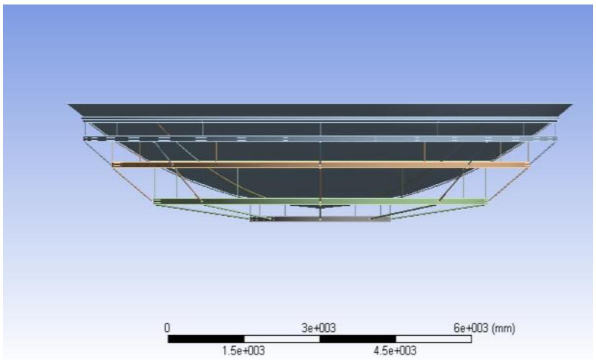


Figure 1: The example antenna double-layer back frame back frame structure

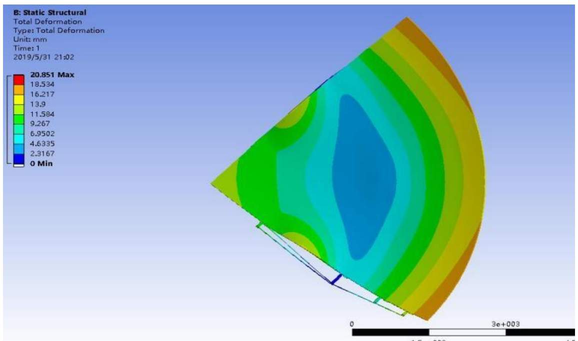


Figure 2: Gravity deformation cloud view of the antenna double-layer backframe for example

Through further observation, it is found that the maximum deformation of the antenna basically appears at the first circle of beams on the outer edge of the antenna back frame. In order to reduce the overall deformation of the antenna reflector and increase its stiffness, it is necessary to strengthen the antenna backframe. After comparative analysis, it was finally decided to add 36 cable-stayed beams to the connection between the inner and outer backframes of the antenna to increase the stiffness of the antenna backframe and improve its bearing capacity. Therefore, this paper also provides an umbrella-shaped antenna back frame design method (Figure 3), the structure can be evenly dispersed to the various parts of the antenna reflective surface, which can avoid the situation of uneven deformation of the antenna caused by concentrated loading, and can also reduce the difficulty of connecting the back frame and the base, which can be achieved by supporting the top of the umbrella-shaped back frame and the center point of the umbrella-shaped back frame pitch structure [4].

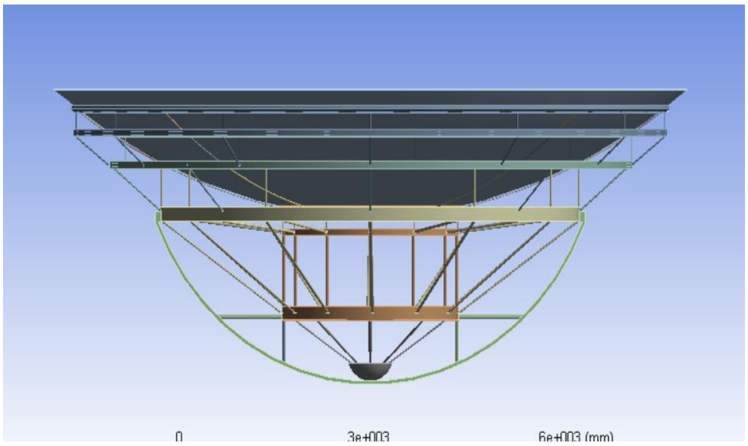


Figure 3: The structure diagram of the antenna umbrella back frame in this article is exampled

3. Analysis of Gravity Deformation of Antenna Reflector

At the same time, in this section of the analysis, in order to compare the deformation of the antenna reflective surface under different conditions, the deformation of all points on a line in the radial direction of the antenna reflector and its average value are selected as the main data for comparison in the simulation analysis results of each example in this paper. Table 2 is the main material parameters used in this section. The two sets of analysis results of Figure 4 and Figure 5 are that the aluminum alloy skin adopts two structures, and the results of the max deformation are concluded in Table 3 and Table 4 respective. The double-layer back frame and umbrella-shaped back frame, and carbon fiber composite skin adopts double-layer back frame and umbrella-shaped back frame structure.

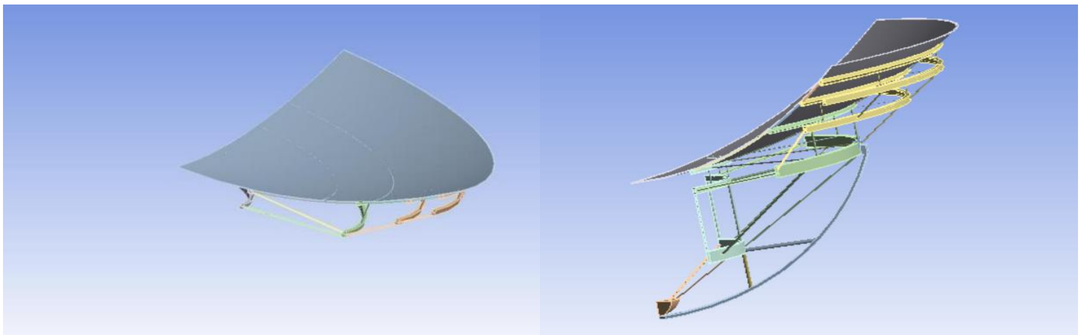
Table 2: Carbon fiber composite material parameters back frame and a double-decked back frame, respectively

Material Properties	parameter
Carbon fiber material densityt/(kg m^-3)	1451
carbon fiber prepreg resin conten/w_m/%	34
Carbon fiber prepreg thickness/mm	0.12
Carbon fiber prepreg tensile strength/GPa	2.35
Carbon fiber prepreg elastic model/GPa	130
Carbon fiber shaft conduction thermal coefficient (W m^-1 C^-1)	1.3
Carbon fiber diameter guide thermal coefficient(W m^-1 C^-1)	1.1

As shown in Figure 4 (a) and Figure 4 (b), the simulation deformation cloud of Group A is shown in Figure 3, and Table 3 shows the gravity deformation value when the third set of antennas uses different backframes. Figure 4 (a) shows the deformation cloud of the antenna reflective surface of the umbrella-shaped backframe structure, the maximum shape value is 25.504m, and the smallest variable of the antenna is 0mm. The antenna reflective surface is evenly deformed. Figure 4 (b) is the deformation of the antenna reflector when the double layer back frame, compared with the overall deformation value of the antenna is reduced in Figure 4 (a), the maximum deformation value of the antenna reflector is 19.183mm, the minimum deformation value of the antenna is 0mm, the most central center of the antenna reflector is basically no deformation, the deformation of the reflective surface is radial, and the deformation of the reflective surface reaches the maximum at the outermost edge. The deformation of the antenna back frame is mainly concentrated at the outermost edge beam, which is also the largest deformation of the entire structure.

Table 3: Gravity deformation value (mm) of different backframes

No.	Umbrella back frame	Double layer back frame
1	17.919	18.142
2	15.9218	16.326
3	13.937	14.111
4	11.946	12.095
5	9.19547	10.079
6	7.9638	8.0632
7	5.9728	6.0474
8	3.9819	4.0316
9	1.9909	2.0158
…	…	…
average value	8.882867	9.0911



a) double-deck backframe b) the umbrella backframe

Figure 4: The antenna adopts a quarter model of an umbrella-shaped

Combined with the data of Table 3, it can be seen that when using the carbon fiber material reflective surface and the aluminum alloy backframe and the honeycomb core layer structure, the overall deformation value of the antenna reflector is small when using the double-layer backframe, and the deformation of the antenna reflective surface is radial, compared with the umbrella-shaped backframe, the deformation of the antenna reflective surface of the double-layer backframe is less balanced, and the possibility of local large deformation is large.

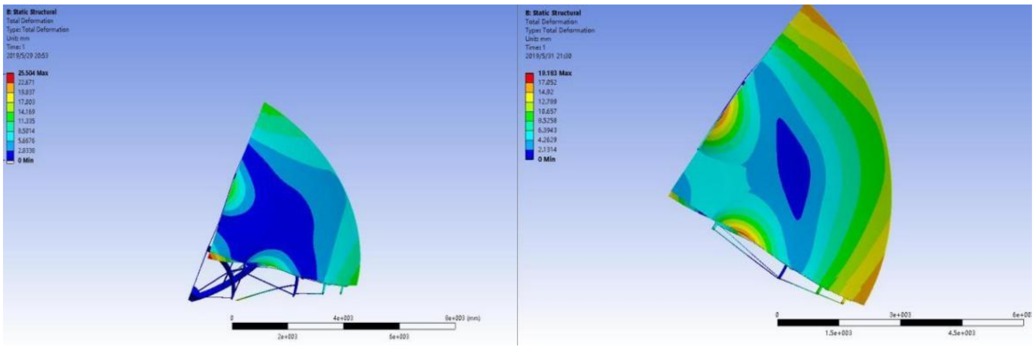


Figure 5: Group A antenna deformation cloud image of double-layer backframe and the umbrella-shaped back frame

Figure 5(a) and 5(b) are simulated cloud diagrams of Group B, and Table 4 is a summary of the values. Figure 5 (a) can be seen that the overall deformation value of the antenna is small, the maximum deformation value of the antenna is 17.919mm, the minimum deformation value is 0mm, the radial distribution is radial and the deformation of the antenna reflective surface is uneven, and the maximum deformation value appears in the outermost ring of the back frame. As shown in Figure 5(b), the overall deformation value of the antenna is low when the umbrella-shaped back frame is used, the maximum deformation value is 18.412mm, and the minimum deformation value of the antenna reflector is 0mm. There is basically no deformation in the middle of the antenna reflective surface, and the deformation in the outermost antenna reflective surface is the maximum value. In the entire antenna structure, the outer edge beam of the antenna back frame is the maximum deformation.

Combined with Table 4, it can be concluded that under the premise that the reflective surface is aluminm alloy, the back frame is structural steel and the reflective surface structure of the honeycomb core, when using the double-layer backframe, the deformation value of the antenna reflector is low, and the overall deformation of the antenna reflector is small. However, when using a double-layer backframe, the deformation value of the antenna reflective surface is unbalanced compared to the latter, which will have a certain impact on the accuracy of the antenna reflective surface

Table 4: Gravity deformation values of antennas in group B

No.	Umbrella back frame	Double layer back frame
1	25.504	19.183
2	22.671	17.152
3	19.837	14.92
4	17.003	12.789
5	14.169	10.657
6	11.335	8.5258
7	8.5014	6.3943
8	5.6676	4.2629
9	2.8338	2.1314
…	…	…
average value	12.75218	9.60154

Based on the above simulation results, comparing the gravity deformation cloud map and the average deformation amount, it can be obtained:

The skin of the reflective surface is made of aluminum alloy material, and the back frame is structural steel material: 1) When the antenna adopts a double-layer back frame, the deformation of the reflective surface of the antenna is consistent with the actual working conditions, which proves that the finite element model in this paper is accurate. 2) The maximum deformation of the antenna reflective surface occurs on the outer edge of the antenna reflective surface, the middle deformation of the antenna reflective surface is the smallest, the innermost ring of the antenna has greater deformation and upturned deformation, and the overall reflective surface deformation is unbalanced. 3) Compared with the umbrella-shaped back frame, the possibility of local large deformation increases, which has a greater impact on the accuracy of the antenna reflective surface, and the rms value of the reflective surface deformation becomes larger, resulting in the antenna accuracy being affected, so it is recommended to use the umbrella-shaped back frame.

The reflector surface skin is made of carbon fiber composite material, and the back frame is aluminum alloy material: 1) When using carbon fiber composite material, the antenna reflector deformation is large, because although the carbon fiber material itself is low in density and light in weight, it will be seriously deformed if the bearing capacity is not enough to make the back frame. However, the back frame takes both sides and the umbrella shape has less impact on the deformation of the antenna, and the deformation of the two structures is close.

4. Conclusion

Based on the deformation analysis and structural optimization project of the 10-meter aperture large reflective surface antenna, this paper modeled the reflective surface antenna through the three-dimensional mapping software Soildworks and performed a static analysis of the reflective surface antenna using the finite element analysis software ANSYS, and compared the two backframe structures and the two skin structures in the 10-meter reflective surface antenna only considering the advantages and disadvantages of gravity deformation, because the deformation caused by self-weight is an important factor in the deformation of the reflective surface antenna, so the backframe structure is optimized on the basis of this paper. Get an improved backframe structure that provides effective guidance for practical engineering. Next, the factors of heat should be further considered, and the influence of the honeycomb core layer on the thermal deformation of the reflective surface should be analyzed in depth.

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