Research on composite material in RMS control of antenna

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Abstract. In this paper, the main factors of the deformation of composite satellite antenna reflector are analyzed, and the related basic research work is carried out from two aspects of tooling material selection, structural design and product main material selection. The conclusion can be used to guide the follow-up work, and also provide ideas and basis for high-precision antenna.

1. Preface
Carbon fiber composite has been widely used in Aerospace Satellite Antenna because of its excellent lightweight, high-strength characteristics and dimensional stability. With the development of satellite manufacturing technology, the accuracy level of composite antenna is higher and higher. For the antenna with large size and high profile accuracy, it is an urgent task to control the deformation of composite components. In this paper, the main factors affecting the profile accuracy of a satellite composite antenna reflector are analyzed based on the structural type and characteristics of the antenna reflector, and some basic research work is carried out from two aspects of tooling material selection, structural design and product material selection, in order to reduce the deformation. The deformation of composite components and the improvement of antenna profile accuracy are proposed[1].

2. Product structure
The reflector of a star composite antenna is irregularly shaped, and the reflector is shaped. The projection aperture of the reflector is 1200mm (in the xoy plane of the antenna design coordinate system), and the reflector offset is 843.33mm, Reflector focal length: F = 960mm. It is composed of inner and outer carbon fiber skin and porous aluminum honeycomb sandwich. The skin material is carbon fiber prepreg with high modulus (p9051f-7 fiber), which is a medium temperature curing epoxy resin (curing temperature is about 130℃). The honeycomb sandwich structure belt of the whole reflector is cemented in the way of [0°/+ 45°/- 45°/90°/c7.5] s, with four layers in total. See Figure 1 for the structure[2].

Figure 1 product structure of antenna bare surface
2.1 Test scheme design
For composite antenna, there are many factors that affect its deformation, forming process method, curing process parameters and so on. This paper will focus on the analysis and discussion of the influence of the material and structure design of forming tooling and the selection of main materials of products on the accuracy of antenna profile.

2.2 Material selection and structure design of forming tooling
The commonly used materials for composite molding tooling are steel (thermal expansion coefficient $11 \times 10^{-6} \degree C^{-1}$), aluminum (thermal expansion coefficient $23 \times 10^{-6} \degree C^{-1}$), cast iron (thermal expansion coefficient $10.8 \times 10^{-6} \degree C^{-1}$), etc. In view of the large difference in thermal expansion coefficient between metal materials and carbon fiber composite products (thermal expansion coefficient less than $1 \times 10^{-6} \degree C^{-1}$), therefore, in the past, we chose cast iron with comprehensive consideration of performance and cost factors Material used as tooling. However, with the increase of antenna size, the increase of shaping degree and the improvement of profile accuracy requirements, the composite materials with high price but very close thermal expansion coefficient to the product materials as tooling materials have been mentioned above the discussion et process. In the development process, we selected 1.2 m shaped antenna for test, and processed 2 sets of forming tooling at the same time, 1 set is ball milled cast iron tooling processed by five coordinate CNC milling machine, and 1 set is carbon fiber composite tooling processed by imported materials. The processing method of the composite tooling is first to process the transition die by numerical control, and then to turn over the composite forming die based on it. Through the test, the influence degree of different thermal expansion coefficient of tooling on product profile accuracy is determined, and the influence rule of composite tooling transfer error on product profile accuracy is found out.

In addition, the heat capacity and heat conduction of the tooling are mainly considered in the design of the tooling structure, which are related to the temperature gradient formed on the two surfaces (the profiling surface and the backing bag surface) during the curing of the composite parts, so the final deformation of the composite parts is greatly affected[3].

2.3 Selection of main materials
At present, the unidirectional epoxy prepreg belt is selected for the antenna reflector skin. Due to the thermal stress generated during the curing process, the composite parts are more or less deformed. When using the material, it is very important to analyze the curing process parameters, especially the influence of curing temperature and post-treatment temperature on the deformation of the composite, but this is not the focus of this paper. We want to think about and solve the problem of antenna deformation from another angle. At present, a new material and new technology have been used abroad to solve this problem. As a technical reserve, we have introduced this kind of low-temperature curing high modulus carbon fiber prepreg (p9051f-7 fiber) from abroad. Its initial curing temperature is 50-80 °C, and then post-treatment is carried out at high temperature. We still take the 1.2m antenna as the test object, use the material and raw materials for forming comparative test, verify the contribution of different materials of curing system to product deformation, and study the relationship between different initial curing temperature, different post-treatment temperature and deformation[4].

3. Test purpose
1) Select the same antenna product, use different materials (cast iron, carbon fiber composite material) tooling, use the same process method to verify the impact of tooling on the accuracy of antenna profile.
2) Select the same antenna product, use the main materials with different curing temperature, use the same tooling and process method to verify the influence of the main materials on the accuracy of the antenna profile.
4. Test tooling and materials

(1) Tooling
For cast iron tooling and carbon fiber composite tooling, see Figure 2 for the structure.

![Figure 2 Schematic diagram of test tooling structure](image)

(2) Materials
Material 1: high modulus epoxy prepreg unidirectional tape (p9051f-7) cured at medium temperature;
Material 2: low temperature curing high modulus epoxy prepreg unidirectional tape (p9051f-7).

5. Test content
1) The accuracy test of antenna metal tooling surface;
2) The accuracy test of antenna composite tooling surface;
3) In the metal tooling, the antenna is processed with p9051f-7 epoxy prepreg unidirectional tape (material 1), and the profile accuracy of the antenna is tested;
4) In the composite tooling, the medium temperature curing p9051f-7 epoxy prepreg unidirectional tape (material 1) is used to machine the antenna, and the accuracy of the antenna profile is tested;
5) The antenna is machined on the metal tooling with p9051f-7 epoxy prepreg unidirectional tape (material 2) cured at low temperature, and the profile accuracy of the antenna is tested;
6) The antenna is processed by the low temperature curing p9051f-7 epoxy prepreg unidirectional tape (material 2) on the composite tooling, and the profile accuracy of the antenna is tested[5].

6. Test results
The profile accuracy testing equipment is a three coordinate CNC measuring machine of DEA company of Italy, with a resolution of 1um.
1) Profile accuracy test of antenna metal tooling: Profile accuracy 0.04 mm (RMS);
2) Profile accuracy test of antenna composite tooling: Profile accuracy 0.104mm (RMS);
3) In the metal tooling, the medium temperature curing unidirectional belt is used to process the antenna. The main curing process parameters are as follows:
   At the first stage of temperature (85±5)°C, it is kept for 30 min; at the second stage of temperature (135±5)°C, it is kept for 90-120 min;
   Curing pressure (0.3±0.02) MPa; Antenna profile accuracy is 0.198mm (RMS). Note: add 0.158mm (RMS) to tooling profile accuracy, i.e. increase 395mm (RMS).
4) In the composite tooling, the antenna is processed with the medium temperature curing unidirectional belt: Antenna profile accuracy is 0.195mm (RMS) (676 test points). Note: increase 0.091mm (RMS) in tooling profile accuracy, that is, increase 87.5mm (RMS).
5) Low temperature curing unidirectional band processing antenna is used for metal tooling, and the main curing process parameters are as follows: The initial curing temperature is (55±2) °C; the curing time is 24 hours; the curing pressure is (0.15± 0.02) MPa; the post-treatment curing temperature is (180±5) °C; the post-treatment time is 3 hours; the whole process of post-treatment is vacuumized over + 0.08 MPa.
Antenna profile accuracy 0.11 mm (RMS) Note: add 0.07 mm (RMS) to tooling profile accuracy, that is, add 175 mm (RMS)).

6) Use ltm45-l material to process antenna on composite tooling:Antenna profile accuracy 0.11 mm (RMS) Note: add 0.006 mm (RMS) to tooling profile accuracy, that is, add 5.8 mm (RMS).

![Figure 3 Influence of tooling and materials on profile accuracy](image)

7. **Conclusion**

Through the above test work and analysis of the test results, the following conclusions can be drawn:

1) The use of composite tooling can effectively reduce the deformation of composite antenna reflector and improve the profile accuracy.

2) The main material solidified at low temperature has obvious effect on controlling product deformation.

3) If composite tooling and low-temperature curing main material are combined, it is the most effective to improve the product profile accuracy, which is almost the same as tooling.

4) Due to lack of experience, the profile accuracy of the processed composite tooling itself is not high, only 0.104 mm (RMS). Further improvement of the profile accuracy of composite tooling is needed to give full play to the advantages of composite tooling in antenna products, especially in large-scale and high-precision antenna processing.

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