Development of submicron high precision CFRP reflector

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Abstract—**Antenna gain affected by reflector surface figure accuracy and dimension stability directly, so one of the most important tasks is how to ensure the surface precision and dimensional stability. It is hard to control surface precision for springback of metal, so carbon fibre reinforced polymer (CFRP) usually be adopted to fabricate high precision reflector. With the rapid development of electronic technology, especially millimetre and terahertz wave technology, the precision of reflector needed increasingly. A Φ300mm CFRP flat reflector is developed for process study. In order to improve the thermal stability, a special "all CFRP" structure adopted. Optical replica process used to realize surface modification of CFRP reflector blank, final surface figure accuracy RMS reaching 0.1 μm, and roughness Ra reaching 2nm. Further thermal stability tests show that the thermal stability reaching 13nm/℃. A Φ500mm CFRP aspherical reflector also fabricated, and surface accuracy reaching 0.4 μm. The study is of certain reference value for the development of CFRP reflector in millimetre wave and terahertz wave band.**

INTRODUCTION

Due to the low density, high stiffness, low thermal expansion coefficient, etc., carbon fibre reinforced polymer (CFRP) material usually used to fabricate space antenna reflector. With the rapid development of electronic technology, especially millimeter wave and terahertz technology, there are challenges and opportunities for carbon fibre composites industry to develop antenna reflector with higher figure accuracy [1].

90s of last century, Composite Optics Incorporated (COI) conducted a large number of sub-millimeter and even infrared reflector, including SAO, JPL, MLS, and FIRST verification mirror [2] [3]. EADS-Astrium GmbH developed a 1.1m all CFRP reflector in order to accumulate technology for PLANCK [4], and surface accuracy RMS reaches 4μm, heat distortion only 2μm within a temperature range of 140 degrees.

A Φ300mm flat and a Φ500mm aspherical CFRP reflector developed in this study. The figure accuracy RMS is superior to 0.1 μm, the thermal stability reaches 13nm/℃.The work is of certain reference value for high precision reflector fabrication.

PROCESS FLOW OF CFRP REFLECTOR

CFRP reflector comprises a front panel, back panel and meshgrid reinforced structure, and the same CFRP material system choice for the three parts. Taking into account the in-plane isotropic and process convenience, triangular meshgrid structure used.

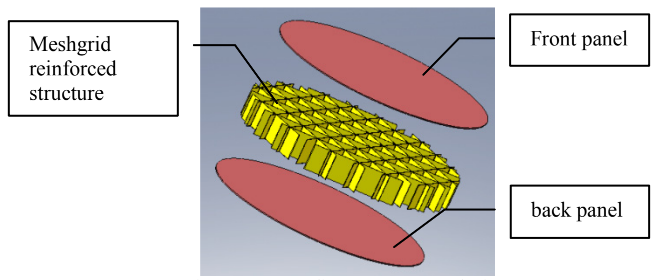

Fig. 1 CFRP reflector structure design

The process flow of high precision CFRP reflector shown in Figure 2:

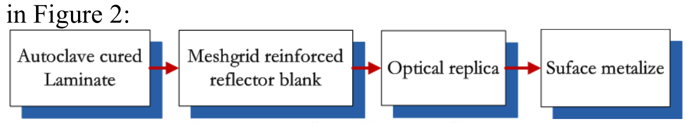

Fig. 2 Process flow of CFRP reflector

Material choice

In this study, epoxy matrix HM4J/3236 material selected to fabricate reflector, cured at 120 ℃temperature.

Autoclave moulding

In order to improve thermal stability, it requires the use of quasi-isotropic laminate. However, due to manufacture deviation of each ply, even quasi-isotropic laminate, still produces thermal deformation. So it needs to reduce thermal deformation from both ply design and manufacture deviation [5].Angle error with hand layup is about ± 2°, laminates with poor figure accuracy after autoclave curing. One automated fibre placement machine used and angle error can be controlled to ± 0.1°.

Reflector Blank

Taking into account the structure character of the CFRP laminate, the honeycomb sandwich structure is one of the most effective means to increase rigidity and thermal stability. Here a patented core structure designed with excellent thermal stability performance. The process flow of CFRP reflector blank shown in Figure 3.

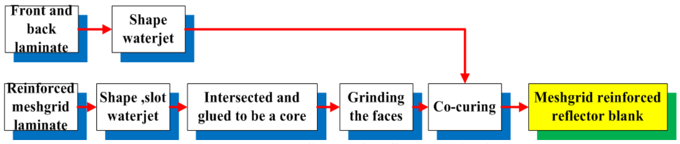

Fig. 3 Process flow of reflector blank

Optical Replica Process

Since the two-phase material properties of carbon CFRP, it can't be used as reflective surface, here the optical replication process selected for surface modification.

The main process flow of optical replication shown in Figure 4:

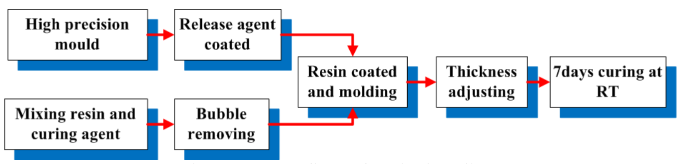

Fig. 4 Process flow of optical replica

Optical replica finished after 7 days curing at RT. Completed Φ300mm CFRP flat reflector shown in Figure 5. Figure accuracy is about 0.1μm, as shown in Figure 6, at 20.2 ℃ room temperature environment. Roughness Ra reached 2nm, completely copying the roughness of the mould.

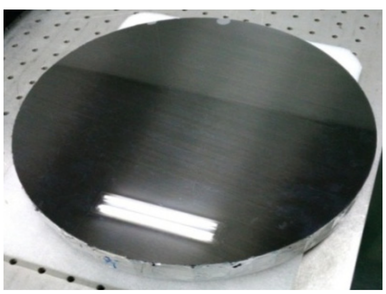

Fig. 5 Φ300mm CFRP reflector completed

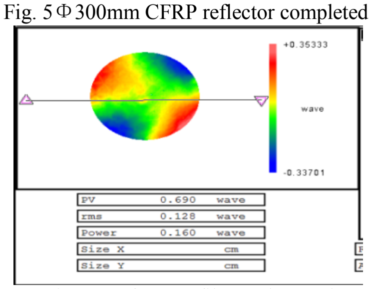

Fig. 6 Surface profile result tested

THERMAL STABILITY TEST

In order to verify thermal stability of the Φ300mm carbon fibre reflector, the laboratory temperature reduced from 20.2℃ to 11.4 ℃, surface accuracy variation shown in Figure 7.

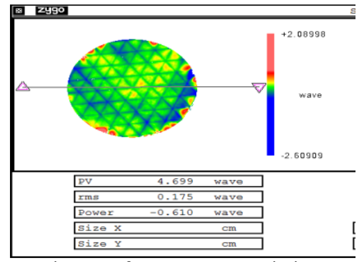

Fig. 7 surface accuracy variation

Figure 7 shows the deformation is mainly "grid effect", RMS variation 0.11 μm for 8.8 ℃ temperature difference, so its thermal stability is about 13nm/℃.

Φ500MM PARABOLIC REFLECTOR

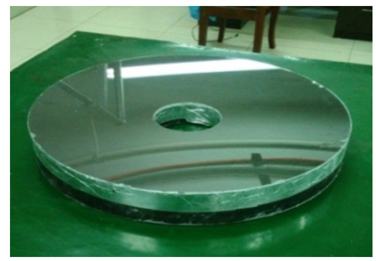

Fig. 8 Φ500mm CFRP reflector completed

A Φ500mm CFRP parabolic reflector fabricated as shown in figure 8, and the figure accuracy RMS can achieve 0.4 μm. The figure accuracy is enough for millimetre wave and terahertz application.

CONCLUSIONS

1) A Φ300mm CFRP flat reflector fabricated, Surface accuracy RMS eventually reached 0.22 μm, roughness 3nm. Thermal stability reached 13nm/℃.

2) Meshgrid reinforced reflector blank adopted. The patented cell structure improves thermal stability.

3) The optical replication process can be used to modify surface, figure accuracy downgrade existed in current replica technology, and roughness completely copied.

4) Thermal deformation of "all CFRP" reflector is mainly about "grid effect".

5) Optical replication layer is not conductive, the metalize processing needed to improve the electrical properties of the reflector.

REFERENCES

[1]Liaohui Ao. "Application of CFRP in antennas," Telecommunication Engineering , 38[2]:41-44,(1998). (in Chinese)

[2]James P.Gormican, Shel Kulick and Eldon P.Kasl. Dimensionally Stable Graphite-fiber reinforced composite mirror technology. SPIE,1993, V1945.

[3]Abdel Abusafieh Dan Federico and others.Dimensional Stability of CFRP Composite for Space Based Reflectors.Optomechanical Design and Engineering, 2001, V4444.

[4]G.Helwig. Highly Dimensional Stable Composite Structures.Workshop on advanced Materials for High precision Detectors. 1994.

[5] XU Liang, XIE Yong-jie, DING Jiao-teng, etc, "The design and optimization of carbon fiber laminates based on thermal stability and bending rigidity," Fiber Reinforced Plastics/Composites, 2, 57-61, (2016).(in Chinese)