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The method to realize the performance of FAST reflector unit

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ABSTRACT

The Five-hundred-meter Aperture Spherical radio Telescope(FAST) project locates in the mountainous region of Guizhou Province, China. Due to the huge scale of the project and the precise observation performance requirements of the telescope, the reflector unit is required to have characteristics of small quality and high precision. Due to the high humidity on the site, it is necessary to ensure that the reflective surface unit has good anti-corrosion properties. This article studies how to solve the problem of the structural performance of the reflective surface unit and its implementation method. Based on the research in this paper, the error of the surface accuracy of the reflecting surface unit is less than 2.5 mm, and the central deflection of the block constituting the unit is less than 1 mm. In addition, this type of unit has good anti-corrosion properties. This paper also proposes the method of accuracy assurance in the construction process. In the end, the research results were successfully applied to the FAST project.

Keywords: FAST project, Reflector unit, Accuracy, Anti-rust, Deflection, Aluminum alloy, Space grid structure, Adjuster

1. INTRODUCTION

Five-hundred-meter Aperture Spherical Radio Telescope (FAST) is a national major science and technology infrastructure project during the Chinese Eleventh Five-Year Plan. Its core construction content is to use a natural karst landscape in Guizhou to build an active reflector[1-2]. The 500-meter radio telescope of the lightweight feed cabin is designed to achieve astronomical observations with high sensitivities, covering 40° zenith angles. The scientific problem FAST answered was not only astronomy but also faced all humanity and nature. The site selection and early pre-research work began in 1994, and construction began on March 25, 2011. September 25, 2016 Sunset became active and lasted 22 years.

The main structure system of FAST project is an active reflector, which consists of ring beam-lattice structure, cable net structure, reflector, actuators and so on. The structure is shown in Fig. 1. As one of the three innovations, the active reflector is a 500m spherical sphere with a radius of 300m. It consists of 4450 reflective surface elements and is laid into a cable network consisting of 6670 main cables and 2225 pull down cables. The load is transferred to the supporting structure of the ring beam by 150 retractor plates on the edge of the cable net[3,4].

FAST project is located in mountainous areas of rainy season in Guizhou Province. The annual average air humidity is greater than 90%. The steel is easily rusted in the air. The reflecting surface is installed on the cable net to form reflecting surface. The reflector is about from 4m to 50m away from the ground. It is difficult to maintain after its completion. Based on the above reasons, the FAST reflector unit shall have the characteristics of good anti - corrosion performance and light weight in addition to high precision which requires that RMS should not be greater than 2.5mm.

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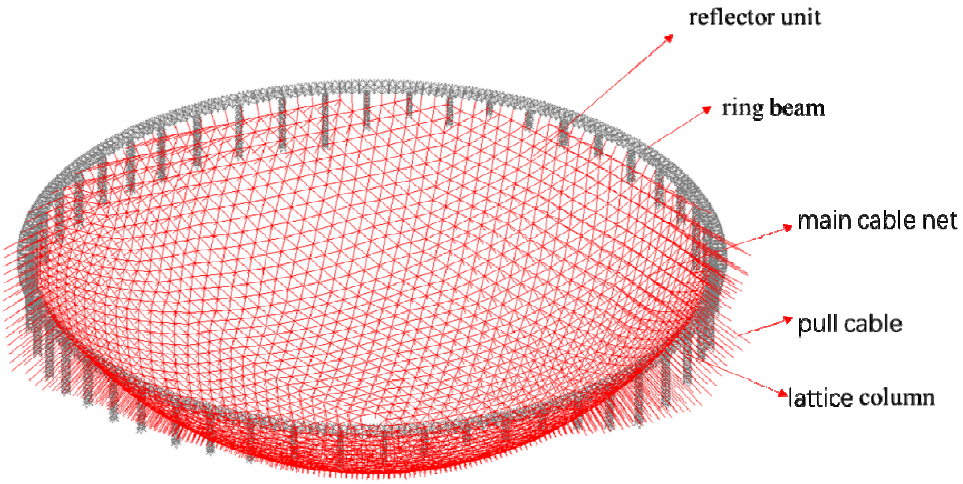


Figure 1 Reflection surface structure composition

Active transformation is an innovation point of the FAST reflector. The 300m aperture instantaneous paraboloid is formed by active control to converge electromagnetic wave. The focused electromagnetic wave is received by the receiver in the feed tank. The position of the reverse plane unit is adjusted by the traction cable of the actuator, so that the paraboloid is pointed to the view. The celestial bodies are measured by parabolic surfaces, and the celestial objects are observed through the real-time displacement on the 500m sphere crown. The schematic diagram is shown in Figure 2.

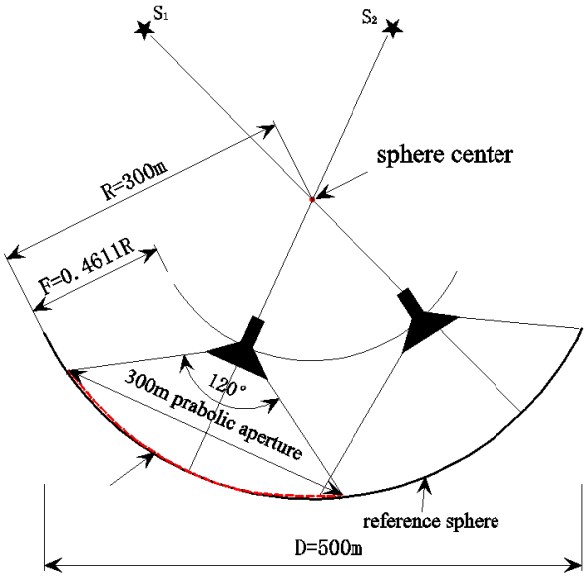


Figure 2 Observation principle diagram

In the early stage of FAST project, we have developed many kinds of elements, such as single layer steel structure reflector element, chord branch steel structure reflector element, space grid steel structure element and so on. The above units can not meet the technical requirements of the project, so each scheme is denied[5]. The main problems of various units are shown in Table 1.

Table 1 The original backup frames performance contrasts

Backup types	Reflector unit surface density (kg/m²)	Maximum displacement (mm)	RMS (mm)	Characteristics
Monolayer steel structure	10.1	12.64	2.94	Higher dead weight; Larger displacement and RMS; Easier corrosion to welded joints
String prestressed steel structure	8.21	17.52	3.89	Higher dead weight; Larger displacement and RMS; Hard to control the prestressed force of steel rod; Easier corrosion to welded joints
Steel truss structure	8.04	19.44	3.56	Higher dead weight; Larger displacement and RMS; Easier corrosion to welded joints
Steel space truss structure	9.64	3.67	1.84	Higher dead weight; Easier corrosion to welded joints

The main work of this paper is to describe the method of realizing the performance of reflector unit in the process of FAST project construction.

2. DESIGN METHOD OF REFLECTOR ELEMENT

The performance metrics required by FAST reflective surface units are mainly in the following aspects:

Radius of the reflector surface unit panel: 315m;

Panel penetration rate : ≥ 50%;

Surface accuracy: RMS ≤ 2.5 mm;

Areal density: ≤ 8.5kg;

Center deflection of sub-unit:≤1.5mm ; sub-unit gap: ≤1mm.

Aluminum alloy has good rust-proof performance, using aluminum alloy structure to solve the problem of rust-proof maintenance. The reflector element is divided into panel element and backup frame element. The backup frame element provides support for the reflector element, provides the strength and stiffness required by the reflector element, and bears the functions of the self-weight, wind, snow load and overhaul load of the reflector element. It is most reasonable to adopt the form of triple cone bolted ball space truss, and the structure is light, the members and joints are single, the size is not large, the storage, loading and unloading, transportation and assembly are convenient, which is suitable for the actual situation of the project. The frame unit is shown in the diagram. At the same time, in order to reduce the self-weight of the grid structure and the requirement of resisting atmospheric environment corrosion, the other components are made of aluminum alloy except the high-strength bolt and the fastening screw made of stainless steel. The unit model is shown in Figure 3. The length of the triangular element is about 11 m.The finite element is used to calculate the element. The calculation of the orifice reflector element is shown in figs. 4.

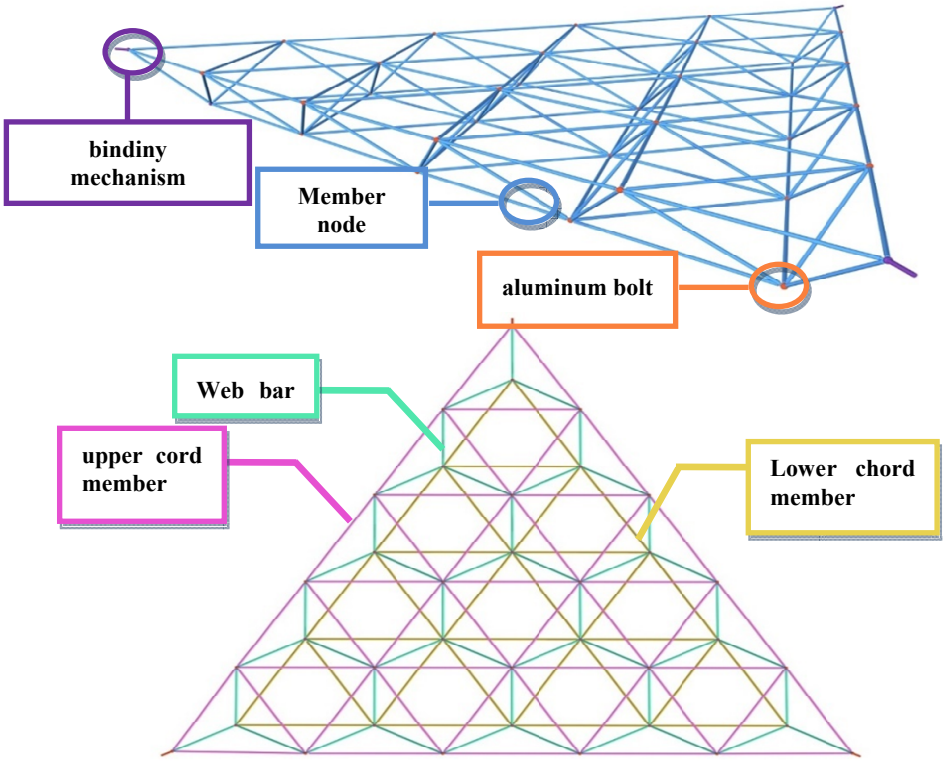
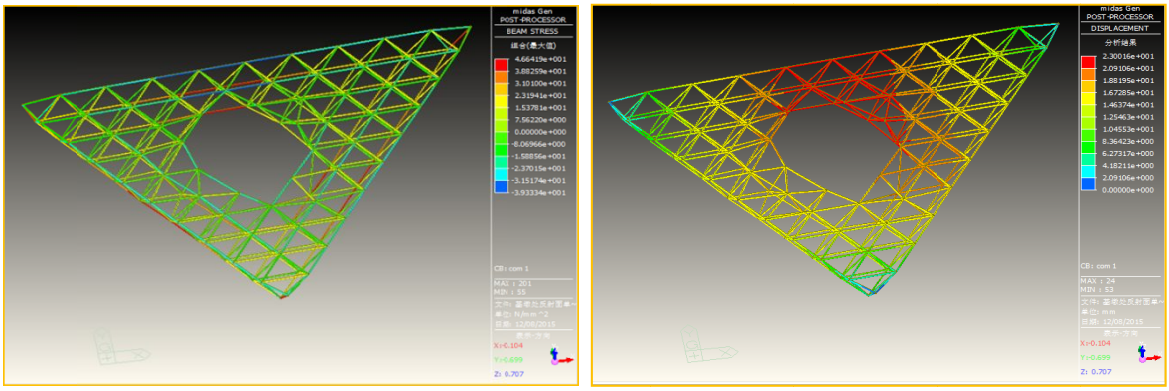


Figure 3 Design of back frame Unit



(a)stress (b) displacement

Figure 4 Calculation of orifice element

The calculation results show that the displacement and precision of the element meet the requirements of the reflector element, and the stress ratio of the member is less than 0.5, which satisfies the performance of the material. This design scheme can be applied to FAST engineering. The panel adopts punched aluminum plate, the punching rate is more than 50, the weight can be reduced, the sun can pass through, the vegetation in the lower part of the reflector can grow normally, and the harm of soil erosion to the telescope can be reduced.

3. MANUFACTURING PROCESS CONTROL OF REFLECTOR UNIT

The accuracy measurement of 4450 reflector units in FAST project is an important work of field assembly, and the workload is enormous. This scheme adopts the automatic intelligent photogrammetry system, the whole process of measurement and data processing is controlled by computer program, the photos are sent to the calculation software by wireless transmission device, the coding mark is automatically recognized, the code mark of the reference scale is coded, the picture is transmitted to the calculation software by the wireless transmission device, The reflection mark of measuring points can automatically eliminate gross error, and the orientation, matching and adjustment of photographic images can be automatically completed by automatic measuring software, and the 3D coordinates of each characteristic point, the accuracy of the unit surface shape of the reflector and the error value of adjusting points are calculated. Guide the adjustment of the surface shape accuracy of the reflector unit. Measurement and data processing processes do not require human intervention, the measurement scheme is fully automated, intelligent and efficient. The image acquisition time of the system can be completed in 6 min, the calculation time is better than 2 mins, the measuring time of each reflector unit is better than 10 mins, and the measuring accuracy can reach 0.135 mm.

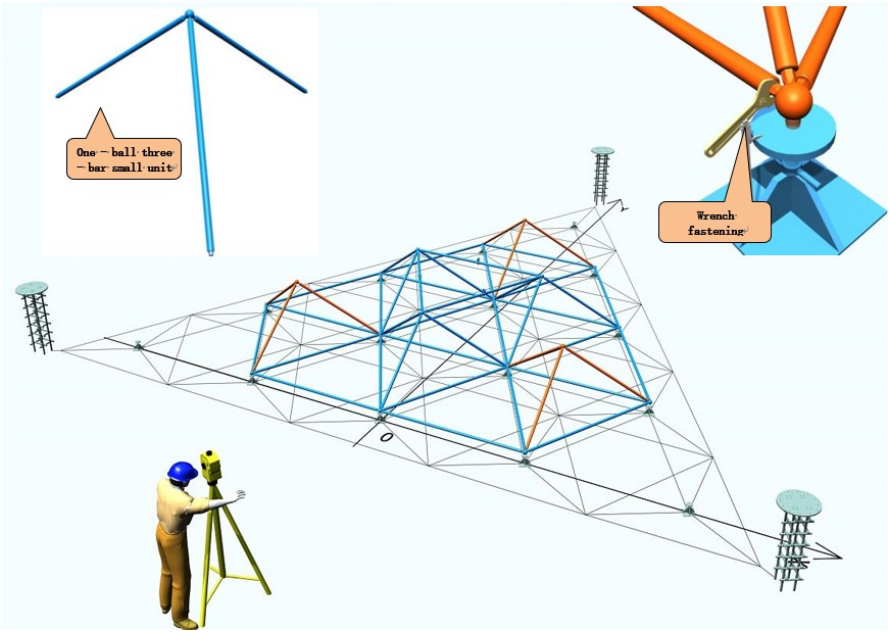


Figure 5 Field installation measurement control method

The detailed procedure is described below:1) according to the diffusion of the lower string assembly, assemble the upper "one ball three bar" small unit. The connection between the web rod and the upper string bolt should be tightened once, and the connection between the web rod and the lower string bolt should not be tightened first. The lower string bolted ball and the lower chord are diffused to three angles to assemble 3) according to the diffusion of the lower string, the upper small unit is assembled. When assembling, we should avoid the shift of chord components and use total station to track and monitor. Tighten with a rubber wrench to avoid damage to the oxide film. After the assembly is completed, the aluminum back frame joint, the connecting hole position of the bar and the corner part shall be inspected after unloading, and the aluminum back frame joint, the connecting hole position of the bar and the corner part shall be inspected, and the special automatic photogrammetry equipment shall be used to measure the aluminum back frame joint, the connecting hole position of the bar and the corner part, etc. Check if the underside deflection meets the design requirements.

4. CONCLUSION

According to the method provided in this paper, the technical requirements of FAST engineering reflector unit are realized, and the reflector is successfully constructed. This paper mainly solves the following problems:

1). The weight of the reflector element is reduced and the load of the cable net structure is reduced, which guarantees the reliability of the cable network in the operation of FAST.

2). The design scheme and manufacturing process ensure the accuracy of the plane shape and meet the performance requirements of the telescope reflector.

3). The aluminum alloy structure has good antirust performance, and eliminates the anticorrosion and maintenance of the reflector during the operation of the telescope.

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