Chin. J. Astron. Astrophys. Vol. 6 (2006), **Suppl. 2**, 329–332
(*http://www.chjaa.org*)

Chinese Journal of
Astronomy and
Astrophysics

A Self-Adaptive Connector for Active Main Spherical Reflector of FAST

Yi Chen[1,2], Yuan-Gen Qu[1] and Jia-Ning Wang[1]

[1] National Astronomical Observatories / NIAOT Chinese Academy of Sciences, Nanjing 210042
[2] Graduate School of Chinese Academy of Sciences

Abstract A new kind of position control system for basic elements of sphere is introduced in the paper. Based on mechanical principle, structure analysis is made for the control system, which proved that it meets special need of the position control system of FAST (Five-hundred-meter Aperture Spherical Telescope). In addition, kinematics analysis is made for the compensation fit of the system and compensating size is calculated. Lastly, some results of experiment are given.

Key words: techniques: radio astronomy — methods: analytical

1 INTRODUCTION

Astronomers reached unanimity at the 24th URSI Conference in Kyoto, Japan, in 1993, and proposed to construct the next generation of large radio telescope (LT) (Nan et al. 2000). From then on, astronomers of China have begun a project of FAST as the prototype of the LT (Qiu 1998; Peng et al. 2000). In the FAST, the main spherical reflector is divided into more than 1800 identical hexagons units with sides ∼7.5 m long. Each units has a spherical surface with a radius of $R = 300\,$m, and mounted on a mechanism with three degrees of freedom and can be set to a given position in each coordinate. It is one of the key techniques in FAST.

The illuminated part of the main spherical reflector is to be continuously adjusted to fit a paraboloid of revolution in real time by actuated active control, synchronous with the motion of the feed while tracking a radio source (Qiu 1998). Each element has three actuators to fix its position and connect it with adjacent elements, and there would be an average of one actuator per element. The support with its actuator is directed towards the center of the sphere. It is well know that the distance between two points on the new formed paraboloid of revolution is shorter than that on original sphere. So the length and angle between two joints on actuator and back structure of unit should be changed. In our case, the movement of unit is 670 mm (Qiu 1998) along the normal of sphere and the distance between two actuator is 12.5 m. The changes are 3.1 degrees and 35 mm. The frame of actuator is on the ground but the back structure of unit is a rigid body. So the joint on actuator and back structure must be a special joint which can compensate the above changes. A new parallel mechanism is designed and can be used for the purpose of compensation.

2 THE PRINCIPLE OF MECHANISMS

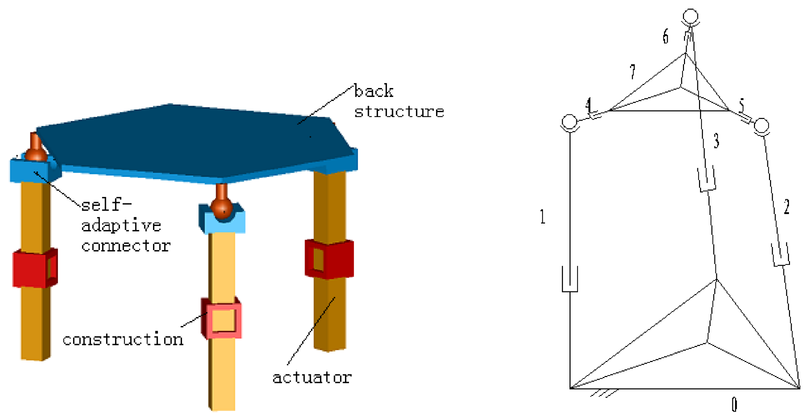
Figure 1 shows the motion principle of this mechanism. The support with its actuator is directed towards the center of the sphere. Actually, it is a 3-PSP parallel space mechanism consisting of eight components, including three spherical and six slides. Among the eight components, there are three initial component (No1, No2, No3) and one frame. According to Kutzbach grubler formula:

$$M = 6(n - g - 1) + \sum_{i=1}^{g} f_i \,, \tag{1}$$

⋆ E-mail: ychen@niaot.ac.cn

where M is the number of degrees of freedom in the space mechanism, n the number of links in the space mechanism including the ground link and g the number of joints having n degrees of freedom each. f_i is the i link's degrees of freedom. $M = 6\times$(8–9–1)+(3×3+1×3+1×3)=3.

The freedom of this mechanism is 3, the same value as the number of initial link, because all links of No1, No2 and No3 are initial links. Therefore, the motion of this mechanism was completely controlled. In other words, three actuators can control the position of unit, at the same time it provide automatically compensation of the change of length and angle between the joint of supporting point and reflector back structure caused by new-formed paraboloid.



(a) (b)

Fig. 1 Mechanistic principle.

3 CALCULATING THE VALUE OF COMPENSATION

We can calculate the value of maximum compensation when the actuator moved to the terminal station. Figure 2 shows four positions of the actuator. Figure 2a shows three actuators (A_1, A_2, A_3) at origination position. Figure 2b shows one actuator (A_1) rises to the highest position and the other two actuators (A_2, A_3) at origination position. Figure 2c shows two actuators (A_1, A_2) rises to the highest position and the other actuator (A_3) at origination position. Figure 2d shows three actuators (A_1, A_2, A_3) rises to the highest position. The movement of unit is 700 mm along the normal of sphere and the distance between two actuator is 12.99 m.

From Figure 2b, at $\triangle A_2A_1A_1'$, A_2A_1= 11250 mm, A_1A_1'=700 mm. $\angle A_2A_1A_1'$= 90°–$\arcsin(7.5/300)$ = 88.57°

$$A_2A_1{}' = \sqrt{A_2A_1{}^2 + A_1A_1{}'^2 - 2A_2A_1 \times A_1A_1{}' \times \cos\angle A_2A_1A_1{}'} \qquad (2)$$

A_2A_1'= 11254.3 mm, A_2A_1–A_2A_1'= –4.3 mm.

$$A_1A_1{}'/\sin\alpha = A_2A_1{}'/\sin\angle A_2A_1A_1{}', \qquad (3)$$

$\alpha = 3.57°$. From Figure 2c, $A_1'A_2' = A_1A_2\times 299.3/300 = 12.99\times 299.3/300 = 12.96$ (m) A_1A_2–$A_1'A_2'$= $12990 - 12960 = 30$ (mm) From Figure 2d, A_1A_2–$A_1'A_2'$= $12990 - 12960 = 30$ (mm) A_2A_3–$A_2'A_3'$= $12990 - 12960 = 30$ (mm) A_3A_1–$A_3'A_1'$= $12990 - 12960 = 30$ (mm).

So the value of maximum compensation are 3.57 °and 30 mm.

4 EXPERIMENT AND RESULTS

As a key of FAST's pre-research, a 1:3 scale model of active main reflector has been built, the parallel mechanism is used in model. To reduce the tear and wear, the compensating joint is actually composed of a line motion joint and a spherical. Figure 3 shows the precision of actuators have been test. The result shows in Table 1.

Table 1 Restoration Deviation of Zero Position in Actuator

Test point	Starting position (m)			Actuator rose 240 mm and came back (m)			Error (mm)		
	X (m)	Y (m)	Z (m)	X (m)	Y (m)	Z (m)	ΔX	ΔY	ΔZ
A	3.826	13.204	–3.782	3.826	13.205	–3.782	1	0	0
A_1	3.956	13.325	–3.575	3.956	13.325	–3.576	0	0	1
B	2.662	16.585	–1.619	2.661	16.585	–1.619	0	1	0
B_1	2.907	16.487	–1.549	2.907	16.487	–1.549	0	0	0
C	6.826	16.235	–2.590	6.826	16.235	–2.589	0	0	1
C_1	6.643	15.951	–2.537	6.643	15.950	–2.537	1	0	0

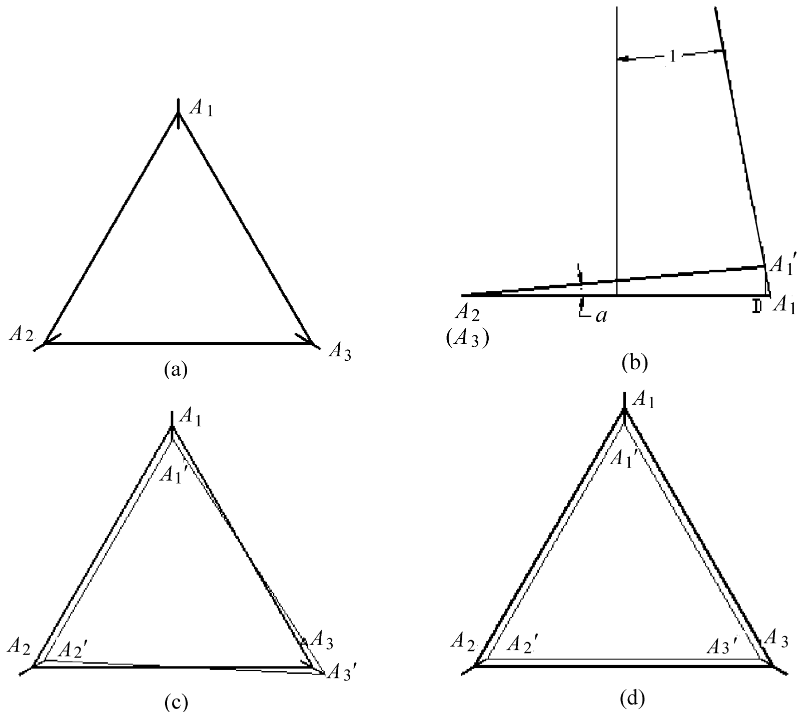


Fig. 2 Utmost position of the actuator.

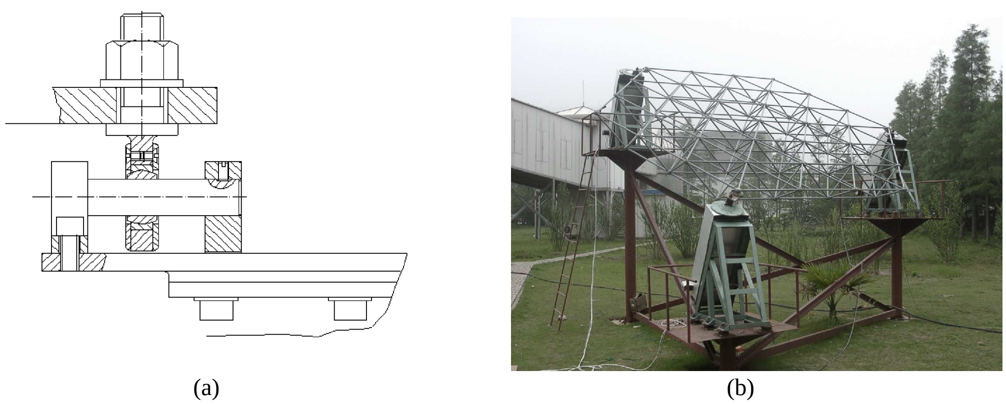


Fig. 3 Structure of self-adaptive connector and the picture of 1:3 scale model.

5 CONCLUSIONS

The self-adaptive connector is a key of FAST's active main spherical reflector. The structure of self-adaptive connector is very simple, which will effectively reduce the cost of the main spherical reflector. Modeling experiments results show that the actuator can adjustment the position of the back structure with millimeter precision.

Acknowledgements This work is supported by the Fund of Large Radio Telescope Laboratory, National Astronomical Observatories,Chinese Academy of Sciences (No. Fast—A-07).

References

Nan R. D., Peng B., 2000, Acta Astronautica, 46, 667
Qiu Y. H., 1998, MNRAS, 301, 827
Su Y., Zheng Y., Peng B., 1999, in Chen P. S., eds., the Proc. of the 4th EAMA, Publisher: Yunnan Observatory, Chinese Academy of Sciences, ASP, 94