Modeling and Simulation of a 6-DOF Parallel Platform for Telescope Secondary Mirror

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ABSTRACT

The 6-DOF parallel platform in this paper is a kind of Stewart platform. It can be used as supporting structure for telescope secondary mirror. In order to adapt the special dynamic environment of the telescope secondary mirror and to be installed in extremely narrow space, a unique parallel platform is designed. PSS Stewart platform and SPS Stewart platform are analyzed and compared. Then the PSS Stewart platform is chosen for detailed design. The virtual prototyping model of the parallel platform is built. The model is used for the analysis and calculation of multi-body dynamics. With the help of ANSYS, the finite element model of the platform is built and then the analysis is performed. According to the above analysis the experimental prototype of the platform is built.

Keywords: parallel platform; Stewart ; telescope secondary mirror ; FEM; multi-body dynamics

1. INTRODUCTION

In1965, D.Stewart put forward a concept of a special mechanism which was named Stewart platform. The Stewart platform is a parallel mechanism which consists of a moving platform, a fixed base and six limbs. The main features of the Stewart platform is that the moving platform has six degrees of freedom. The Stewart platform has several advantages which are listed as follows:

1) simple structure. The Stewart platform can be comprised of general component such as ball screw, spherical hinge, guide etc.

2) high specific stiffness. The closed loop structures of the parallel mechanism form frame with high specific stiffness.

3) non-cumulative error. The errors of kinematic pair, hinge and drive in one limb don't cumulate to other limb. The accuracy of moving platform is influenced by all limbs.

The size and weight of the Stewart platform are restricted when it is used for supporting system of secondary mirror for telescope. The maximum allowed radial dimension of the platform must be less than the diameter of secondary mirror. The axial dimension and the weight of the platform are restricted by the stiffness of the telescope wing and serrurier truss. A reasonable design should solve these contradictory.

Ground-based and Airborne Telescopes V, edited by Larry M. Stepp, Roberto Gilmozzi,
Helen J. Hall, Proc. of SPIE Vol. 9145, 91452P • © 2014 SPIE
CCC code: 0277-786X/14/$18 • doi: 10.1117/12.2055856

2、THE COMPARE OF SPS PLATFORM AND PSS PLATFORM

According to the different arrangement of kinematic pair and hinge, there are two kinds of 6-DOF parallel platform on the principle of machinery（figure 1）.

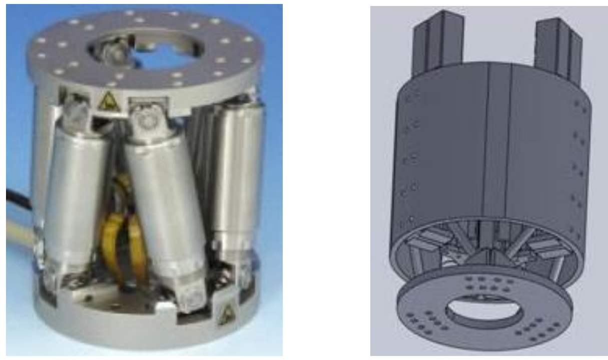

figure1. SPS hexapod(left) and PSS hexapod(right)

The feature of SPS platform is that the length of the six limbs can be changed and the feature of PSS platform is that the six rigid limbs slid on guide. Comparing two different parallel platform ,the advantage of SPS platform is that the motion space of moving platform is bigger. But the drive force is stronger, the environment for thermal control is worse, and the change of vibration performance is more, in which the performance of the PSS platform is reverse. The most noteworthy is that the arrangement of assembly for PSS platform has a big advantage, which is useful for supporting system of secondary mirror for telescope.

According to the characteristics of telescope, the project in this paper will based on the PSS platform. The basic technical requirements of the platform are listed as follows:

The weight of load is 20kg. The maximum allowed radial dimension is 300mm. The Scope of translation along X, Y are ±3mm,and along Z is ±6mm. (Z is the axial direction of secondary mirror.)

3、 ANALYZE AND DESIGN ON DETAIL

3.1、analyze on multi-body dynamics

We layout the six limbs on down triangle when seeing secondary mirror along Z direction. In that case, when the telescope runs on all the range of altitude angle, the number of limb whose stress state changes is least. The multi-body model is built as shown in the figure2.

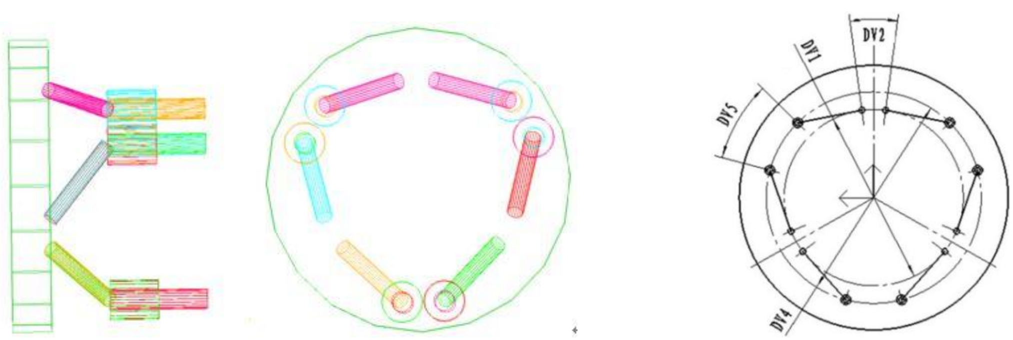

figure 2. multi-body model and parameters

A brief description of parameters is listed below:

meaning	parameter
The radius of the initial position circle of the hinge on moving platform	DV1
The inclined angle between adjacent hinge-center connecting line on moving platform	DV2
The distance between moving platform in the initial position and fixed base	DV3
The radius of the initial position circle of the hinge on fixed base	DV4
The inclined angle between two adjacent hinge-center connecting lines on fixed base	DV5

The limb force and driving force are optimized and the parameter values is listed below:

parameter name	value	parameter name	value	parameter name	value
DV1	100mm	DV3	60mm	DV5	43°
DV2	20°	DV4	120mm		

When the altitude angle (DV7) changes from 0° to 90°, the limb force and driving force are drawn in figure 3 and figure4.

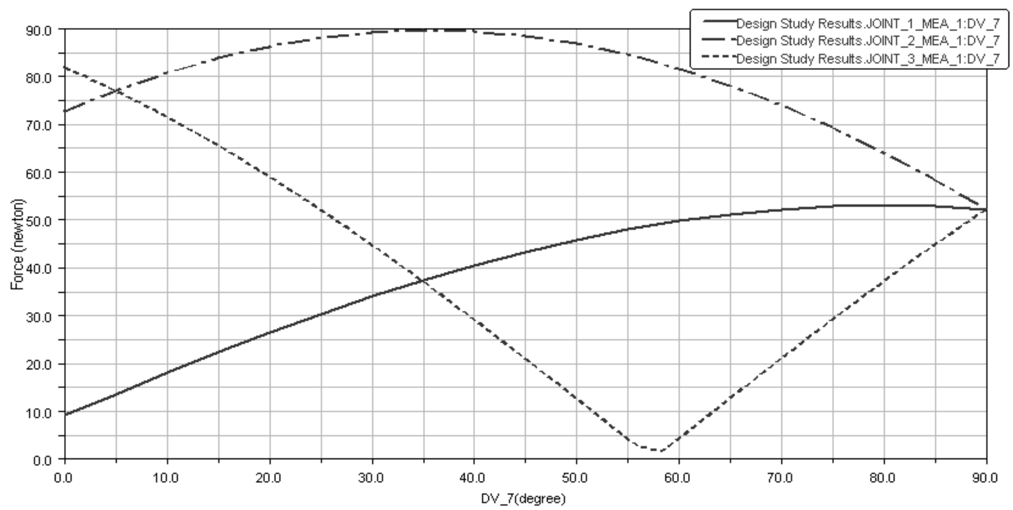

figure 3. the limb force

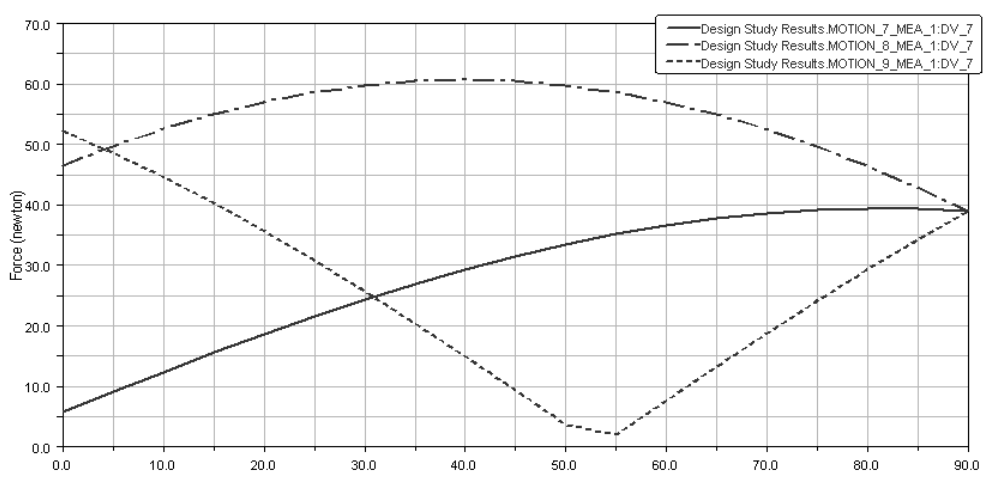

figure 4. the driving force

Here are some explanations:

1）The maximum of the limb force is 89.6N.

2）All the limb force are 53N when the altitude angle is 90°.

3）Two limbs whose stress state change when the altitude angle changes from 0° to 90°.

4）The maximum of the driving force is 60.7N.

3.2、finite element analysis of the PSS platform.

As shown in figure 5, the PSS platform for experiment is designed and more details will be introduced in the next section. The static analysis (figure 6) and modal analysis (figure 7-10) are listed below.

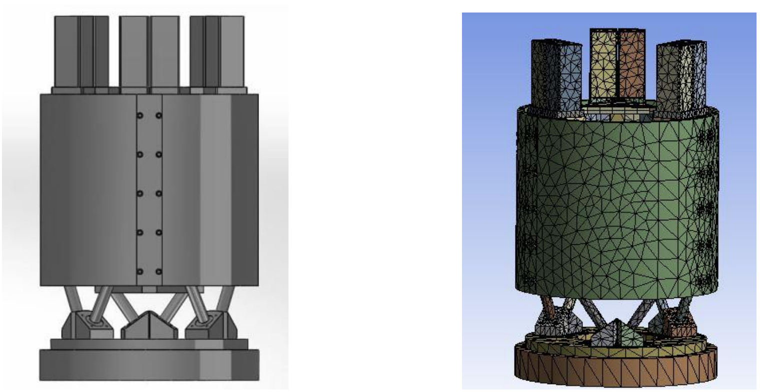

figure 5. the 3D image and the finite element grid of the PSS platform

In this paper, the finite element software ANSYS/Workbench is adopted to calculate and analyze. The 3D model is imported into ANSYS, then the model is meshed. The number of nodes is 203353 and the number of elements is 104755.

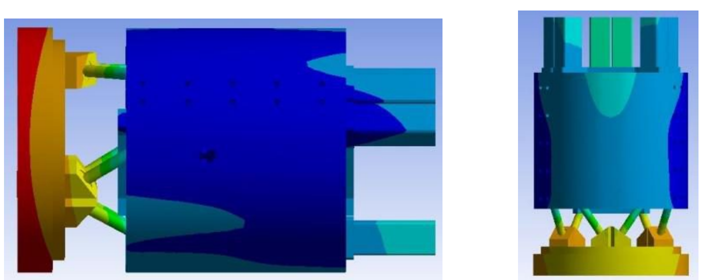

figure 6. the static deformation figure of horizontal (The maximum displacement is 2.11um, on the left surface) and vertical (The maximum displacement is 0.53um, on the undersurface).

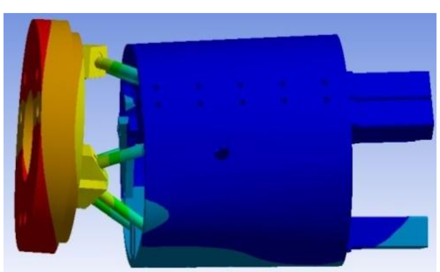

figure 7. The fundamental frequency is 363.5Hz.

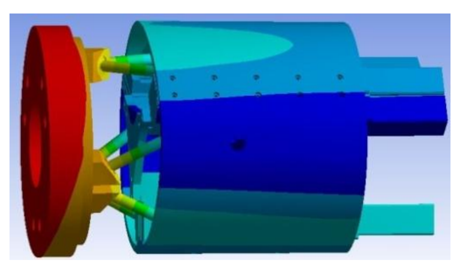

figure 8. The second frequency is 367.5 Hz.

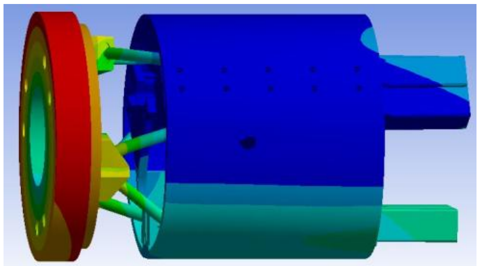

figure 9. The third frequency is 523.4Hz.

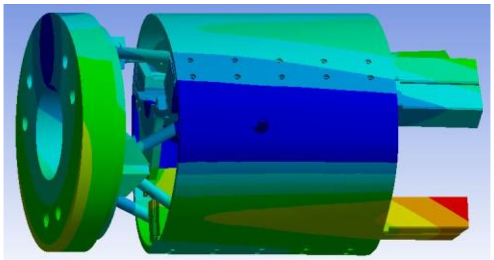

figure 10. The fourth frequency is 577.2 Hz.

3.3、the design in detail

The stiffness of the platform in every direction is needed when the platform is used for supporting system of secondary mirror of telescope. The structure is optimized for good stiffness. In the experimental device, the drives and guides are arranged along the axial direction of secondary mirror, which takes full advantage of the wide space of axial direction. As shown in figure 11,a cylinder force bearing structure is designed.

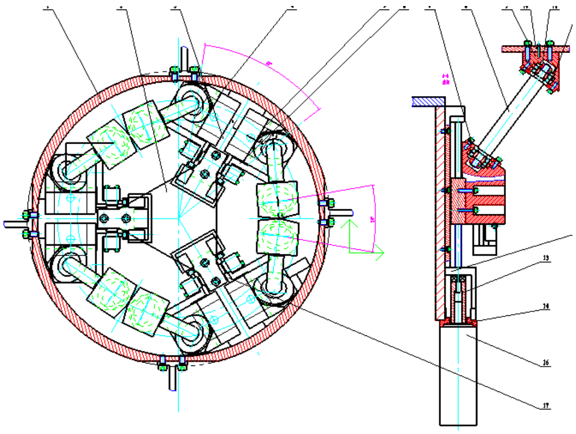

figure 11. the drawing of the PSS platform

3.4、the design of limb and spherical hinge

The length of limb can influence the distance between moving platform in the initial position and fixed base, the angle of deflection of the limb, the maximum of the driving force and the maximum of the limb force, which is listed below:

length of limb(mm)	angle of deflection (degree)	distance（mm）	max driving force(N）	max limb force(N）
94	±5	58.96	59.97	89.40
98	±4.5	65.15	64.07	90.85
103	±4	72.45	69.23	93.41
110	±3.5	82.10	76.26	97.69
121	±3	96.34	87.07	105.51
138	±2.5	116.98	103.43	118.85

The limb connect the moving platform and the fixed base with two spherical hinges, as shown in figure 12. All thing considered, the length of limb is set to 105mm. Then, the angle of deflection of the limb is $\pm 3.82°$, the distance between moving platform in the initial position and fixed base is 75.27mm, the maximum of the drive force is 71.22N, the maximum of the limb force is 94.57N.

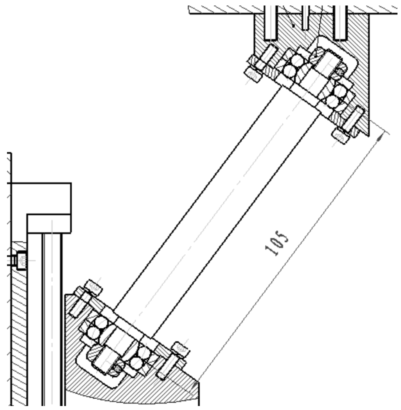

figure 12. the design of limb and spherical hinge

3.5、the 3D model and the photograph of the parallel platform

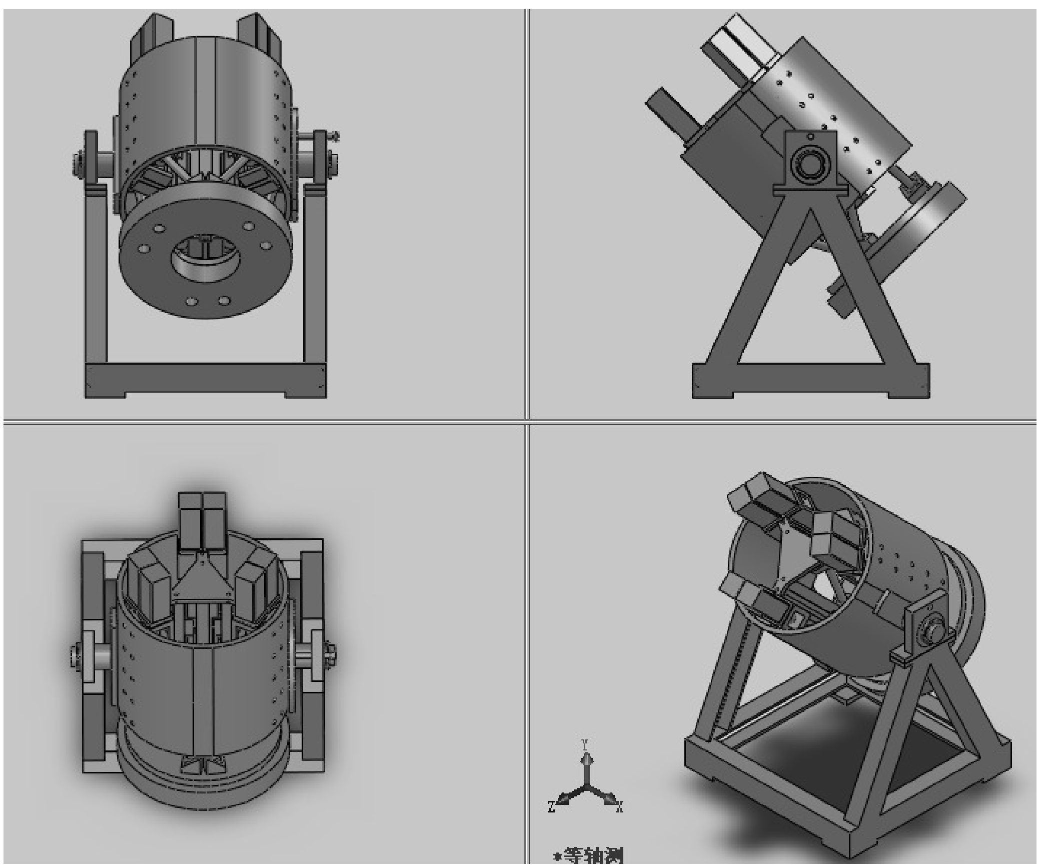

figure 13. the 3D model of the parallel platform

figure 14. the photograph of the parallel platform

4、CONCLUSIONS

The 6-DOF parallel platform in this paper is a Stewart platform, which has several advantages that make it used as supporting structure for telescope secondary mirror. The PSS Stewart platform is suitable for the experimental device in this paper. The multi-body dynamics analysis and the finite element analysis are useful for ensuring correct design. In the process of the construction of the PSS Stewart platform, inspection and test careful are necessary. Only when you take all the steps serious would the high precision arrive.

ACKNOWLEDGEMENTS

This project is supported by the Six degrees of freedom dynamic compensation mechanism, Chinese Academy of Sciences, China (Grant No.2911C09700).

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