

Study on the Deployable Sub-module of Space Solar Power Station Based on Origami

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Abstract

Due to the increasingly severe energy crisis, and the advantages of the space solar power station, such as high utilization rate of light energy, unaffected by atmospheric environment and no occupation of cultivated lands, more and more countries and institutions have studied the related technologies of the space solar power station. The concentrator of the GW level power station is large, which needs deployment and modular assembly on orbit. At present, the deployment mechanism at home and abroad cannot meet the requirements of SSPS at the spatial scale. As a result, it is urgent to carry out the innovative design and research work of SSPS large scale deployable sub-module structure. In this paper, the space solar power station is the research object, the deployable sub-module of which is studied based on the origami theory. This paper put forward a new method of sub-module splicing for spherical concentrator to determine the configuration and size of the sub-modules. Based on this, the folding method of the thin membrane and the deployment plan of the sub-module are designed. The details are as follows:

The form design of the concentrator splicing. The concentrator is designed by modularization, and a SSPS oriented deployable sub-module which can be assembled into spherical concentrator on orbit is designed. The advantages and disadvantages of various splicing methods are analyzed from the aspects of joint difficulty, surface density, stiffness and so on. According to the principle of uniform distribution and small specification, a new spherical splicing method is proposed, and the hexagonal configuration and corresponding dimensions of the sub-modules are determined.

Study on the folding method of thin membrane based on the origami theory. According to the configuration and size of the sub-module, based on the origami theory, the shape and folding mode of the film on the sub-module are studied and analyzed. First, we compare and optimize the shape of thin membrane, such as triangle, quadrilateral and hexagon, and select the scheme of high utilization, high stability and high stiffness. Comprehensive analysis shows that the performance of hexagonal thin membrane is the best in sub-module. On this basis, the folding mode of hexagonal thin membrane is studied. A comparative analysis of leaf-out fold pattern, leaf-in fold pattern, skew leaf-in fold pattern, rotationally skew fold pattern and Miura-Ori fold pattern is made, and the final selection by the deployment mechanism to drive the hexagonal corner of the membrane. The spring-mass system is applied to simulate the deployment process of the thin membrane. The membrane is divided into triangular units, and the mass of the

membrane is equivalent to the particle at the vertex of the triangle, the three length is replaced by springs. The initial spring length is the original length, and the length changes during the deployment process. Therefore, the spring has internal force, which can be used to equivalent the membrane internal force of the membrane. In the system, the particle motion under the action of spring force and external load is described by the Lagrange equation.

Design of sub-module deployment scheme. According to the shape of the membrane and the fold pattern, the expansion scheme of the sub-module is designed to achieve the high expansion ratio of the module and the high accuracy of the membrane. This paper put forward hoop truss deployable module scheme, bi-stable tape spring deployable module scheme and six prismoid shaped unit deployable module scheme. The comparison and analysis of these three deployable module schemes are carried out from the aspects of folding, deployment size and surface density, as shown in Table 1. Among them, bi-stable tape spring deployable module scheme has good synchronization, easy control, less deployment units, lighter quality and smaller surface density. The large aperture and weak stiffness of sub-module may cause many dynamic problems in the course of attitude adjustment and on-orbit splicing. The finite element model of sub-module is built by using ANSYS software. The modal analysis of member structure is carried out, and the natural frequencies and corresponding vibration modes of structure are obtained. At last, the influence of section parameters of member structure is studied, and the method to improve the first natural frequency is proposed.

Table 1: Comparison of sub-module deployment scheme

	hoop truss	bi-stable tape spring	six prismoid shaped unit
folding size /m	diameter: 4 height :0.8	diameter:3.6 height :0.6	diameter:4.6 height :0.6
deployment size /m	diameter: 50 height :2.5	diameter: 50 height :2.5	diameter: 50 height :2.35
surface density/ kg·m ⁻²	0.082	0.066	0.079