Research on Solar Power Generation Disaster Relief Tent
Based on Inflatable Structure

Bai-lin FAN¹, Mao-yuan SHI², Jia-cheng PANG², Jiang-qi WANG² and Jian-wu WANG²

¹University of Science and Technology Beijing, School of Mechanical Engineering, Beijing 100083, China
²University of Science and Technology Beijing, College of Higher Engineering, Beijing 100083, China

Keywords: Disaster relief tent, Inflatable structure, Thin film solar energy technology, Structural design, Form finding, Arch.

Abstract. The local structure of disaster relief tent was analyzed by ANSYS. The deformation of inflatable column was basically consistent with the deformation of inflatable column after expansion, and the stress at different positions was also consistent with the basic size. The optimum ratio of height to width of arch was obtained to ensure the strength and stability of arch. At the same time, the optimal ratio of long axis to short axis of ellipse with small stress and strain was obtained. The suitable size was chosen to design the overall structure of the inflatable tent. The practical number and distribution mode of solar energy film was formulated, and the solar energy film was combined with tent. Finally, the inflatable structure tent with power generation function for disaster areas was obtained.

Introduction

In earthquake disasters, clothes and other materials were needed by the victims, and tents that could shelter the wind and rain were more needed in harsh environments [1]. On May 12, 2008, a strong earthquake of magnitude 8.0 struck Wenchuan, China, requiring more than 3 million tents were erected in a few days.

"Water Cube" stadium was the largest membrane structure project in the world at present, which means that domestic research on the materials and fabrication technology of inflatable membranes has gradually matured [2]. Inflatable membrane structure had been widely used in tent field [3].

Disaster relief tents were mainly used for temporary and short-term emergency relief. Most of the fabrics used were PVC or PU coated fabrics with poor air permeability or impermeability, which had poor warmth retention, thermal insulation and air permeability. Comfort was also a difficult problem in the design of tents in disaster areas. The existing disaster relief tents were heavy and inconvenient to transport. At the same time, the construction of disaster relief tents needs cooperation of many people to complete.

Wind resistance of tents was mainly studied in the literature of new integral folding frame tent structures [4]; the feasibility of emergency tents and extension services from a spatial perspective were mainly studied in the literature of the design of emergency tents in post-disaster public space [5]; The design and research of inflatable tent [6] could reduce the difficulty of tent construction, and had the characteristics of lightness and convenient transportation.

In the early stage of disaster relief, lighting was a big problem. An inflatable tent with solar power could solve the problems of simple lighting difficulties and fast construction.

Structural Design

The inflatable structure of the tent was shown in Figure 1. Elliptical structure was adopted at the bottom and arch structure was used at the top as the tent skeleton [7]. The tent was composed of four parts: inside tent, outside tent and tent skeleton. The tent was equipped with solar power film,
and the tent had built-in USB interface. The tent outside was equipped with tent door and tent window. It was difficult to design the ellipse with the radius of the long axis and the short axis [8]. It was the key to the design that how to choose the ratio of height to width of the arch structure to make the tent have the best stability, and the optimal strength and stiffness.

![Elliptical structure Arch structure](image)

Figure 1. Tent Structure.

**Structural Analysis**

The inflatable column airbag itself had no compression performance, but after being prestressed, it can obtained tension and had a certain rigidity to bear external loads. In the study, the finite element analysis method was used to analyze the bearing capacity of the inflatable structure using ANSYS software. First, the initial state of the membrane was known, and the balanced shape was solved by ANSYS[9]. Then, on the basis of shape finding, the actual engineering load was applied to the model structure for load analysis.

**Form Finding Analysis**

The reasonable prestressing force distribution was obtained by the form finding analysis using the method of support displacement and lifting and the approximate surface method.[10].

The boundary points of the membrane were lifted by support and the membrane surface was cooled to exert pre-tension. The reference temperature of the membrane surface was set to 0 degrees. According to the formula $\alpha E = \Delta T$, the temperature was lowered and the prestressing force was applied. In the formula, for the surface tension of the membrane, $E$ took 1/1000 of the true modulus of elasticity, $\alpha$ was the thermal expansion coefficient of PVC, set to 1.[11].

For inflatable columns, the elastic modulus was 2.36e9 pa, the virtual elastic modulus was 2.36e5 pa, and the Poisson's ratio is 0.37.

Under the same prestressing force, 150 form-finding analyses were carried out on the model, and evenly uniform prestressing force was obtained. On this basis, engineering loads were applied to the air column, and load analysis was carried out. The maximum axial stress was 2.28 Mpa, which acts near the confined ends of the air column. The maximum circumferential stress was 2.65 Mpa.

**Performance Analysis of Arch**

It was proposed to use inflatable column material as PVC fabric, and the properties of all arch materials to be tested were set as follows: elastic modulus: 2.36e9, poison’s ratio: 0.37. In order to simulate the forces acting on the inflatable arch under real conditions, both ends of the inflatable column legs are completely fixed, and the load pressure on the top bearing surface was 20pa[12].

This method completed the analysis experiment of several groups of models with aspect ratio of 0.2 to 0.7, and obtained the relationship between the maximum deformation displacement of arch and aspect ratio under different aspect ratios, the same inflated column diameter, the same load and load position as shown in Figure 2. The relationship between max stress max deformation and aspect ratio of arch was show at table1.
The analysis show that when the aspect ratio of arch was between 0.2 and 0.5, the maximum deformation displacement of arch tends to decrease. When the aspect ratio was 0.5, the maximum deformation displacement was the smallest, but the stress reached the maximum. When the aspect ratio was 0.4, the stress reached the minimum. When the height-width ratio of arch was between 0.5 and 0.55, the maximum deformation displacement of arch increased obviously with the increase of the height-width ratio, basically increasing, while the maximum stress decreased. When the aspect ratio was 0.6, the maximum deformation displacement appeared a lower value. The position of the dangerous interface of the arch had also changed significantly. With the increase of aspect ratio, the dangerous section moves gradually from two fixed sections to the middle of the inner ring.

### Table 1. Value of experimental parameters.

<table>
<thead>
<tr>
<th>Aspect ratio</th>
<th>Maximum deformation /mm</th>
<th>Maximum stress /pa</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>4.35E-02</td>
<td>52516.6</td>
</tr>
<tr>
<td>0.3</td>
<td>1.58E-02</td>
<td>50675.9</td>
</tr>
<tr>
<td>0.4</td>
<td>1.72E-02</td>
<td>49473.5</td>
</tr>
<tr>
<td>0.5</td>
<td>5.10E-04</td>
<td>58358.9</td>
</tr>
<tr>
<td>0.6</td>
<td>0.0101</td>
<td>51493.5</td>
</tr>
<tr>
<td>0.7</td>
<td>1.88E-02</td>
<td>52994.9</td>
</tr>
</tbody>
</table>

**Performance Analysis of Elliptic Structures**

In order to improve the utilization of space and adapt to the limited living environment in disaster areas, the bottom of the tent was oval or circular. The ratio of the long axis to the short axis of an ellipse had a significant effect on the mechanical properties of an ellipse structure [13]. By analyzing several ellipses with different ratios of long to short axes, the relationship between the maximum deformation displacement and stress and the ratio of long to short axes was obtained.

Both ends are fixed and the surface load pressure is 20 Pa. A series of models with the ratio of long axis to short axis from 1.0 to 1.5 were simulated and analyzed. The relationship between deformation and stress and aspect ratio of arch under different ratio of long axis to short axis, the same diameter of inflatable column, the same load and load position was obtained, as shown in Figure 3.
Figure 3. The relationship between maximum deformation displacement and ratio of long to short axis of ellipse.

The analysis show that the maximum deformation displacement of the elliptical structure has no obvious change, and it tend to decrease with the increase of the ratio of the long axis to the short axis.

The maximum stress of an ellipse increases with the increase of the ratio of the long axis to the short axis. The maximum stress of a circle was the smallest and the distribution was the most uniform. The position of the dangerous interface of the ellipse changes obviously.

Entity Model

Figure 4. Solar Charging Tent.

After defining the final plan of the tent, the project designed a set of solar power tents: inner length: 2.461 m, inner width: 1.819 m, inner height of 1.187 m. Considering the load-bearing and comfort, the air column was designed with a diameter of 0.26m[14] . The product was shown in Figure 14, and the model was tested for waterproofing, as shown in Figure 4.

Conclusion

1) Solar Power Generation Disaster Relief Tent had basic lighting, charging and other functions, strong life application, energy saving, earthquake resistance, convenience and comfort;

2) When the ratio of the semi-circular arch was 0.5, the stress was the largest, but the deformation displacement was the smallest; therefore, the recommended dimensions of arch structure are 0.25-0.4 and 0.55-0.65 in aspect ratio. At this time, semi-circular arch had better strength and stiffness.

3) The maximum deformation displacement of all kinds of elliptical structures was not obvious, the ratio of long axis to short axis was between 1.1 and 1.35, the deformation was the smallest, and the stress was relatively small.

Acknowledgement

This research was financially supported by National Innovation and Entrepreneurship Project. Number 2018181A61.
References


[14] Shi Maoyuan, Pang JiaChengi, Solar power generation disaster relief tent based on inflatable structure University of Science and Technology Beijing, School of Mechanical Engineering, Beijing 100083, China, 2018-11-28.