Application of UAV Radar Scanning Technology in the Operation and Maintenance of Air-Supported Membrane Structure

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Abstract. With the gradual advancement of the country's environmental protection policies, the air-supported membrane structure, characterized by its short construction period, cost-effectiveness, and high safety during construction, has been widely used in the full enclosure renovation of open-air coal yards in coal-fired power plants, the construction of all-weather sports venues, logistics and warehousing, and has gradually entered a large-scale construction phase. The widespread application of air-supported membrane structures has placed higher demands on their operation, maintenance, and scientific monitoring. Taking a coal shed at a power plant in Hengshui city as an example, this article proposes the use of drones equipped with high-precision scanners to scan existing air-supported membrane structures and establish models. This method reduces the differences between the computational analysis model and the actual structure, enhancing the accuracy and reliability of the computational analysis results, thus providing support for the safe operation and maintenance of existing air-supported membrane structures.

Keywords: air-supported membrane structure, UAV radar scanning, existing membrane structures

1 INTRODUCTION

The air-supported membrane structure concept originated with inflatable field tents in 1917 and was later popularized at the 1970 Osaka Exposition [1]. In recent years, with the vigorous development of China's national fitness campaign and the adjustment of national environmental protection policies, the application of air bearing membrane structure has been rapidly developed. Among them, regardless of the size or span of monomer, the air-supported membrane structure used for environmental protection sealing coal and material yards is increasing year by year.

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At present, the largest span of the air-supported membrane structure coal shed has been built over 200m, and the largest area of the single is more than 10,00m^2. Air-supported membrane structure is a kind of closed building with high performance membrane material as the "outer shell" of the building, which uses fans to fill air into the membrane and forms a certain stiffness based on internal and external pressure difference to adapt to various weather conditions [2-5]. With the increase of span, the membrane surface stress increases gradually. In order to transfer and reduce the membrane surface stress, the membrane surface stress is shared by covering the cable net to further increase the stiffness and stability of the structure. The air bearing membrane structure consists of membrane material, stiffening cable and internal supporting air to form a force system. Air-supported membrane structure is a typical nonlinear flexible large-span spatial structure. The structural characteristics of air-supported membrane structure -- light weight and high flexibility, and sensitive to wind and snow loads, have become one of the important factors limiting its development [6-7]. Therefore, it is necessary to simulate the gas-supported membrane structure to determine its normal operation under different environmental factors.

However, there may be some differences between the actual model of gas supported membrane structure coal shed and the model in design drawings. In the actual modeling process, due to measurement errors, data conversion errors and other factors, there may be some differences in accuracy between the actual model and the model in the design drawing. At the same time, in the actual construction process, the structure may be adjusted and optimized according to the actual situation, resulting in certain differences in details between the actual structure and the model in the design drawing. Secondly, in the actual service environment, the air-supported membrane structure coal shed may be affected by some unpredictable environmental factors, such as wind speed, wind direction, temperature, air pressure, etc., which may have a certain impact on the real-time shape of the structure. Therefore, in order to reduce the difference between the computational analysis model and the actual structure, and to enhance the accuracy and reliability of the computational analysis results, it is particularly important to select the appropriate model acquisition method.

Radar scans can obtain the complete model of the air-supported membrane structure coal shed without any damage or influence. The high-resolution camera and laser scanner carried by the UAV can obtain the high-precision air-supported membrane structure coal shed model, improving the accuracy and precision of modeling. The UAV can obtain a large amount of gas bearing membrane structure coal shed data in a short time, thus speeding up the modeling process. The use of UAV scanning can reduce the cost of obtaining the data of air-supported membrane structure coal shed, while reducing the labor intensity of surveyors and improving efficiency.

2 PROJECT INTRODUCTION

The power plant is located in Hebei Hengshui. There are two coal sheds in the plant. The structure is air-supported structure. Among them, the scale of the first phase of the project (length × width × height) is : 185.6 meters ×92 meters ×38.5 meters; Phase II project scale (length × width × height) is: 180m × 142m × 40m, structural design service life of 50 years, structural design safety level 2, coal yard gas film structure layout diagram is shown in Figure 1.

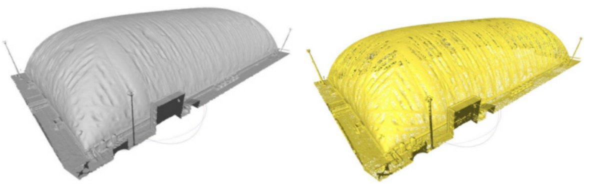
Fig. 1. Real picture of an air-supported structure in a power plant

The building safety and health intelligent monitoring system is composed of a UAV equipped with a lidar scanner. Its components are shown in Figure 2. Through remote control UAV to achieve automatic flight control, designated point hover, using different parameters of the camera to take photos or scan the structure surface, through the intelligent processing system to collect information data analysis and processing, generating point cloud data files.

Fig. 2. Safety and health intelligent monitoring system components

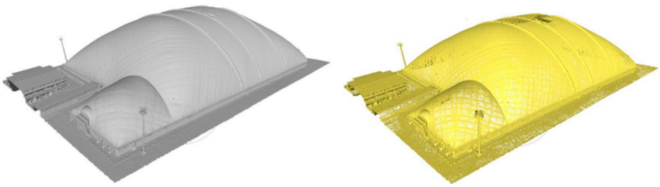
3 THE PROCESS OF MODEL BUILDING

The UAV is equipped with a high-precision scanner to obtain a three-dimensional point cloud model of a coal shed with a air-supported membrane structure, as shown in Figure 3 and 4.



(a) (b)

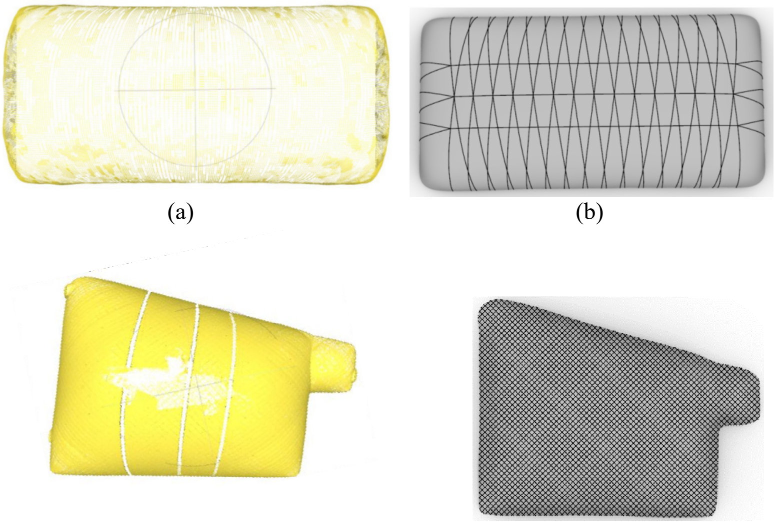
Fig. 3. 1# air-supported membrane structure coal shed (a) original 3D model and (b) original point cloud model.



(a) (b)

Fig. 4. 2# air-supported membrane structure coal shed (a) original 3D model and (b) original point cloud model.

MeshLab software was used to delete part of the point cloud with non-gas-supported membrane structure in the model, and the processed model was imported into Rhino. The point cloud model was processed to form a triangular mesh model, and the mesh model was further optimized to repair the missing parts of scanning, as shown in Fig. 5. After repeated optimization, the model was formed into a smooth surface that could be used for finite element calculation.



(a) (b)

(b) (d)

Fig. 5. (a) (b) (c) (d)Shows the formation process of 1# and 2# model suitable for finite element calculation, respectively.

4 FINITE ELEMENT SIMULATION UNDER SNOW LOAD

The strength of the two structures under snow load was checked, and the load condition expression was as follows: $1.3G + 1.5Q1 + 1.0Pmax,s$.

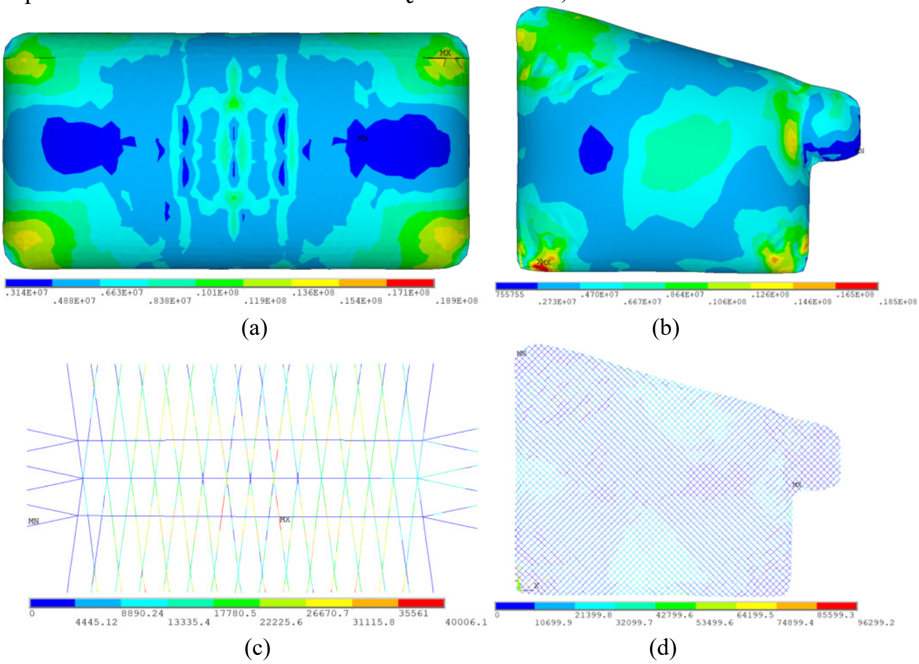


Fig. 6. (a) (b)Membrane stress cloud image (Pa) ,(c) (d)Axial force cloud image of cable (N)

Through calculation and analysis, the load distribution and the most unfavorable position of the cable and membrane are determined. The design strength of the membrane is 30MPa, and the maximum bearing capacity of the cable is 155kN. Both the cable and membrane inner are within the maximum bearing capacity and the allowable range of the code, as shown in Fig. 6.

5 CONCLUSION

In response to extreme weather such as typhoons and snowstorms, UAV technology can effectively reduce personnel working at altitude and solve the problem that it is difficult for personnel to go up and inspect. It not only improves the safety of operations, but also enables timely access to important information to support disaster response and maintenance.

The data obtained by the UAV can be directly applied to the digital modeling of the existing gas bearing membrane structure coal shed, which not only improves the modeling efficiency, but also ensures the accuracy of the building structure.

Therefore, the use of drones to scan gas-supported membrane structure coal shed to obtain models can greatly improve the efficiency and accuracy of modeling, reduce costs, and provide more efficient and accurate data support for the management and maintenance of gas-supported membrane structure coal shed.

For the existing air-supported membrane structure, this application can help the management unit to maintain the structure safely and extend the service life of the structure. This case provides a strong reference for the safe operation of large coal sheds, warehouses and gymnasiums with air-supported membrane structure, especially for super large ones.

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