The Simulation Analysis of Long-Span Membrane Structure

Zhongcheng Wang   Yunpeng Ma

School of Aeronautic Science and Engineering, Beihang University, Beijing, 100871, China

Abstract: The analysis of wind load characteristics of gas-ribbed film structure plays an important role in the performance of the long-span membrane structure. This paper mainly researches on the long-span rib membrane structure. Surface wind pressure of the membrane structure is calculated by fluent, the distribution of force and surface pressure of the membrane structure under different angles and wind speeds is obtained. The worst working condition of the wind approach angle is 60°. Maximum force angle is positively correlated with windward angle and the length of structure.

Keywords: Long-Span; Simulation; CFD; Surface pressure; Windward angle

Corresponding Author: Zhongcheng Wang, Email:loywang@163. com

1.Introduction

Inflatable membrane structure include gas-bearing structure and air-ribbed structure. The inflatable structure has the advantages of short molding time, low construction cost and light structure weight, which has been gradually attracted worldwide attention in recent years.[1-4] The U.S. military has developed various inflatable hangars, which have im-proved the aircraft attendance rate and reduced the cost of the aircraft's whole-life maintenance costs. The long-span inflatable structure is greatly affected by wind load, many accidents occurredunder the influence of typhoons. This paper presents a simula-tion analysis of the long-span gas-rib membrane structure. The modeling and simulation is carried out in different windward angles and wind speeds, and the worst condition is carried out, this simulation can help provide helpful reference for the construction of membrane structure.

2. CFD Modeling

In this paper, the wind load characteristics of long-span gas-ribbed film are analyzed by means of CFD.

The model is established every ten degrees from 0° to 90°, model coordinates are shown in Figure 1.

Theturbulence model adopts k-ωSST model, the boundary condition are shown in Table 1.

Table 1. The boundary condition

Name	Boundary type
inlet	velocity-inlet
outlet	pressure-oulet
inwall	wall
outwall	wall

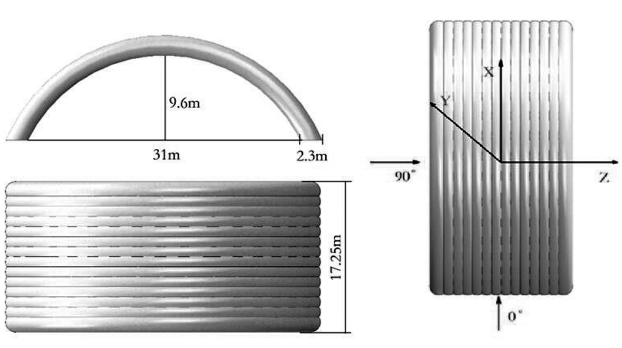

Figure 1. Initial model of CFD calculation

3. Simulation Results

The distribution of wind pressure under different angles and wind speeds of the same model is calculated respectively, wind speed increased from 5 meters per second to 25 meters per second, with a spacing of 5 meters per second.

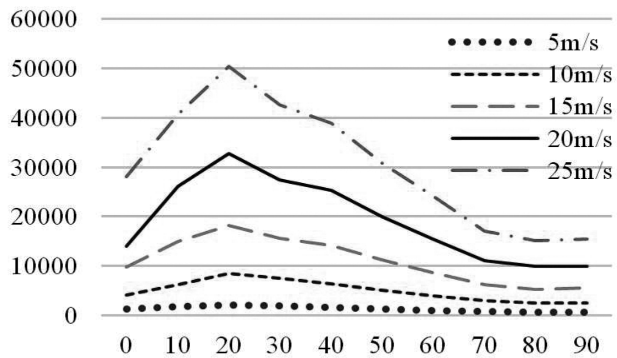

Figure 2. Drag force of X direction under different angles and wind speeds

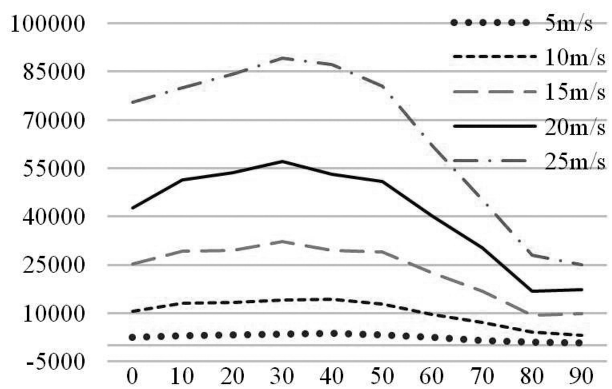

Figure 3. Lift force of Y direction under different angles and wind speeds

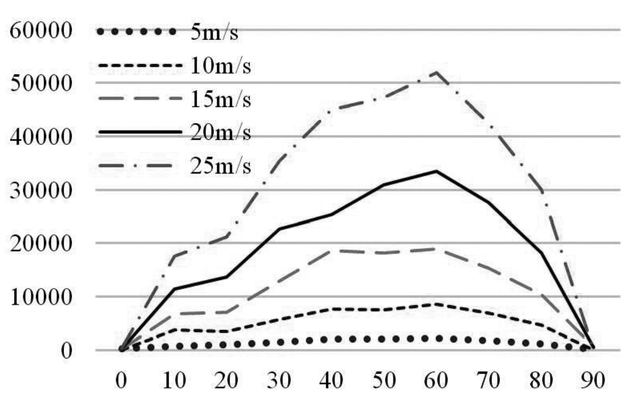

Figure 4. Drag force of Z direction under different angles and wind speeds

The angle of maximum drag and lift force at the same wind speed is different in dif-ferent length-width ratio. Under the wind speed of 20 meter per second, the wind load of the same span ratio with different width models is shown in Figures below.

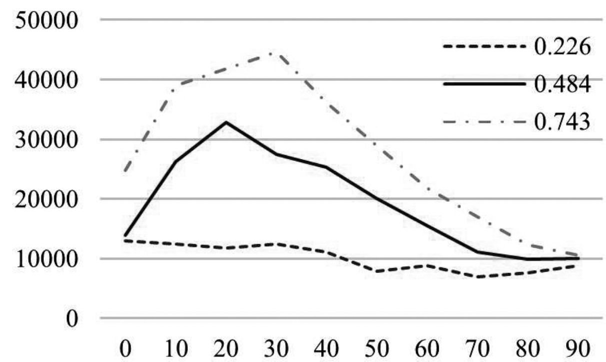

Figure 5. Drag force of X direction under different angles and length-width ratios

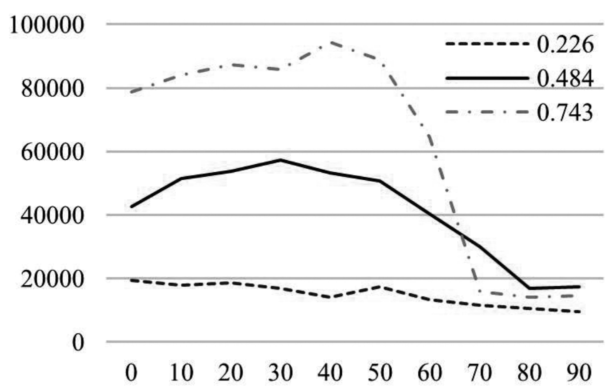

Figure 6. Lift force of Y direction under different angles and length-width ratios

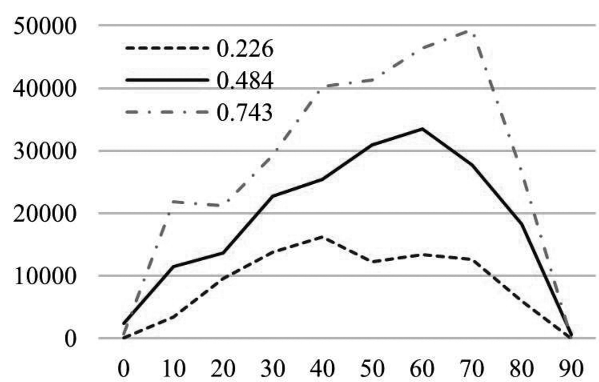

Figure 7. Drag force of Z direction under different angles and length-width ratio

4. Simulation Results Analysis

The wind load of the long-span arch film structure includes horizontal drag force and lift force, both the drag and the lift are influenced by the structure and wind direction.

4. 1 Effect of Windward Angle on Surface Wind Pressure

From the calculation above, wind direction has a great influence on the lift and drag. The length-width ratio of the initial model is 0. 484, drag force of X direction reaches maxi-mum in the angle of 20 degrees of different wind speeds in Figure 2, lift force of Y direc-tion reaches maximum in the angle of 30 degrees in Figure 3, and the drag force of Z di-rection reaches maximum in the angle of 60 degrees in Figure 4. Maximum force degree is not related to wind speed but to the wind direction according to the calculation.

4. 2 Effect of Length-Width Ratio on Surface Wind Pressure

The result indicates that length-width has a great influence on the surface wind pressure. Take the inlet wind speed as 20 m/s, Figures above show the influence of the length-width ratio. When the ratio is small, the worst working condition may be less af-fected by the windward angle as the Figures shows above, the changes of lift force and drag force in X direction is relatively smooth when the length-width ratio is 0. 226. As the ratio increases, the effect of wind load becomes more obvious.[5]

Figure 5 shows that the develop of the ratio increase the maximum angle of drag force in X direction, the same rule is shown in lift force and drag force in Z direction.

5. Conclusion

The air flow can pass through the membrane structure, with the increase of windward an-gle, drag force changes rapidly. The increase in lift force caused by wind angle changes is relatively small, however the drop is obvious after reached the maximum.[6-8]

The drag force of X to the drag of Z is approximately symmetrical. However the dis-tribution is different at 0°and 90°, because the force of Z direction is close to zero.

The worst working condition is 60 degrees in the wind direction. The air flows along the oblique, the outer of the windward side and the inner of the lee side are subjected to higher wind pressure, when the air bypassed the gas-rib structure, turbulence generated, thus the inner of the windward side and the outer of lee side are subjected the negative pressure.

In which the drag force reaches the maximum, while the lift force is relatively small, in this case, membrane structure is more likely to collapse.

In the case of equal wind speed, maximum force angle increase as the length-width ratio, however if the ratio is too small, the change is not so obvious, as the calculation shows.

References

[1] Yue Wu, QingshanYang, ShizhaoShen. The current status and prospects on analysis theory of membrane structures[Z]. Special Invitation Report of the 22nd National Structural Engineering Academic Conference. 2013. CS-TAM2013-P28-E0012. (in Chinese)

[2] Xiaoying Sun, Yue Wu, shizhao Shen. A combined numerical approach for wind-structure interaction of membrane structure[J]. CHINA Civil Engineer Journal, 2010:31-35. (in Chinese)

[3] Gonghui Zhang, Zhihang Li, Zhihong Zhou. Air-Passage Structure Improving of Pneumatic Electromagnetic Valve Based on Flow Field Simulation withing Fluent[J]. Hydraulics Pneumatics ＆ Seals, 2010:41-42. (in Chinese)

[4] Taibi He , Shuai Wang, Qipeng Yan, et al. Failure mechanism of civil mem-brane-structure architecture with gas rib[J]. Journal of Southwest Jiaotong University, 2016:714-720. (in Chinese)

[5] Xihu Jiang, Buying Xie, Huijin Chen. Satic and dynamic non-linear finite element analysis of air-supported membrane structure by ANSYS[J]. Structural Engineers, 2006:38-42. (in Chinese)

[6] Yuanhong Feng, Wenkui Yang, Jigang Yin, et al. Experiment and analysis of the mechanical performance of air-inflated arch during inflating stage[J]. Spatial Structures, 2009:75-77. (in Chinese)

[7] Yongqiang Yang, Yunpeng Ma , Kang Lin, et al. An optimizing design method of large span inflatable structure based on genetic algorithm[J]. Journal of Harbin Institute of Technology, 2014:86-91. (in Chinese)

[8] Changguo Wang, Xingwen Du, Xiaodong He. Bending-Wrinkling behavior analysis for inflatable membrane boom[J]. Engineering Mechanics, 2009:210-215. (in Chi-nese)