Design and Structure Research of Concrete-filled Steel Tube Wind Turbine Tower

Qu Chengzhong[1, a], Tang Bing[1, b] and Yu Bo[2]

[1]Department of Architectural Engineering, Northeast Dianli University, Jilin, 132012, China
[2]State grid Penglai city in Shandong province electric power company, Penglai, 265600, China

[a]tbyoyo1987fz@163.com, [b]623360719@qq.com

Keywords: Concrete filled steel tube, Lattice, Structure research.

Abstract. Wind power is an important part of the new energy in the rapid development of the world. Wind turbine tower play a role for wind power and normal production safety. In this paper, using a power of 5MW horizontal axis wind turbine as a prototype, design a new steel concrete lattice wind turbine tower. To meet the needs of everyday production work, and it has a good economy.

Introduction

Concrete steel lattice tower wind power is an important support structure of the wind turbine. According to the basic parameters of 5MW wind turbine, a tower designed to meet the requirements of wind turbines.

Parameter Selection

This design prototype a 5 MW three blade wind tower systems. Tower for the DD128 sea amphibious three impeller type horizontal axis wind turbine design, rated at 5MW, 128 m impeller diameter, blade length 62 m hub height of 100 meters, the yaw bearing diameter 6m, the impeller, the nacelle and generator quality respectively, 90t, 50t and 135t. Rated wind speed 13m / s, cut-out wind speed 25m / s, storm wind speed 50m / s. Speed at rated power 23rpm. According to the relevant parameters of the selected generators, wind turbine tower design.

Tower structure design concept refers to the basic design principles and design ideas engineering experience, mechanics concepts, geometric concepts and the like, a determination process architecture and detail of the tower structure.

Tower Design

Tower structure design concept refers to the basic design principles and design ideas engineering experience, mechanics concepts, geometric concepts and the like, a determination process architecture and detail of the tower structure.

The Height Design of Tower

Tower for wind turbines play a supportive role, and its height shall meet to make wind turbine reaches its normal operating state, and secondly, to determine the height of the wind turbine tower and the terrain and topography relevant, considering the technical and economic terrain specific location factors, topography and other aspects. The height of tower is limited to a certain range, the minimum height is determined by the formula.

$$H=h+C+R$$

H-the hight of tower;
h-the height of the obstacle near the wind wheel;
C-the highest point of the obstacle to wind rotor swept plane distance (minimum 1.5~2.0m);
R-radius of the wind wheel.

Select the Tower Form

Tower facade Selection, choose the appropriate facade shape. From concept design theory, the shape of the tower facade structure close to the moment of the envelope, the concept stems from the design of equal strength. The main form of load or load to some extent determines the form of the tower facade. According to structural mechanics concepts, wind turbine tower can be reduced to a cantilever, to wind round horizontal force acting on the top of the tower.

Combined with the existing transmission tower design experience, the paper recommended that its elevation contour line designed for small under the large ramp straight, oblique line slope and width of the tower at the top, bottom width and height related.

Select the Tower Planar Form

Wind turbine tower structure separated flat contour form usually triangular, rectangular, hexagonal, eight Sectional shape of the polygon, etc.

In the same section size member, the cross-section side a few more, the need to ensure the cross-section torsion auxiliary materials and stability, the greater the amount of its steel. And the more the number of sides of the tower cross-section, the number of nodes increased its construction, wind area also increased, the tower the greater the wind load. But with the increase in the number of tower main material, its mechanical properties, such as enhanced carrying capacity. Taking these reasons, combined with practical engineering, this paper take up to use regular quadrilateral cross-sectional shape of the tower level.

The Form of Web Member

Lattice tower tower mainly by the main material, the diaphragm and the diagonal web members and other rod components. Tower webs system layout is reasonable or not, not only influence the performance and architectural style tower that, but also affect the amount of steel tower, for more disposed webs tower, its steel consumption could reach a total weight of tower 40% to 45%. Therefore, selecting appropriate form of webs is particularly important. Tower webs can be divided into: oblique rod, cross-type, K type, Torx type, then fractional and mixed, etc.

The tower web member selected, should be considered the height of the tower, reducing wind resistance factors and stress properties. In the national grid typical design steel tower design part, and the towering structure large span steel tower applications in practical engineering, the webs form a crossover-type and mixed type more, we use a structure in which cross more concise form.

Width Determination of Tower Top

In the conventional cylindrical tower at the top of the cone width design, the width of the top of the tower depends on the wind turbine yaw bearing size, depending on the wind turbine parameters, taking the tower top width 6 m.

Width Determination of Tower Bottom

Width of the bottom of the tower is an important body parameters of the tower, the tower bottom of the tower the size of the horizontal displacement of the top of the tower for the role of wind load, dynamic characteristics (vibration type, period, frequency), have a relationship based on force. In determining the width at the bottom of the tower, you should consider requiring the normal operation of the wind turbine, the tower bottom to prevent too wide, small slope tower when the tower reaches the displacement limit, a little portion of the blade and tower collision. Currently, There are no specific method for determining wind turbine lattice tower structure width at the bottom, this article will determine the width at the bottom of the tower according to the wind wheel normal operating requirements.

In addition, according to the relevant industry specifications tower construion, tower bottoms width of not less than the total height of 1/25. The steel structure design specification (GB 500017-2003) specified value of the total height of a bottom width of 1/6 to 1/10. This article takes 1/6.

The Angle of Webs and Towers and the Height of Stratification

Angle value webs and towers of the tower have an impact on the level of capacity and stiffness. In determining the height between the tower section, must ensure that the abdominal oblique angle control lever and the tower within a certain angle range, according to the design of steel structures (GB 500017-2003) of the relevant provisions of the webs and towers Angle column often take 30 ° to 60 °, this design takes 45 °. According tower and webs angle θ and edge width D, determine the height of each tower.

The Tower Material and Component Section

For the purposes of wind turbine towers, because of its high altitude, suffered a larger load. Therefore, the requirements of its member larger size, steel concrete with compressive bearing capacity, good ductility and toughness, easy construction and fire performance and other advantages, so the tower of the main material used in the steel concrete. The tower webs primaries round steel section mainly has the following three reasons: First, the circular pipe cross-section belong to the center of symmetry, the symmetry allows each to give full play to each rod material properties, while torsional effect for bars It is also more favorable. Secondly, with respect to the combination of angle circular steel pipe, its large cross- sectional radius of gyration. For the whole rod, its slenderness ratio can be reduced, the overall stability of the tower will be greatly improved. Finally, the circular steel structure belonging to streamline body shape, size wind pressure coefficient is small, it tends to reduce the tower tower wind load, so that cross-sectional dimensions and reduced load requirements, access to certain economic benefits.

Modeling by Using Finite Element Software

In this paper, the wind turbine tower Ansys software finite element modeling, the main material for the concrete column, the upper end of the lower crude fine using beam189 beam element modeling, variable cross-section of a solid circular cross section; the diaphragm, abdominal rod, etc. circular steel pipe, the same beam element cross-section of the pipe cross-section, the impeller, the cabin uses Mass21 quality element simulation.

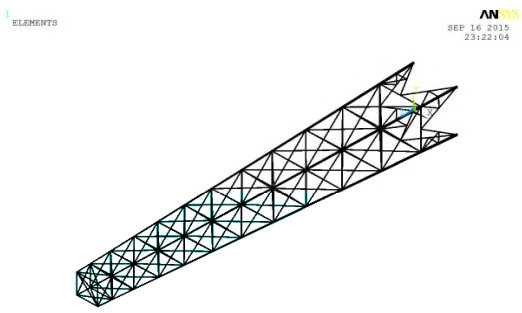

Fig. 1 Model of tower.

Structure Study

Tower as the main wind turbine tower carrying member, greatly affect the size and parameters of selecting the entire tower of performance and economy. The tower used in the steel concrete

composite material, in many control parameters CFT, the steel ratio for all aspects of performance CFT plays a decisive role, steel ratio is too low, resulting in lack of concrete steel internal constraints, leading to overall performance. With concrete containing steel improving steel ratio, steel ferrule capacity for internal concreterein force- ment, so that the elastic modulus of the material, the nature of the integrated density, compressive yield strength are greatly improved, but higher steel prices, along with improve steel ratio, the tower also decreased the overall economy. Therefore, selecting a control parameter containing steel tower was designed, and should be controlled within an appropriate range selection. According to the theory, considering the performance and economic factors, including the value of steel ratio should be controlled at 0.04 to 0.2.

In this paper, a unified theory of concrete steel concrete steel pipe as a fibrous material. Selection Q345 steel and concrete composite C50. Referring transmission tower, communications towers and other related engineering examples. Tower pipe wall thickness t select 14mm, 16mm, 18mm, 20mm four specifications. Take steel ratio of 0.11 to 0.2, and in accordance with design of steel structures (GB 500017-2003) regarding the relevant provisions of the concrete pipe portion, tower diameter to thickness ratio ranging from 20 to 90, in a truss structure, in order to make weight like steel, and so reduce the amount of steel, an aspect ratio of about 25 to take appropriate paper value controlled at 20~40. According to the control parameters, determined to take a different combination of tower-sectional dimension.

Table 1. Tower main timber size.

No	t(mm)	α	D/t	r(m)	Y/N
1	14	0.11~0.2	——	—	N
2	16	0.12	36.30501	0.29	N
3	16	0.11	39.33755	0.31	Y
4	18	0.15	29.63174	266	N
5	18	0.14	31.53868	0.28	Y
6	20	0.18	25.18087	250	N
7	20	0.17	26.49018	0.264	Y

Compare Economy

Table 2. Economy of different types of cross-section column.

No	t(mm)	r(m)	Steel and Concrete	price
3	16	0.31	103.4+109.92	40.53
5	18	0.28	126.5+91.08	48.28
7	20	0.264	130.06+80.8	49.25

Above table we can be seen, the 3rd section, i.e. a wall thickness of 16mm, with a radius of 0.31m, the economic optimum.

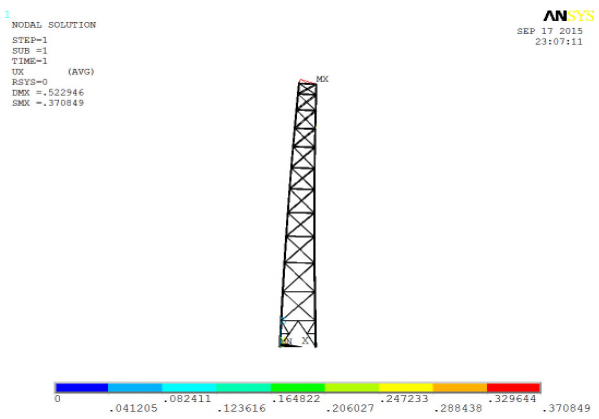

Fig. 2 The maximum horizontal displacement.

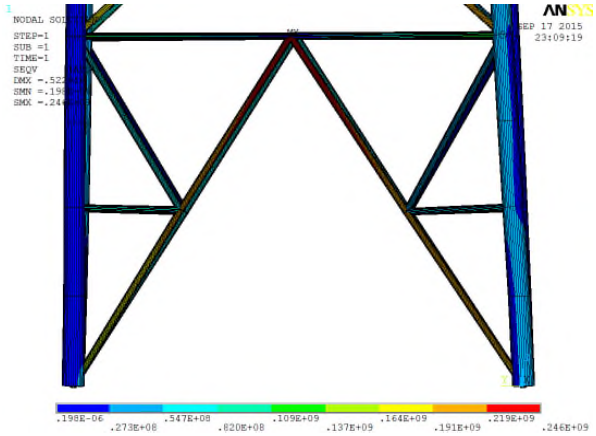

Fig. 3 maximum stress of tower.

Modal analysis

As one of the main load wind load wind turbine towers, will produce vibration tower work, therefore, the tower dynamic analysis is necessary. In this paper, the modal superposition transient dynamic analysis of the tower.

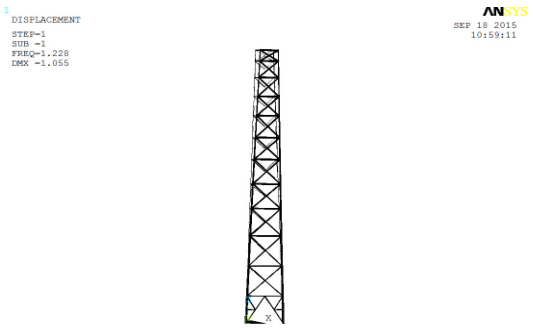

Fig. 4 The firs modes.

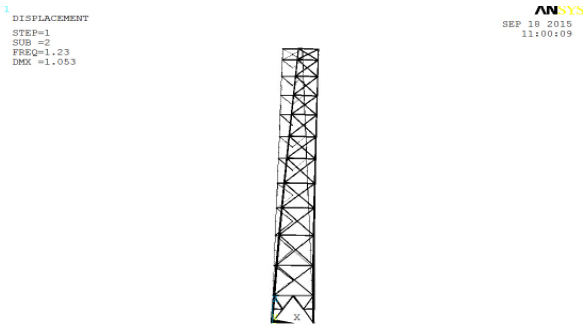

Fig. 5 The second modes.

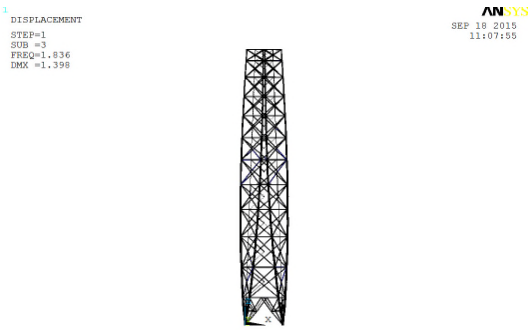

Fig. 6 The third modes.

According to relevant regulations, the design of the tower, avoid the natural frequency of the blade rotation frequency resonance. Tower and blade resonance will not occur when the fan is working properly.

Conclusions

This article will apply concrete steel lattice tower wind turbine design, give full play to the steel concrete with high capacity, good plasticity and toughness, good fire resistance, corrosion resistance and good characteristics of concrete filled steel tubular trellis tower structure reasonable selection and design to meet the performance requirements of a variety of conditions.

References

[1] X. M. Rui and Y. B. Liu, Wind turbine design, Mach. Ind. Press, 2 (2010) 150-151.

[2] Industry standard of the People's Republic of China.《Design of steel structures》(JG5007- 2003), (2003) 259-282.

[3] S. T. Zhong, Steel concrete unified theory - Research and Application, Tsinghua U. Press, 8 (2006) 41-50.

[4] Industry standard of the People's Republic of China.《Towering structure design specifications》(GB 50135-2006), 2006:105-109.

[5] R. Z. Zhao and G. Lv, The horizontal axis wind turbine towers of Modal Analysis, Lanzhou U. Technol. 35(2) (2009) 33-35.