E3S Web of Conferences **375**, 02006 (2023) https://doi.org/10.1051/e3sconf/202337502006
ESAT 2023

Study on Amplification Effect of Wind Turbine Blade Stopping Position on Vortex Induced Vibration of Tower

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Abstract. This project takes XX unit as the analysis object to study the first-order vibration wind speed of wind turbine under shutdown vibration. The vortex-induced vibration response is calculated and the displacement under resonant wind speed is calculated by fluid-solid coupling method. The above analysis techniques and methods are forward-looking and advanced in vibration characteristics of domestic wind turbines. On the basis of fluid dynamics analysis, the suppression measures are studied emphatically. Through the optimization and comparison of different inhibition schemes, the effect of inhibition measures was quantitatively analyzed. The analysis shows that the vibration characteristics of wind turbine with high flexible tower has its own particularity. The first order vibration probability and vibration displacement can be effectively reduced by pneumatic method and external measures.

Keywords: Wind Turbine; vibration characteristics; first-order vibration; fluid-solid.

1. Research Background

Vortex-induced vibration (VIV) is a complex air-elastic coupling phenomenon[1]. The wind passes around the non-fluid section of the structure to form vortexes, and the periodic shedding of vortexes will arouse the structure's vibration perpendicular to the direction of incoming flow[2-3]. In the case of specific wind speed, when the frequency of vortex shedding coincides with or is close to the natural frequency of the structure, resonance occurs, and the vibration amplitude is large, so it will cause greater fatigue damage to the structure[4-5].

As for the research on VIV, the current research methods are mainly based on calculation evaluation and field test verification based on standards. However, due to the complexity of the problem and the fact that the phenomenon of VIV intensification caused by blades is difficult to be calculated by engineering algorithms, it is impossible to provide guidance for the test work, and the analysis of this content in the industry is not sufficient, so it is necessary to conduct in-depth research. From the perspective of mechanism research and engineering application, this project plans to use CFD simulation calculation method to study the vortex-induced vibration risk of unit during and after hoisting, and verify the consistency of simulation results through field tests.

2. Vortex-excited vibration background

The vortex generation of vortex induced vibration can be divided into 2S, 2P, 2T and 2C. In the form of 2S vortex, two vortexes with little difference in intensity fall off in each vibration period, and the two vortexes rotate in opposite directions. The well-known Karman vortex street is 2S form. In Figure 2-6, (a), 2S form trailing vortexes occur during vortex-induced vibration. In the form of 2P vortex, two vortex pairs with different strengths occur on both sides of the cylinder in opposite directions, as shown in Figure 1 (b) and (c).

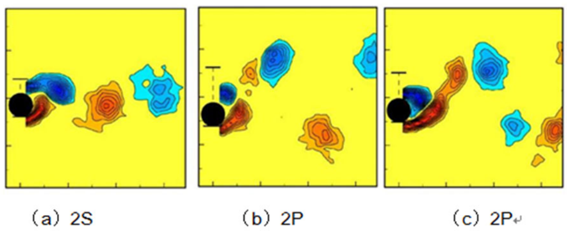

Figure 1 Whirlpool configurations of different types

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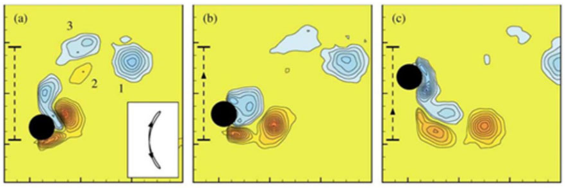
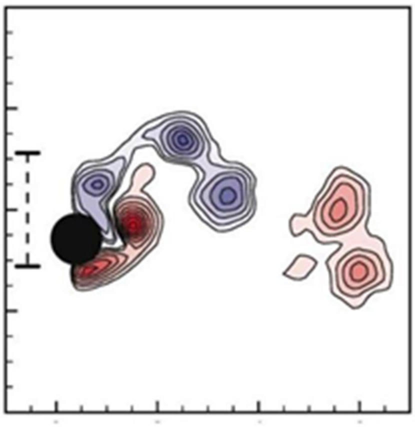
The vortex form of 2T is formed every half cycle, three vortices occur on the cylinder, two rotating in the same direction and the other opposite. And the intensity of the vortex in the same direction is obviously greater than that of the single vortex. The analysis shows that the type of 2T vortex is affected by the mass ratio and the degree of freedom. With the increase of the mass ratio in the case of two degrees of freedom, the 2T vortex type gradually transforms to 2P. Type 2C vortex mode means that one vortex pair occurs on each side of the cylinder, with the same internal rotation and opposite rotation of the two vortex pairs, as shown in Figure 2.



(a) 2T



(b) 2C

Figure 2 Different types of whirlpools

A follow-up study found the P+S vortex pattern. In the form of P+S vortex, one vortex pair and one counter-rotating vortex occur respectively on both sides of the cylinder, as shown in Figure3. At first, this vortex form was only found in forced vibration, and it was believed that it could not appear in self-excited vibration. In recent years, many scholars have discovered the P+S vortex form in self-excited vibration studies, and supplemented the production principle. The formation of P+S vortex only occurs in the Reynolds number range of 300 to 500, and is not found at higher and lower Reynolds numbers. So far, the research on the morphology of P+S vortex is only superficial, and further research is needed.

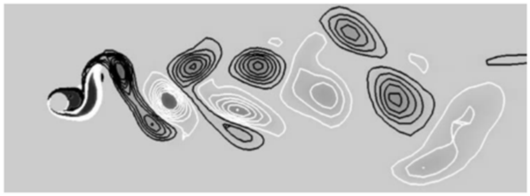


Figure 3 P+S vortex

3. Pitch Angle variation _ flow condition

According to the results of two-dimensional calculation, the calculation model of the whole machine was established. The model stops unchanged and the pitch angles are 90 degrees, 0 degrees, 15 degrees, 30 degrees and 45 degrees respectively.

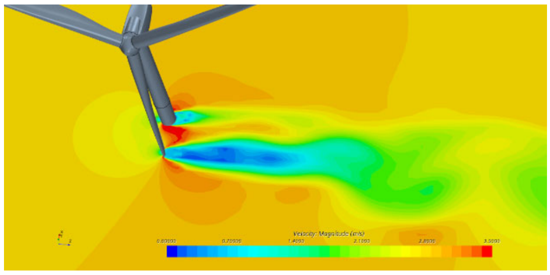


Figure 4 Contrast of different pitch angles at 120m height (90 degrees)

From the cloud image calculation results of the whole machine, it is consistent with the 2D results. Due to the influence of double column flow around the tower cylinder shedding vortex is greatly affected by the blade. This effect is eliminated when the distance between the blade and the tower barrel is greater than 2D, and when the distance between the blade and the tower barrel is less than 100m.

4. Parking impact

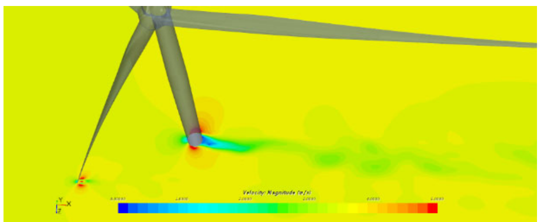


Figure 5 Impact of 30 ° on wake flow

Figure 5 shows the change of wake flow at 30 degrees at the terminal. From the perspective of wake impact, the front-end blade has an important effect on the wake of the tower barrel. The vortex shedding of the tower barrel is intensified by the wake action of the front blade. More intense double column shedding was formed. This result is consistent with misplacement shedding in double column shedding.

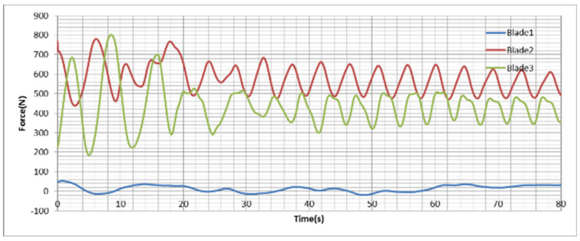


Figure 6 Mechanical changes at 30 degrees in the terminal

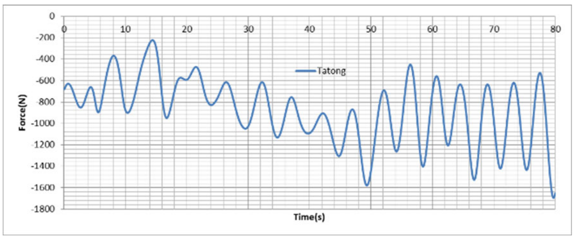


Figure 7 Force change of 30 ° tower barrel at the parking position

At 30 degrees, the wind is blowing upstream from the side. Both the blades and the tower barrel form their own strong periodic loads. The vibration of the tower barrel is changed into the superimposed vibration of the tower barrel and the blade. When the standing position is 30 degrees, the two upstream blades are in vibration state, and this superposition effect will significantly magnify the vibration amplitude of the tower barrel.

5. Stop with pitch Angle

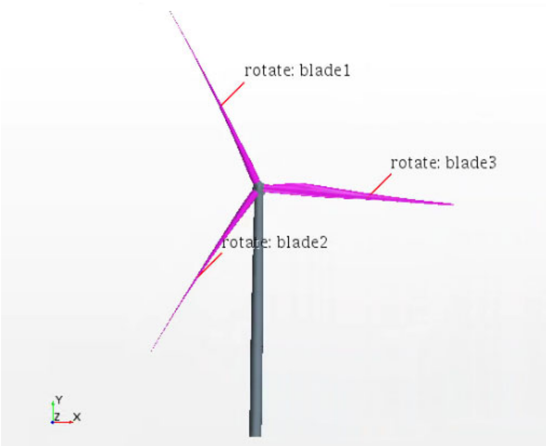


Figure 8 Single blade pitch Angle 0 °

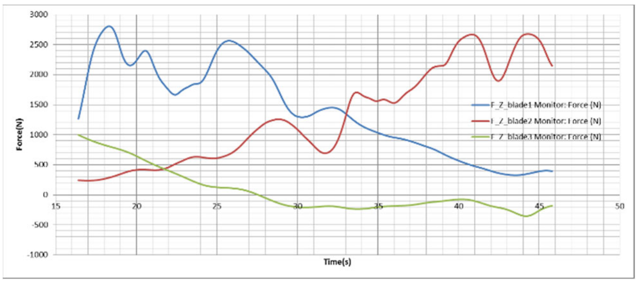


Figure 9 Forces on blades in the Z direction

It is calculated that the wind wheel rotates at a low speed (1rpm) at a low wind speed. The pitch Angle of blade3 is 0 degrees, and that of blade1 and 2 is 90 degrees. FIG. 9 shows the stress changes of three blades in the Z direction. Under the combined action of low speed rotation and pitch Angle, the blade's periodic force in the Z direction is eliminated. The overall z-direction amplitude will be greatly reduced.

6. Summary

In this chapter, the influence of the standing position of the blade on the vibration characteristics is calculated. Some conclusions are drawn as follows:

1. Due to the influence of double column flow around the tower cylinder shedding vortex is greatly affected by the blade. This effect is eliminated when the distance between the blade and the tower barrel is greater than 2D, and when the distance between the blade and the tower barrel is less than 100m.
2. The superimposed force of the blade on the tower barrel changes with the change of blade pitch Angle. According to the two-dimensional and three-dimensional integrated results, the column with pitch Angle <45 degrees is eliminated by blade influence. When the pitch Angle is less than 60 degrees, the vibration state of the cylinder is greatly reduced. At the same time, the aerodynamic force of the blade changes under the influence of pitch Angle.

3, the parking position has a blade in the upstream of the tower barrel, such as deflection 30 degrees. The upstream blade also has an independent vibration shedding vortex, which is superimposed with the vibration of the tower barrel.

4. To sum up, the adjustment of blade pitch Angle can change the vibration characteristics of blade and tower barrel. Pitch Angle should be at least 60 degrees or less.
5. After comprehensive consideration, the expected effect is achieved through the effect of parking position and pitch Angle.

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