A numerical CFD study of the wind flow distribution around the overhead conductors

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Abstract. The CFD numerical model of smooth circular conductor and stranded conductor are established, and the flow field distributions of these two kinds of conductors in different wind speed and diameter are analysed by using DES method. The study shows that: the numerical simulation method is applicable to the vortex-shedding simulation of smooth circular conductor and strand conductor; with the increase of wind speed, the vortex shedding frequency of transmission conductor is accelerated, the space distance of the vortex increases, the vortex street becomes irregular, and the length of the trailing vortex is significantly longer; as the diameter of the conductor increases, the sizes of wake zone and vortex are larger, and the vortex shedding frequency becomes slower; in the same diameter and inlet wind speed, the resistance and vortex street effect of the smooth circular conductor are stronger than the strand conductor.

1. Introduction

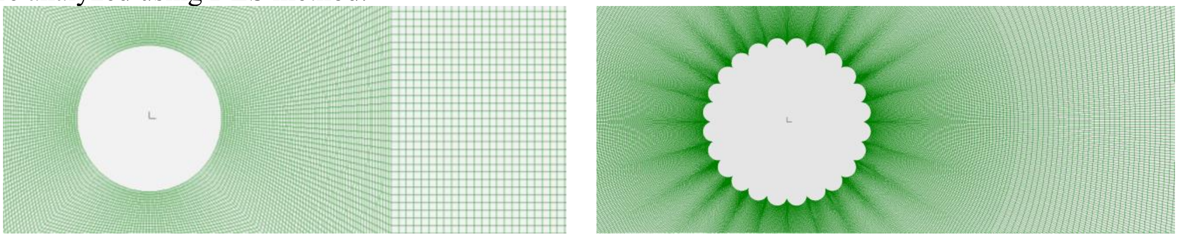
Existing data show that under the effects of environmental wind, overhead conductors are generally in a state of aeolian vibration. The aeolian vibration of overhead conductor is a high frequency microamplitude vibration induced by the alternating shedding of vortex street (Rawlins 1979, Poffenberger 1965), which is a significant cause of the fatigue and damage of conductor and hardware. With the construction of the extra-high voltage engineering, the conductors have larger span and higher sag and the nonlinear characteristics of conductors are more obvious. It is no longer applicable to calculate the response of the large-span conductors by using a single drag coefficient. Random vibration analysis is necessary on the basis of random wind excitation, which can be obtained from CFD simulation (Braun 2005) or wind tunnel test [(Laneville 1999, Loredo-Souza 2002).

In this paper, the CFD numerical model of smooth circular conductor and stranded conductor are established, and the flow field distributions of the two conductors in different wind speed and diameter are analyzed using DES method.

2. CFD model

The conductor surface can be seen as a rigid section. The two-dimension CFD models of two types of conductors are established by using ADINA platform (see Figure 1). In order to simulate the distribution of flow field near the surface of the conductor accurately, local encryption should be carried out in the CFD mode. The whole model should be meshed in regularization grids. The upstream dimension of flow field should not be less than 5D, and the downstream dimension is not less than 15D, and the height is not less than 10D. The upper and lower edges of the flow field are set to sliding boundary condition, and the outer surface of the conductor is non-slip boundary condition. The velocity load is applied at the inlet boundary. The air density is 1.29kg/m^3, and the dynamic viscosity of air is 1.82×10-5N•s/m^2. DES method is used in calculating, which combines the advantages of RANS and LES simulation. This method can reduce the number of grids and computation time greatly on the premise of ensuring the accuracy of the calculation. The transient analysis module and SIMPLE algorithm need to be selected in Adina program. The number of steps is 100 steps, and the time step length is 0.02s.

In this paper, the CFD numerical model of smooth circular conductor and stranded conductor are established, and the flow field distributions of the two conductors in different wind speed and diameter are analyzed using DES method.



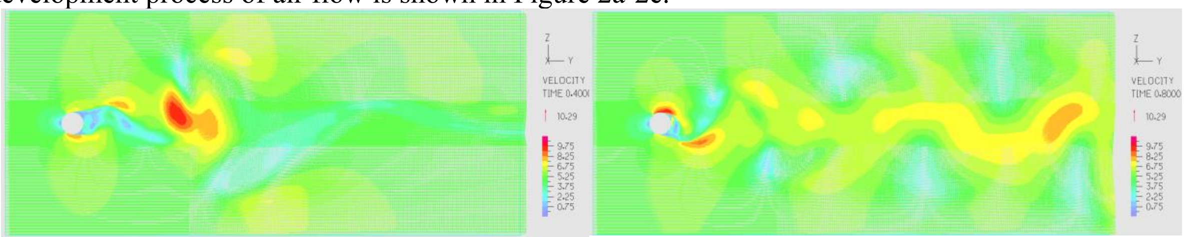
a. smooth circular conductor b. strand conductor

Figure 1. CFD models of two different conductors (local)

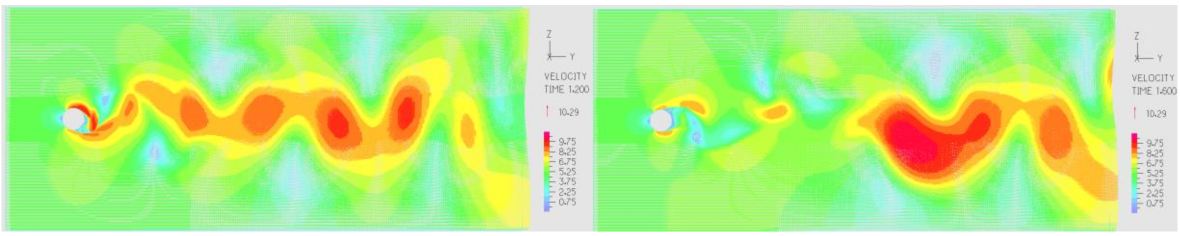
3. Results and analysis

The inlet wind speed, the diameter and shape of the conductor section are basic parameters which affect the distribution of flow around the conductors. So it is necessary to analyze the influence of these parameters on the distribution characteristics of conductor flow field.

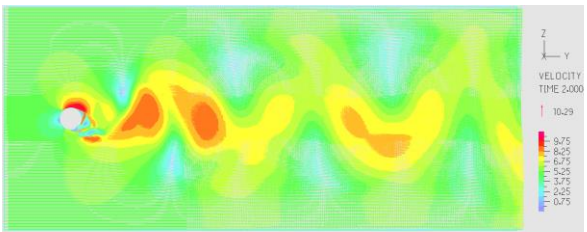
For example, the CFD simulation of a smooth circular conductor with a diameter of 50mm is completed. The Karman vortex streets are obtained when the inlet wind speed (V_0) is 5m/s, and the development process of air flow is shown in Figure 2a-2e.



a. t=0.4s b. t =0.8s



c. t=1.2s d. t=1.6s



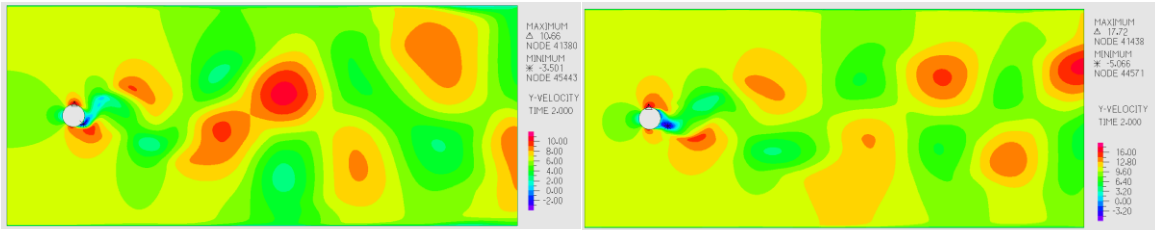
e. t=2.0s

Figure 2. Develop process of velocity streamlines of the 50mm conductor (m/s)

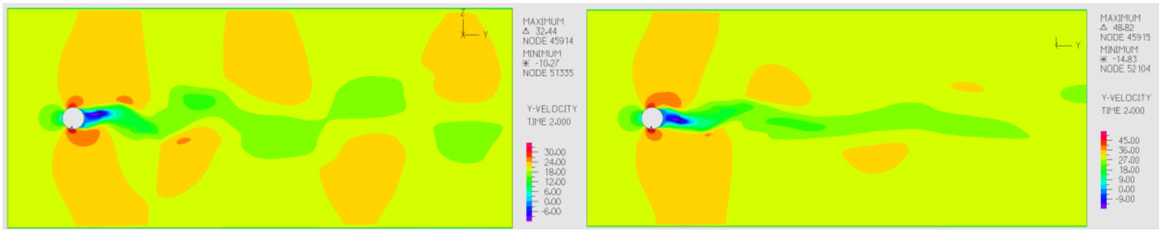
As shown in Figure 2, after wind round the windward frontier of conductor, separation vortex form in the upper and lower sides and strong trailing vortex form near the leeward side. The maximum wind speed in the center of separation vortex reach 10.29 m/s and the maximum wind speed in the center of trailing vortex is about 7.28m/s, both of them are considerably more than the inlet wind speed. With the passage of time, the negative pressure of the separation side began to occur alternately, and the wake area began to appear regular vortex street phenomenon.

3.1 influence of the inlet wind speed

When the inlet wind speed is respectively 6m/s, 10m/s, 20m/s and 30m/s, the wind velocity distributions in the horizontal direction (Y-direction) at 2.0s are shown in Figure 3a-3d.



a. V_0=6m/s b. V_0=10m/s



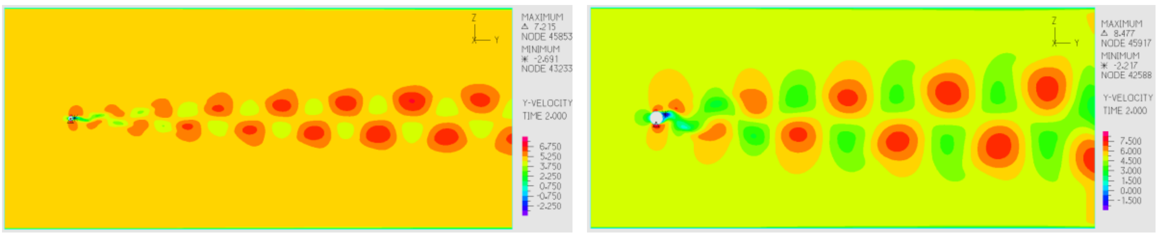
d. V_0=20m/s c. V_0=30m/s

Figure 3. Velocity distributions of the 50mm smooth circle conductor at 2.0s with different inlet wind speeds (m/s)

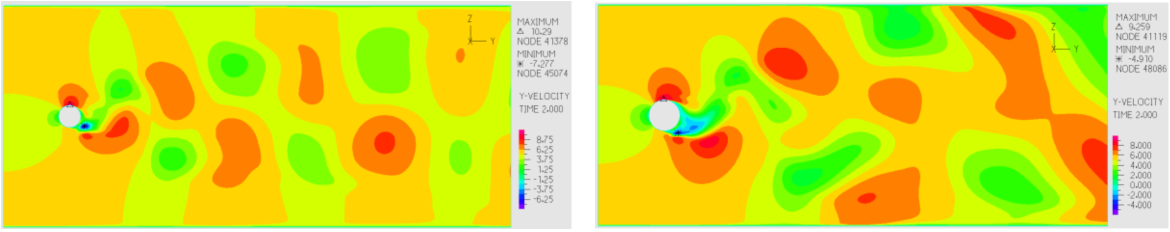
It can be seen that, with the increase of wind speed, the vortex shedding frequency of the same conductor is accelerated; the space distance of the vortex increases and the alternating regularity of vortex streets get worse and the vortex streets become weaker. In addition, the length of the trailing vortex is significantly longer.

3.2 influence of the conductor diameter

Similarly, when the inlet wind velocity equal to 5m/s, the distribution characteristics of the round flow field of the smooth circular conductor with 20mm, 30mm, 40mm, 50mm and 70mm diameter are calculated respectively, as shown in Figure 4a-4e.



a. D=10mm b. D =30mm



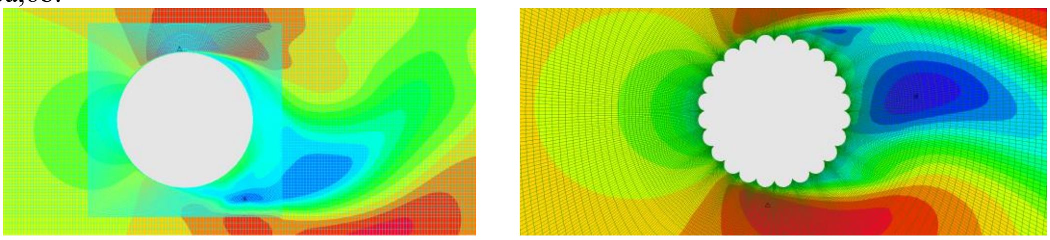
c. *D*=50mm d. *D*=70mm

Figure 4. Velocity distributions of conductors at 2.0s with different diameters (m/s)

It can be seen that: the maximum value of instantaneous wind speed of conductors with different diameters in the separation zone on both sides, and the minima value of instantaneous wind speed appears in the center of trailing vortex near the leeward side; with the conductor diameter increasing, the size of disturbance zone and vortex of the wake flow are larger, and the frequency of vertex shedding decreased; the extreme wind speed of conductor has a first rise and then fall with the diameter increasing.

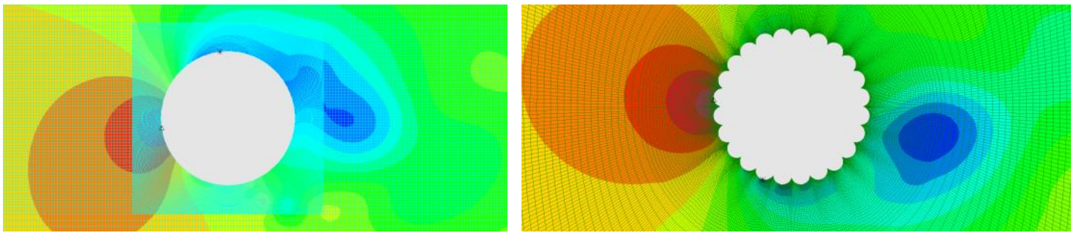
3.3 influence of the conductor section

When the inlet wind speed V_0 = 5m/s, the flow distributions of the smooth circular conductor and the strand conductor with a diameter of 70mm are calculated and compared as shown in Figure.5a,5b and Figure 6a,6b.



a. smooth circular conductor b. strand conductor

Figure 5. Velocity distributions of two different conductors at 2.0s (m/s)



a. smooth circular conductor b. strand conductor

Figure 6. Pressure distributions of two different conductors at 2.0s (m/s)

It can be seen from Figure 5 and Figure 6 that the wind resistance of smooth circular conductor is larger than that of strand conductor; the wake vortex street effect on smooth conductor is more obvious than that of strand conductor.

4. Conclusions

Based on CFD technology, the wind field distributions of conductors with different inlet wind speeds, different diameters and different cross-section profiles are studied. Some conclusions are obtained as follows:

(1) the numerical simulation method in this paper is applicable to the vertex street simulation of

smooth round conductor and strand conductor;

(2) with the increase of the wind speed, the vortex shedding frequency of the same diameter conductor is accelerated and the alternating regularity becomes worse; the size of vertex streets increases and the length of the trailing vortex is significantly longer;

(3) as the diameter of the conductor increases, the size of disturbance zone and vortex street of the wake flow become larger, and the law of vertex shedding begins to deteriorate;

(4) with the same diameter and inlet wind speed, the wind resistance and wake vortex effect of the smooth circular conductors are stronger than the strand conductor.

Acknowledgments
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