Study of the Establishment of Typical Wind Speed Model Based on Numerical Simulation

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Abstract: The wind power industry in our country has a rapid development. The continuous innovation of wind power technology has made wind turbine generators and electrical equipment integrated into one and has become a complicated mechatronic device. Wind power equipment has been greatly improved. Wind turbines have different categories in different ways，which according to the structure of wind turbines can be divided into two categories, including horizontal axis wind turbines and vertical axis wind turbines. Currently employed to grid-connected power generation are mostly horizontal axis wind turbines. The wind turbine is a complicated and systematic device that integrates electromechanical and electrical equipment. Aerodynamics is the sole energy source for the systematic equipment to output electrical energy. The aerodynamic characteristics of the wind turbine directly affect the ability of the crew to capture wind energy. The overall performance of the fan plays a crucial role, becoming an important issue in the development of wind power technology at home and abroad.

1 Introduction

In recent years, computational fluid dynamics (CFD) numerical simulation has become more popular with researchers. Because of its wind tunnel test does not have some of the advantages which include the ability to easily various parameters, low cost, short cycle times, high efficiency, and the ability to study the effects of different parameters. However, when using the CFD numerical simulation, strict attention must be paid to the calculation area and the meshing settings. With the development of fluid mechanics theory and the improvement in computer hardware and software, CFD will become a promising method.

Many experts and scholars at home and abroad have made certain progress in the study of aerodynamic characteristics of fans using FLUENT, and various analytical ideas and methods are constantly being verified.Rae W-West and others modeling the NACA2410 airfoil blade and using the aerodynamic characteristics of the impeller analyzed by FLUENT (Wang, 2012). Rosario Lanzafame and Stefano Mauro used FLUENT software to model the 2D CFD model of the H-type Darieu wind turbine. The FLUENT solver was used to predict the aerodynamic performance and optimize the geometry of the wind turbine (Rosario L, 2014). Alexandros Makridis and John Chick used the computational fluid dynamics software FLUENT to study the wake influence of wind turbines and the wind conditions of complex terrain (Alexandros M, 2013). R-Lanzafame and S-Mauro and others used FLUENT solver to study the aerodynamic characteristics of a three-dimensional (CFD) model of a horizontal axis wind turbine. Compare with the developed BEM-based model, R-Lanzafame and S-Mauro proved the accuracy of the FLUENT method (Lanzafame R, 2013). K-Pope, I-Dincer and others have used computational fluid dynamics software to calculate and analyze the aerodynamic performance of each system of horizontal-axis and vertical-axis wind turbines (Pope K, 2010). Ma Na, Yuan Qilong and others analyzed the variation of the flow characteristics and aerodynamic characteristics of rotating blades under different wind speeds, and numerically simulated the application of FLUENT software. At the same time, a small wind turbine was tested experimentally to verify the accuracy and effectiveness of the numerical simulation scheme (Ma Na, 2014). Many scholars at home and abroad apply FLUENT's grid technology to the research of aerodynamic performance of fans. Zhao and Cao used the nested grid technique and the explicit

Runge-Kutta method to simulate the flow field of the blade surface. The pressure distribution on the blade surface was numerically simulated and compared with the experimental data. The results show that the accuracy of the above scheme.

The most important prerequisite of the fan outflow simulation and aerodynamic load calculation is the establishment of wind speed model. At present, the wind speed simulation is not paid enough attention. The establishment of the wind speed model is mostly limited to a single constant wind speed and does not take into account that the operating environment of the wind turbine is complex and changeable. In this chapter, some wind speed models that may be encountered during the operation of the wind turbine are simulated, including vertical shears winds, gusts, extreme gusts and varying directions with extreme gusts. This is the actual operation of the fan has some engineering value. According to "JBT103002001" IEC61400-1 provides the basic parameters of force genset level [53] as shown in the following table 1 and table 2: The data in the table is the wheel hub height value used, where A indicates the type of higher turbulence characteristic; that B indicates lower turbulence characteristics.

Table 1 wind turbine rating basic parameters

wind turbine normal safety rating	I	II	III	IV
V_{ref} (m / s)	50	42.5	37.5	30
$V_{ave}(m/s)$	10	8.5	7.5	6

Table 2 wind turbine rating basic parameters

Turbulence range	Turbulent intensity characteristic value	Slope parameter
A	0.18	2
B	0.16	3

2 Wind Conditions in Wind Turbine Design Requirement

When designing a wind turbine, take the external conditions into account that the fan is located. Various types of external conditions can be roughly divided into two categories, one is the external conditions of the normal environment, one is the external conditions of extreme environment. The long-term load and operating status of the fan structure belong to the former, and several wind conditions studied in this paper belong to the external conditions of the extreme environment.

In order to meet the requirements of the safety rating of wind turbines, both the extreme wind conditions and normal wind conditions mentioned in this section should be taken into account when designing the fans. Table 1 and Table 2 provide different wind speed and wind turbulence parameters and the corresponding wind turbine safety rating. Specify the extreme external conditions and normal external conditions to be considered when designing a fan. The characteristic values of different sites can be expressed by different turbulence parameters and wind speed values. Table 1 shows the average reference wind speed for 10 minutes, which represents the average annual wind speed of the hub height. The standard wind speed in IEC 614000-1 (Bontempo R, 2014) is 0.2, that is, the reference wind speed is five times faster than the annual average wind speed. Table 2, A and B means high and low range of turbulence characteristics.

The wind speed distribution determines the frequency of occurrence of each load state and is of great importance of the wind turbine design. The wind profiled shows the variation on average wind speed with the height of the ground. The meaning of " wind turbulence " means that the wind speed changes randomly. The turbulence model should include the influence of wind speed, wind direction and cyclic sampling. The standard deviation of the

longitudinal wind speed component σ_1 and the longitudinal turbulence scale parameter Λ_1 is calculated as follows.

$$\sigma_1 = I_{15}(15 + av_{hub})/(a+1) \quad (3\text{-}1)$$

$$\Lambda_1 \begin{cases} 0.7Z_{hub}, Z_{hub} < 30\ m \\ 21 \qquad Z_{hub} > 30\ m \end{cases} \quad (3\text{-}2)$$

Where a is the slope parameter, Z_{hub} is the wind turbine hub height, V_{hub} is the average wind speed of the hub for 10 minutes.

2.1 User Defined Function (UDF) Introduction

User-Defined Functions UDFs are the user interfaces provided by Fluent and also are a distinguishing feature of Fluent software from other software. When the Fluent standard module can not meet the needs of the user's simulation, you can write your own algorithm through the UDF, including the definition of boundary conditions, material properties and other model parameters. UDF can identify programs written in VC ++, so user-defined functions are generally written in VC ++ and compiled and run. After the successful compilation and debugging of VC ++ can be imported and run through the Fluent UDF interface.

UDF source files are therefore files stored in.C format.

2.1.1 UDF Macro

UDF macros as part of user-defined functions play a crucial role in the user's own functions. If the user-written functions must be imported and executed through the UDF interface, the UDF macro acts as a real execution and invocation. UDF has a very powerful DEFINE macro. Including the passed DEFINE macro functions and DEFINE macro functions that match specific models, can be widely used in chemical reaction, physical operation process with time or space changes. Many commonly used variables, including speed, pressure, temperature, quality, can be defined for the user's use. Usually UDF functions as the FLUENT solver to obtain data information, and solver data information and grid data. A huge grid system is composed of many grid cells. As shown in figure (Yu Yong, 2012)1.

Fluent introduced a set of macro functions to access solver data onto the data exchange and processing functions as C programs and meshes, as shown in Table 3. These functions are linked to the data onto grid nodes to exchange and process data. As shown in the table is related to the grid node macro function, as well as with the grid surface and the grid unit related to the macro function, in which not to enumerate.
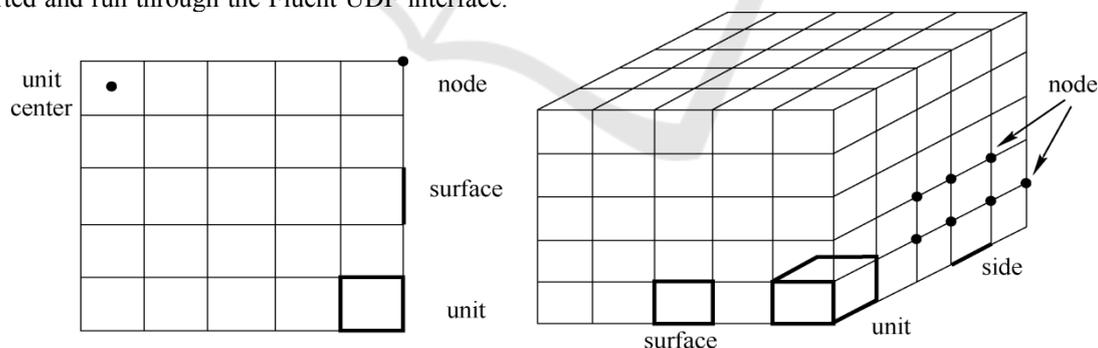

Figure 1 Mesh node information

Table 3 Mesh node-related macro functions

Macro function name	return value	head file
NODE_X (node)	Returns the coordinate value of X for the node	metric.h
NODE_X (node)	Returns the Y coordinate value of the node	metric.h
NODE_X (node)	Returns the coordinate value of Z of the node	metric.h
F_NNODES	Returns the number of nodes on surface f	mem.h

For the wind speed entrance plane, we choose the surface loop macro begin_f_loop and the grid coordinates function C_CENTROID (x, c, t) to set the wind speed entrance. Surface looping macros can loop through all surface meshes. The grid coordinates function returns the coordinate value of the center node of each grid surface, which can be applied to the wind speeds function as a function of position. We choose the macro command RP_Get_Real ("flow-time ") to define the wind speed model over time. The return value of this command can be used as a time variable.

2.1.2 UDF Compilation

UDF program is written in C language, the program can be VC ++ recognized, and stored in. C file extension file, the file can be opened Notepad to read. The preparation of the program through VC ++ software debugging before being imported from the UDF interfaces to run. UDF is divided into interpreted and compiled as shown in picture 2. Both enable user-defined function reads. The difference is that compilation is computationally faster,. So we chose compiled UDFs to import wind speed models.
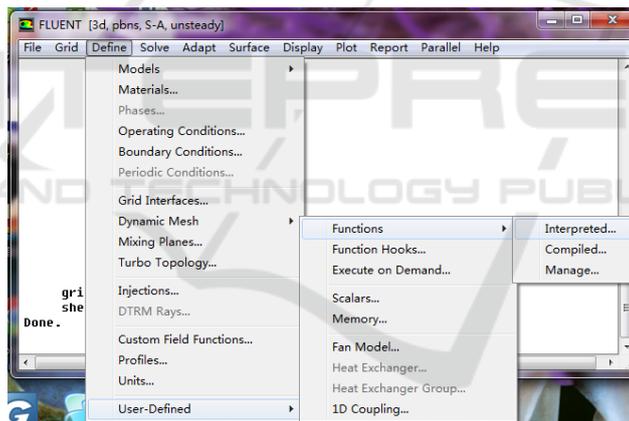

Figure 2 UDF compilation type

3 ESTABLISHMENT OF EXTREMELY RELATED GUST MODEL

According to "Wind Turbine Design Requirements Standard JBT103002001", the following correlation (1-1) should be used to determine the extreme gust wind speed. Assuming that the amplitude of the extreme correlation gust is $v_{cg} = 15$ m / s, the normal wind specified in Equation (1-2) Profile model.

$$V(z,t) = \begin{cases} V(z) & t < 0 \\ V(z) + 0.5V_{cg}[1 - \cos(\pi t / T)] & 0 \le t \le T \\ V(z) + V_{cg} & t \ge T \end{cases} \quad (1\text{-}1)$$

$$V(z) = V_{hub} \left(\frac{Z}{Z_{hub}}\right)^{\alpha} \quad (1\text{-}2)$$

In the formula, Z_{hub} is hub height, Z_{hub} =80m; α is wind profile, $\alpha = 0.2$;

V_{hub} is the average wind speed at hub height, V_{hub} =10m/s;

z is the ground clearance,
among them, $T = 10s$ is gust enhancement time;

Substituting each parameter value into (1-2), the wind profile function becomes equation (1-3)

$$V (z) = 10 \left(\frac{z}{80} \right)^{0.2} \quad （1\text{-}3）$$

Here the value α is non-integer, we expand the formula according to the binomial series, as shown in Equation 1-4.

$$(1+x)^{\alpha} = 1 + ax + \frac{a(a-1)}{2!}x^2 + \dots + \frac{a(a-1)\dots(a-n+1)}{n!} + \dots \quad （1\text{-}4）$$

Here we introduce the FLUENT predefined macro to access the coordinate data of the grid center point, where the introduction of height coordinate variables $x[1]$, The variables in Eq. 1-11 will be from the original height above the ground z expressed as a grid containing the center of the height coordinate value of the expression $m = z = x[1] + 80$,take $y = m / 80$ The wind profile function becomes equation (1-5):

$$V(z) = 10[1 + (y-1)]^{0.2} \quad （1\text{-}5）$$

The formula (1-5) and V_{hub} value into the formula (1-1) we can get the equation of extreme gusts as shown in (1-6) below:

$$V(z,t) = \begin{cases} 10[1+(y-1)]^{0.2} & t < 0 \\ 10[1+(y-1)]^{0.2} + 7.5[1-\cos(3.14t/10)] & 0 \le t \le 10 \\ 10[1+(y-1)]^{0.2} + 15 & t \ge 10 \end{cases} \quad （1\text{-}6）$$

We select several observation points at the plane hub height of the wind speed entrance to further measure the wind speed values corresponding to the different time points, as shown in Fig. 3 to Fig. 7 for the wind speed inlet plane observations of 1s, 3s, 5s, 10s and 11s. It can be observed from the figure that the wind velocity values corresponding to the different moments coincide with the theoretical curves of the wind speed variation of the hub height and wind speed of the extreme wind speed inlet shown in FIG. 8.

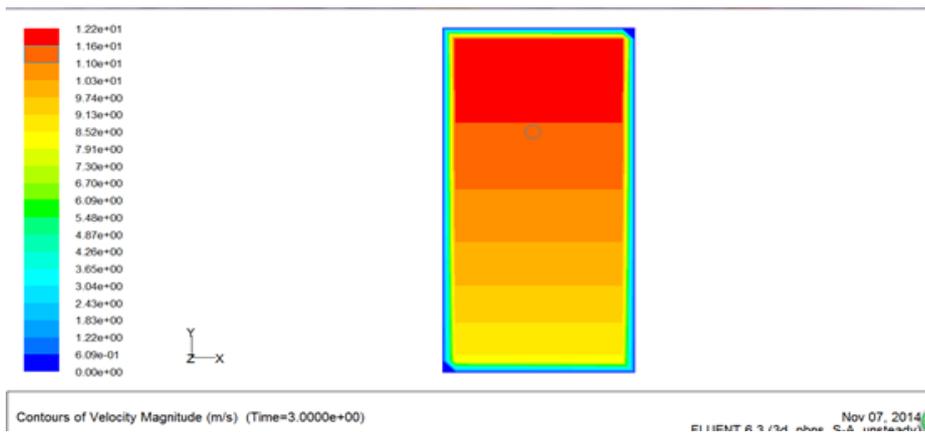Figure 3 (ECG) wind velocity at t = 1s entrance velocity cloud

Figure 4 (ECG) wind velocity at t = 3s entrance velocity cloud

Figure 5 (ECG) wind velocity at t = 5s entrance velocity cloud
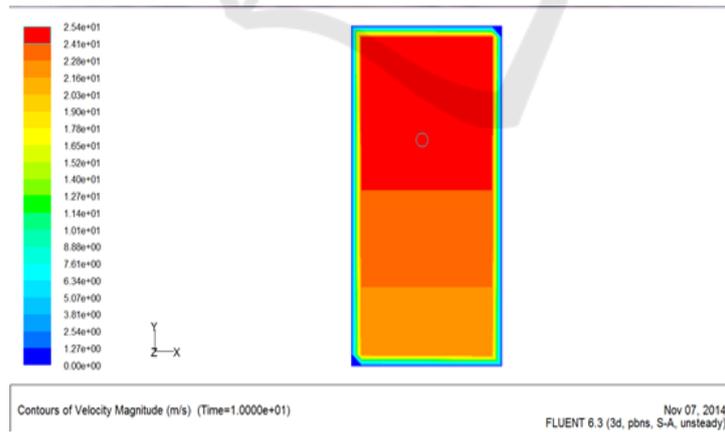

Figure 6 (ECG) wind velocity at t = 10s entrance velocity cloud
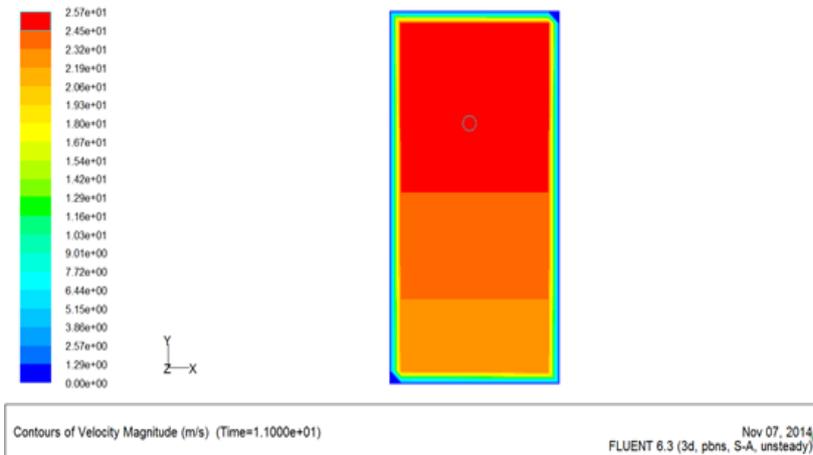
Figure 7 (ECG) wind velocity at t = 11s entrance velocity cloud
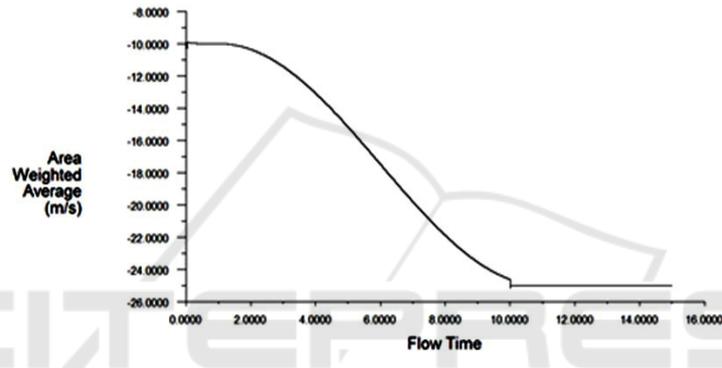

Figure 8 hub height wind speed inlet plane wind simulation curve

Our experimental setup for extremely rugged gust experiments, with one low-power blower for the main equipment, is highly adjustable. Axial flows fan, a wind pressure instrument. Axial fans which can rotate around a small power fan angle of 360 degrees. We conducted experiments on extreme gust wind speeds by simulating different wind speeds at the same angle with an axial fan and measured the wind speed at the hub of the small fan by a wind pressure gauge. The experimental results of the extreme gust wind speed are obtained and compared with the simulation values. The comparison results are shown in Figure 9, and the two curves are basically fitted. Therefore, the correctness of the simulation of the extreme gust wind speed is also verified.
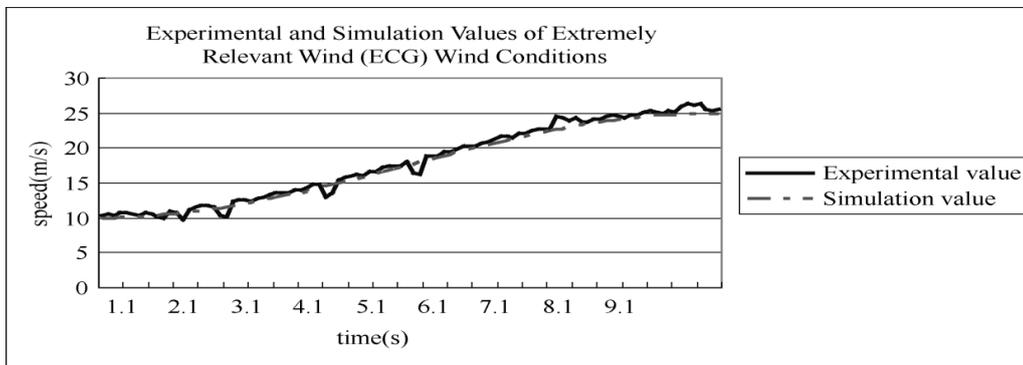

Figure 9 Experimental and simulated values of extreme wind gust (ECG) wind conditions

The wind speed model is the focus on this chapter. In the selection of wind conditions, we consider the extreme correlation gusts model under abnormal operating conditions considering the complicated wind speeds encountered with the actual operation of the wind turbine, including formula the derivation, as well as the specific algorithm compilation process. Through the UDF interface simulation, the velocity simulation curves and speed curves of each wind speed model are obtained. Experimental data are obtained through the experimental equipment, and compared with the simulation value to verify the correctness of the Fluent simulation.

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