Research on 3D Modeling and Forming Technology of 20KW Wind Turbine Blade

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Abstract:

The wind turbine blade is the key component to provide wind power generation. It converts wind pain into mechanical energy to provide the rotating torque required by the wind turbine. Whether the blade design and manufacturing process are reasonable or not is related to the power generation efficiency of the fan. In this paper, the 3D curved surface modeling and manufacturing technology of wind turbine blades are studied. Based on the secondary development of SolidWorks, the 3D curved surface modeling of 20KW wind turbine blades is carried out. According to the characteristics of blade material molding process, the wind turbine blade is manufactured by vacuum-assisted molding process. Finally, the performance of the wind turbine blade is tested. According to the test results, it is greatly improved, which saves the cost for enterprises and achieves good economic efficiency.

Keywords: *20KW wind turbine blade, 3D surface modeling, Blade material, Auxiliary vacuum molding process.*

I. INTRODUCTION

In recent years, wind power technology has developed rapidly in China, and wind power equipment is constantly innovating. The wind power generator is a unit system that converts wind energy into mechanical energy and then converts mechanical energy into electrical energy [1]. The efficiency of wind power generation has a great influence on the aerodynamic configuration of blades. Blade is one of the key components for converting wind energy into mechanical energy. The aerodynamic shape of the wind turbine blade determines the aerodynamic performance of the whole wind turbine. A blade with good aerodynamic shape can improve the energy conversion efficiency of the unit to obtain more wind energy [2]. The material and structure of the blade are the important factors to ensure its strength and rigidity. The right material and good processing technologyis one of the preconditions to ensure the manufacturing of large-size components with complex and aerodynamic shapes.

In this paper, the blade of 20KW wind power generator is taken as the research object, and the 3D curved surface modeling and optimization of the wind turbine blade are completed on the platform of SolidWorks secondary development, which has completed the aerodynamic shape design and modeling of the blade [3]. Combined with the technological characteristics of resin materials, the vacuum-assisted molding technology is used to manufacture blades. This method is to lay reinforced fiber substrates (reinforced materials and basalt fibers) on the forming die, seal them with plastic films, and then vacuumize them. Then, the liquid resin is injected, which is completely immersed in the fiber substrates and hardened by the negative pressure principle [4].

II. 3D CURVED SURFACE MODELING OF WIND TURBINE BLADES

The SolidWorks secondary development plug-in is run, which includes three modules: the input of basic parameters of aerodynamic shape design of wind turbine blades, the selection of airfoil of wind turbine blades and optimized calculation and curve generation. The operation steps are as follows.

(1) Calculating the diameter of the wind turbine blade

Enter the basic parameters of the blade in the parameter interface of wind turbine blade design, with power P=20KW, design wind speed 12m/s, tip speed ratio of 8, blade number =3, wind energy utilization coefficient =0.46, generator efficiency =0.93, air density of 1.225kg/m3. Calculate the diameter of blade wheel to be rounded.

(2) Generating curves of each blade element

In this paper, Solidworks software is used to model the wind turbine blade. The spatial coordinates of the discrete points of each section of the fan are based on the original airfoil data, and are converted by the spatial coordinates. The principle is shown in Figure 1.
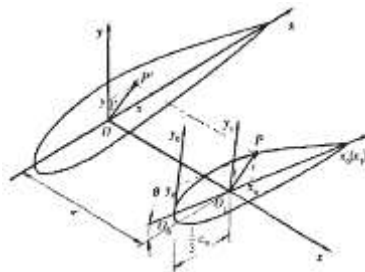
Fig 1: schematic diagram of spatial coordinate conversion

The coordinates (X_0, Y_0) of the original airfoil point are directly derived by Profili software, and the obtained data are all percentages relative to the chord length, which need to be multiplied by the actual chord length in the calculation. The two-dimensional coordinate takes the leading edge of the airfoil of the wind turbine blade as the origin. The chord direction is the X-axis, while the spatial coordinate system takes the plane with r=0 as the XOY plane, and the aerodynamic center of the wind turbine blade as the origin.The direction of the chord of the wind turbine blade from the trailing edge to the leading edge is the positive direction of the X-axis, which is perpendicular to the wind turbine blade. The chord pointing to the upper chord is the positive direction of the Y-axis, and the positive direction of the Z-axis is the direction along the blade span. Let the reference chord length of the original airfoil be C_0 and the distance between the aerodynamic center and the trailing edge of the airfoil be $\frac{1}{3}C_0$.

The calculation formula of coordinates is divided into three different situations as follows:

$$
\begin{cases}
X_1 = X_0 - \dfrac{1}{3}C_0 \\
Y_1 = Y_0 \quad (1)
\end{cases}
$$

When X<0

$$
\begin{cases}
X = -\dfrac{C}{100} \times \sqrt{X_1^2 + Y_1^2} \times \cos(\arctan\dfrac{Y_1}{X_1} + \theta) \\
Y = -\dfrac{C}{100} \times \sqrt{X_1^2 + Y_1^2} \times \sin(\arctan\dfrac{Y_1}{X_1} + \theta) \\
Z = r \quad (2)
\end{cases}
$$

When X>0

$$
X = \dfrac{C}{100} \times \sqrt{X_1^2 + Y_1^2} \times \cos(\arctan\dfrac{Y_1}{X_1} + \theta)
$$
$$
Y = \dfrac{C}{100} \times \sqrt{X_1^2 + Y_1^2} \times \sin(\arctan\dfrac{Y_1}{X_1} + \theta)
$$
$$
Z = r \quad (3)
$$

The above coordinate conversion process is encapsulated in SolidWorks by the secondary development language VB. The handle of the wind turbine blade can be simplified into a cylinder according to the actual installation mode, and the radius depends on the installed hub. The blade element of the wind turbine blade can be simplified into several circles with the aerodynamic center as the center. Select some points on each circle as discrete points, and calculate the coordinates of all points, so that the cross-sectional curve of the blade can be generated, as shown in Figure 2.
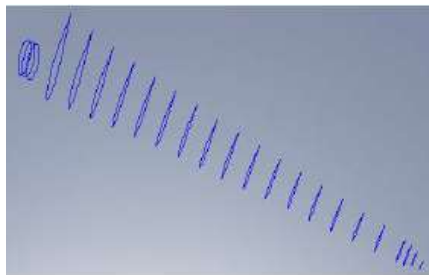

Fig 2: blade element curve of wind turbine blade

(3) Selecting the airfoil of 20KW wind turbine blade

According to the menu of sectioning, determine the number of sectioning, and input the distance value from each sectioning to the blade center. The airfoil data is selected with reference to the corresponding airfoil database data. According to the structural characteristics of 20KW wind turbine blades, NACA 63-415 airfoil is adopted in this paper [5]. The selection interface of NACA 63-415 airfoil is shown in Figure 3.
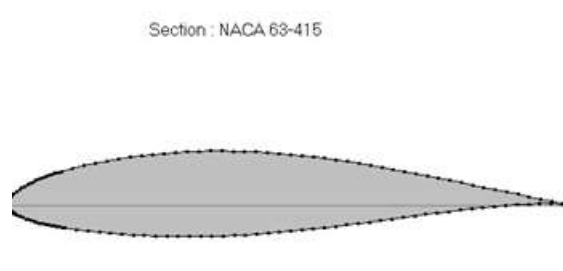

Fig 3: airfoil selection window

(4) Optimized calculation/curve generation.

Open the optimization calculation window of secondary development and click the

software calculation button. The system will automatically calculate the chord length and twist angle of each section according to the optimization calculation method and display them in the window. The data are shown in Table I.

TABLE I. Chord length and twist angle of each section

CROSS SECTION	CHORD LENGTH (DEGREE)	TWIST ANGLE (M)
1	24.2018	0.9995
2	19.1410	0.8815
3	15.5203	0.7690
4	12.8504	0.6742
5	10.8158	0.5968
6	9.2221	0.5336
7	7.9463	0.4816
8	6.8973	0.4385
9	6.0367	0.4017
10	5.3018	0.3705
11	4.6711	0.3437

After clicking the generation curve, SolidWorks will automatically generate curves and guide lines of each section.Select the root circle menu of the wind turbine blade, input the root circle radius according to the designed installation size of the 20KW wind turbine blade, and generate the root circle curve after confirmation, as shown in Figure 4.

Fig 4: root circle curve of wind turbine blade

(5) Get the 3D lofting surface of the aerodynamic shape

Through the lofting surface function of SolidWorks itself, select the guide line and each section curve, and get the 3D lofting surface of the aerodynamic shape of the blade.

(6) Generating the 3D model of the blade

The blade is divided into several parts along the span direction according to the different paving layers, and then the sharp points of the blade element curves of each part are selected in turn by using the command of lofting surfaces. The skin surface of the blade is generated after sweeping, so that the blade becomes a whole composed of several surfaces. Finally the 3D surface model of the whole blade is generated by combining the bladehandle data, as shown in Figure 5.
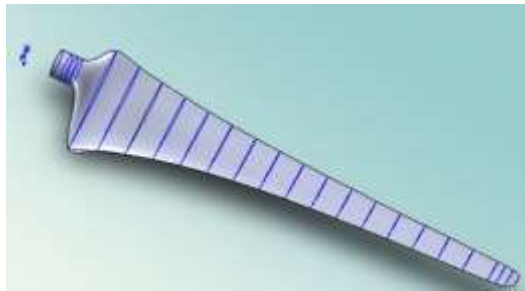

Fig 5: 3D surface model of the blade

III. THE RESEARCH OF WIND TURBINE BLADE FORMING TECHNOLOGY

Because the wind turbine blades obtains wind energy by directly facing the wind, it is required that they have a reasonable structure, advanced materials and scientific technology, so that they can reliably bear the bending moment and pulling force given to the blades by the wind force, the dead weight of the blades and centrifugal force. Therefore, the strength and rigidity of the material of the wind turbine blade is the key to determine the performance of the wind turbine [6].

3.1 Selection of blade materials

With the continuous development of the wind turbine blade industry, the application technology of composite materials in wind turbine blades has also been rapidly developed [7]. At present, most of the materials used for wind turbine blades are metal, glass fiber reinforced composites and carbon fiber reinforced composites. Among them, FRP blade material has become the preferred material for large and medium-sized wind turbine blades because of its light weight, good mechanical properties and stability. To meet the use requirements of wind turbine blades, the technological innovation of glass fiber is also taking place at present. The

interfacial bonding strength and single fiber tensile strength of glass fiber after surface treatment are higher than those of glass fiber without surface treatment, and the new generation of reinforced glass fiber can improve the performance of blades without increasing the cost of blades. In the actual manufacturing process of thermosetting composite structural parts, glass fiber cloth and glass fiber felt are often laid alternately to improve the interlaminar fracture resistance of composite laminates. In this paper, the material of wind turbine blades is resin composite YD535LV.

3.2 Forming technology of blades

According to the blade model designed in front, the blade mold is made. In this project, the vacuum-assisted molding process is adopted in the blade manufacturing process. The designed composite-based fibers are pre-cut, put into the mold. The rigid foam is wrapped in the middle of the fibers, and then the mold is closed. The subsequent process is completely completed and guaranteed by the mold and injection system, without any resin exposure, so that the technical and environmental requirements for workers are far lower than those of the hand paste process, and the product quality can be effectively controlled. The closed molding process adopted by the vacuum molding process realizes one-step molding without secondary bonding. The middle foam sandwich layer fills the thickness of the blade cavity, effectively transferring the skin load, reducing the layup, improving the efficiency and reducing the cost. See Figure 6 and Figure 7 for process schematic and flow chart.
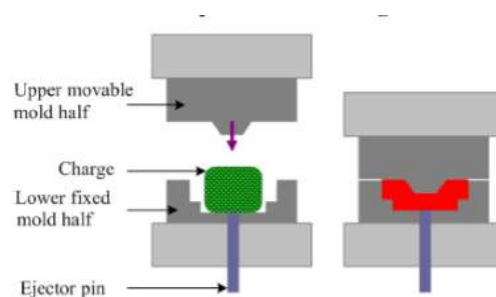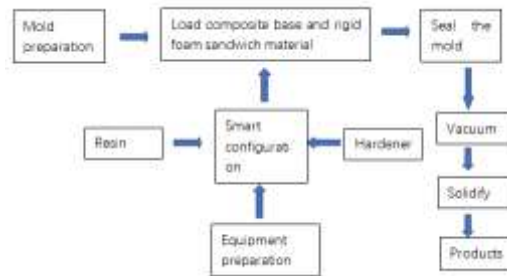

Fig 6: technological flow chart

Fig 7: flow chart of vacuum-assisted molding process

3.3 Technological operation process of blades

3.3.1 Mold cleaning

Blow the dust on the mold surface with compressed air, and then wipe the mold cavity and negative pressure belt with clean towel. The new mold needs stripping wax. When waxing, fold 4-6 layers in half with clean cotton cloth of appropriate size. The waxing direction must move in the same direction, with one person waxing before and one person wiping later. Missing waxing should be avoided. Wipe off the traces of wax. It is required that no obvious traces can be found at rakinglight. After 6-8 products have been produced by used molds, the negative pressure belt part should not be waxed any more, and the cavity of manufacturing 3-5 products must be waxed once, which requires uniform waxing and can not be missed.

3.3.2 Glue coat spraying and demolding cloth

Clean up the mold before spraying gel coat, and ensure no dust, dirt and other foreign matters. 8-12mm along the edge of the cavity, attach a film with sealing tape for one cycle. When the temperature is 25-30°C, the curing agent ratio is 1.0-1.5%. The gel coat and curing agent must be mixed evenly. The gel coat should be stirred evenly before use. The distance between the nozzle of the spray gun and the surface of the mold is 40-60cm. The gel coat shall be sprayed vertically. The spray gun is required to first move horizontally and then vertically, and the spraying should be uniform and the thickness should be controlled at 0.5-0.6 mm.

Immediately after spraying the gel coat, remove the film attached to the mold, and the sprayed gel coat must not be damaged. After the gel coat is solidified, lay 160-120g fine cloth

according to the design requirements, and lay with release cloth to complete the manufacture of wind turbine blades.

3.3.3 Test results

Through testing, the blade made by vacuum-assisted molding process has no bubbles, with good performance in interlayer and deformation and stable quality. It reduces labor intensity of workers and causes no pollution to the environment. See Table II for test data.

TABLE II. Test results

SERIAL NUMBER	TEST ITEM NAME	UNIT	TEST RESULTS			TESTING BASE
			average value	standard deviation	Dispersion coefficient	
1	Tensile Strength	Mpa	681.85	59	8.66	ISO527-4
2	Tensile modulus of elasticity	Gpa	35.00	1.8	5.08	
3	Bending strength	Mpa	805.17	110	14.23	ISO14125
4	Flexural modulus of elasticity	Gpa	28.89	1.1	3.73	
5	Fiber content	%	70.88			ISO1172

IV. CONCLUSION

By modeling the 3D surface of 20 kW wind turbine blade on Solidworks secondary software development platform, the original airfoil data can be converted into the spatial coordinates of discrete points of each section of the wind turbine blade by means of spatial coordinate conversion, and the chord length and twist angle of each blade element can be calculated and corrected.

(1) On Solidworks secondary development platform, the spatial coordinates of each section of aerodynamic blade can be directly converted. Through SolidWorks' own lofting surface function, the 3D lofting surface of the aerodynamic shape of the blade is obtained.

(2) For the composite component of the wind turbine blade, the resin will flow inside the

preform, and the resin pressure will compress the preform.

(3)The vacuum-assisted molding manufacturing process developed in this project can fully eliminate bubbles, reduce the void ratio of products, effectively control the rubber content of products and improve the quality of products. Moreover, the whole tooling system is closed with little organic volatile matter, which can form mass production, reduce the cost and finally lay a good foundation for further large-scale production of resin composite wind turbine blades.

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