CHEMICAL ENGINEERING TRANSACTIONS

VOL. 62, 2017

A publication of AIDIC

The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Fei Song, Haibo Wang, Fang He

ISBN 978-88-95608- 60-0; **ISSN** 2283-9216

DOI: 10.3303/CET1762193

Application of Three-dimensional Printing Technology in the Manufacture of Wind Turbine Generator Equipment

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To discuss the application of 3D printing technology in the manufacture of wind turbine generator equipment, the three-dimensional modeling technology is used to model the components of the wind turbine generator unit. Based on this, the wind turbine model is established, which has certain academic reference value. On the basis of three dimensional printing technology, through 3D printers, the material object of each component of wind turbines is obtained, and the physical model of wind turbine is acquired through the assembly. It achieves a single direction award, yaw and wind wheel rotation, and contributes to a more intuitive and clear understanding of the organizational structure and working principle. This paper summarizes some problems, including the distribution of the model on the substrate, the characteristics of the model, the model itself and the situation of the model consumables in the printing process of 3D printers and the relevant solutions are put forward. In summary, this paper successfully printed and assembled the wind turbine generator by 3D printing technology.

1. Introduction

Fossil energy has always played an indispensable role in the energy structure of mankind, and the total amount of its resources is limited. They are constantly exploited and utilized, and they will dry up one day. As the world energy pressure consumption becomes more quickly, because air pollution, global warming and other environmental damage and ecological balance problems caused by the use of coal, petroleum, natural gas and other fossil energies seriously affect people's daily life, people will have to face the increasingly serious energy crisis. Therefore, in order to achieve the coordinated development between energy use, environmental protection, and ecological civilization construction, to vigorously develop renewable energy will become the dominant direction of future energy use. Many of the world countries have shifted their attention to the exploitation and utilization of renewable energy, and has promulgated a series of laws and regulations to support renewable energy development.

Wind energy is an important component of renewable energy. It has abundant reserves, clean and environmental protection, and inexhaustible characteristics. It is one of the most valuable renewable energy sources. The use of wind energy and natural gas, gas and oil needs to be dug from a certain depth underground, and then transported to the thermal power plant to carry out combustion. The energy for power generation is different and the water energy is also different. Therefore, it is necessary to build large items to promote the operation of the turbine. The utilization of wind energy is not only simple but also flexible, and its utilization is varied. The utilization efficiency of wind energy is significantly improved from the early windmill water extraction, ship navigation, and modern wind generation. Nowadays, wind power has become the most mature and the most promising renewable energy source that can be developed and utilized in various energy technologies. The wind power generation, due to a huge potential for development, is paid attention to by all countries in the world. Many countries have invested huge amounts of money and issued a series of preferential policies and support measures of wind power, to encourage large-scale exploitation of wind power. In this way, the use of fossil energy can be reduced, the tense situation in the energy can be alleviated, and greenhouse gas emissions amount as well as the environmental pollution burden can be reduced, so as to further realize the sustainable development between economy and ecological environment.

As the research of wind energy utilization becomes more and more thorough, wind power generation capacity

Please cite this article as: Xinyan Duan, 2017, Application of three-dimensional printing technology in the manufacture of wind turbine generator equipment, Chemical Engineering Transactions, 62, 1153-1158 DOI:10.3303/CET1762193

is increasing gradually, but many people only understand its structure and working principle in theory. While research on this subject, not only can make the wind turbine model become material object, but also make people intuitively understand the structure and principle of wind turbine. And in engineering, we use the 3D printer for printing material object model, and provide a new idea for the materialization of the models with other functions. At the same time, it provides a new channel for reducing the cost of innovation in the development of new products. Meanwhile, some problems on the Dimension 3D printer are summarized and solved, having a very good practical reference.

2. Method

2.1 3D modeling technology

With the rapid development of computer application technology, 3D modeling technology has been researched and applied in many fields, and it has made great changes in modeling methods, objects and other aspects. At present, for the object modeling, there are three kinds of methods on the whole: modeling through 3D drawing software, such as Solidworks, Pro/E and UG; modeling after the measurement through specific equipment, such as 3D scanner (called 3D digitizer) (Bassett et al., 2015); modeling through the image or video using the IBMR method. This method is based on the image and rendering technology, which can complete faster, more convenient and more accurate modeling.
In the object of modeling, the model of 3D modeling technology also changed greatly. At the beginning, it is the 3D wire-frame model, and the 3D solid object of this model was constructed by line and polygon. It is difficult to be used to represent the cylinder and sphere surface, which cannot constitute an entity. Then, based on the above findings, three-dimensional modeling system is formed after some relevant data that can form the solid surface are added. This modeling system cannot calculate the quality of established model and moment of inertia and other physical properties parameters, and it can only represent the surface and boundary of the object. The solid model system appeared next can define the entity properties of objects. The characteristics parametric technology can make high correctness of the design object and rapid production efficiency. The variable technology is more advanced, which can well specify the size "parameter" in the characteristics parametric technology and change to constraint of shape and size.
The 3D modeling technology is widely used in the machinery industry. The design process, technical steps, assembly production and maintenance all aspects of the product has been changed to a great extent. It significantly improves the efficiency of the development of new products, and reduces the cost of developing new products. Now, the commonly used three-dimensional modeling software includes Autodesk Inventor, SolidEdge, Prol Engineer, CATIA, UG, Solidworks and so on.

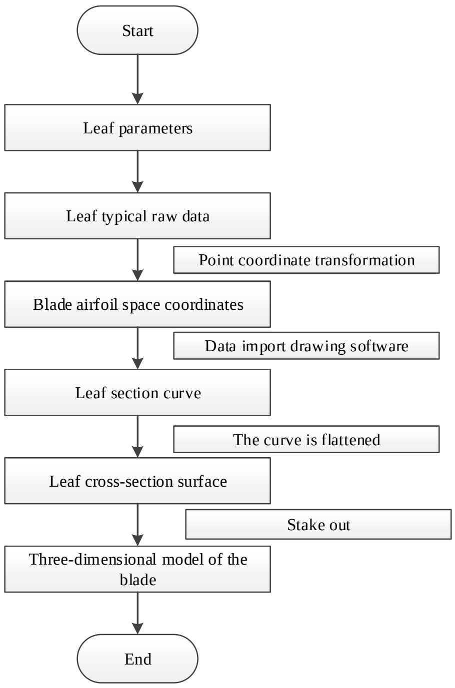

Figure 1: Flow chart of blade modeling

2.2 Modeling of main components of wind turbine generator unit

Blade: The blade is the most basic and key wind turbine component. Whether the design of wind turbine blades is good, if the quality is reliable and whether the performance is superior are the decisive factors for whether the unit is normally and stably operated. In the meantime, it directly determines the wind machine performance and efficiency. Therefore, the design of wind turbine blade has a very important position in the design of wind electrification unit (Ferrari et al., 2017). The 3D modeling of the blade can be realized by UG, Pro/E, CATIA, SolidWorks and other 3D graphics software. This paper combines Solidworks and Matlab to complete the modeling and the modeling process is shown in figure 1.

Blade parameters: In this paper, three-dimensional modeling of 1.5MW wind turbine blade shape is conducted, and the wind wheel radius is 35m. The distribution of the chord length and twist angle is shown in table 1. The section shape of the wind turbine blade is complex, and the blade is often used with different airfoils at different sections, so the selection of blade airfoil is very critical. The airfoil of the blade used here is Naca230xx series, and its type and distribution are shown in table 2.

Table 1: Distribution of the blade chord and twist angle

r/R(%)	Chord length (m)	Twisted angle / (°)
0	1.93	12.5
5	1.93	12.5
25	3.03	12.5
35	2.52	10.1668
45	1.93	7.42193
55	1.68	4.68690
65	1.33	2.46580
75	1.14	1.32242
85	0.87	0.90787
95	0.56	0.36392

Table 2: Types and analysis of airfoil on blade interface

r/R(%)	Airfoil types
0	Cylinder
5	Cylinder
25	Naca23018
45	Naca23018
55	Naca23018
75	Naca23021
85	Naca23021
95	Naca23024

Wheel hub and spindle: The wheel hub is the hinge of the wind wheel, which is an important component of wind turbine, and is connected with the blade and spindle, bearing all the loads from the blade. These loads include the thrust, bending moment, torque, and gyroscopic moment of the blade, which are transmitted through the wheel hub to other structures of the unit. In the modeling of wheel hub, the wheel hub is achieved by two concentric spheres and four cylinders through certain steps.

The spindle of wind turbines is responsible for supporting the role of various loads transmitted from the wheel hub. At the same time, the load is transferred to the cabin and tower, which is an important component of the wind turbine (Han et al., 2016). Whether the design has safety and rationality affects the performance of the whole wind turbine. In this paper, deep groove ball bearing is used as main shaft bearing, and the main supporting way of the spindle is two points support.

Nacelle base: The nacelle base is the main component of the wind turbine to bear the load. The wind wheel, generator, transmission system and other components are supported by it. The middle part of the nacelle has a yaw reducer which needs to be supported, and it is connected with the moving coil of the yaw bearing.

Yaw bearing: The yaw bearing is located at the bottom of the engine room, and it is one of the key components to determine the operation performance of the wind turbine. The inner ring is connected with the

engine room by bolt, and the outer ring is also connected with tower body with bolt, and the gear teeth have two kinds of internal and external teeth (Haselhuhn et al., 2014). External gear teeth are on the bearing outer ring, easy for being processed. The internal gear teeth are on the inner ring of the bearing, having compact structure, and able to get better fitness. Which specific form of gear is selected should be in accordance with the specific structure and the overall layout of the wind turbine.
Tower: The tower is the load-bearing component of the wind turbine, supporting the engine room and the wind wheel, and the wind wheel and the engine room can run at the designed height (Kabir and Ng, 2016). It not only bears the load of the wind wheel and the engine room, but also bears the load generated by the limited wind speed, and it is also the foundation for the whole wind motor sister to bear the load.

3. Printing and assembly of wind turbine generator equipment model

3.1 Printing of main parts of wind turbine generator set

The 3D printer that used in the components printing is Stratasys company's Dimension 3D printer. The FDM technology is used in the coating process, the model material uses the P430ABS, and the supporting material uses P400 SRP91 (Kreiger and Pearce, 2013). The size of the printer forming space is the length, breadth, and height of 200mm, 200mm, 300mm cuboid. The printing layer thickness is 0.1778mm and 0.2540mm two kinds. The method of the model internal printing has solid, loose - low density and high density three kinds, and the support filling form includes foundation, semi solid, SMART and surround four kinds (Ning et al., 2015). Therefore, the material object that the 3D printer can print not only has the size limit, but also has the precision limit.
According to the models of the typical parts, such as blade, wheel hub, spindle, engine room base, tower and foundation, some printing parameters are set up, respectively. Because the height of the printing tower is more than 300mm, it can be divided into two parts for printing: upper parts and lower parts. Table 3 is the printing data of a typical component. Among them, in addition to the basic use of printing method with the layer thickness of 0.2540mm, loose internal model, a high density, support filling SMART, others all use the printing method with the layer thickness of 0.1778mm, loose internal model, a high density, support filling for half solid (Noura et al., 2016).

Table 3: Printing data of typical components

Name	x/mm	y/mm	z/mm	Model material /cm^3	Supporting materials/cm^3	Printing time /h
Blade	46.5	36	275	51.22	3.60	9.33
Wheel hub	75.5	93.4	81.9	52.12	59.73	21.06
Spindle	56.0	56.0	76.0	30.76	3.92	5.25
Nacelle base	120.0	85.0	30.0	75.39	16.02	11.57
Tower (top)	77.9	77.9	220.0	120.69	61.78	31.08
Tower (bottom)	84.0	84.0	200.0	103.56	90.64	33.31
Base	200.0	170.0	40.0	397.97	71.87	28.34

3.2 Problems encountered in printing and Solutions

Because the print size and print accuracy of 3D printer used in this paper are limited to a certain extent, in some components of the printing wind turbine, there will inevitably appear a variety of problems. And the problems encountered are mainly displayed in the following aspects:
The distribution of the model on the substrate: Each model is printed on a substrate as a platform. The printing time and results of the same model are affected by the distance between the models and the density of the model. The distance between the model is closer, the print time will be reduced. But the separation model of materials and support materials at the end of printing may increase a certain degree of difficulty, especially for larger models (Orlandi et al., 2015). At the same time, if the distribution of model on the substrate is more intensive, it is possibly that some of these models failed to be printed. Therefore, the distance between the models should be appropriate when printing, and the model should not be too dense on the substrate.
The characteristics of the model: Each model part has its own features, such as holes, cylindrical surfaces, spherical surfaces, rounded corners, threads and so on. The print accuracy of 3D printer that this paper uses is not high. The printing effect of some characteristics is very poor. For instance, thread cannot print out the expected results, unable to be used for the assembly, thus replaced by other features. The printing effect of some features is just passable. For example, the spherical, because it is a hierarchical processing, it has obvious traces on the sphere and so on. Therefore, the printed model should not be too complex, and some features need to be removed or replaced by features with relatively good printed effect.

The model itself: Some models require to achieve their own functions after printing. For example, bearings can rotate, gear can be dried and so on (Rafiee et al., 2017). Like gear and bearing this kind of standard parts, in accordance with the standard, direct printing will not achieve the expected roles. At that moment, part of its size and structure should be changed into non standard, such as removing the bearing cage, changing the ball size etc. This kind of situation should be changed according to the function of the model itself.
Model consumables: When a 3D solid model carries out printing, the model material needed is unchanged, but the supporting material is affected by the relative position of the surface of the model itself and the substrate. When printing, the consumables should be as small as possible, but at the same time, we should also consider the ease for the separation of two kinds of materials. In addition, the same batch printing model should be the molding for one time, not allowed to change the material box halfway.

3.3 Entity assembly of wind turbine model

Because the printing accuracy of the 3D printer is not high, and components printed out are not all able to cooperate, the information of components unable to be matched is feedback to the modeling. Modify components model and re print until all components of the wind turbine completed printing, and then we can start in solid assembly. In addition to the components the assembly printed out, five motors are added in the assembly process, which are installed at the junction of the blade and wheel, and the connection of the nacelle base and the yaw bearing and the tower. Install three pitch motors in the connection of the blade and the wheel, which is used to achieve variable pitch (blade rotation). The rated voltage of pitch motor is 6V, the rated speed is 20rpm, and the working voltage is 3V (Prasad and Dimitriadis, 2017). A main drive motor is installed on the base of engine, used to achieve the rotation of the wind wheel. The rated voltage is 12V, the rated speed is 30rpm, and the working voltage is 6V. A yaw motor is installed on the junction of the yaw bearing and tower, used to achieve the yaw (rotation of cabin and wind wheel). The rated voltage is 12V, the rated speed of 30rpm, and the working voltage is 3V. The model realizes the pitch, yaw and wind wheel rotation of the wind turbine. Figure 2 is the physical model of the established wind turbine after assembly.

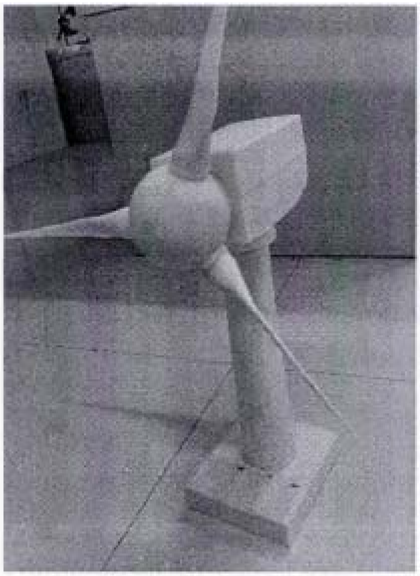

Figure 2: Physical model of wind turbine model

4. Conclusion

In this paper, the simulation model of the wind turbine is taken as the research object, to carry out related research work. The main contents and results are as follows: to establish the 3D model of the various components of wind turbine by using 3D modeling technology, and combined with Solidworks and Matlab software, to complete the three-dimensional modeling of wind turbine blades. The Solidworks software is applied to complete the modeling of the wheel hub and tower as well as other parts, and the simulation model of the wind turbine is obtained through the assembly, having certain academic reference significance. 3D printing technology is used, to print out the completed modeling of various components of the wind turbine by 3D printer into material objects, and assembly physical model of wind turbine. It achieves the variable pitch, yaw, and wind wheel rotation function of wind turbine, which can make display and so on functions and has very good inspiration effect. This paper summarizes the problems encountered in the use of Dimension 3D printer, and gives the relevant solutions, which has certain practical reference value.

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