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INVESTIGATION ON OPTIMAL LOCATION OF SEPARATION PART FOR LARGE SCALE WIND TURBINE BLADE

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Abstract

Around the world, fossil fuel energy is being replaced with renewable energy due to environmental problems and sharp price increases. Many countries are making a change in the direction of moving toward eco-friendliness by reducing carbon emissions. Among renewable energies, the wind energy is eco-friendly because it produces electricity by wind power without carbon emissions, and it attracts attention worldwide as a great alternative to the exhausted fuel energy. To improve the efficiency of wind turbines, large and extra-large wind turbines have been developed all over the world by increasing install and diameter. These wind turbines have difficulty in transport after manufacture because of their size and height. Since the height of wind turbine blades is higher than the existing tunnel height, it is impossible to transport them. In this study, therefore, a 5 MW class large blade was separated for transport easiness as wind power generators became larger globally. Aerodynamic design and analysis was carried out for the blade. After performing structural design and analysis with the model designed, the stress concentration of the analyzed model and the various factors for consideration when separating were considered to conduct the study of selecting the optimal blade separation positions.

Key Words : Wind turbine blade, Aerodynamic analysis, Structural analysis, Separation blade

1. Introduction

Fossil fuel energy is being replaced with renewables around the world due to environmental problems and sharp price increases. EU aims at carbon neutrality by 2050 and agreed to reduce emissions to less than half by 2030. In South Korea, it is aiming to be carbon neutral by 2050. The wind energy attracts attention worldwide as a renewable energy source. The wind turbine generator is a system that converts kinetic energy from the wind into electrical energy to produce electricity, and the produced electricity could be used for home and industrial use. In these days, the wind power provides relatively inexpensive renewable energy source and produces carbon-free electricity in many countries, so there are the increasing number of studies and applications in the related field. The wind energy tends to pursue a larger size, and as the diameter becomes larger, its efficiency increases more, so extra-large wind generators are developing around the world.

Recently, as the wind power generation system's blades become larger, their increasing weight and length leads to difficulty in transport blades. In South Korea, there are many mountainous areas, and due to geographical characteristics of onshore wind power generators, large-scale blades are limited in transport. In addition, there is height limit when transporting by train to construct very large wind power generators in the landlocked countries. In this paper, therefore, to study how to put together after producing separated blades, recent research trends were analyzed on the basis of the existing cases where developed separated blades, and the optimal separation position was examined.

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2. Performance and Design of Horizontal Axis Wind Turbines

To achieve the performance of wind turbines as much as the target value, the design should be conducted for the efficiency of turbines, quantity of electricity produced, and aerodynamic factors affecting turbines. A large-scale wind turbine should have better efficiency than multiple small-scale wind turbines. Therefore, the performance should be evaluated by designing according to whether a single turbine generates enough electrical power and how much resource the blades of the turbine consume while generating.

2.1. Generator Efficiency

The power coefficient of wind could show efficiency up to 0.593 which is the highest theoretical efficiency of Betz. Currently the efficiency of most wind turbines showed about from 0.43 to 0.48, which considered mechanical efficiency and wind speed depending on the type of turbine. Calculating the moment coefficient with Eq. (1) and multiplying the tip efficiency of blade as Eq. (2), Cp could be found simply.

$$C_M = \frac{2M}{pSV_1^2R} = 2\int_0^1 (1-k^2)E\cot I\frac{r}{R}d(\frac{r}{R}) \quad (1)$$

$$C_p = C_M \times \lambda_0 \quad (2)$$

2.2. Characteristics of Airfoil

Figure 1 shows the relationship between lift and drag force of the blade's cross section. It shows the relationship diagram between aero twist angle, inclination angle and incidence angle if the wind blows straight from the left. It shows the direction of the force that airfoil receives when the airfoil is rotated with an idle angle given and the air encounters the airfoil.

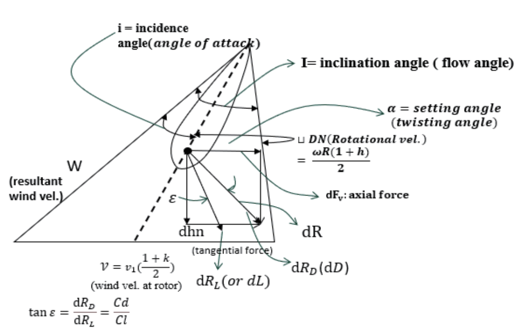

Fig. 1 Relationship between lift and drag force of wind turbine blade cross section

2.3.Aerodynamic Design

Wind turbine blades require a combination of multiple airfoils to improve efficiency. In addition, a lot of airfoil coordinates are needed to create airfoils effectively. The airfoil coordinates were gotten from the NREL database. CATIA 5 was used to design the blade by transferring coordinates to the program with an Excel file. Table 1 is the airfoils applied. The airfoil shape was applied to design. The final design result is presented in Table 1.

Table 1 Section of a wind turbine blade

r/R	r(m)	α(°)	l : chord	airfoil
0.187	10.846	15.78	7.009	DU99 W 405LM
0.252	14.616	14.09	5.343	DU99 350
0.317	18.386	12.4	4.646	DU99 350
0.382	22.156	10.71	9.321	DU97 W 300
0.447	25.926	9.02	8.228	DU97 W 300
0.512	29.696	7.33	7.135	DU97 W 300
0.577	33.466	5.64	2.696	DU91 W2 250
0.642	37.236	3.95	5.717	DU91 W2 250
0.707	41.006	2.26	5.391	DU91 W2 250
0.772	44.776	0.53	2.259	DU93 W 210LM
0.837	48.546	0.29	2.133	DU93 W 210LM
0.892	51.736	0.16	2.044	DU93 W 210LM
0.935	54.23	0.07	1.982	DU93 W 210LM
0.978	56.724	0.02	1.929	DU93 W 210LM
1	58	0	1.904	DU93 W 211LM

Figure 2 is the result that reflected the design result of Table 1 and modeled by CATIA program. This modelling was used to conduct CFD in ANSYS to carry out aerodynamic analysis. As a result of checking the analysis result, the efficiency of 5 MW reached 0.45 which was the target and the reliability was secured.

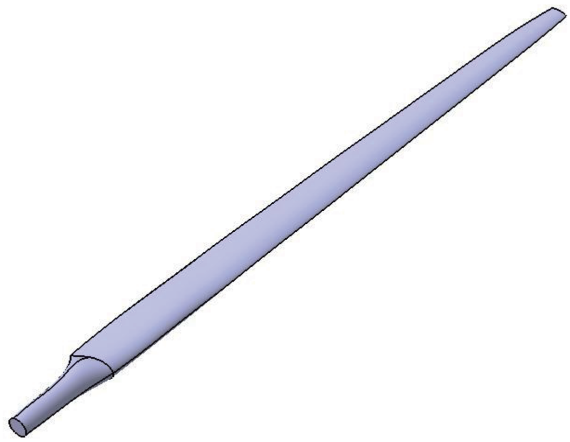

Fig. 2 Model of the designed wind turbine blade

3. Conclusion

Wind turbines are being developed for the purpose of producing electricity eco-friendly due to fossil fuel depletion and price increases. In this study, 5 MW-class horizontal-axis wind turbine blades were designed and the aerodynamic and structural design was performed. The blades were modeled with CATIA 5 and the analysis was conducted using ANSYS. This analysis was carried out to secure reliability. Various factors such as weight and stress concentration were considered to choose optimal separation positions. In this study, therefore, separation positions were analyzed for large scale wind blades to transport and optimal positions were selected.

Acknowledge

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