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Design and Optimum arrangement of a Blade Flap for Improving the Power Generation of a Horizontal Axis Wind Turbine

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ABSTRACT: In this research, a new type of add-on flap is presented and the effect of adding it to the blade of a horizontal axis wind turbine and optimizing its location and length is investigated. The use of an add-on flap is more cost-effective than other conventional methods since it does not need major modifications to the existing blades. For increasing the accuracy of the blade element momentum algorithm, the aerodynamic coefficients of the blade section are obtained by numerical solution of the governing equations, while in most similar studies, methods based on airfoil linear theory were used. The results showed that the modification made in the blade momentum element algorithm increased the accuracy of the solver while maintaining its computational speed. The results show that using this type of flap arrangement, the value of the base turbine power coefficient was increased from 0.29 to 0.41, which shows a significant increase compared to other methods.

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1- Introduction

One type of renewable energy is wind energy, and wind turbines have the ability to convert wind kinetic energy into electrical energy [1].

Over the years, various researchers have proposed methods to improve the production capacity of existing horizontal axis turbines by modifying the geometric parameters of their blades through aerodynamic analysis [2-7]. But an important point has always been how to apply these geometric modifications with the least changes in the production line and the lowest cost.

One of the new ways to increase wind turbine power is to use flap surfaces [7, 8]. By installing on the blade, these surfaces allow the blade manufacturers to control the blade condition and increase power generation.

According to the research of Sins and Zhang [7, 8], it can be acknowledged that if a suitable flap is selected, there is a possibility of a significant increase in wind turbine power coefficient. Therefore, in this paper, a new model of add-ons flap that matches the airfoil camber at the trailing edge is presented, which has better aerodynamic efficiency due to its special design. On the other hand, due to the need for fewer changes in the blade production line, the cost of this improvement will be much lower than other methods that require a change in the design of the entire blade.

In the present study, the blade element momentum theory was used to calculate the power coefficient [9, 10]. Existing commercial software such as Q-Blade uses the X-foil solver based on simplified linear methods to calculate aerodynamic coefficients. However, this solver usually shows the lift value more than the actual value and the drag value less than the actual value. Therefore, to prevent this error, a numerical solver is used to calculate the required aerodynamic coefficients.

The base turbine in this project was the wind turbine of the University of Berlin called TU-Brett [11], the image of the above turbine model is shown in Fig. 1.

Fig. 1. Image of TU-BERT turbine blade in a wind tunnel

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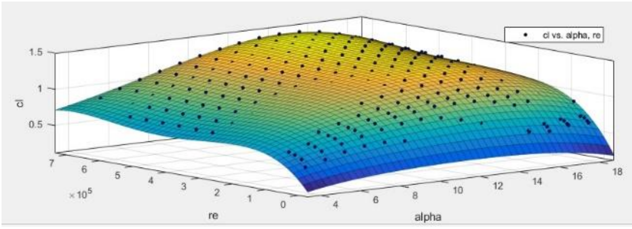

Fig. 2. The surface coefficient procedure in terms of angle of attack and Reynolds number for cross-section without flap

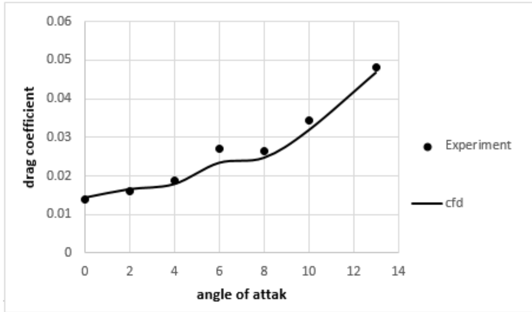

Fig. 4. Comparison of numerical solution results with experimental solution results

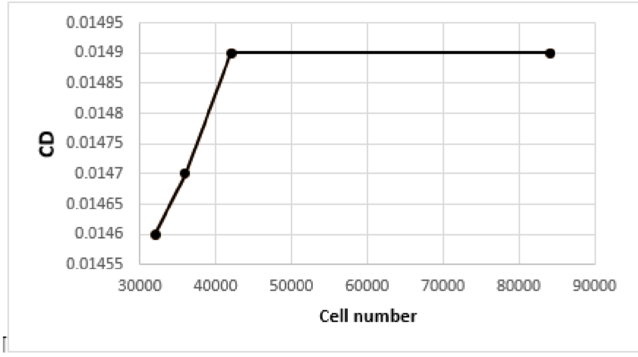

Fig. 3. Post-coefficient changes with the number of network cells

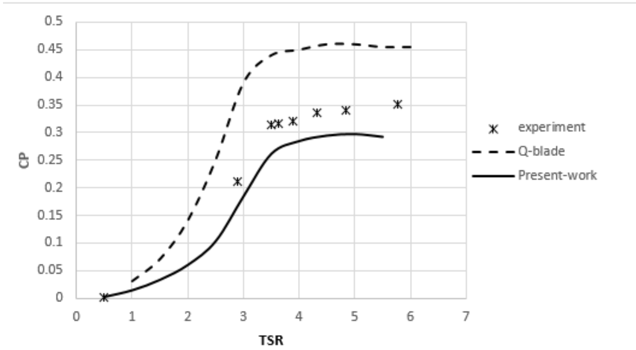

Fig. 5. Comparison of power factor obtained from cuboid solution and the code developed in this research with experimental data

2- Methodology and Validation

A modified Blade Element Momentum (BEM) algorithm was used to calculate the wind turbine performance in this study.

In this study, in order to improve the accuracy of the results, a new method was used, so that instead of coupling X-foil engineering software with the BEM algorithm, a combination of two methods of flow numerical solution and BEM algorithm is used. By having the aerodynamic coefficients in different flow conditions such as Reynolds number and angle of attack and extracting the equation of a surface passing through these points, it is possible to obtain each of the lift and drag coefficients in the angle of attack and the desired Reynolds number.

For without flap airfoil, the set of lift coefficient points in terms due to Reynolds numbers and angle of attack is as shown in Fig. 2.

A C-type domain was used to model the airfoil. After a dimension study of the field, a field with a 25C behind the airfoil and a 15C radius was selected. An appropriate grid generated was performed by producing four networks with the specifications listed in Fig. 3 and examining the trend of changes in the drag coefficient. According to Fig. 3, the network with 42,000 cells had the independence of the results and was identified as suitable for further analysis.

After studying the domain dimensions and grid studies, numerical solution settings were applied to validate the results according to the reference [12].

In Fig. 4, the results of the drag coefficient with a numerical solution and experimental data are compared. Now, in order to ensure the accuracy of the numerical solution results, the steps were continued.

In the BEM code, the blade is divided into different elements and for each element according to the flow conditions, including wind speed, tip speed ratio, and geometric characteristics, the Reynolds number and angle of attack are calculated. With the flow characteristics of each element the aerodynamic coefficients are extracted from the numerical solution and as a result, the forces acting on the element are calculated.

Finally, by integrating all the elements, the wind turbine power coefficient is obtained. To validate and ensure the accuracy of the results of this code, its results were compared with experimental data [11].

New flaps were used in this research. The idea of designing this flap is that a surface parallel to the camber line of the airfoil is embedded in the place of the trailing edge.

3- Results and Discussion

Then numerical analysis was performed for the airfoils under different conditions, for example, the velocity contours in case 15% flaps is shown in Fig. 6.

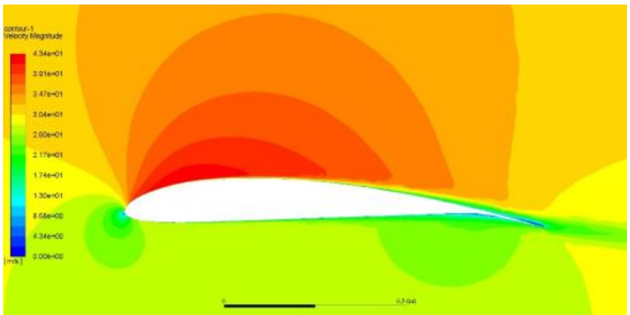

Fig. 6. Contour velocity around the section at zero degree of attack angle and Reynolds number 200,000 Cross-section with flap 15%

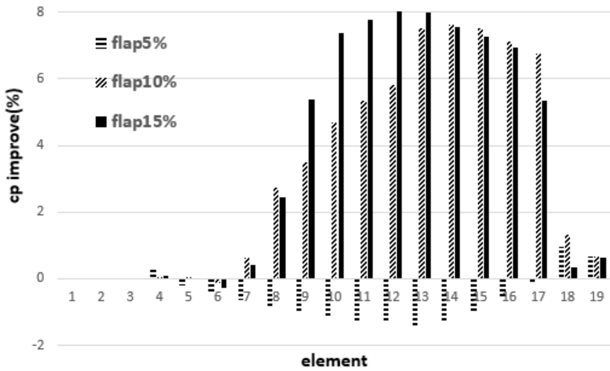

Fig. 8. Percentage improvement of power factor using lifting levels in different elements

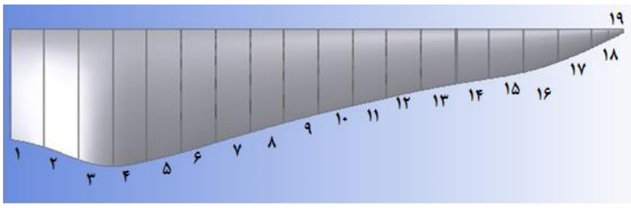

Fig. 7. Elements of blade

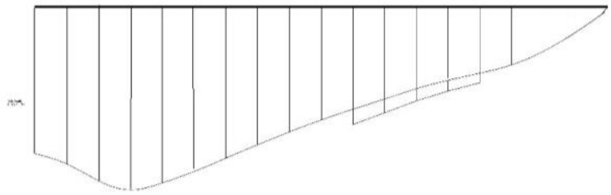

Fig. 9. The TU-BERT blade has the recommended buoyancy levels

In the following, the effect of adding flaps to the blade on the output power coefficient at a wind speed of 10 meters per second is investigated. Fig. 8 shows the image of the elements on the blade.

To do this, flaps add on each element individually and power improvement is calculated. Finally, the percentage of power improvements for different elements (from 1 to 19) with different flaps is shown in Fig. 8.

By investigating the effect of each flap on the wind turbine power, a proposed arrangement for the flap is to apply a 15% chord flap to elements 11 to 14 because the lifting surface performance during this interval is more than 7.5% improvement for each element. Fig. 9 shows the image of the blade with the arrangement of the flaps.

By applying the above geometry in the solver, with a tip speed ratio of 5.5 and wind speed of 10 meters per second, the value of the blade power factor was calculated to be 0.41, which indicates a growth of 40.9% in the power factor ratio. The base is 0.295.

4- Conclusions

The results of this study can be summarized as follows.

In this study, to increase the aerodynamic efficiency of the horizontal wind turbine, a new type of flaps was used, which increases the lift to drag ratio and causes better aerodynamic performance of the blades.

For the wind turbine blade cross-section, which is Clark-Y airfoil, the mounting flaps with a length of 15% has a good performance and has increased the power coefficient of the turbine blade from 0.29 to 0.41, which causes 41% growth in the production capacity of the turbine.

References

[1] E. Branlard, Wind Turbine Aerodynamics and Vorticity-Based Methods, Springer., 2020.

[2] T.Ashuri , M.Zaaijer, Multidisciplinary design optimization of offshore wind turbines for minimum levelized cost of energy, Renewable Energy, 68 (2014) 893-905.

[3] M.Azizi, A.Jahangirian;, Multi-site aerodynamic optimization of wind turbine blades for maximum annual energy production in East Iran, ,journal of Energy Science & Engineering, 8 (2020) 169-2186.

[4] K.Michael , McWilliam, K.Thanasis, A.Helge , Madsen, F. Zahle, Aero-elastic wind turbine design with active flaps for AEP maximization, Wind Energy Science 3, 1 (2018) 231-241.

[5] M.R. Mirghaed, R. Roshandel, Site specific optimization of wind turbines energy cost: iterative approach, Energy Conversion and Management, 73 (2013) 167-175.

[6] Z.J. Chen, K.A. Stol, B.R. Mace, Wind turbine blade

optimization with individual pitch and trailing edge flap control, Renewable energy, 103 (2017) 750-765.

[7] A. Saenz-Aguirre, S. Fernandez-Resines, I. Aramendia, U. Fernandez-Gamiz, E. Zulueta, J.M. Lopez-Guede, J. Sancho, 5 MW Wind Turbine Annual Energy Production Improvement by Flow Control Devices, Proceedings, 2(23) (2018) 1452.

[8] Y.Zhang, V.Ramdoss, Z.Saleem, X. Wang, G.Schepers , C. Ferreira, Effects of root Gurney flaps on the aerodynamic performance of a horizontal axis wind turbine, Energy, 187 (2019).

[9] C. Hansen, NWTC Design Codes: AirfoilPrep, 2012.

[10] B. masood, technical design of wind turbine power staion for iran(in persian), Amirkabir univercity of technology, tehran,Iran, 1996.

[11] A.S.PEÑA, Experimental Assessment of the Effectiveness of Active Flaps to Reduce the Blade Root Bending Moment of Wind Turbine Blades, KTH Royal Institute Of Technology, STOCKHOLM, SWEDEN, 2016.

[12] S. Ghosh, M. Muste, F. Stern, Measurement of Pressure Distribution and Forces Acting on an Airfoil, Laboratory Experiment3 57 (2004) 20.

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