8.Optimization of distribution microtabs on redesign blade wind turbine AWT27

by I Satiawan

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Optimization of Distribution Microtabs on Re-design Blade Wind Turbine AWT-27

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Keywords: Microtabs; Pretwist; Optimization; Design blade

Abstract. This paper is focused on investigating some potential benefits of microtabs in increasing of the energy capture capabilities of blade rather than load control systems. In this design case study, simulation test was performed on a design blade wind turbine AWT-27 (Aerodynamic Wind Turbine–27) equipped with distribution microtabs along the blade span. AWTSim tool has been used to analyze aerodynamic performance and the optimization tool of AWTSimD was investigated the optimization of distribution microtabs and pretwist as a way to increase energy capture capability of blades. Developing a genetic algorithm optimisation tool (AWTSimD) which was especially designed for wind turbine blades and integrating it with the aerodynamic performance analysis (AWTSim). The design optimisation tool was employed to conduct design case studies. The results of design case studies on wind turbine AWT-27 reveal that the optimization of distribution microtabs and pretwist are key parameters to effect the amount of increasing for the power extraction. For constant speed rotors, adding microtabs without re-designing the blade topology can extract the same amount of power production compared with the baseline, while by re-designing blade for both of optimisation microtabs distribution and pretwist the overall enhancement of power generating able to be reached by up to 4%.

Introduction

A wind turbine is designed to extract more wind energy at maximum power. At higher wind speed, power generated and blade loading by a rotor wind turbine is far more the generator capacity and loading its rotors. To protect operation of wind turbine at higher wind speeds control systems based on advanced techniques are needed to limit the power generated and exceed blade loading. This research is focused to solve that problem by optimisation of adding advanced techniques According to [1], the kinds of advanced technique have been performed many initial investigation that aimed for developing of control devices to make easier blade loading. Ailerons, morphing aerofoils, individual pitch control, microtabs, adaptive blades, telescopic blades, trailing edge flaps, and trailing edge are among these of advanced techniques.

A different kind of aerodynamic advanced technique proposed to sophisticating load control technique is microtabs [2-6]. [3] and [6] carried out many initial development works for the developing of microtab concept. Their researchers conducted both computational and wind-tunnel studies on microtabs on the lower surface of the GU25-5(11)8 airfoil.

Microtab is a device placed near to trailing edge of an aerofoil and it can be affected flow in the trailing edge region of aerofoil. Increasing lift can be achieved by deploying the microtab on lower pressure side, while reducing lift can be achieved by deploying a microtab on upper suction side of aerofoil. A microtab is a small device aerodynamic control surfaces by deployment height of magnitude about 0.01 of local chord and those of microtabs are installed close to the trailing edge of the blade span therefore affecting flow in trailing edge region of the aerofoil.

Alternative design approaches has been used as another field of research in this design case study, which recently has become full under attention by many researches. Integrated design, by using computational of intelligence techniques in blade design and optimisation, as well as modification-based design are some examples of this line research [7-9]. [10] has investigated a method to obtain the design optimum of blade shape for the rotor several hundred kW of horizontal axis wind turbines. [11] has developed a computer program package that able to optimise design blade wind turbine with regarding to a number of criteria.

Investigating by adding some microtabs to the blade design is aimed to increase energy capture capability by increase lift coefficient on the blade design. This investigation is concentrated on optimisation of distribution microtabs which is design blade involves distribution microtabs developed for load control to improve energy capture capability.

Potential Microtabs in Power Regulation

A microtab is employed on the aerofoil, it has three states: deployed to downward on the pressure side aerofoil ($MT = +1$), deployed to upward on the suction side aerofoil ($MT = -1$) and neutral which means not deployed for both side on aerofoil. Those states are signed by +1, -1 and 0. When the microtab deployed on a aerofoil, it can change lift and drag coefficients of aerofoil. These changes of lift and drag coefficient are be signed as:

$$\Delta C_L|_{MT} = C_L|_{MT} - C_L|_{MT=0} \;; \qquad MT \in \{-1,+1\} \tag{1}$$

$$\Delta C_D|_{MT} = C_D|_{MT} - C_D|_{MT=0} \;; \; MT \in \{-1,+1\} \tag{2}$$

in which, respectively, The signing of $\Delta C_L|_{MT}$ and $\Delta C_D|_{MT}$ are changes of lift and drag coefficients because of a microtab deployed to downward or to upward, $C_L|_{MT}$ and $C_D|_{MT}$ are lift and drag coefficients because of microtab deployed , and $C_L|_{MT=0}$ and $C_D|_{MT=0}$ are neutral position of microtab which is no microtab deployed or a microtab is in neutral position $MT = 0$.

According to Figs. 1 through 4 show that ΔC_L and ΔC_D are as functions from angle of attack, α, variation distance of microtab from leading edge and variation actuation height of microtab. These results of lift and drag coeffecient were obtained by simulation on ANSYS Fluent 13.0. In this design scenario, the lower microtab was at 95% along the chord length, with a height of 1.1%, 2.2% and 3.3% C, with the 1.1% C.

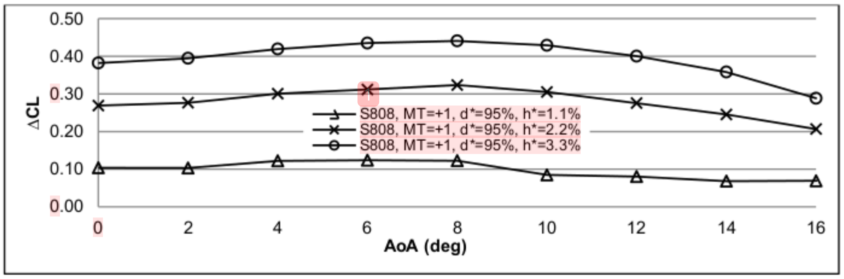

Fig. 1. The Changes of ΔC_L on the microtab deployed to downward

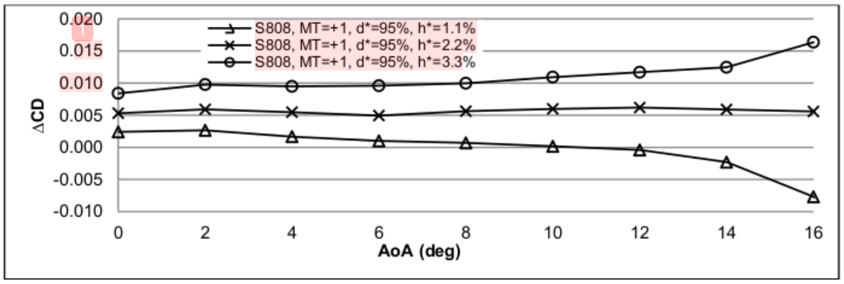

Fig. 2. The changes ΔC_D on the microtab deployed to downward

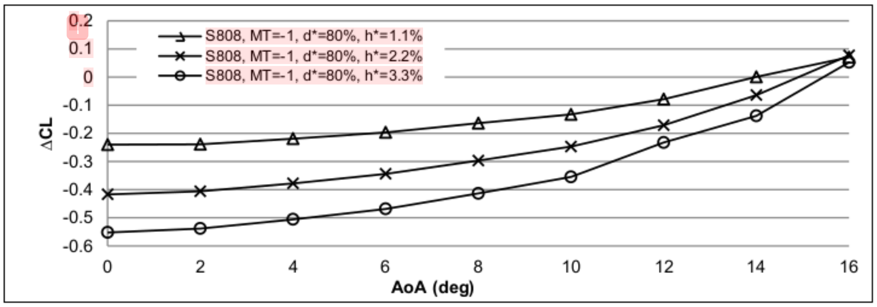

Fig. 3. The changes of ΔC_L on the microtab deployed to upward

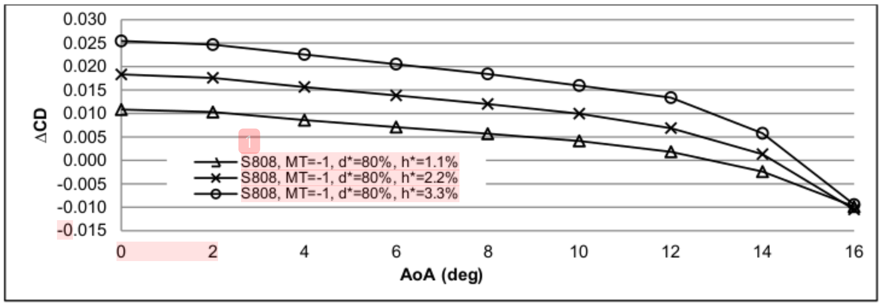

Fig. 4. The changes of ΔC_D on the microtab deployed to upward

Design Approach

To investigate the microtabs effect on power prediction, a software analysis tool, AWTSim, has been developed to analyse and evaluate aerodynamic performance and a design tool package, AWTSimD, as a optimisation tool with genetic algorithms method have been developed.

In this design case study the optimisation problem is to find the maximum average power of the blade. The objective function is henceing the annual average power of wind turbin. The average power is given by average wind speed that based on a Raleigh Frequency Distribution Function. The average power (P_{av}) is defined as:

$$P_{av} = \int_{V_i}^{V_0} PR(V)dV \tag{3}$$

where, $R(V)$ is wind velocity Probability Distribution Function (PDF), P is the wind turbine power and V_i and V_0 are cut-in and cut-off velocity. In this design case study, a Raleigh Probability Distribution Function (PDF) is represented by Equation,

$$R(V) = \frac{2}{V}\frac{\pi}{4}\left(\frac{V}{V_{av}}\right)^2 \exp\left[-\frac{\pi}{4}\left(\frac{V}{V_{av}}\right)^2\right] \tag{4}$$

where V_{av} is the site average wind speed.

In re-design blade from an ordinary blade, many design variables may influence the solution such as pretwist, chord, radius rotor, aerofoil, rotor-speed and microtabs distribution. Here only pretwist and microtabs distribution have been considered and it will be subject to a wide range of the constraints:

- $P \le P_{rated}$
- $M_{\max} \le M_{allowable}$

The different performance lift and drag between original and deploying microtabs ,on the other hand, The BEMT calculator [12] requires some modification design code to optimise and analyse blade aerodynamic performance. Furthermore, in blade discretisation , the number of segments on blade span (n_{seg}) have to be selected so that length of each segment (Δr) is equal to the microtabs length on segement(s_{MT}). By doing of these selected, the number of microtabs (N_{MT}) are distributed equal between of the inboard and outboard on radial locations. Consequently, $R_{MT,s}$ and $R_{MT,e}$ will be exactly the same as the number of segments between two span locations. In other word, each microtabs distribution between $R_{MT,s}$ and $R_{MT,e}$ become a device controlling and each state microtab acts as aparameter controlling which needs to be determined via solving the optimisation problem of Eq. 3.

Genetic algorithms method is used to find the optimum state of each microtab deployed. On the other hand, via solving genetic algorithm method it will be found the optimum disrtibution microtabs on the blade span. In this algorithm, these of parameter such as number of population n_{pop} , number of generations n_{gen} , probability crossover p_c and probability mutation p_m are these parameters involved in the proces optimisation and these parameter should be selected properly. In this algorithm the fitness has been defined as the power generated by rotor ($fit = P$), parent selections method for both crossover and mutation steps for each generation use a random process, and the constraint on the proces optimisation is based on rejection strategy of each solution on population ($P \le P_{rated} + \varepsilon_P$).

The genetic algorithm parameters have been selected to simulation by $n_{pop} = 20, n_{gen} = 50$, $p_c = 0.3$ and $p_m = 0.2$, AWT-27 blade equipped by has been located microtabs between $R^*_{MT,s} = 0.6$ and $R^*_{MT,e} = 0.9$, 20 segments for discretising of blade span, a string from 7 microtabs will be located in the range of $R^*_{MT,s} = 0.6$ to $R^*_{MT,e} = 0.9$, the located of microtabs on the blade are $d^*_{MT} = 80\%$ and $d^*_{MT} = 95\%$ of the chord from the leading edge on both upper and lower surface by an actuation height of $h^*_{MT} = 3.3\%$ of the chord length and paralel to optimise design blade by optimised for pretwist.

Results and Discussion

The potentials of microtab in the increasing of energy capture capability was optimised. In this case only the pretwist was optimised and the amount of increasing power generated was broken down into two parts of contribution, namely, contribution from controlling device of distribution microtab along of blade span and ontribution of the optimisation design blade.

Using the data shown in Fig. 5, share of installing microtabs and optimisation in the increasing power are shown separately in Fig. 7. Figs. 5 and 7 shows comparison of effect distribution microtabs (optimised balde) and baseline (with or without mirotabs) on the increasing power.

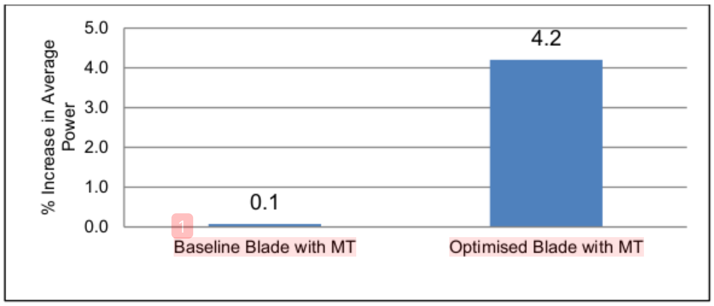

Fig. 5. Comparison of increasing power by microtab with or without optimised blade

According to Figs. 5, 6, 7, 8 and 9, those figures have evident that optimisation of both pretwist and microtabs have significant effect on the power extraction while the baseline blades extract the same amount of power. It shown that optimisation of the blade plays a major role in increasing of power capture capability for design blade with adding microtabs (an advance control system).

According to Fig.7, adding microtabs distribution along the blade span is less significant to increases power while high wind speed microtabs is not effective because microtabs have range of operation based on low angle of attack. The Fig.7 compared to the power of the original blade shows that power increase from wind speed 5 m/s to 12 m/s and from 13 m/s to 25 m/s the resulting power is similar to the original power. In this case, microtabs are just effective to increase power for low wind speed however with re-design blade pretwist, adding distribution of microtabs on the optimized blades can increase the power production by up to 4%.

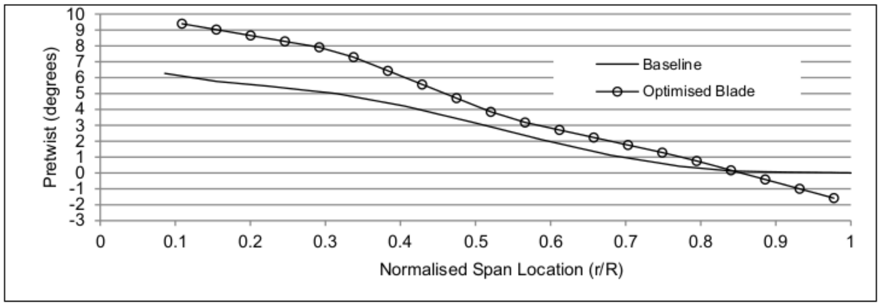

Fig. 6. Comparing of pretwist on optimised blade

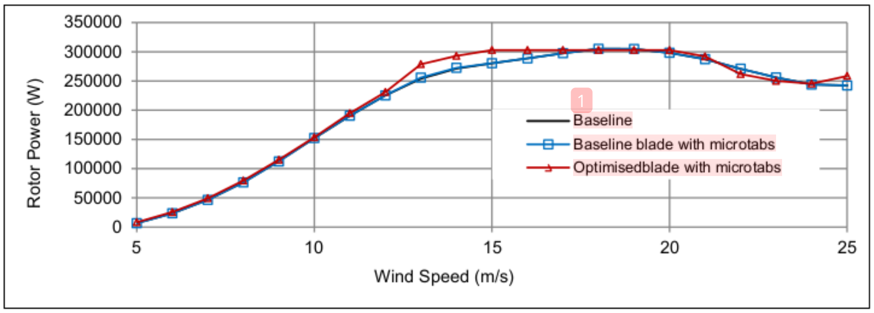

Fig. 7. Comparing of power production for baseline , baseline blade equipped with distribution microtabs with or without optimised blade

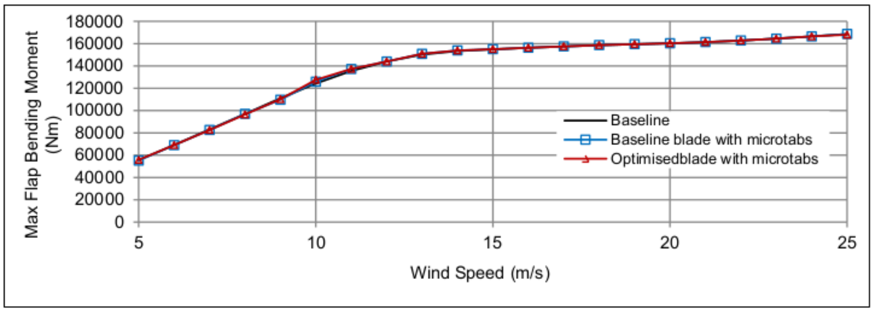

Fig. 8. Comparison of flap bending moment for baseline blade equipped with distribution microtabs with or without optimised blade

Conclusion

Comparison of the results investigation from the above figures, the following conclusion of utilizing blade equipped with distribution of microtabs can be drawn as follow; The optimisation of design blade based on the blade topology (pretwist) is a key parameter for effecting the amount of increasing power extraction and plays a main effect in increasing the power capture capability. The baseline blades with microtabs extract the same amount of power production compared to with or without microtab, unless for both distribution microtabs and the pretwist is optimised for design blade. Distribution microtabs and the pretwist on optimised design blades can increase the power production by up to 4%.

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