Mini-Gurney Flaps for Aerodynamic Optimizations of HAWT Rotor Blades

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Motivation

The Gurney Flap (GF) consists of a flat profile, which is attached perpendicular to the pressure side of the airfoil trailing edge. The crucial geometrical characteristic is the GF-height in %c, i.e. relative to the chord-length. Compared to other passive flow control devices, such as vortex generators, GFs change the Kutta-condition and increase the circulation of a given airfoil [1]. For typical GFs in the range of 1%c ≤ GF-height ≤ 2%c, the lift-increase is accompanied by a detrimental drag penalty. That is why previous research-efforts of the authors suggest the use of very small GF-heights of 0.5%c or less, in order to achieve the lift-enhancing effect while maintaining, or even improving, the airfoil L/D-ratio at Re-numbers of between one and two million [2].

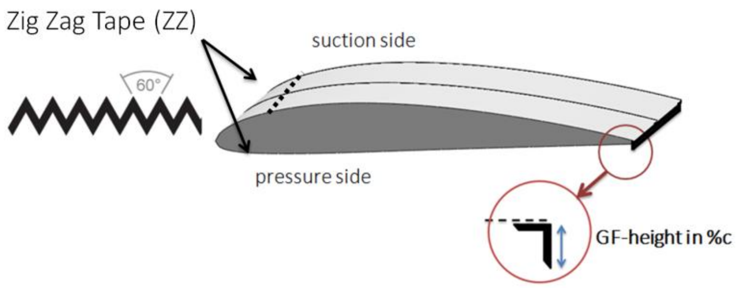

Figure 1 Position of Gurney Flap and Zig Zag Tape on an airfoil section

Airfoil Experiments

The current research project investigates the aerodynamic effect of so-called Mini-GFs with a height lesser than 1%c on two different airfoils which are relevant to the blade design of HAWTs: the DU97W300 and the AH93W174. The experiments were conducted in the 2.0m x 1.4m test-section of the large, closed-loop wind-tunnel of the Institute of Fluid Dynamics at the TU Berlin. The airfoil-based Re-number reaches 1.5 million. Both lift and drag forces were taken statically by means of a six-component force-balance including an AoA-range of -5° to +15°, resulting in relatively high drag coefficients compared to e.g. wake-rake measurements or XFOIL simulations. Furthermore, both free and forced transition cases were considered. In the latter case, Zig Zag tape (ZZ) with a height of 0.4mm was applied close to the leading edge of both suction and pressure side, hence emulating the impact of surface erosion on rotor blades. Subsequently, three different Mini-GFs were attached with heights of 1%c, 0.5%c and 0.25%c. The results of the wind-tunnel experiments confirm that the aerodynamic effects primarily depend on the relation between GF-height and local boundary layer thickness. Hence, the optimal GF-height of the ZZ-configuration is found to be higher due to the expanding boundary layer in case of early transition. Furthermore, it could be shown that the behaviour of stall-onset remains similar, and that the impact on the overall L/D-ratio is most promising for GF-heights of approximately *half* the local boundary layer height, i.e. for Mini-GFs ≤ 0.5%c.

Blade Optimization

Subsequently, the experimental airfoil polar-data was fed into the standard XFOIL and BEM simulation-modules of QBlade [4] in order to investigate the impact of Mini-GFs on a generic blade-design. Results show that Mini-GFs which are used as simple add-ons (*retrofit application*) evoke an increase in both axial and tangential rotor-induction, essentially lowering the effective local angle-of-attack (AoA) by between one and two degrees. This effect can be useful in the root region, i.e. up to a blade-length of 50%R, where high AoA persist due to structural constraints, as such mitigating the adverse effects of early separation and dynamic loads, while slightly increasing the overall energy yield. Furthermore, when applying Mini-GFs as part of the blade-design process (*design application*), the increased lift-coefficients result in a proportional chord-length reduction throughout most of the blade span of up to 20% or 10% for GFs of 0.5%c or 0.25%c, respectively. The practical advantages of slender blades include the reduction of both material-volume and weight, i.e. alleviating fatigue loads due to gravitational effects as well as saving material costs. However, further research needs to determine the aeroelastic performance of such slender blades.

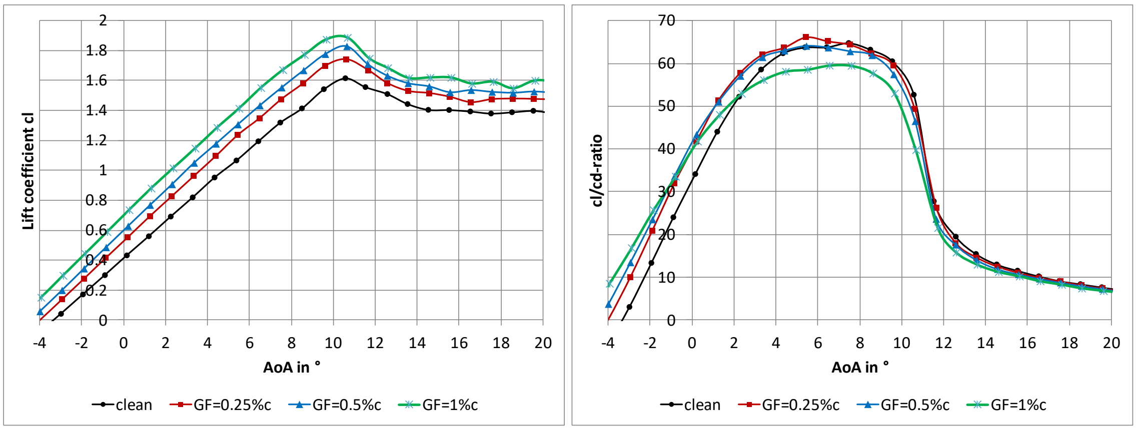

Figure 2 AH93W174, clean configuration (a) Lift over AoA (b) Lift-to-drag ratio over AoA

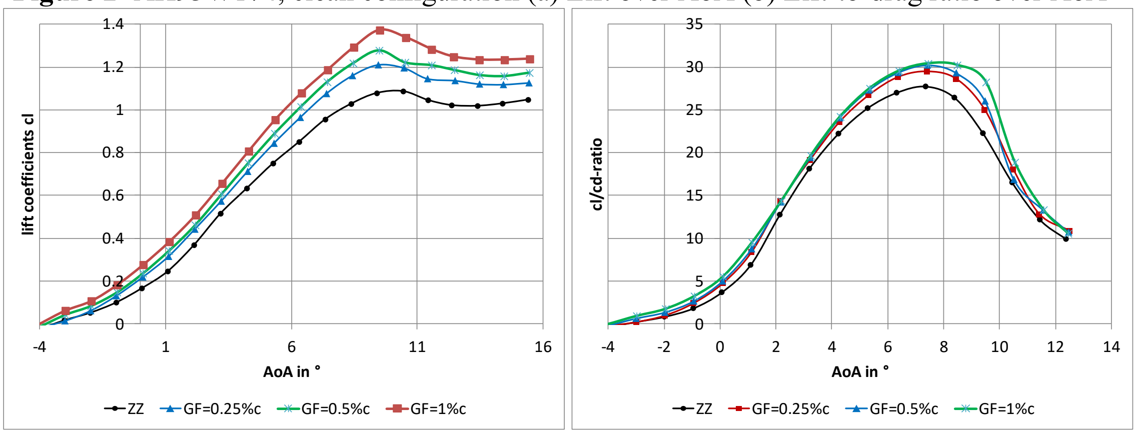

Figure 3 DU97W300, ZZ configuration (a) Lift over AoA (b) Lift-to-drag ratio over AoA

Bibliography

[1] Liebeck, R H, 1978, *AIAA Paper* No. 1976-406, p.547-561
[2] Alber, J, et.al, 2017, *Proceedings of ASME Turbo Expo*, GT2017-64475
[3] QBlade Marten, D, et.al., 2013, *Proceedings of ASME Turbo Expo,* GT2013-94979