Advanced performance improvement of extremely thick blade root wind turbine airfoils

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INTERNATIONAL CAE CONFERENCE

International CAE Conference | Vicenza, Italy | 28-29 October 2019

Main Objectives

- Establishing effective and efficient approaches for improving the performance of thick blade root wind turbine airfoils.
- Obtaining well optimized numerical setup for simulating massively separated flow accurately.
- Utilizing advanced flow control and artificial intelligence approaches in the design process.

Overview

Wind turbine size increases significantly nowadays to supply the clean energy demand, enforcing blade designers to utilize thick airfoils with reduced aerodynamic efficiency. Systematic studies are needed for performance improvement without sacrificing the structural constraints. Design proposals of the attempts carried out at IAG are presented. The work contains advanced airfoil design by an artificial intelligence technique and flow control for boundary layer manipulation. The investigation employs multidisciplinary solvers ranging from simple to high fidelity CFD methods by URANS and DDES.

Industrial constraints:

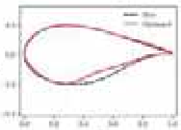
- **Aerodynamics**
- **Structure**
- **Cost**
- **Etc.**

Design

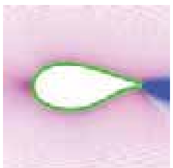
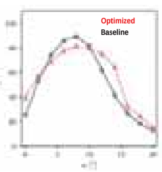
Goal

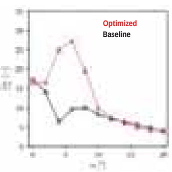
Airfoil reshaping[1]

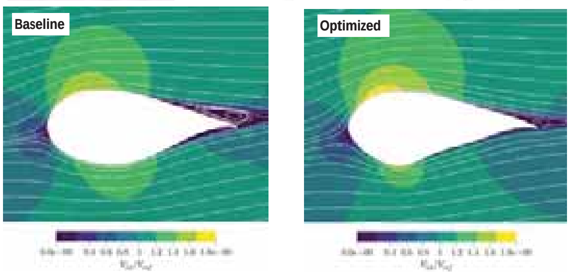
- A new airfoil is redesigned based on existing wind turbine airfoil database.
- The optimization process employs a genetic algorithm approach in combination with the XFOIL code, allowing one to select only the best airfoil shapes in the design process.

- The results are evaluated by computational fluid dynamics (CFD) simulations under clean and soiled conditions employing unsteady Reynolds-Averaged Navier-Stokes (URANS) approach using the FLOWer code.
- The optimized airfoil is able to improve the aerodynamic efficiency.
- Further quantification on the turbine performance by means of blade elemet momentum (BEM) theory using the B-GO[2] code indicates power improvement.
- A gain of 195,000 €/year/turbine is obtained by replacing the baseline airfoil with the improved airfoil.

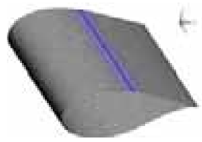
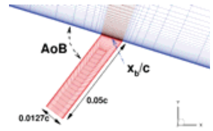





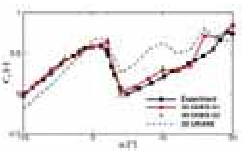


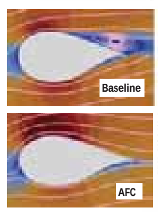
Flow control[3,4]

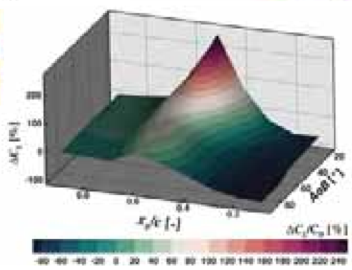
- The main issue of thick airfoils is massively separated flow due to strong adverse pressure gradient.
- This characteristic becomes more severe for soiled conditions where flow transition occurs much earlier than in the original design.
- The present improvement makes use of active flow control (AFC) employing steady/unsteady jet actuator.
- Variations of several important parameters and their combination are tested to obtain the optimal setup of the flow control.

- Accurate flow simulations using URANS and Delayed-Detached Eddy Simulation (DDES) are performed. The results indicate a massive improvement of the airfoil performance. The viscous effects are even becoming weaker than the baseline case under natural transition.
- The improvement reaches 900% depending on the airfoil thickness and Reynolds number.







Conclusion

Systematic studies on designing high performance thick airfoils for the root area of large wind turbine blades have been conducted. The improved design criteria have shown enhanced airfoil performances by the proposed methods. The work reveals several novel design aspects that will be helpful for blade designers to develop efficient modern wind turbines.

References

[1]J. Herrmann and G. Bangga., *J. Renewable Sustainable Energy* 11(4), 043304, 2019.
[2]G. Bangga, *Fluids* 4(3), 73, 2018.
[3]G. Bangga, T. Lutz and E. Krämer, *J. Phys. Conf. Ser.* 1037(2), 022025, 2018.
[4]P. Kankatala and G. Bangga., *Adv. Theory Simulations* 7(2), 1900077, 2019.

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