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Title: On the effect of distributed roughness to the power performance of wind turbines

Abstract

It is well known from literature [1,2,3] that distributed roughness can have adverse effects on an airfoils' power performance. In spite of this knowledge nowadays engineering still suffers from setbacks due to roughness, especially in the field of wind energy.

Thereof the current paper tries to deal with specific roughness related aspects of wind turbine aerodynamics to be taken into account. The phenomena created by distributed roughness originating from manufacturing processes or accumulated during operation (roughness from contamination and erosion) are briefly explained. A more detailed analysis on known related investigations presents the actual state of the art in the field of aeronautics and wind energy. Wind tunnel roughness experiments and numerical investigations[I] on typical wind turbine airfoils as well as aviation airfoils (performed for various Reynolds Number values) are briefly described and thoroughly compared to wind turbine power measurements. The performance data, collected from a wind turbine in the field in combination with photographic material from blade inspections, give evidence regarding the roughness patterns in different span and chord-wise blade locations. Based on these measurements, different cases of theoretical performance models are derived in order to identify the relation between the early boundary layer transition and flow separation due to roughness with the energy production of the wind turbine.

The comparison of the field measurements with the existing literature shows significant discrepancies between the estimated and the wind turbine actual performance. These discrepancies affect the characteristic power curve of the wind turbine and consequently its energy yield. General recommendations and trends for airfoil design and simulation are summarised in order to improve the reliability of aerodynamic wind turbine design in respect to the adverse effects of distributed roughness. Finally, some basic improvements for blade manufacturing and design processes are suggested.

References

[1] Abbott I.H and Von Doenhoff A.E., Theory of wing sections, Dover Publications, 1958

[2] Schlichting H. and Gersten K., Boundary layer theory, Springer, 1999

[3] Hoerner S.F and Borst H.V., Fluid-Dynamic Lift, Hoerner, 1985

Notes:

I. The experimental and numerical information are either measured by the authors at the wind tunnel of H.F.I / TU Berlin or come from relevant literature.