26. 04. 2021 Korjahn, Schlipf, Schaffarczyk

MSc Wind Energy Eng – Summer Semester 2021

Introduction to Wind Turbine Aerodynamics

Development of an Aerodynamic Design Code

KSS-Blade

Work Flow Version 1

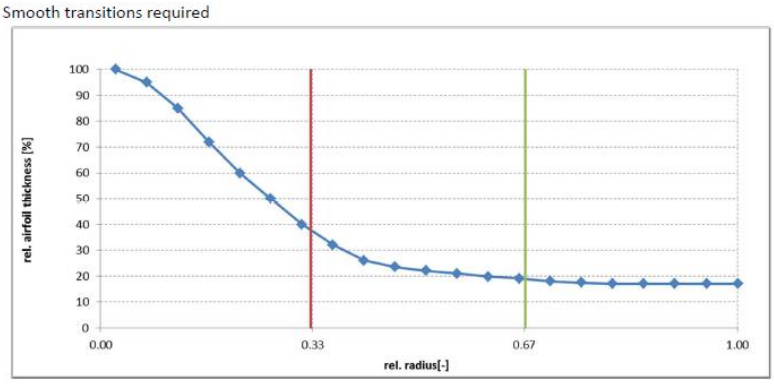
Objective: Determine blade defining quantities

a) Chord (r)
b) Twist (r)
c) Rel. Position to pitch axis
d) Thickness(r) (given as first guess)
e) Pointer thickness -> polar

Output power surface: cP (tsr, pitch) cT (tsr, pitch)

Work Flow:

1. Define power of turbine and length of blade, TSR
2. Read in polars (aoa, cl cd cm) and coordinates (x_i, y_i)
3. Prepare table (and plot) cl-opt as function of thickness
4. Prepare prel. table thickness (t/c) as function of r/r, 0 < r < R



4a) Prepare sectional optimum cL for given thickness

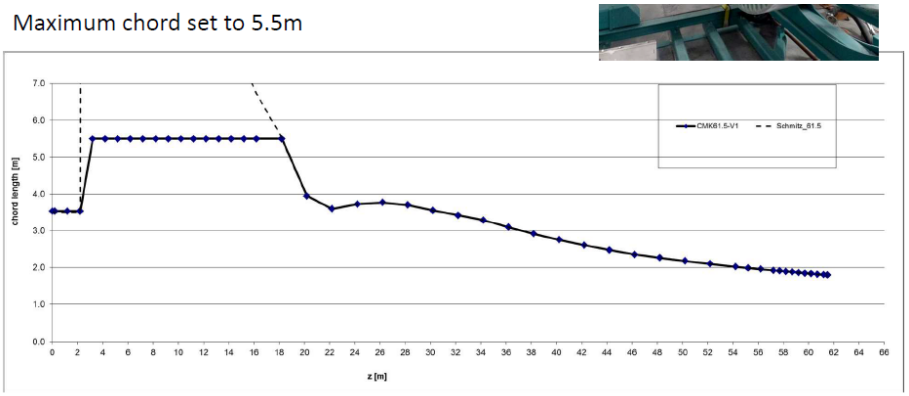
5. Take chord from Schmitz, Glauert or even Betz:

Design rule

Only $a = 1/3$ given, but with TSR= > 3 an equation for chord follows which sometimes is called *Betz' optimum blade shape* :

$$\frac{c}{R} \cdot \lambda^2 \cdot B \cdot c_L^{des} = \frac{16\pi}{9} \cdot x^{-1}, x = r/R \qquad (16)$$

6. Implement chord restrictions:

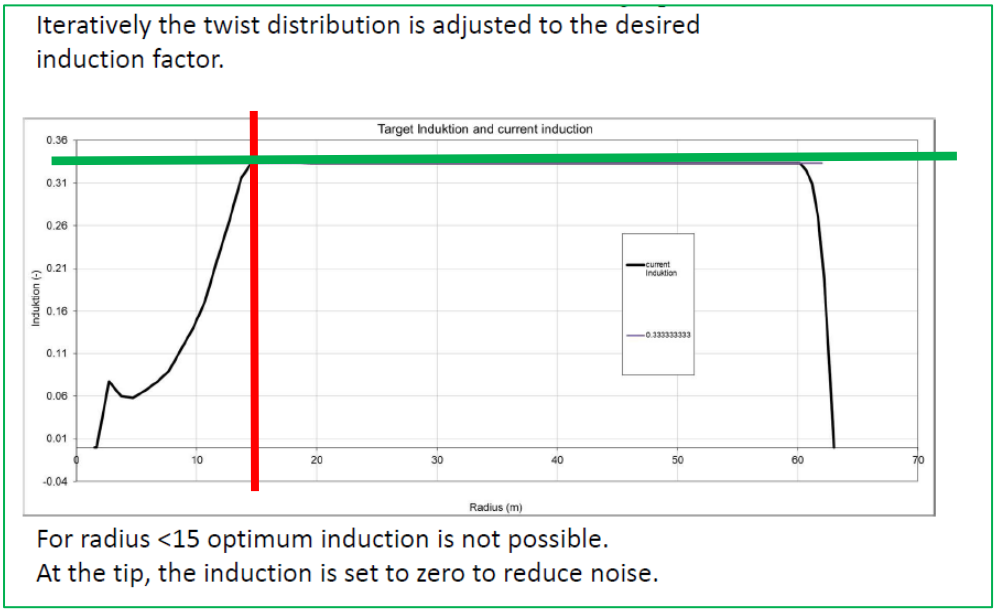


7. **Use (implement) aero BEM-code** to calculate induction and cP and cT

8. iterate for optimum twist and iterate (by using BEM-code from 7)

until pre-defined induction (a = 1/3, …) is met or twist angle exceed limits

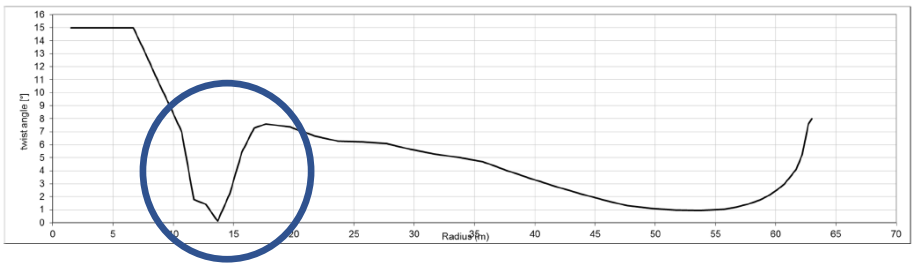
Result: "smooth" induction for r > r_c as seen in the next sheet



9. Analysis:

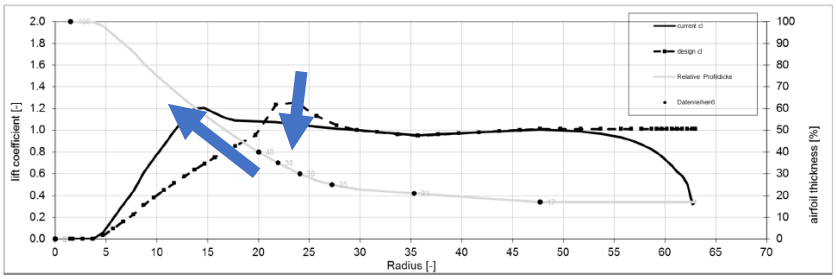
a) twist:

This is what the resulting twist distribution looks like.



b) cL-opt

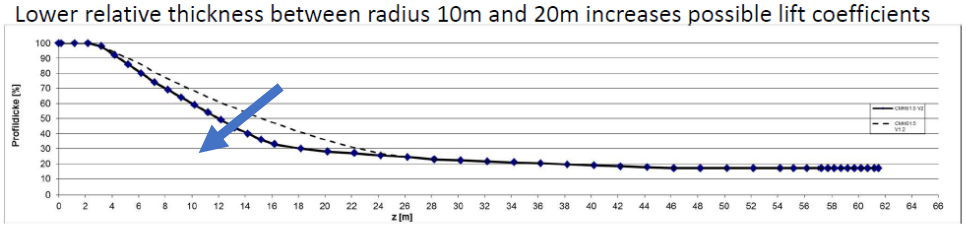
Did we meet the target design cL's at optimum TSR?



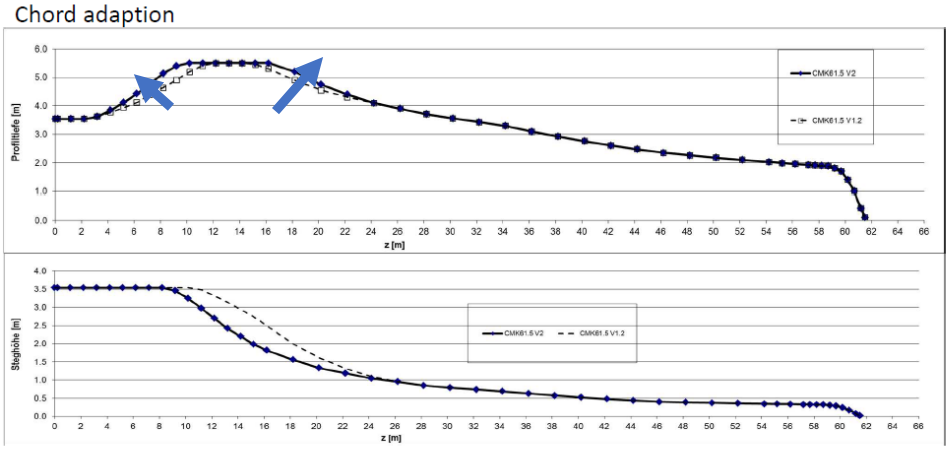
Action needed: for 10 < r < 20: reduce thickness (improve profiles)

Thickness Reduction

Lower relative thickness between radius 10m and 20m increases possible lift coefficients



Chord adaption



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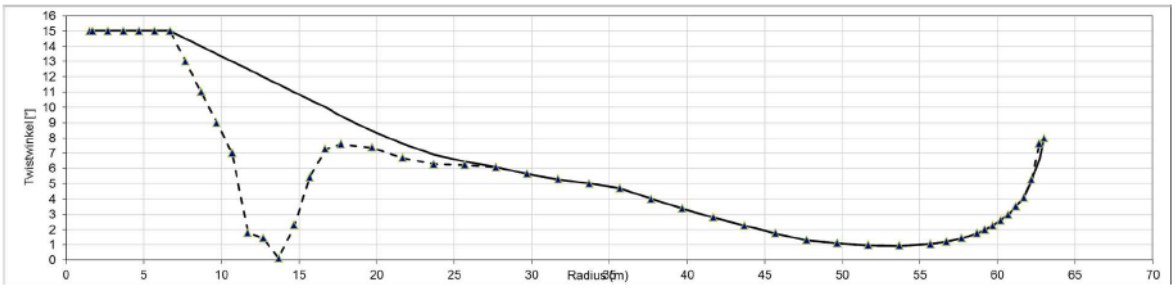
From sheets (1,2) calculate absolute thickness (3)

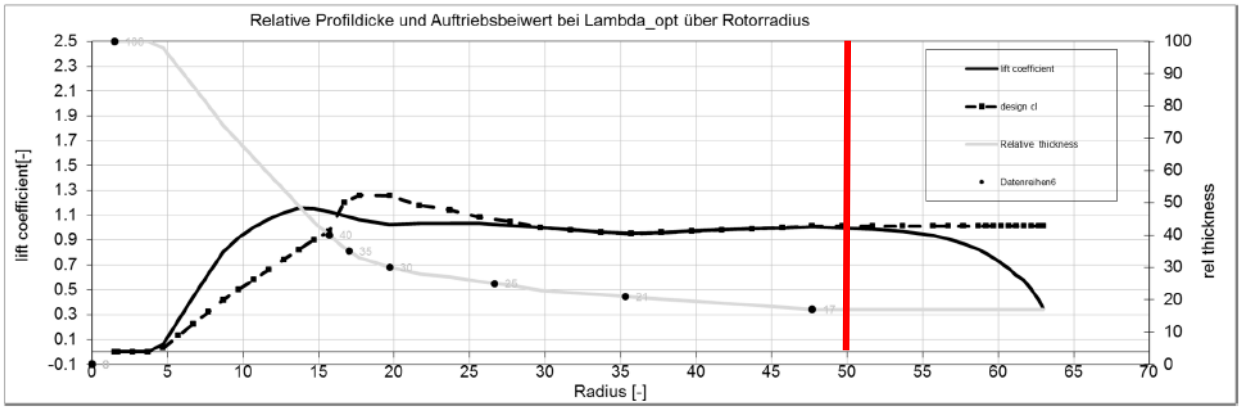
10. Got back to 7 unti twist and cL looks “smooth”

Results @ optimum TSR

Smoothed twist between R 7m and R17m



Did we meet the target design cL‘s at optimum TSR?



Up to 50m looks OK

11. For r > 50 cL to small – what do we have to do?
12. Output power curve

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13. Next step (optional)
    Extend design code to “2 point optimization”:
    do NOT exceed AOA-max @ by some safety margin at rated wind speed:

Maximum Angle of Attack

At rated power, just before the pitch starts, the maximum angles of attack occur. The outer 2/3 of the blade should not be in stall. Therefore the local angles of attack at rated wind speed, without pitch have to be lower than the angle of attack for maximum lift for each airfoil section.

14. Analyse approach of Bak