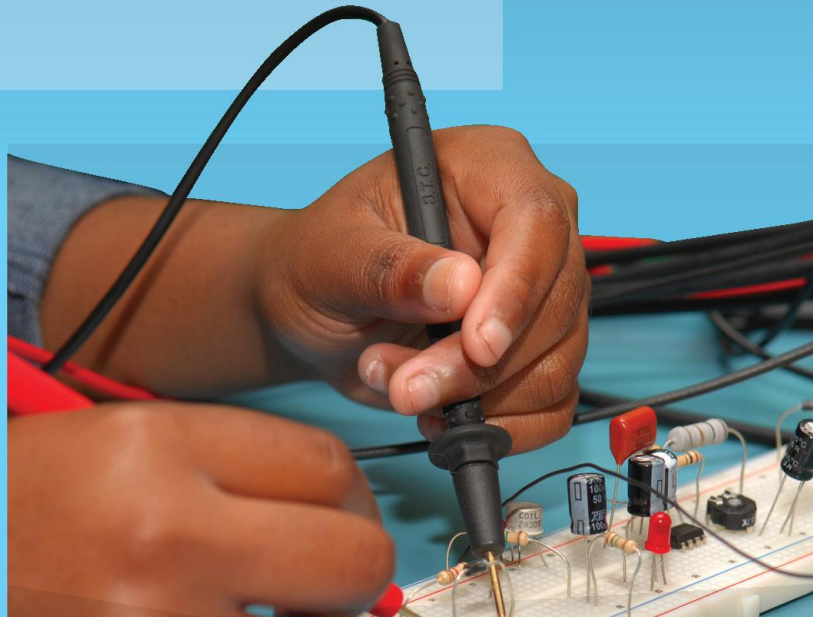
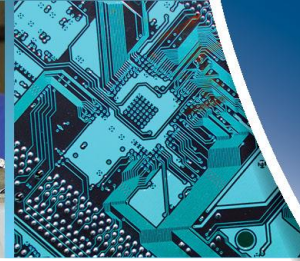


Optimizing Low Reynolds Number Wind Turbine Blades

SAIP2015

Sean Poole





BEM Theory (Introduction)

- Momentum Theory
- Aerodynamic Theory
- Optimization Theory
- Element Theory

Reynolds Optimized Theory

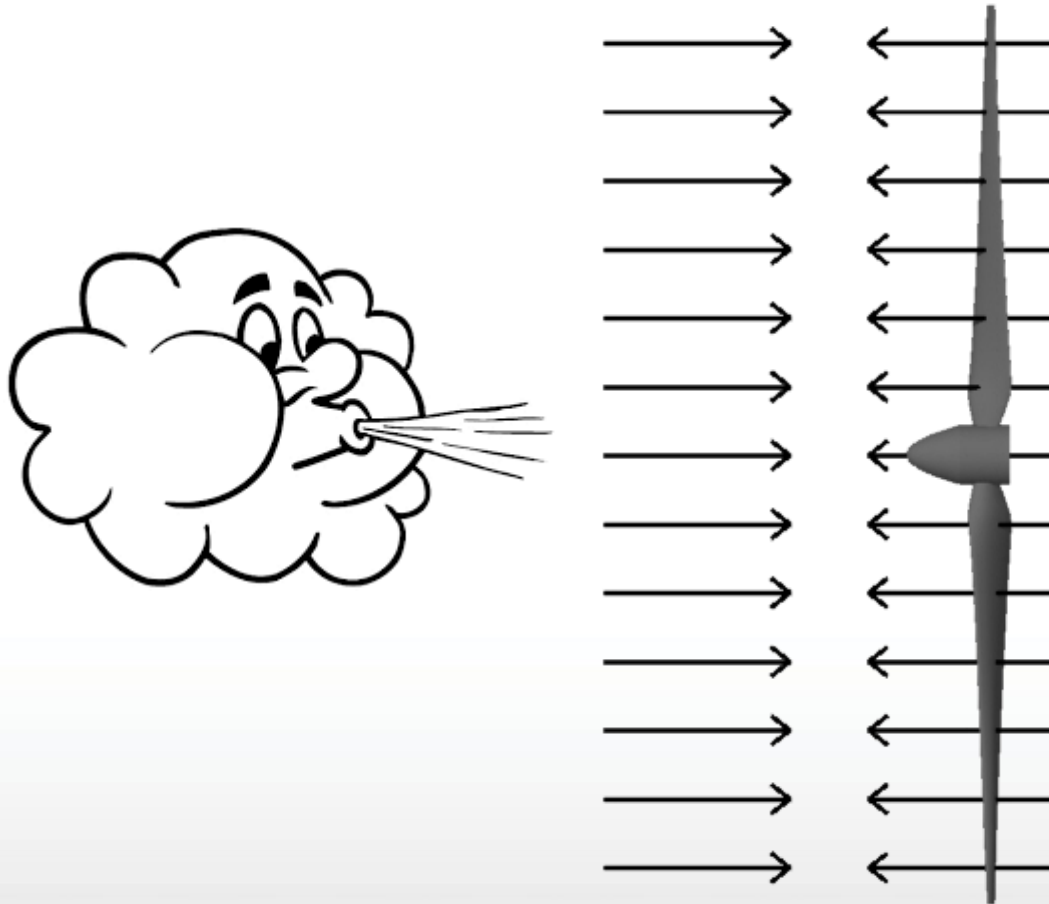
- Definition of Reynolds Number for an Aerofoil
- Optimization of Reynolds Number
- Effects and Benefits of Optimization
- Comparative Results

Conclusion

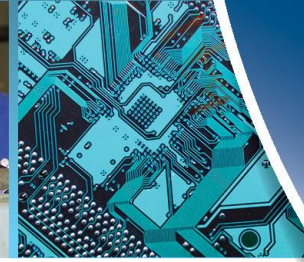
Blade Element Momentum Theory



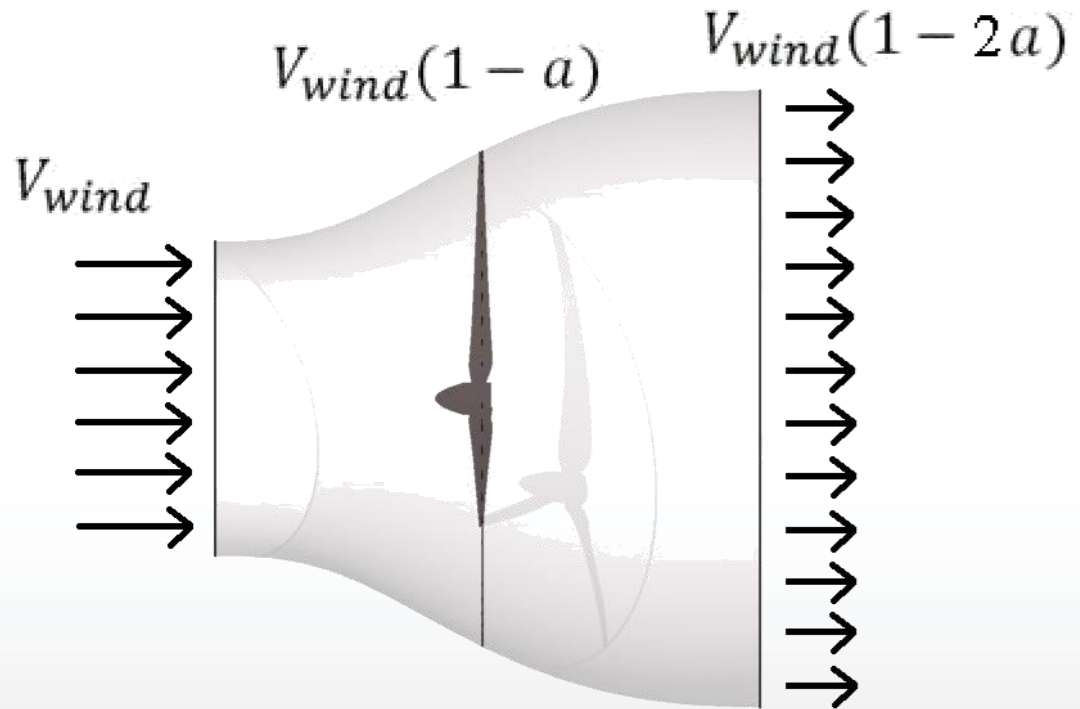
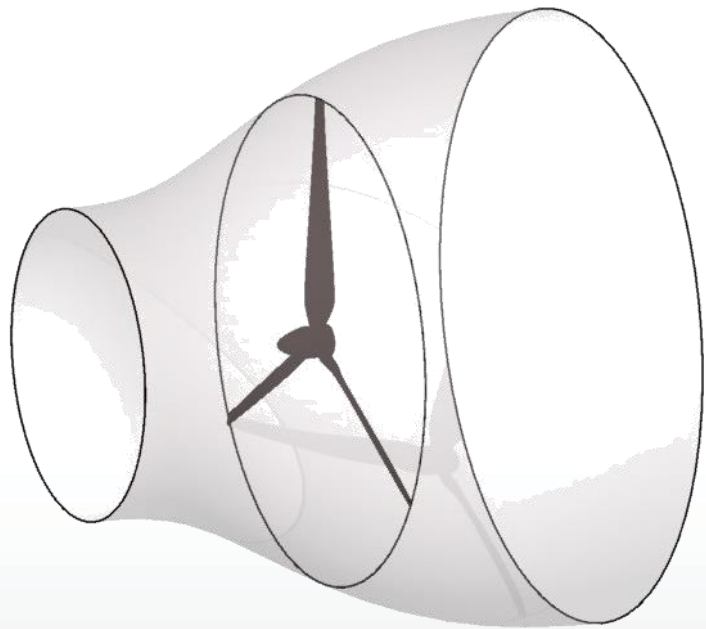
Newton's third law:



Momentum Theory

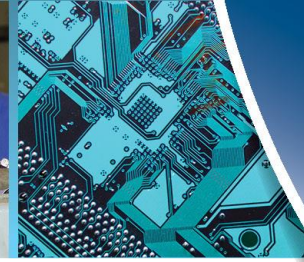


Change in momentum of air due to force applied by wind turbine to extract kinetic energy.

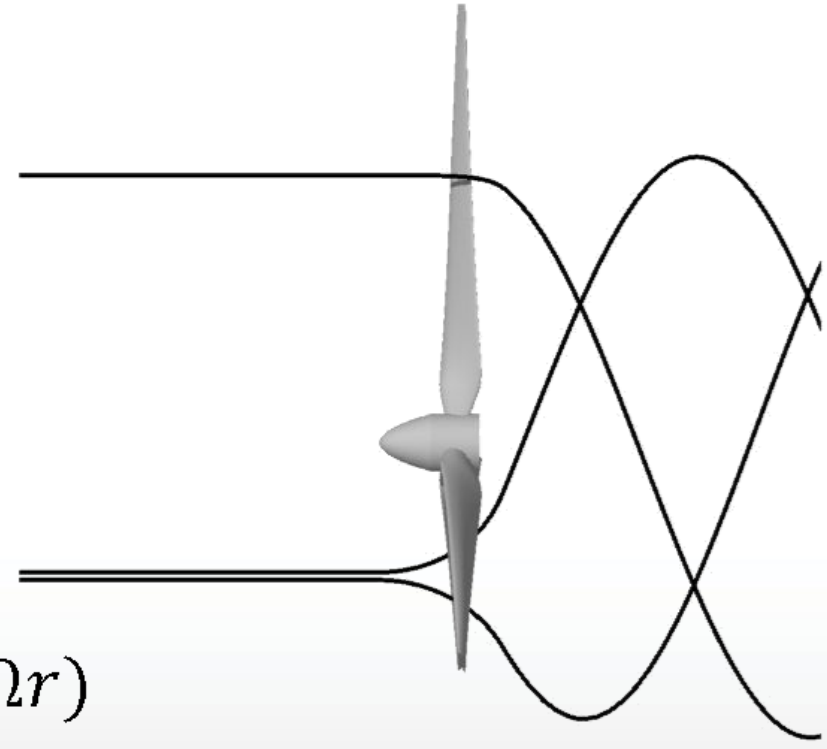
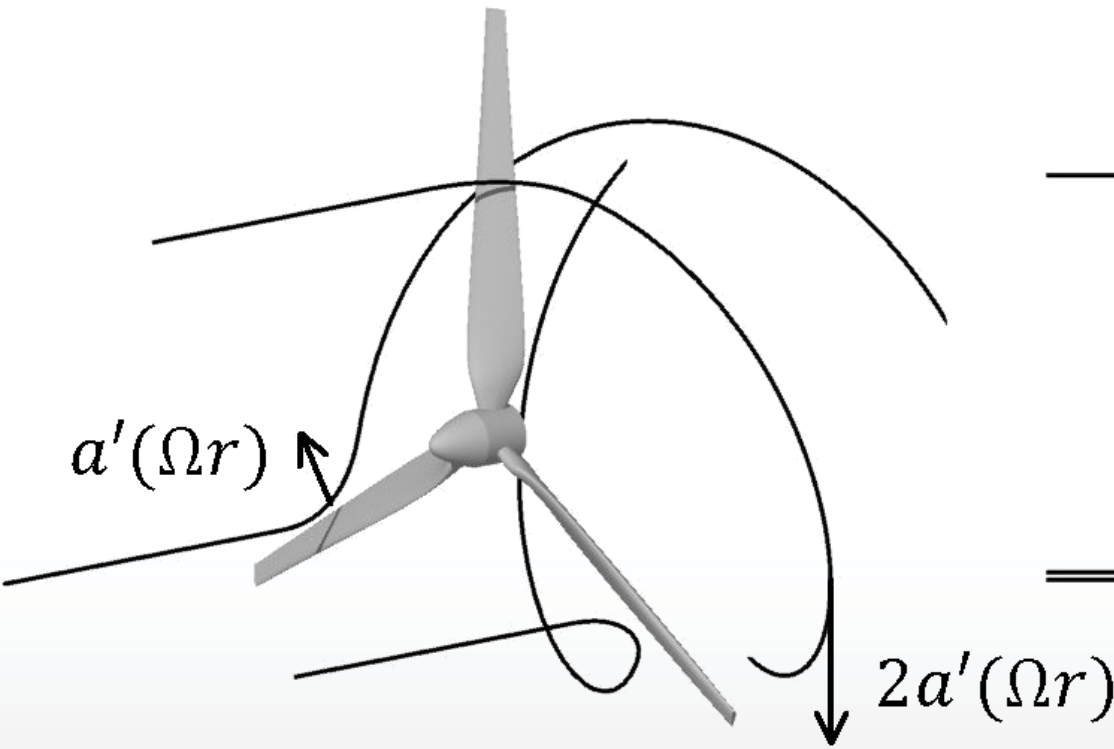


Betz Limit = 59.3% ($a=1/3$)

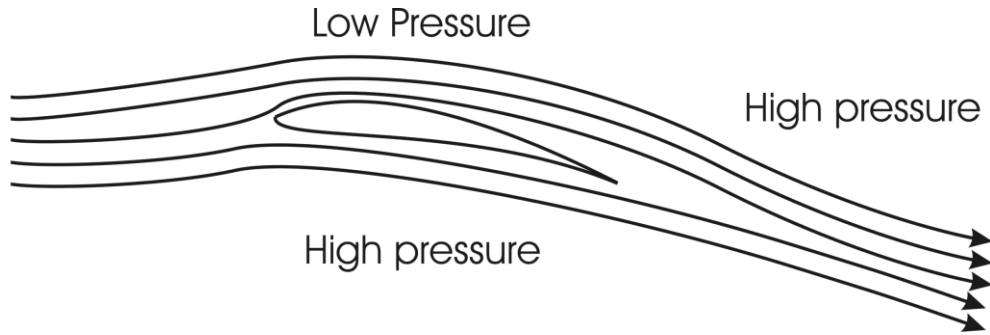
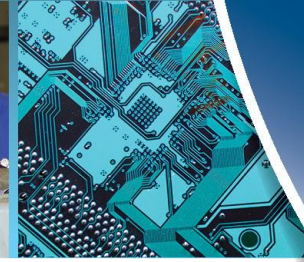
Momentum Theory



Similarly a tangential component is applied to the air flow.

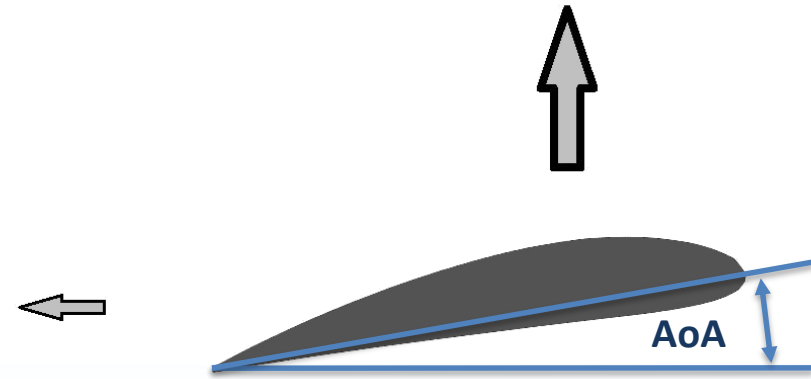
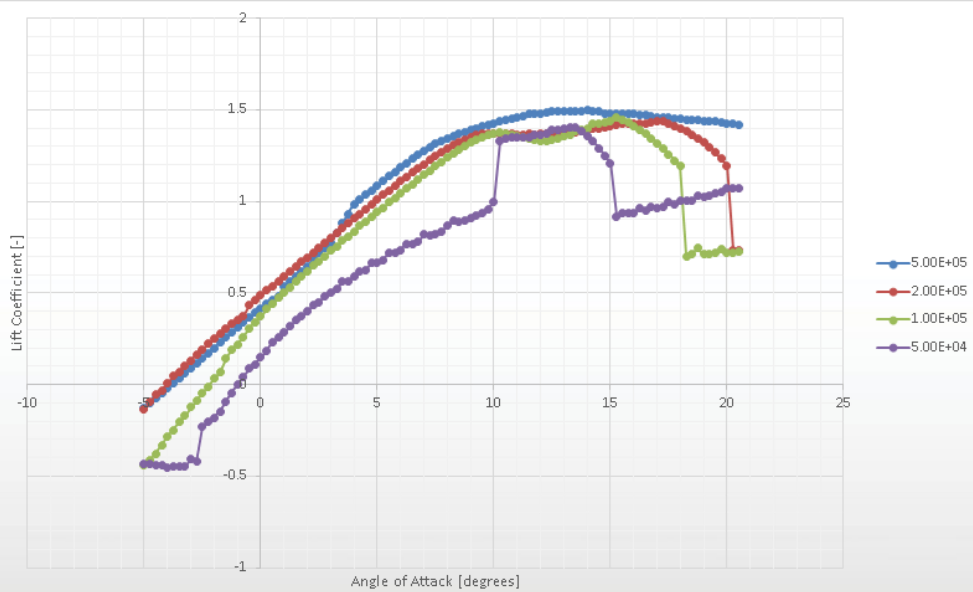


Aerodynamic Theory



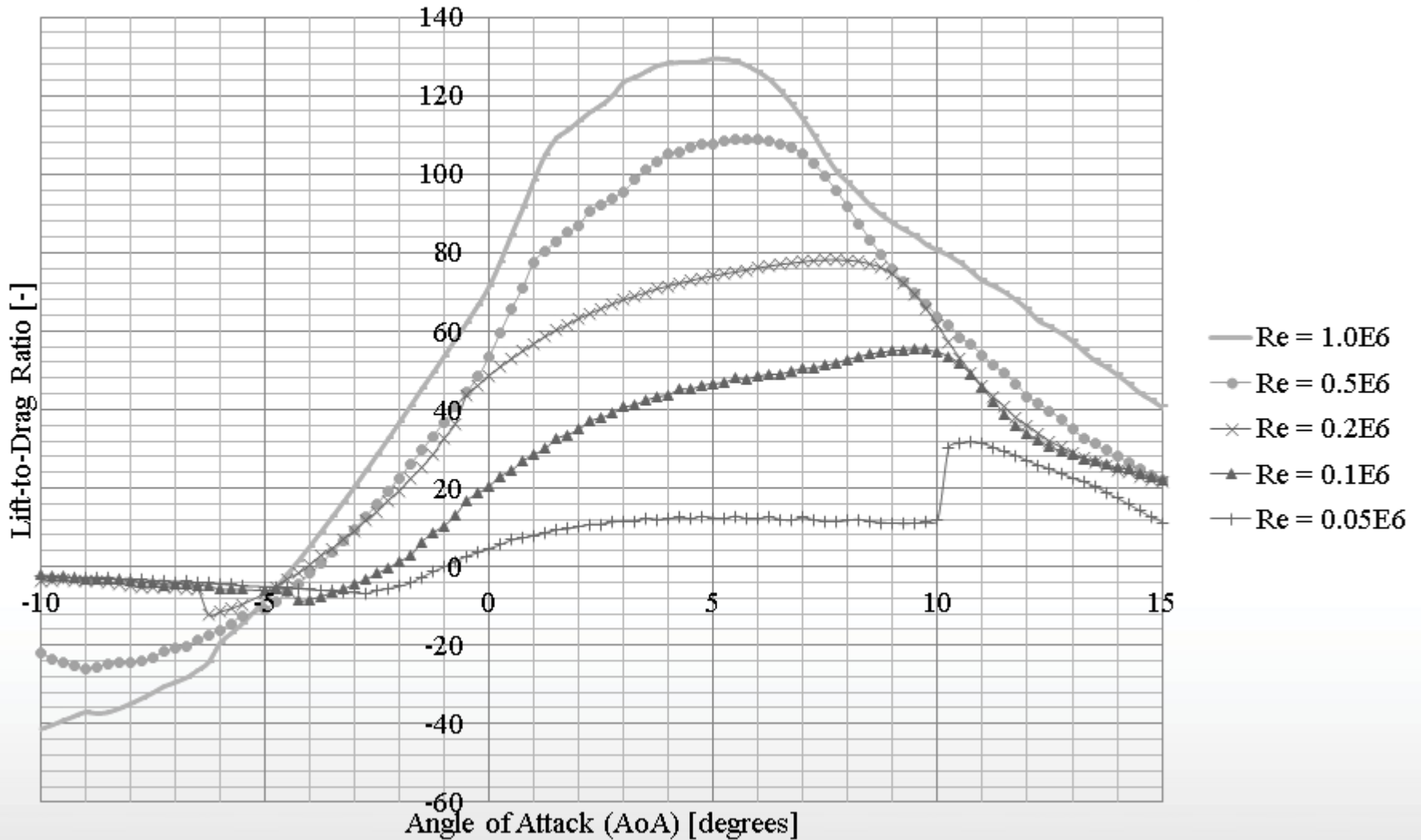
$$L_r = \frac{1}{2} [C_L]_r \rho V_r^2 c \Delta r$$

Lift coefficient for NACA4412 aerofoil profile.

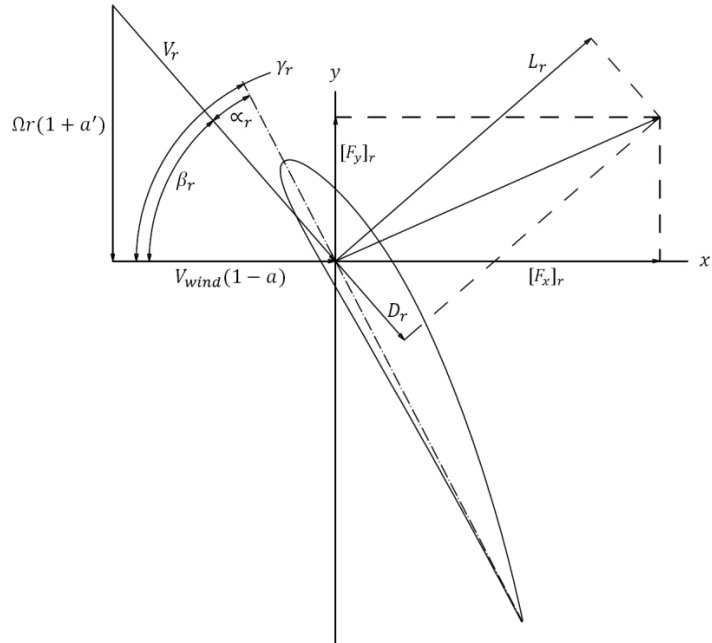
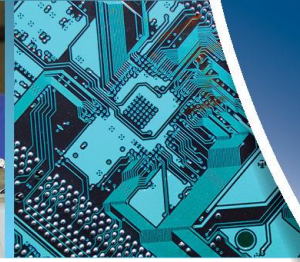


$$Re = \frac{Vc}{\nu}$$

Optimization Theory

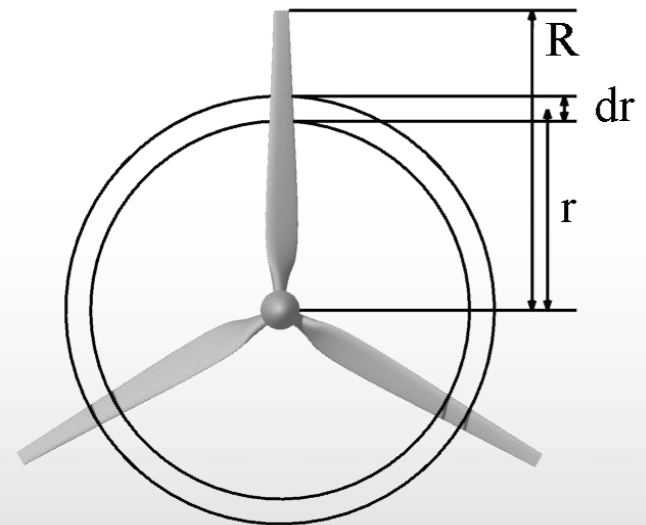
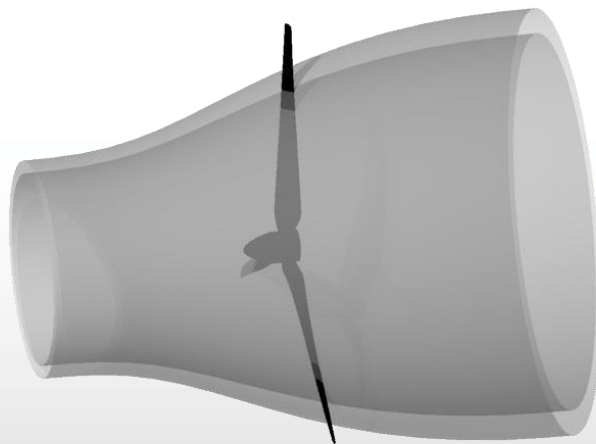


Element Theory

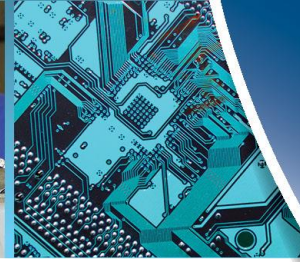


Each element represents a 2D analysis of that section

Control volume and blade segmented.

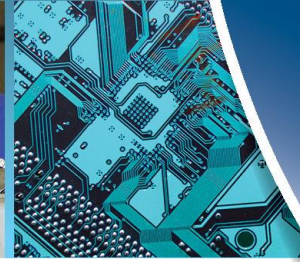


End of BEM Theory



End of Introduction

Definition of Reynolds Number for an Aerofoil



Ratio of momentum forces to viscous forces

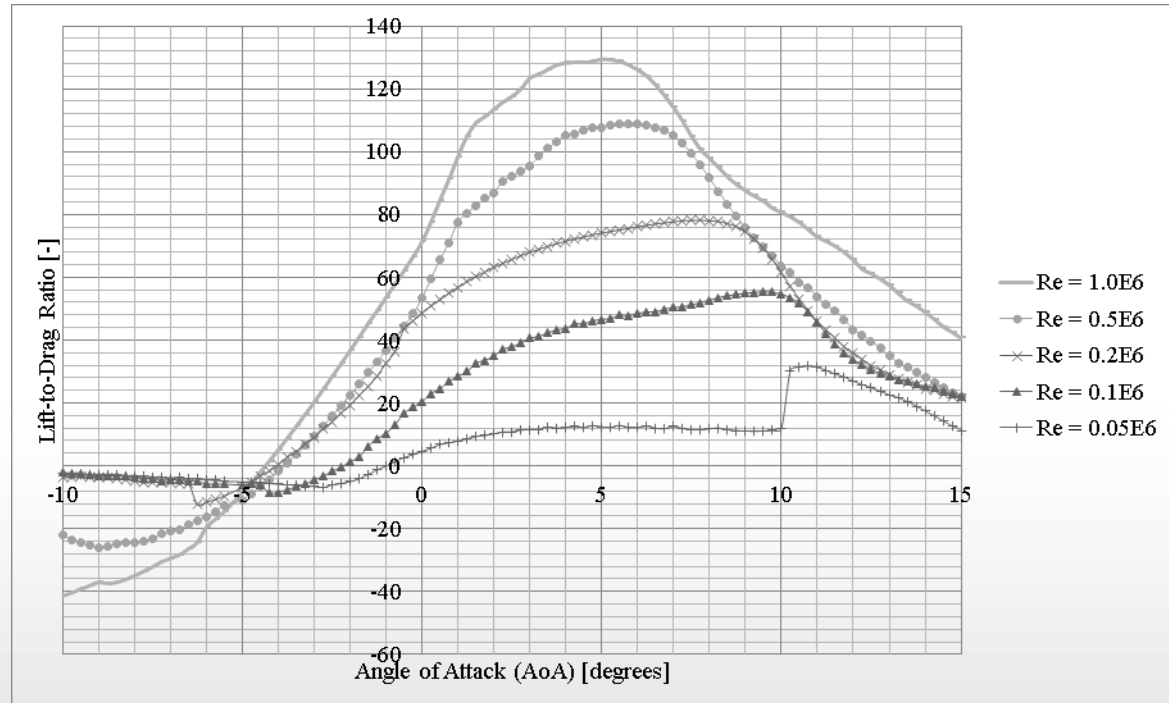
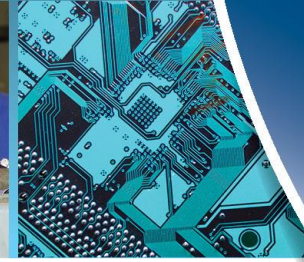
$$Re = \frac{Vc}{\nu}$$

GIVEN (points to V)

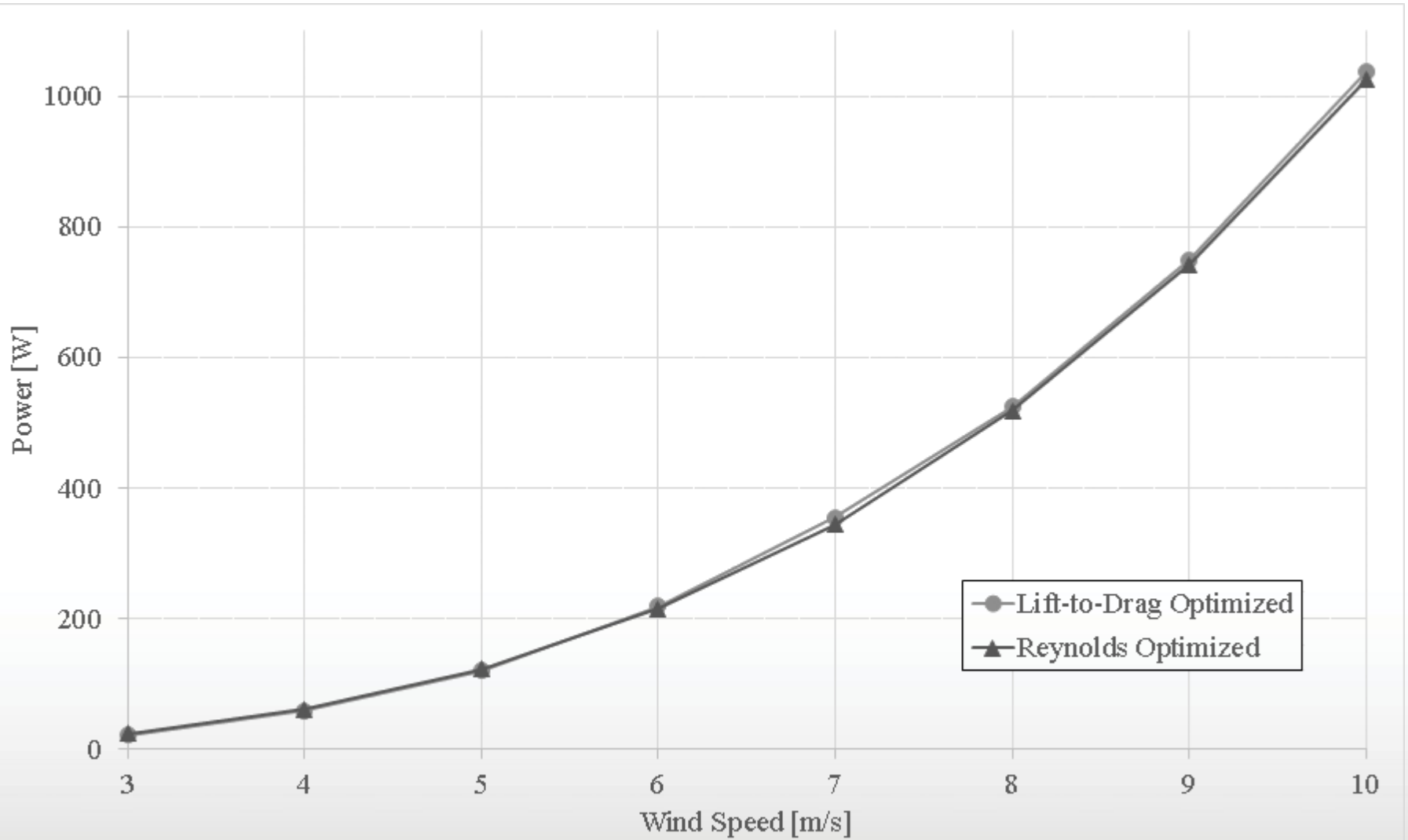
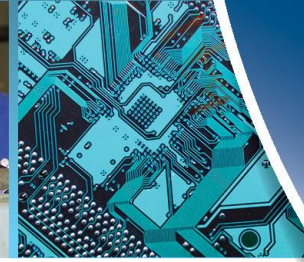
DESIGN CONTROLLED (points to c)

GIVEN (points to ν)

Optimization of Reynolds Number



Comparative Results



Effects and Benefits of Optimization



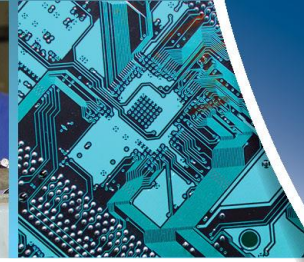
Potential Benefits

- Increased energy yield.
- Decreased cut-in wind speed.
- Turbine performance less dependent on advanced MPPT electronics.
- Increased blade stiffness due to increased section modulus.
- Less structural material required due to increased stiffness.

Potential Disadvantages

- Increased projected area increases loads in extreme winds.
- Increased blade volume requires more material.

Conclusions



Analytical results show great promise for increased energy yield (especially in gusty and turbulent winds)

Next step is to confirm analytical results with practical results (currently underway).

Questions?

