

Ducted Wind Turbines Optimization

Nojan Bagheri-Sadeghi, Brian Helenbrook, Kenneth Visser
Department of Mechanical and Aeronautical Engineering
Clarkson University, Potsdam, NY

Motivation

- Ducted turbines can produce more power per area than non-ducted designs
- Optimal design depends on performance metric
 - Power per rotor area, C_p
 - Power per total cross sectional area, $C_{p, total}$
- Applications requiring high $C_{p, total}$:
 - Space-limited, Portable

Design Variables

- Thrust coefficient of the rotor,

$$C_t = \Delta \rho / 2 * v_{in}^2$$

- Airfoil angle of attack, α
- Axial position of the rotor, z/D
- Gap between the rotor and the duct, $\Delta r / 2$
- Chord length, $c / 3$

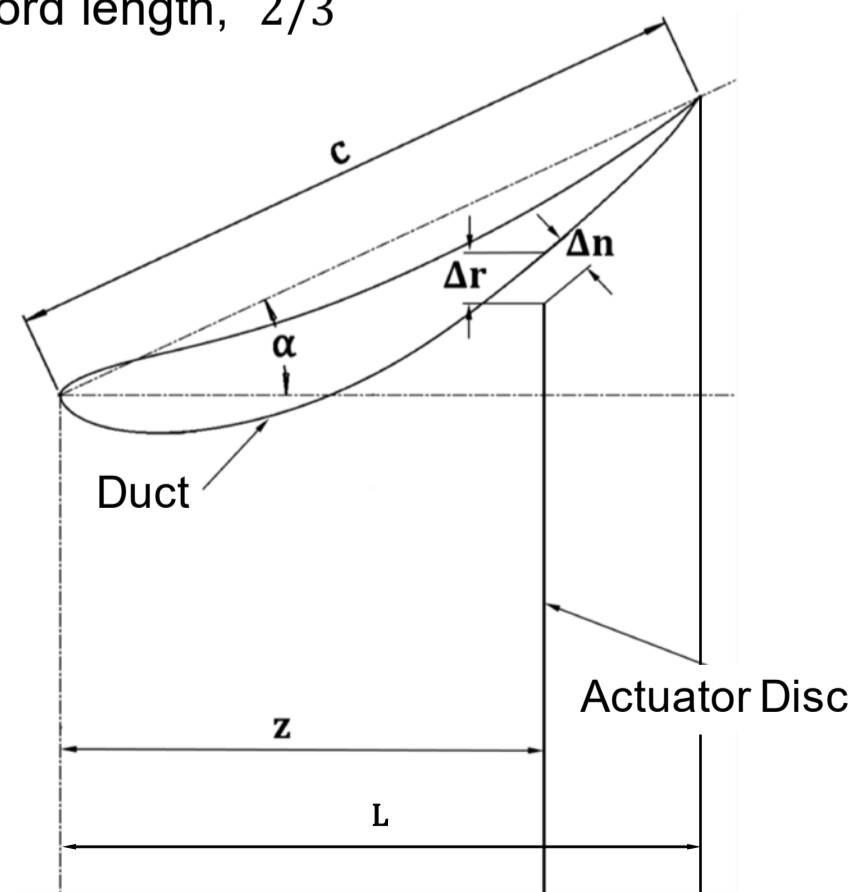


Figure 1 – Design Variables of a Ducted Wind Turbine

CFD Model

- Axisymmetric RANS model in ANSYS Fluent using $k-\omega$ SST turbulence model
- Wind turbine modeled as an actuator disc

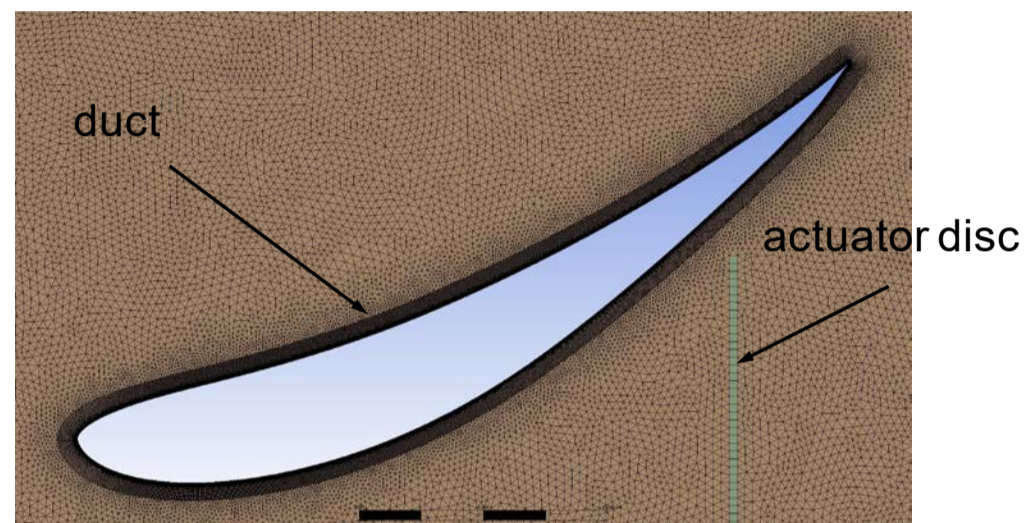


Figure 2 – Grid close to duct

Results

- Optimal design is usually on the verge of separation
- Maximum $C_{p, total}$ at $c/D \approx 20\%$

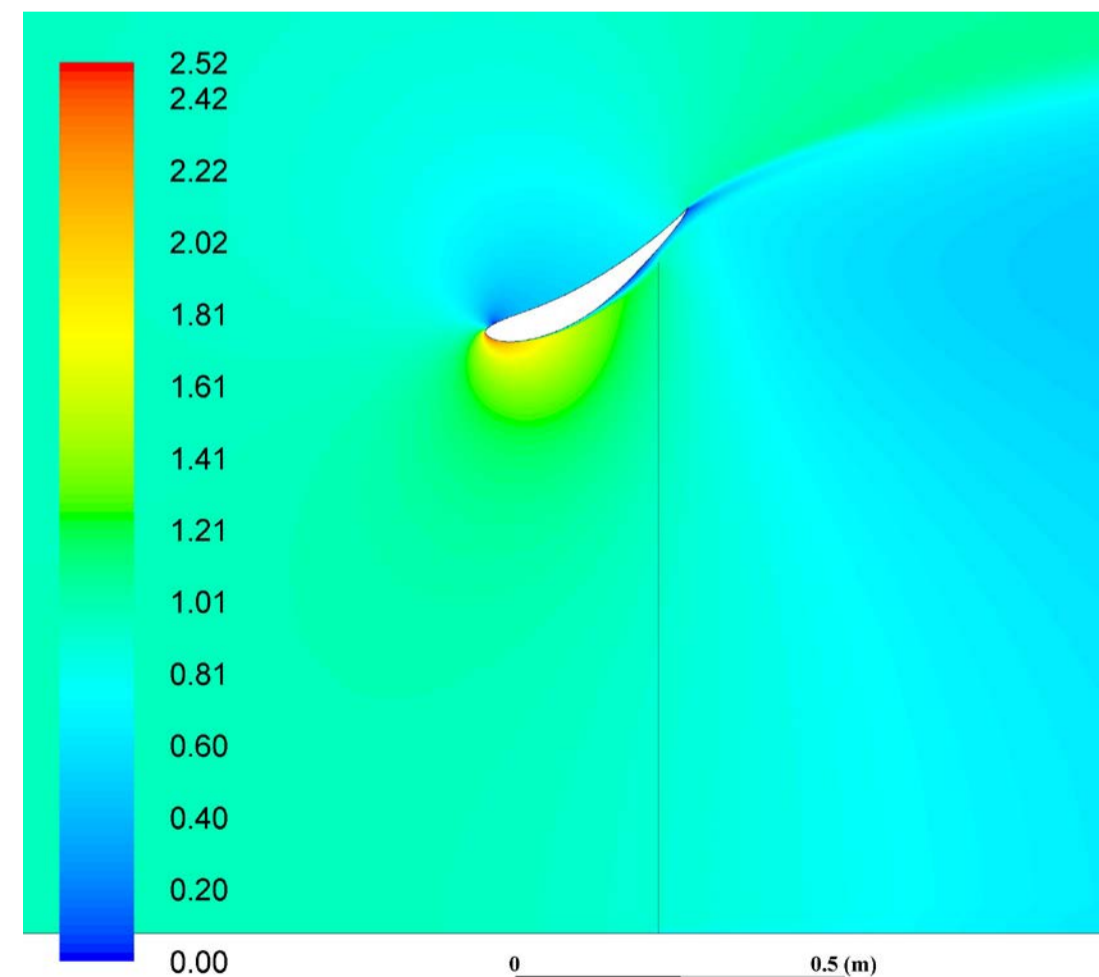


Figure 3 – Velocity magnitude contour of design for optimal C_p

Results (Cont.)

- Maximum $C_{p, total}$ 15% greater than Betz
- Optimal C_t close to open rotor (≈ 0.9)
- Higher optimal angle of attack for short ducts
- Optimal $\Delta r / 2$ nearly constant
- Rotor near back for short ducts

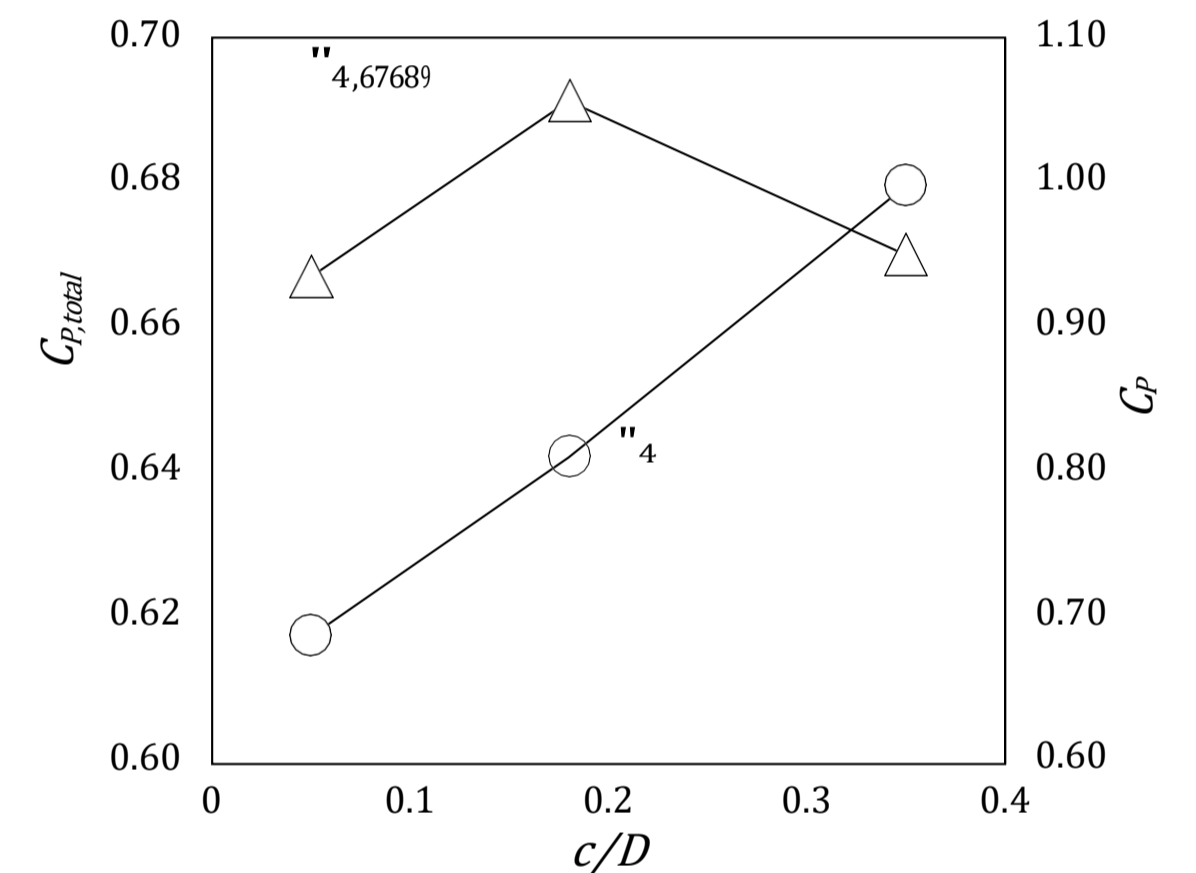


Figure 4 – Optimal $C_{p, total}$ at fixed z/D

Conclusions

- Optimal design of ducted turbines depends strongly on optimization objective
- $C_{p, total}$ optimized design at optimal $c/D \approx 20\%$
- Maximum $C_{p, total}$ (0.69) greater than Betz limit for open rotor. Can get more power per area using a duct