Performance analysis of an idealized Darrieus-Savonius combined wind turbine

Name：Jingna Pan
Department: FPT
Section: Wind Energy
Promotor: Carlos Ferreira
Co-promotor: Alexander van Zuijlen
Contact: J.Pan-1@tudelft.nl

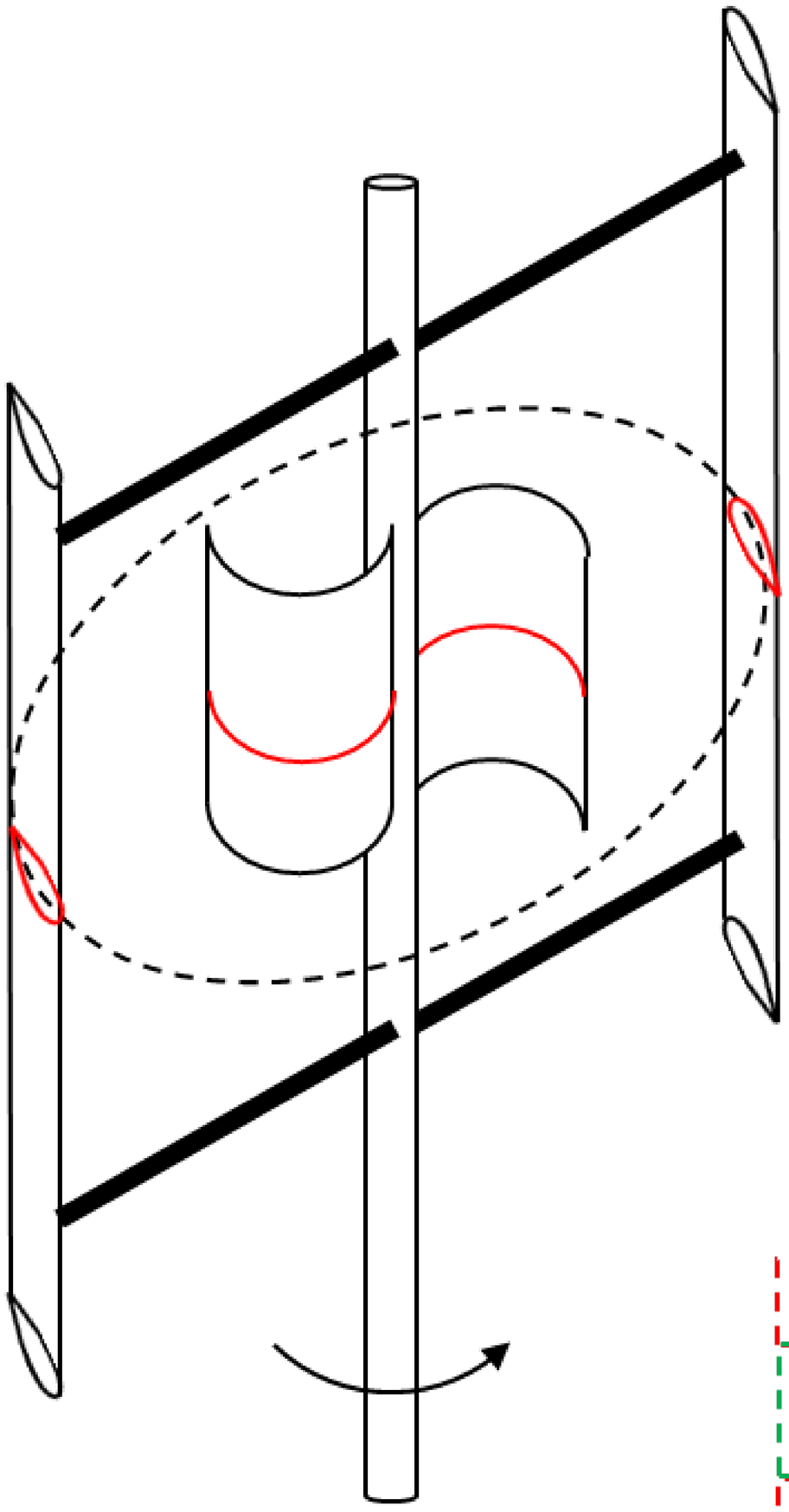

Fig. 1 Schematic of Darrieus-Savonius combined wind turbine (hybrid VAWT)

Introduction

- The concept of Darrieus-Savonius combined wind turbine (also known as hybrid VAWT) originally emerged from the goal that it would not only have a high starting torque but also a high power coefficient.
- Despite its good start-up performance, the power coefficient is a relevant issue that comes to the hybrid VAWT. Various factors can affect the power output of the hybrid VAWT, including airfoil efficiency, tip speed ratio, and rotor shape. Since the power performance is unknown for a hybrid VAWT without the aforementioned factors, the laminar solver simpleFoam is applied to resolve the flow around an idealized hybrid VAWT.

Will the power coefficient of an idealized hybrid VAWT reach the Betz limit[1] ?

- **Numerical model:** The hybrid VAWT is represented by uniformly loaded actuator cylinder and actuator disk in OpenFOAM.

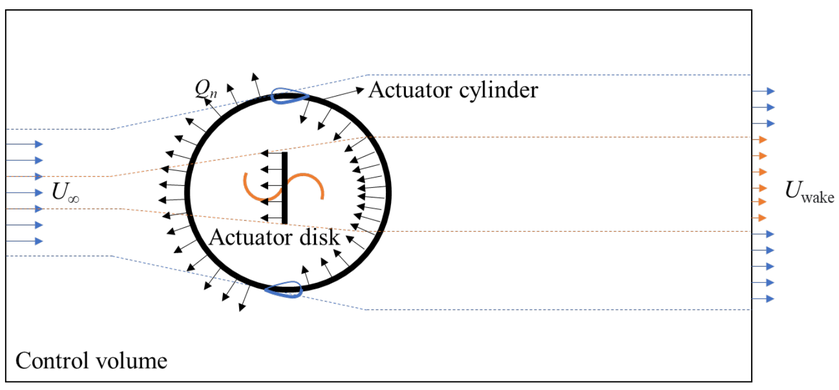

Fig. 2 Schematic of actuator cylinder and actuator disk for hybrid VAWT

- **Analytical model:** As the vorticity system is generated from the force discontinuity, actuator disk and actuator cylinder is analytically equivalent.

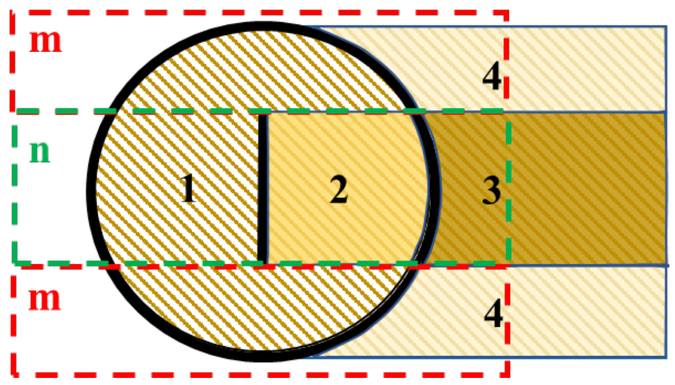

Fig. 3 Representation of computational domain for analytical actuator-disk-in-cylinder model

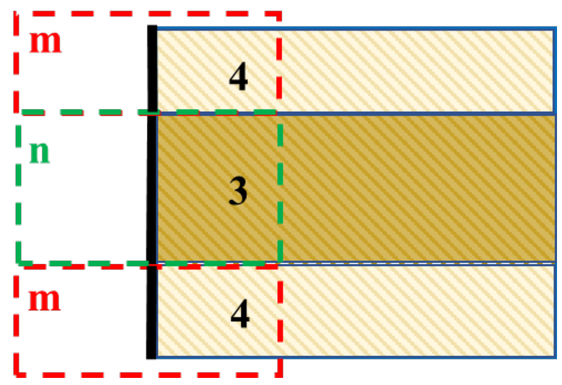

Fig. 4 Representation of computational domain for analytical double-actuator-disk model

Results

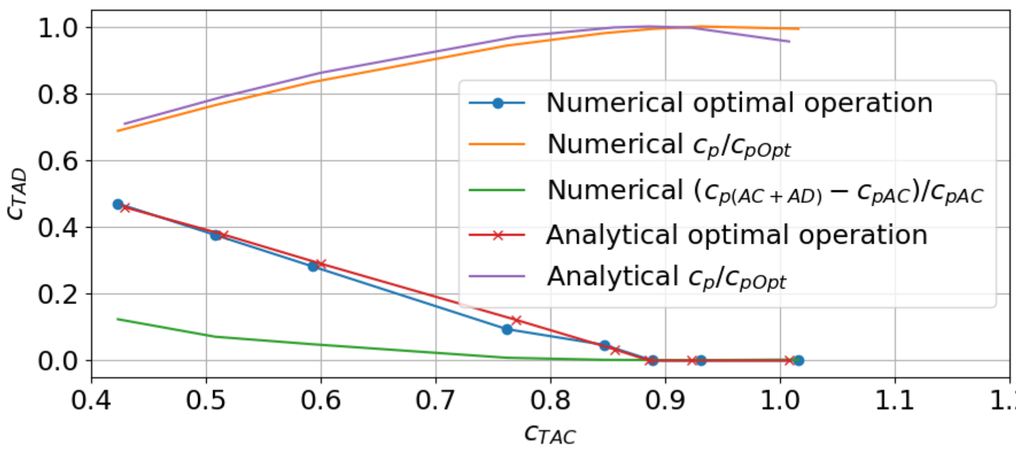

Fig. 4 Numerical and analytical comparison for non-dimensional c_p/c_{pOpt} of hybrid VAWT with given c_{TAC}

- The numerical results agree well with the analytical results in terms of power coefficient.
- The hybrid VAWT **cannot** achieve the maximum power coefficient of the single actuator.
- But the power output of the hybrid VAWT in comparison to single actuator with same c_T **increases up to 12%.**

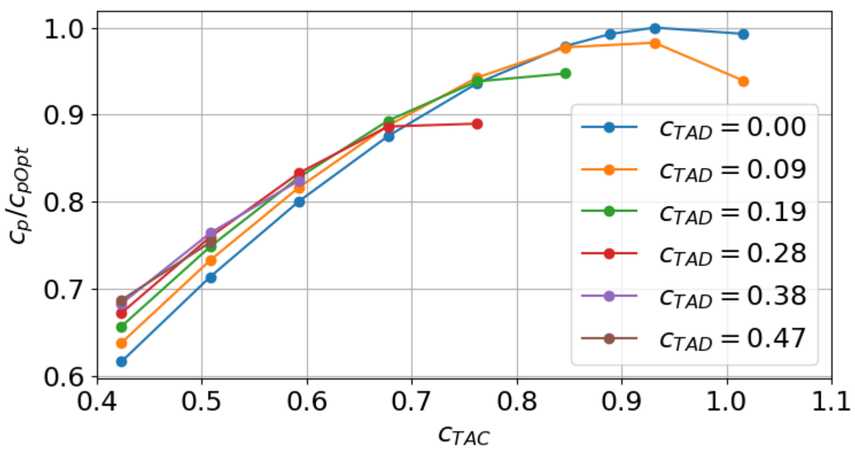

Fig. 5 Non-dimensional c_p/c_{pOpt} vs c_{TAC} for hybrid VAWT

- c_p of the hybrid VAWT is higher than that of the single AC for low c_{TAC} cases.
- While for high c_{TAC} cases, the hybrid VAWT loses power compared with the single actuator with same c_T.

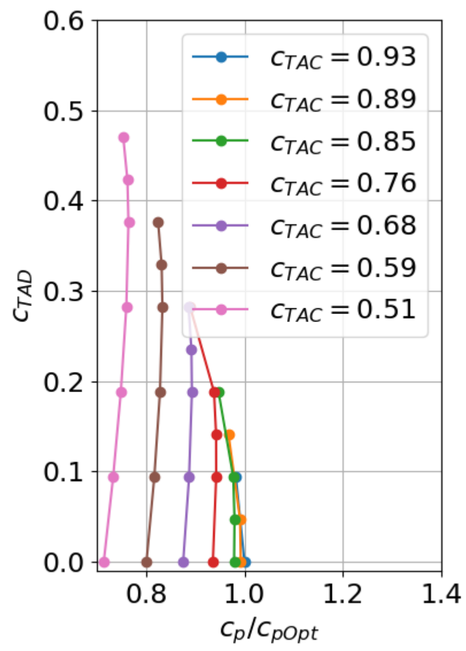

Fig. 6 Non-dimensional c_p/c_{pOpt} vs c_{TAD} for hybrid VAWT

- For low-loading cases $c_{TAC} \leq 0.76$, hybrid VAWT will have a slight power increase when c_{TAD} reaches a certain amount.

References

[1] Albert Betz. Introduction to the theory of flow machines. Oxford: Pergamon Press,1966.