VAWT Aerodynamic Modeling

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February 21, 2013

1 Introduction

The aerodynamic analysis of vertical axis wind turbines (VAWTs) can be accomplished with simple methods based on blade-element momentum theory, more complex vortex methods, or detailed computational fluid dynamics (CFD). The are an abundance of good CFD tools, and Sandia National Laboratories has developed a soon to be publicly available free wake vortex method (CACTUS). These tools fill important roles in the design process, but simpler methods based on blade-element theory are useful for the conceptual design phase where a large range of designs need to be evaluated in a timely manner.

The application of blade-element theory to VAWTs results in a number of theories of increasing complexity: a single streamtube model, a multiple streamtube model, and a double multiple streamtube model. The later approach is pursued in this project and is a good balance between computational speed and model fidelity for initial aerodynamic studies.

2 Double Multiple Streamtube Method

Double multiple streamtube theory allows for the VAWT blade path to be discretized in a 2-dimensional mesh, with separate momentum losses for both the upstream and downstream passes of the blade. The method allows for complex blade geometry (curvature, sweep, pitch), wind shear, high-induction factors (Glauert correction), and any number of blades.

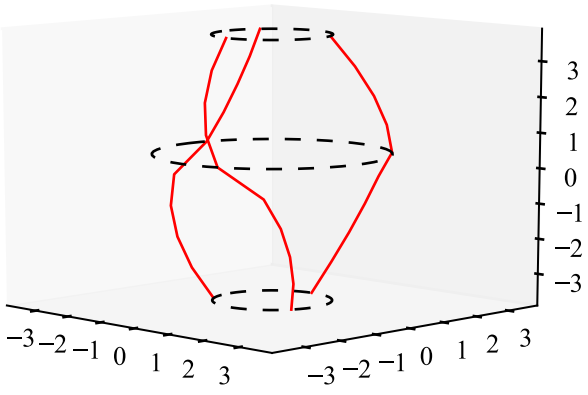
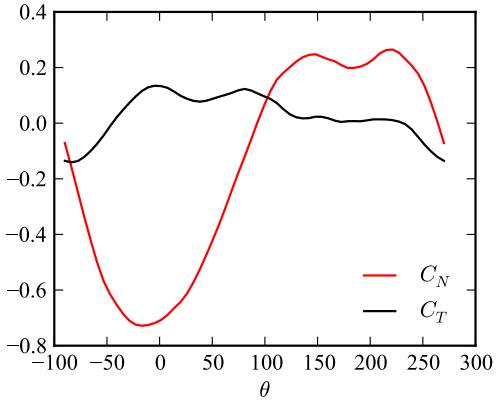


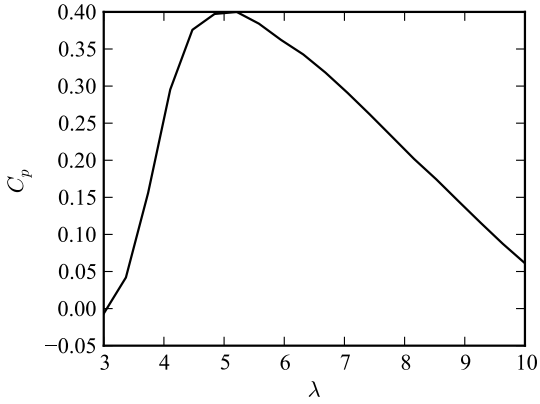
Figure 1: Isometric view of sample VAWT geometry. All units in meters.

As an example, a fictitious 3-bladed VAWT with a 5 meter diameter and 7.5 meter height is shown in Figure 1. The blades are constant chord with a solidity of 0.15 and NACA 0012 sections. The normal and

tangential loads for one blade are shown in Figure 2a, and the variation in power coefficient with tip speed ratio in Figure 2b.



(a) Normal and tangential loads for one blade as a function of azimuthal position at a tip speed ratio of 5.0. The upstream portion of rotation occurs from $\theta \in (-90, 90)$.



(b) Power coefficient of entire turbine as a function of tip speed ratio.

Figure 2: Loads and power coefficient of sample VAWT.