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VERTICAL-AXIS WIND TURBINE START-UP MODELLED WITH A HIGH-ORDER NUMERICAL SOLVER

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Darrieus vertical-axis wind turbines (VAWTs) rotate in a plane parallel to flow, causing torques produced by blades to vary over the course of a rotation, with negative torque production in some sectors. The ability of fixed-blade VAWTs to self-start is doubted by some due to a calculated “dead band” of negative net torque production at certain low tip-speed ratios [6], though self-starting has been observed in controlled conditions [1, 4] and in field tests. The start-up phase of operation is fundamental to design as moderate improvements to starting capability can improve a turbine's annual energy yields greatly [7] by allowing useful energy extraction in lower winds. In this study, self-starting ability is defined after Bianchini et al. [1] as when a turbine accelerates through its entire power curve to its fastest equilibrium state unaided.

Little work has been done on the physics of VAWTs during start-up, much that has been utilises blade element momentum (BEM) methods [1, 4, 5] with some CFD at fixed, low tip-speed ratios [5]. BEM codes are known to overestimate the “dead band” of negative net torques without prior modification of input aerofoil data, limiting their usefulness as design tools for this phase of operation, while CFD simulations are computationally costly. This study attempts to gain better understanding of the start-up process by utilising a novel CFD code coupled with a momentum model to simulate start-up of a turbine from standing.

A high-order Discontinuous Galerkin solver for the Navier-Stokes equations has been developed recently by Ferrer and Willden [2]. It is capable of working with sliding meshes, allowing high-order solutions of rotating bodies, and has been validated for a range of flows, including Darrieus turbines [3].

The code can provide qualitative indications of the phenomena at play during start-up, particularly the blade/wake interactions taking place at varying low tip-speed ratios. This will permit us to investigate the discrepancies between BEM theory and experiment, with vorticity shed by upstream blades impacting on the forces generated by downstream blades in potentially beneficial ways. Fig. 1 depicts the force traces for a unique blade over 4 revolutions (starting on the second) taken using the code, for a single-bladed and three-bladed turbine. Differences between the two traces are due to interactions with wakes other than the blade's own.

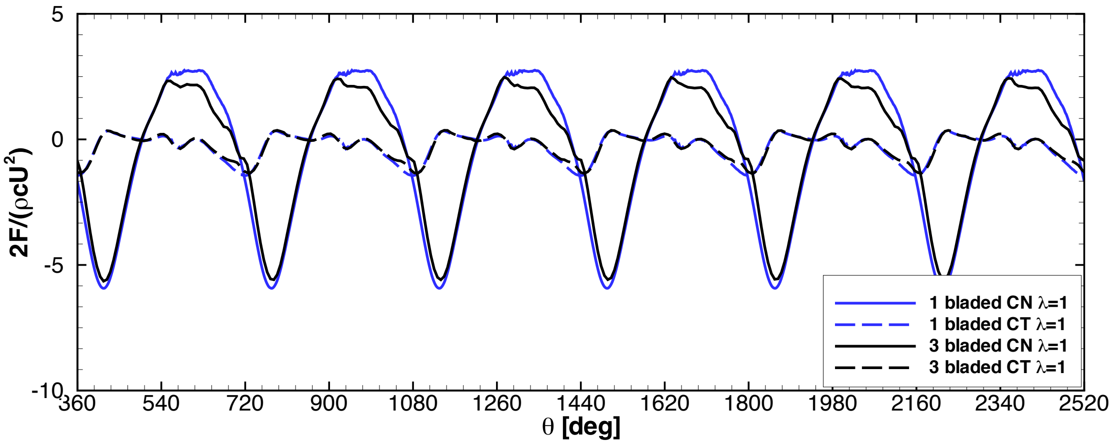

Figure 1: Tangential and normal force coefficients against azimuth, one and three bladed turbines at a tip-speed ratio of 1. Forces shown are for a single blade.

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