Experimental and numerical investigation of the 3D VAWT wake.

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Abstract

The Vertical Axis Wind Turbine, in its 2D form, is characterized by a complex unsteady aerodynamic flow, including dynamic stall and blade vortex interaction.

Adding to this complexity, 3D flow brings spanwise effects and the presence of trailing vorticity and tip vortices.

The objective of the current paper is to bring insight into the 3D development of the near wake of a H-VAWT, understanding:
• Spanwise blade load distribution, upwind and downwind blade passages.
• Trajectory of tip vortices, including inboard movement and radial expansion of shed and trailing vorticity.
• 3D effects on the efficiency of the VAWT.
• Blade vortex interaction of upwind tip vortex with downwind blade passage.
• Induction due to trailing vorticity.

The investigation is composed of experimental wind tunnel research with Stereo-PIV and modeling of the rotor and wake with a 3D unsteady panel method.

A two bladed H-Darrieus VAWT model was tested in the low speed/low turbulence wind tunnel at Delft University of Technology. Stereo-PIV measurements were used to visualize the flow in the near wake focusing on the flow field around four tip geometries. The measurement planes cover several sections of the rotor volume, allowing for a reconstruction of the evolution of the tip vortex. The formation, convection and dissipation for each tip vortex were located and quantified (see example Figure 1).

The experimental PIV data is used to validate the 3D, unsteady, multibody, free-wake panel method developed to model a VAWT (see example Figure 2).

The combination of the results of the panel model validated by experiments, in particular the Stereo PIV results, allows to understand the impact of the near wake development in the upwind blade passage, as well as the energy conversion process at the downwind blade passage.

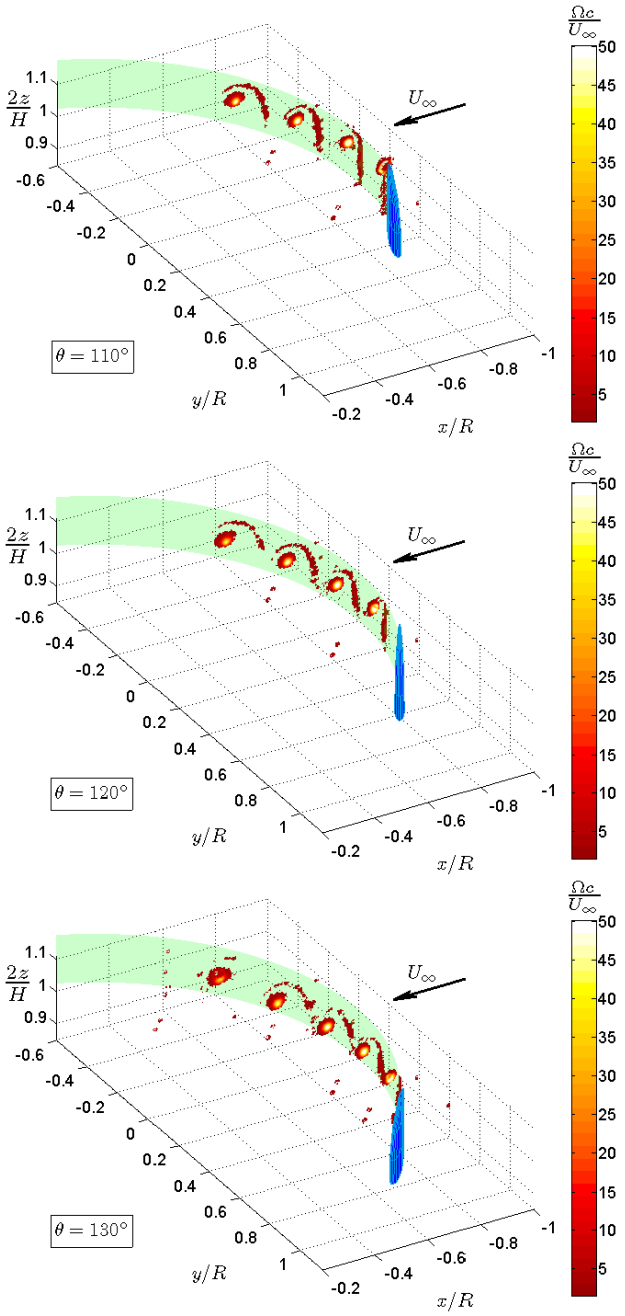

Figure 1: Experimental PIV measurement of vorticity in planes y R = −0.42, −0.21, 0 ,0.21 and 0.42, for azimuth angle of the rotor θ = 110◦, 120◦ and 130◦.

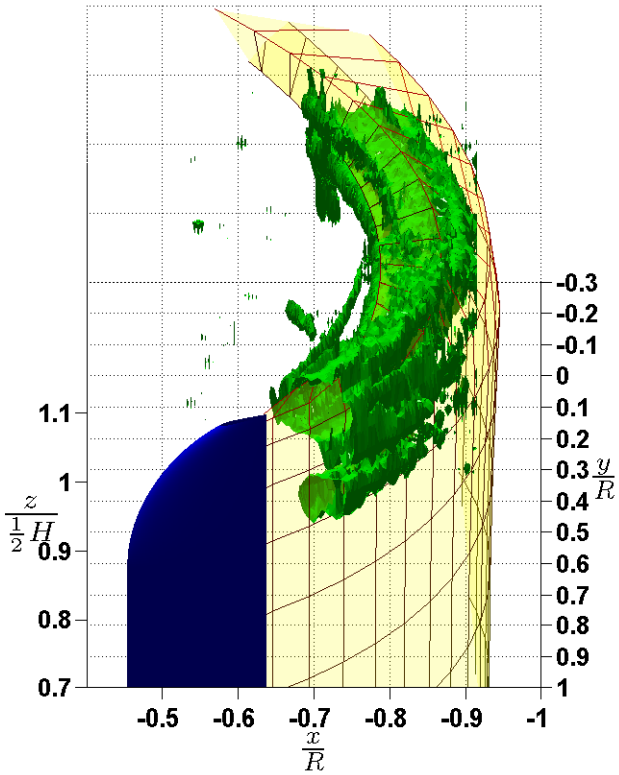

Figure 2: Comparison of 3D reconstruction of experimental PIV iso-vorticity surface (Ωc U∞ = 5) and near wake from panel model, at θ = 150◦.