# Experimental characterization of the unsteady airfoil aerodynamics for wind turbine applications

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## Background

1. Rapid increase in wind turbines rotor diameters
2. Difficult to replicate dynamic similarity for large scale wind turbines
3. Lack of understanding around dedicated wind turbines airfoil behaviour at high Reynolds numbers
4. Interest in dynamic loads oscillations due to the increased size of HAWT blades

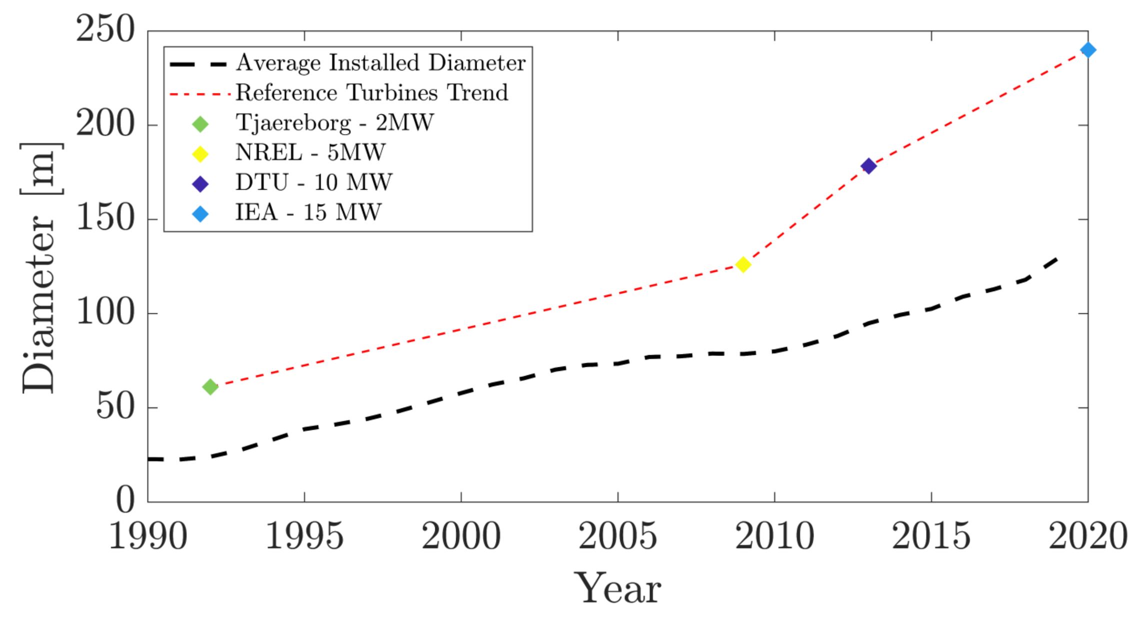


Fig. 1: Increase in mean installed diameter over the years

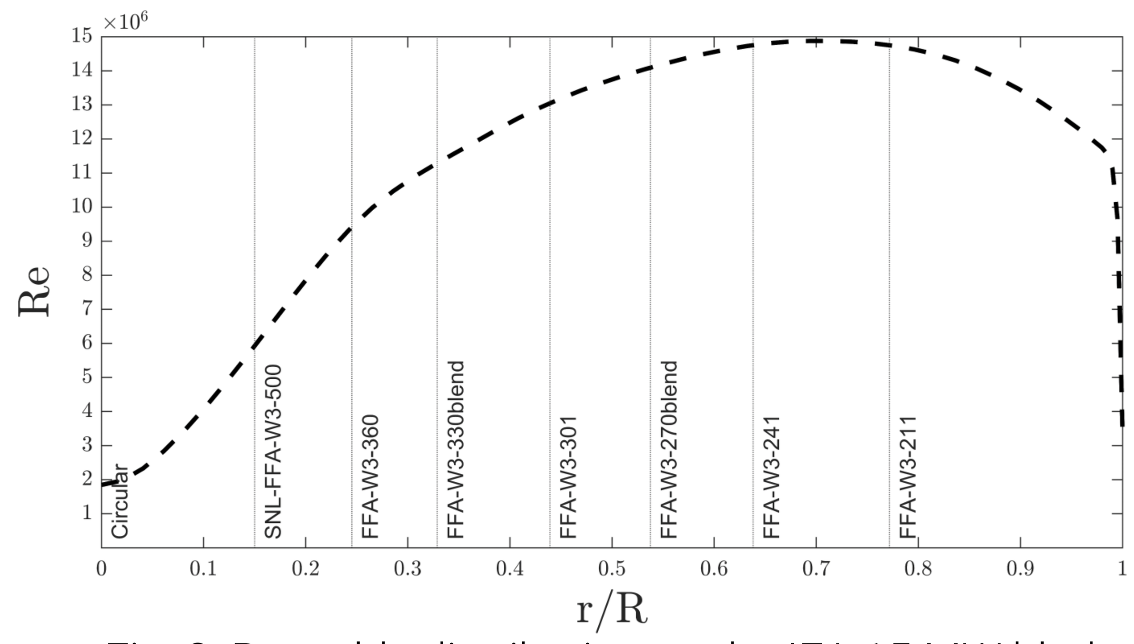


Fig. 2: Reynolds distribution on the IEA 15 MW blade

## Methodology

Fig. 3: LTT testing section

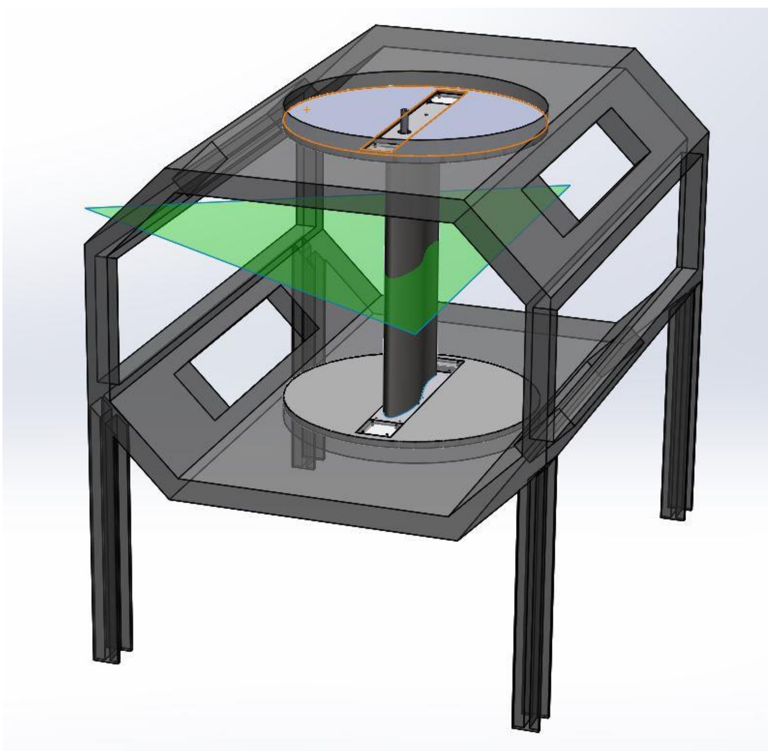

Fig. 4: experiment CAD

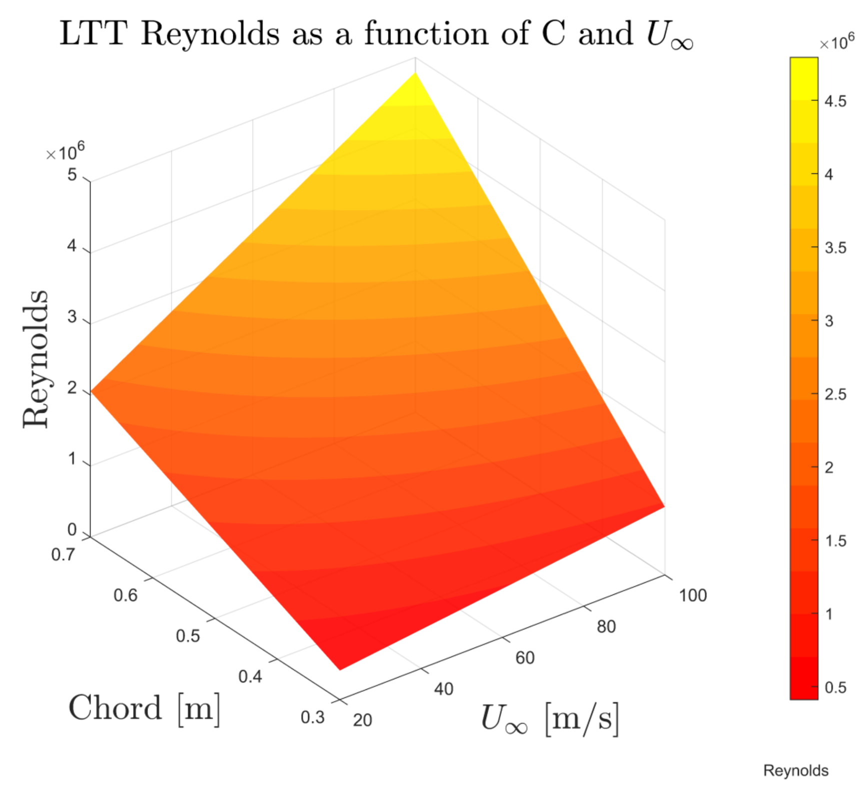


Fig. 5: experiment trade-offs

The experiment will run in April and will use pressure taps, rake and PIV to acquire the static and dynamic polars for the FFA-W3-211 airfoil. A flow field characterisation will be carried out to determine the evolution of deep stall vortices for varying reduced frequencies and Reynolds. The experiment will replicate relatively high reduced frequencies, which are of interest in the literature to understand dynamic loads.

## Preliminary Results

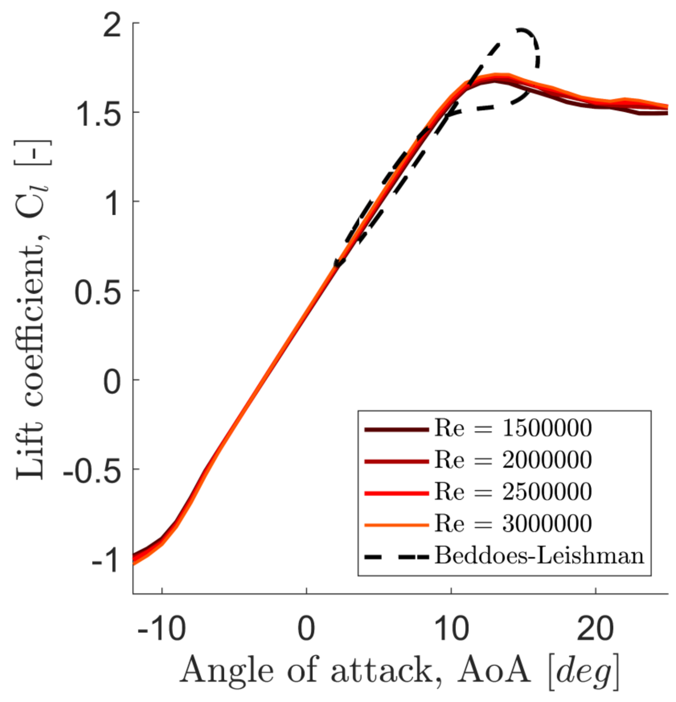


Fig. 6: static polars – FFA-W3-211 XFOIL results

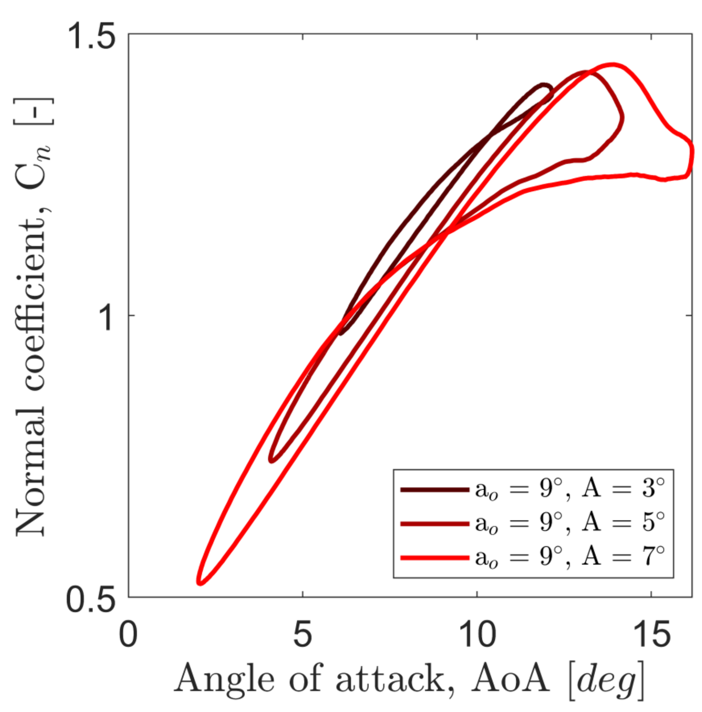


Fig. 7: dynamic polars – DU17DBD25 Experimental results from [1]

Reduced frequency has been found to delay the stall angle, with differences between upstroke and downstroke phases. The effect of Reynolds number are deemed of secondary importance for the stall delay and deep stall vortex formation. The Beddoes-Leishman dynamic stall model is used to provide an esteem of the equivalent lift coefficient loop from computational results.

## Future work

Longer blades are associated with greater unsteady loads. Wind-shear, blade-vortex interaction and yaw misalignment are responsible for fluctuating aerodynamic and structural loads on the blade. Additionally, high Reynolds are difficult to replicate experimentally in controlled conditions, and isolating the effects of Reynolds number is challenging in traditional low speed facilities.

My PhD project will investigate the steady and unsteady behaviour of traditional airfoils experiencing, with the final aim to use the current airfoil knowledge to design high performing airfoils designed for the next generation of wind turbines, operating at high Reynolds.

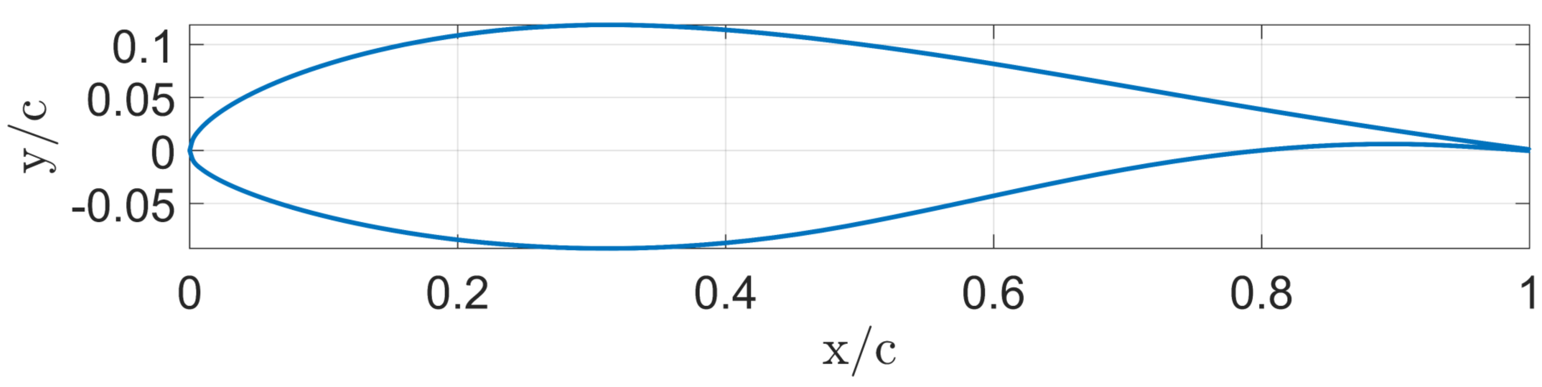


Fig. 8: FFA-W3-211 airfoil coordinates

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[1] D. De Tavernier, C. Ferreira, A. Viré, B. LeBlanc, and S. Bernardy, “Controlling dynamic stall using vortex generators on a wind turbine airfoil,” Renewable Energy, vol. 172, pp. 1194–1211, 2021.