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Unsteady Hydrodynamics of tidal turbine blades

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Motivation

Tidal turbines encounter a range of unsteady flow conditions, some of which may induce severe load fluctuations. A rotor's blade can experience stall delay, load hysteresis and dynamic stall. This PhD project addresses the need for the quantification of the unsteady flow and the loads on a full-scale tidal turbine to improve fatigue analysis and enable strategies for load mitigation.

Methodology

A model for the unsteady hydrodynamics of the rotor has been developed which comprises blade-element momentum, unsteady attached flow, dynamic stall and rotational augmentation implementations.

Results I

A parameter study across a range of flow conditions is carried out to identify the most severe conditions for the root bending moment. The following general conclusions are drawn.

1. Waves, followed by turbulence, are the main sources of unsteadiness (Fig. 1).
2. In these conditions, dynamic stall occurs near the root while it is attached near the tip (Fig. 2).
3. Commonly-adopted quasi steady approaches would over predict trailing edge separation (Fig. 2).

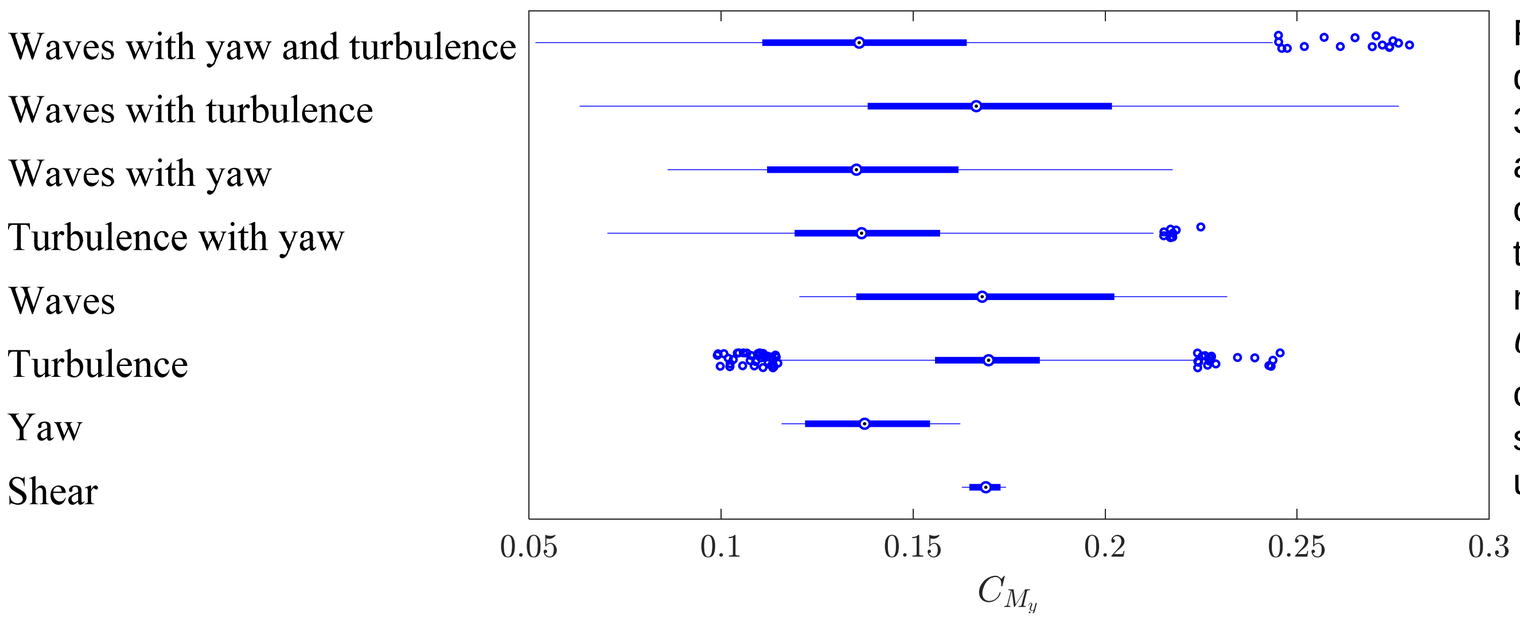

Figure 1: Inner quartile range (bold), 3 quartile range (line) and outliers (circles) of the time series of the root bending moment coefficient C_{M_y} for several combinations of sources of unsteadiness

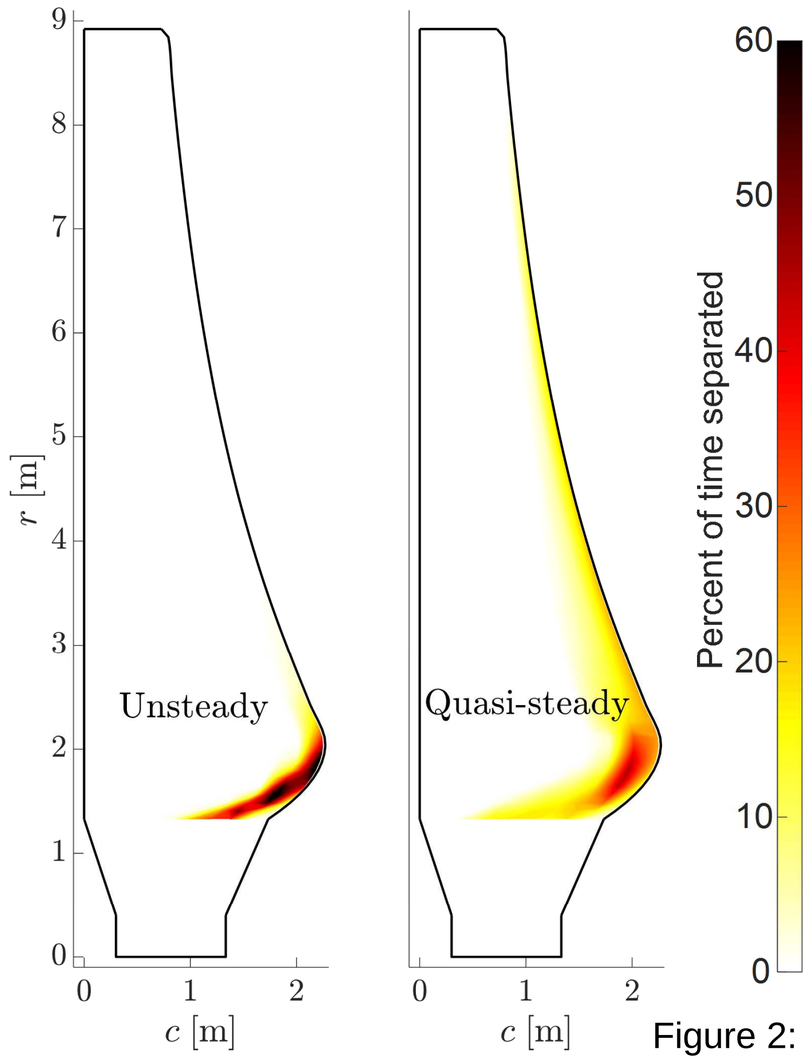

Figure 2: Separation on the suction side of the blade computed with the developed unsteady model and with a quasi-steady approximation

Results II

Velocity field measurements (ReDAPT project), during large, yet realistic wave conditions are used as input to the model. The following results are found.

1. The root bending moment (C_{M_y}) and the moment due to the torque (C_{M_x}) oscillate by half of their mean values (Fig. 3*).*
2. Dynamic stall occurs near the blade root, resulting in a twofold overshoot of the local lift coefficient.
3. Below the optimal tip-speed ratio, dynamic stall may occur over most of the blade.

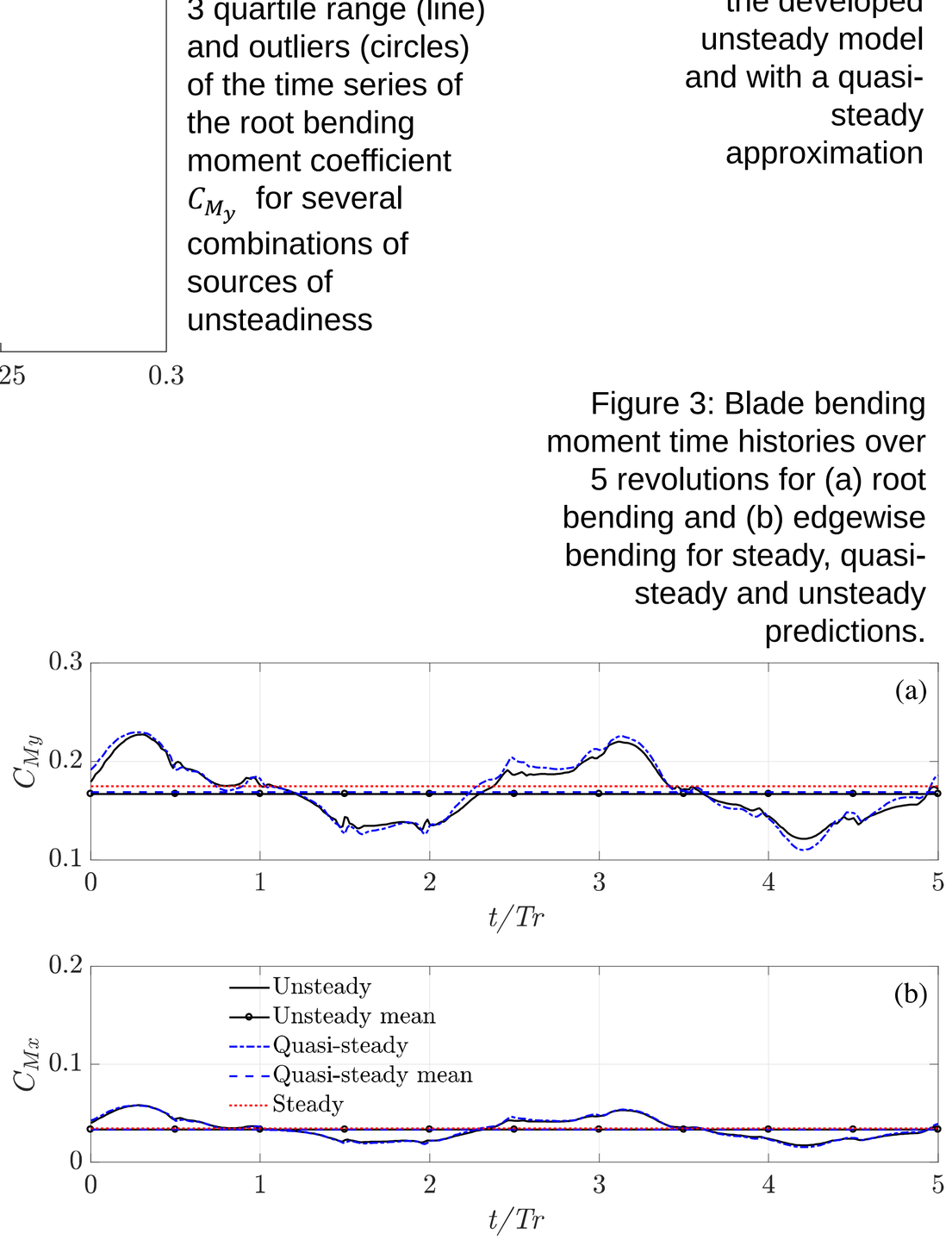

Figure 3: Blade bending moment time histories over 5 revolutions for (a) root bending and (b) edgewise bending for steady, quasi-steady and unsteady predictions.

Impact

These results inform designers of the governing loads which are important for fatigue analysis, enabling improvements of a turbine's reliability by design and, in turn, reducing the LCOE.

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