Nonlinear hydrodynamic effects for bottom-fixed wind turbines

Master thesis in Marin hydrodynamics

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Problem

Bottom fixed offshore wind turbines are a possible solution to the future's need for green energy. These turbines might interact with steep waves, on the verge of breaking. In such waves considerable nonlinearities are present. Possible responses in the structure are both springing and ringing. Springing is usually defined as steady state resonant oscillations, and ringing a transient burst of resonant oscillations. The topic of interest is to study improved wave models and force models, in order to be able to predict such events.

Outline of Work

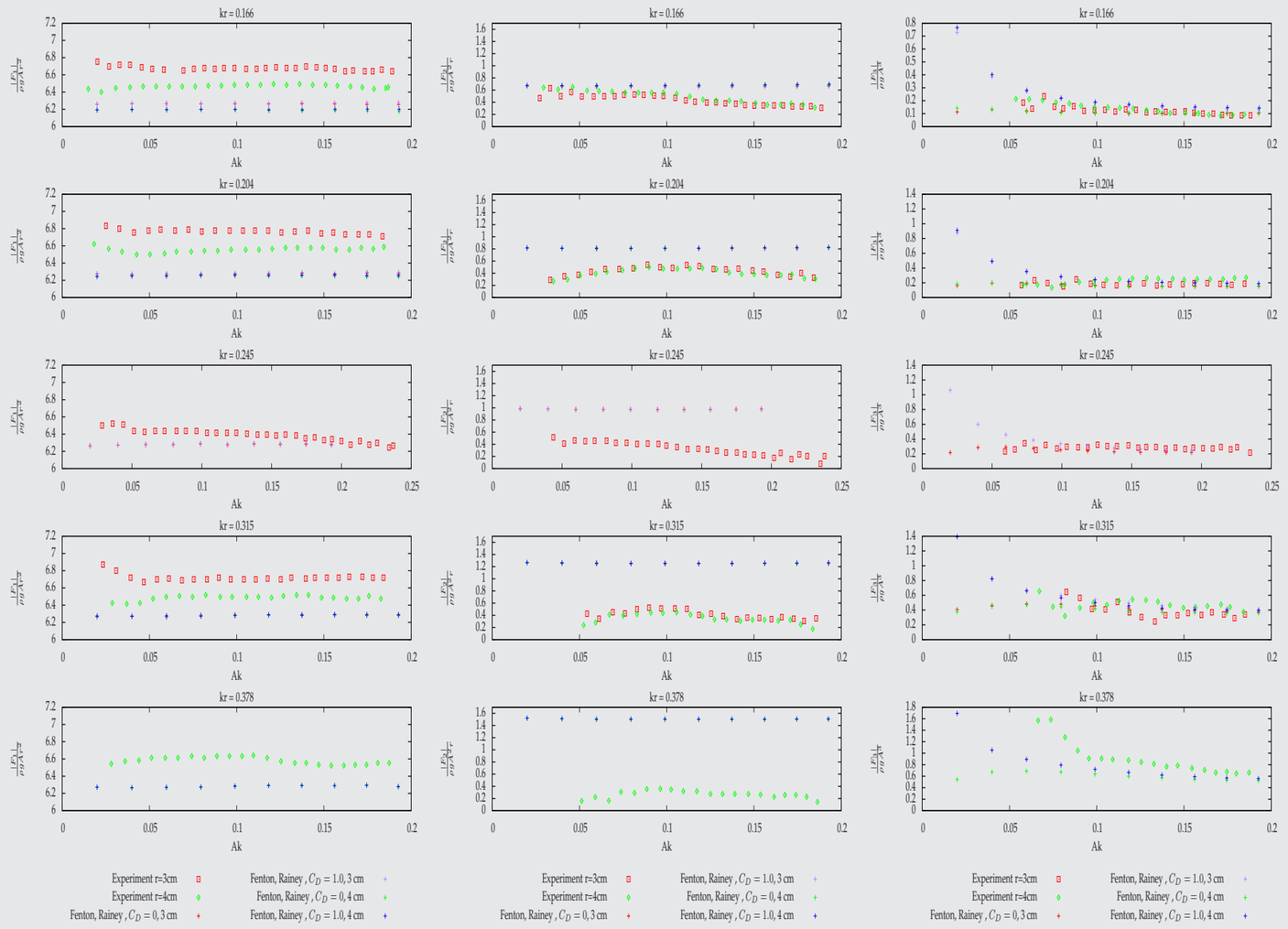
The load formulation developed by Rainey are implemented in the open source wind turbine tool FAST. Comparison between numerical calculations with Morison's equation and Rainey's expressions are compared with idealised experiments on a cylinder in regular waves. Incident waves in the numerical model are both the existing feature of linear incident waves, and also Fenton generated nonlinear waves.

For the case of a fully coupled aero-hydro-servo-elastic simulation, the two load formulations are compared on realistic cases with both linear irregular sea, and fully nonlinear irregular sea.

Results

- Severe springing can occur for special cases
- Transient resonant oscillations close to ringing behaviour is possible in special cases
- Wind turbine motion seems to be governed by the aerodynamic loads
- Nonlinear effects in incident waves usually more important than the nonlinearities from the load formulation

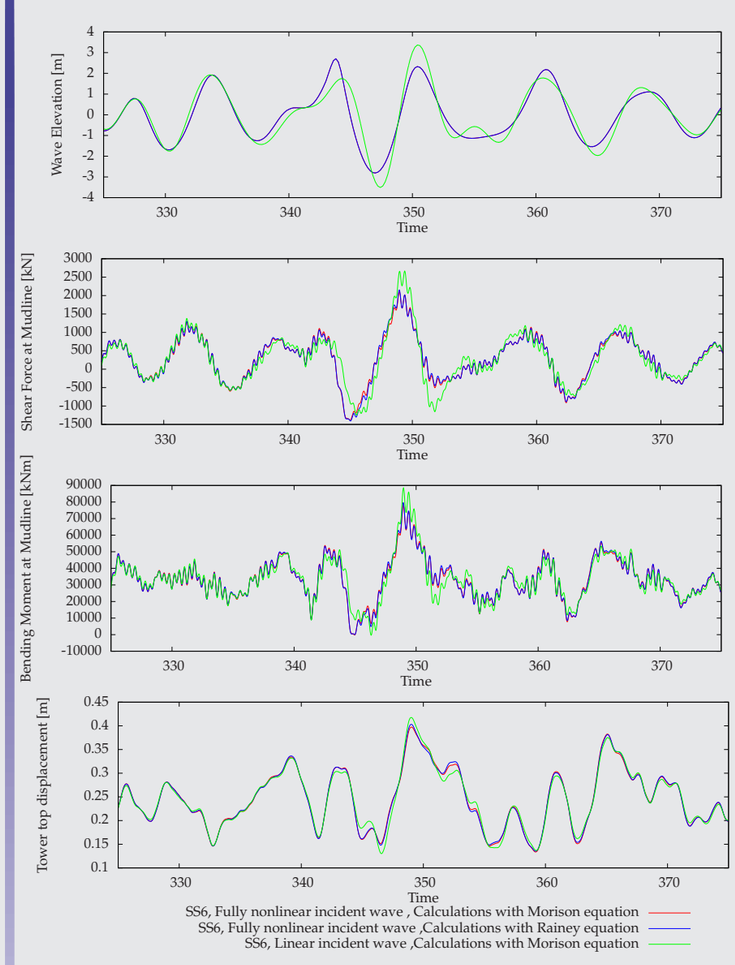
Comparing harmonic loads with experiment



Comparing the three first harmonic loads with experiments. Forces by Rainey and incident waves by Fenton

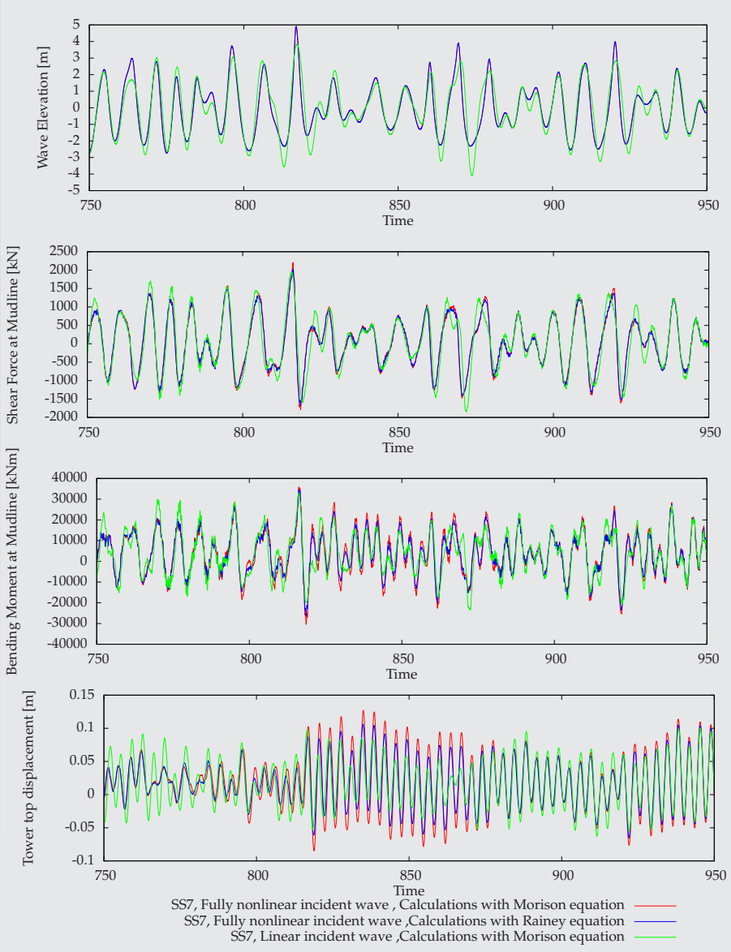
Good agreement is found between experimental values and the numerical calculates values for the lowest kr values. Significant overprediction is found for the second harmonic load as the slenderness of the structure is reduced, i.e. larger kr ratio. The third harmonic load is reasonably good predicted for all kr values with the Fenton generated incident waves.

Different models



Clear differences are seen regarding the different load calculation models, and also the incident wave model. Differences appear to be larger between a fully nonlinear incident wave model and linear incident wave model.

Resonant phenomena



The resonant phenomena appears to have a burst like increase in amplitude for the tower top oscillations