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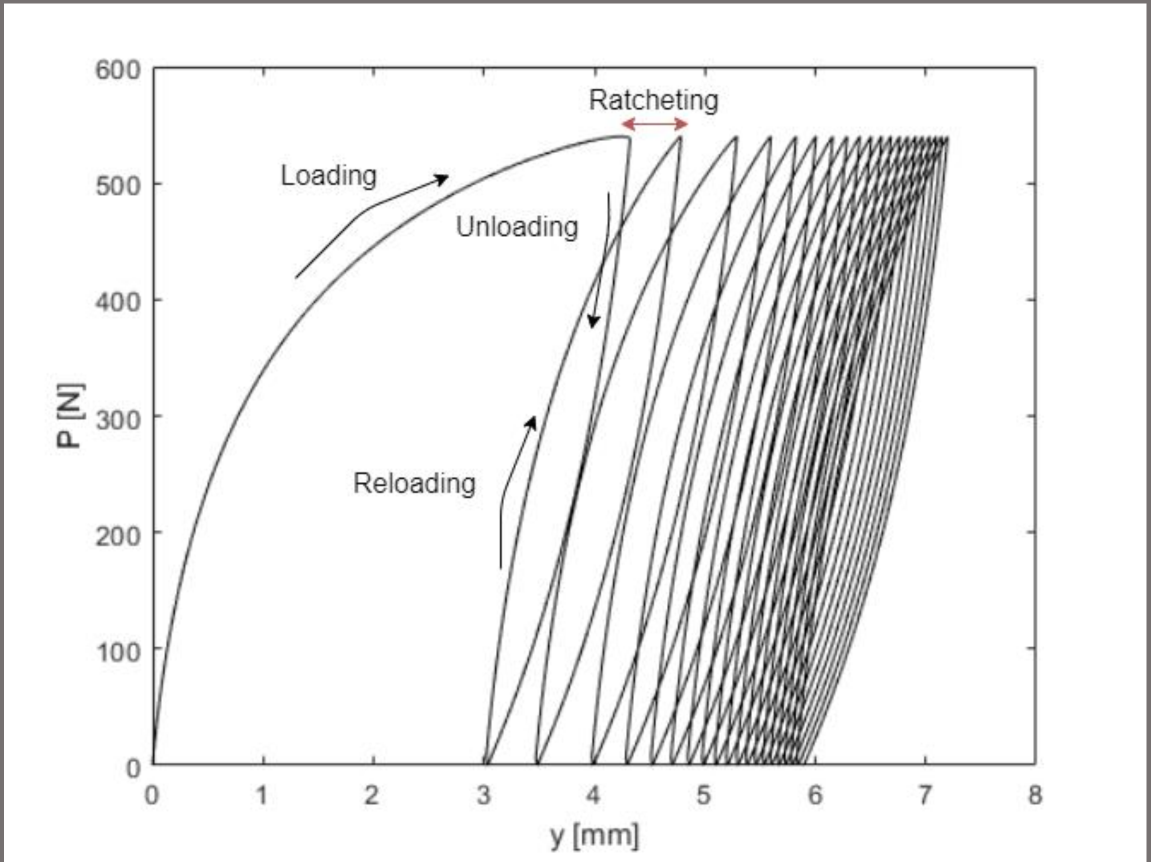
Modelling of offshore wind turbine monopile-soil interaction under multidirectional environmental loading

Stephen A. Williams, Loizos Pelecanos, Antony P. Darby

Introduction

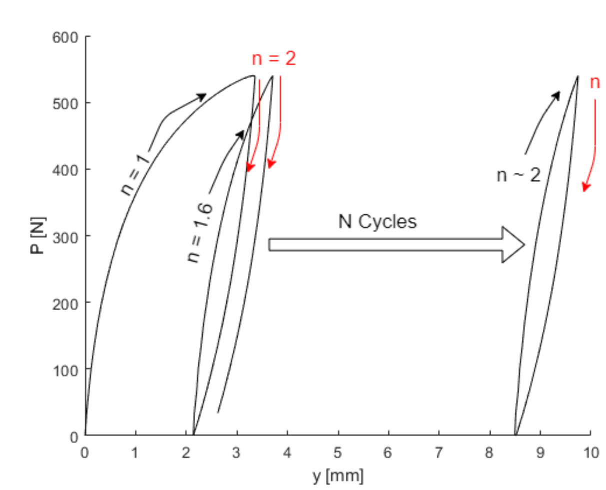
- Ratcheting is accumulated rotation caused by non-zero mean external loads on OWTs
- OWTs are subjected to complex multidirectional loads from wind and waves
- Experiments show that changing load direction increases the observed ratcheting [1,2,3]
- A novel model of multidirectional ratcheting is applied to a reference OWT

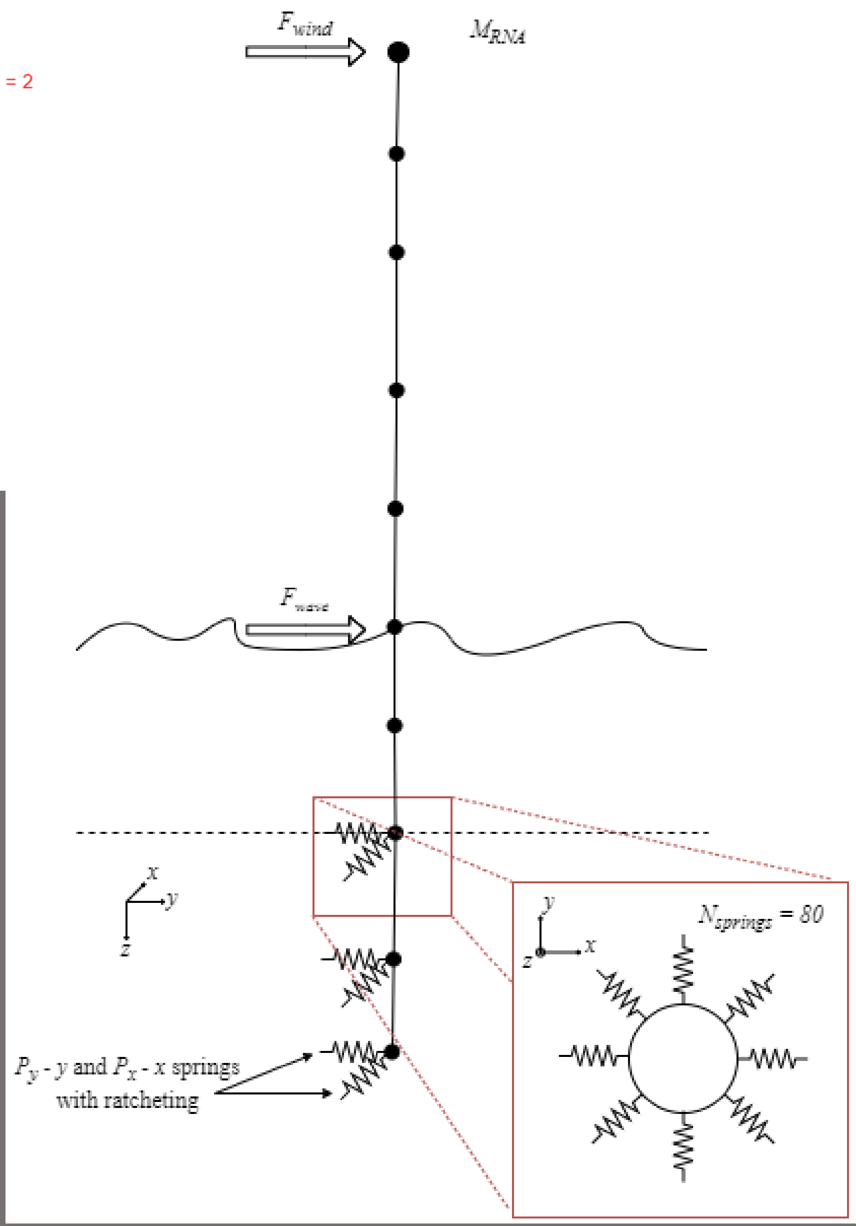


The model

- Built on Winkler finite element method
- Non-linearity is modelled with a hyperbolic response, and multidirectionality is included using the approach of Lovera et al. [4]
- Ratcheting is modelled using the Masing factor n

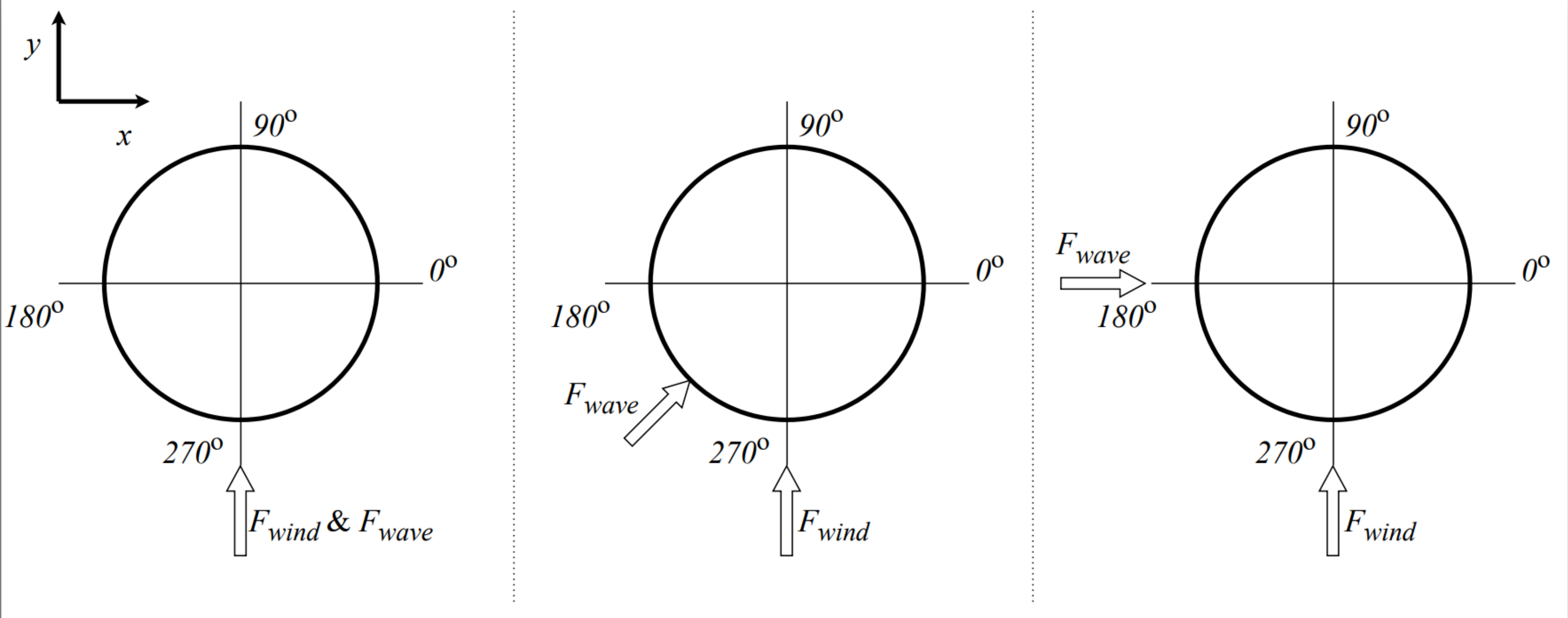
$$n = \begin{cases} 2 - \dfrac{F_{max} + F_{min}}{F_{max}} \left(\dfrac{1}{1 + \dfrac{P_{ult}}{F_{max}}} N_{cyc}^{-\alpha_r} \right) & \text{if } n_{prev} = 2 \\ 2 & \text{else} \end{cases}$$





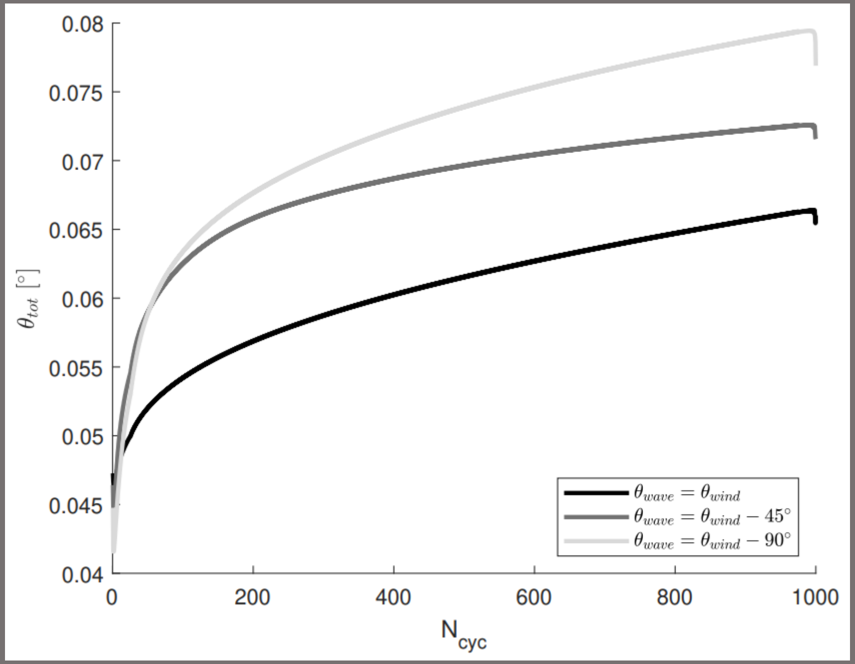
The case study

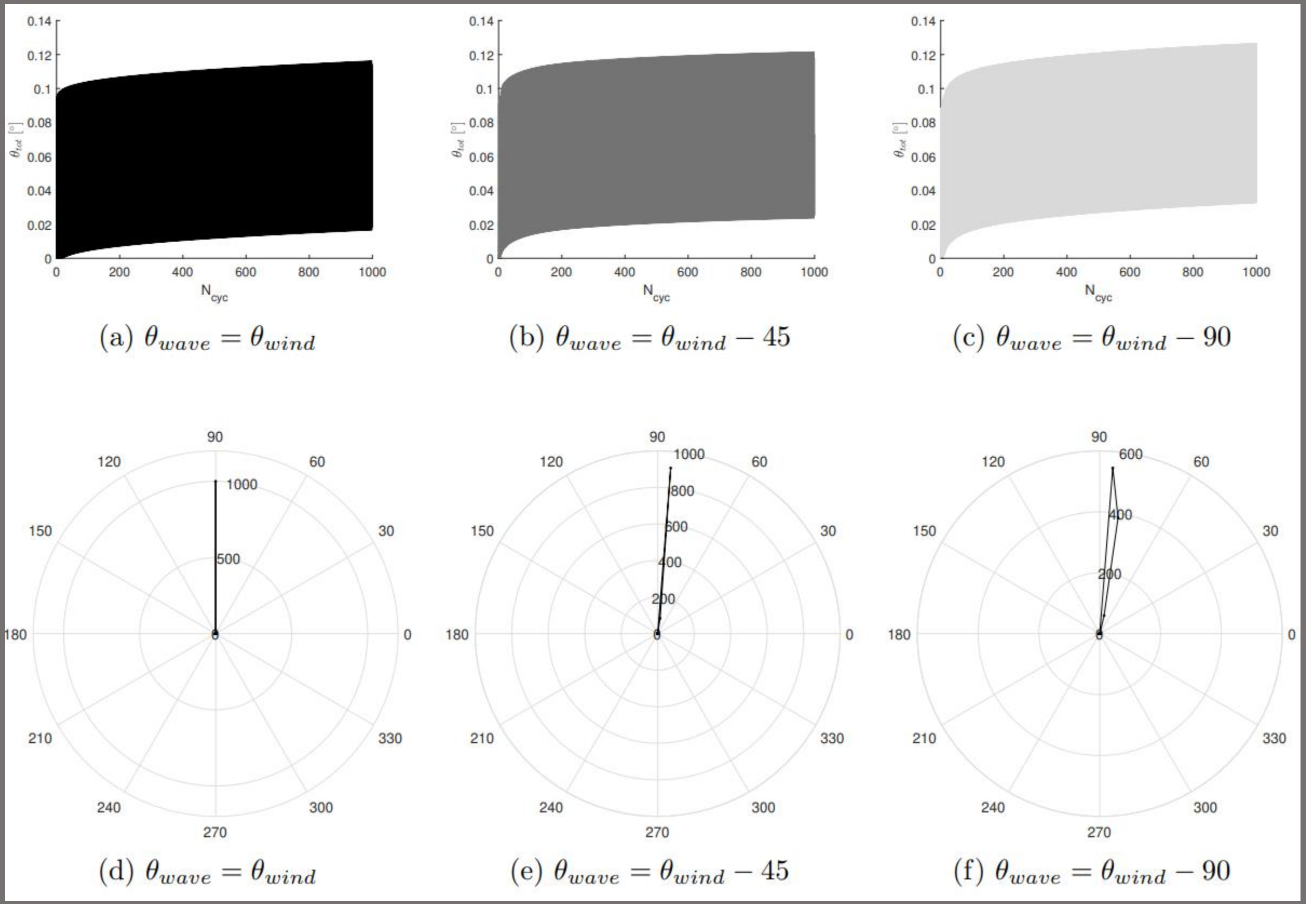
- NREL 5 MW reference OWT used
- 3 wind-wave load cases considered;
  - Unidirectional
  - 45° difference
  - 90° difference



Results

- Orthogonal wind and wave loads resulted in 20% more ratcheting that unidirectional case





(a) $\theta_{wave} = \theta_{wind}$ (b) $\theta_{wave} = \theta_{wind} - 45$ (c) $\theta_{wave} = \theta_{wind} - 90$

(d) $\theta_{wave} = \theta_{wind}$ (e) $\theta_{wave} = \theta_{wind} - 45$ (f) $\theta_{wave} = \theta_{wind} - 90$

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Summary

- Ratcheting likely to occur due to non-zero mean environmental loads, and multidirectional ratcheting more damaging
- This novel, single-parameter ratcheting model can predict increase in ratcheting for multidirectional load
- Orthogonal wind and wave loads result in 20% additional ratcheting

[1] Duhrkop J and Grabe J 2008 Bautechnik 85 317–321 ISSN 09328351
[2] Rudolph C, Grabe J and Bienen B 2014 Canadian Geotechnical Journal 51 1196–1206 ISSN 12086010
[3] Richards I A, Byrne B W and Houlsby G T 2019 Geotechnique 1–15 ISSN 0016-8505
[4] Lovera A, Ghabezloo S, Sulem J, Randolph M F, Kham M and Palix E 2020 Geotechnique 1–11 ISSN 0016-8505