

Digital twins-enabled probabilistic deterioration assessment of floating offshore wind turbine towers under uncertainties

Heng, Junlin; Zhang, Jiaxin; Dong, You; Kaewunruen, Sakdirat; Baniotopoulos, Charalampos

License:
Creative Commons: Attribution (CC BY)

Citation for published version (Harvard):
Heng, J, Zhang, J, Dong, Y, Kaewunruen, S & Baniotopoulos, C 2023, 'Digital twins-enabled probabilistic deterioration assessment of floating offshore wind turbine towers under uncertainties', MODENERLANDS Strategic Workshop 2023, Luxembourg, Luxembourg, 15/05/23 - 16/05/23 pp. 49-51.

[Link to publication on Research at Birmingham portal](#)

General rights

Unless a licence is specified above, all rights (including copyright and moral rights) in this document are retained by the authors and/or the copyright holders. The express permission of the copyright holder must be obtained for any use of this material other than for purposes permitted by law.

- Users may freely distribute the URL that is used to identify this publication.
- Users may download and/or print one copy of the publication from the University of Birmingham research portal for the purpose of private study or non-commercial research.
- User may use extracts from the document in line with the concept of 'fair dealing' under the Copyright, Designs and Patents Act 1988 (?)
- Users may not further distribute the material nor use it for the purposes of commercial gain.

Where a licence is displayed above, please note the terms and conditions of the licence govern your use of this document.

When citing, please reference the published version.

Take down policy

While the University of Birmingham exercises care and attention in making items available there are rare occasions when an item has been uploaded in error or has been deemed to be commercially or otherwise sensitive.

If you believe that this is the case for this document, please contact UBIRA@lists.bham.ac.uk providing details and we will remove access to the work immediately and investigate.

Digital twins-enabled probabilistic deterioration assessment of floating offshore wind turbine towers under uncertainties

Junlin Heng^{1,2}, Jiaxin Zhang³, You Dong³, Sakdirat Kaewunruen², Charalampos Baniotopoulos^{2*}

¹ Shenzhen University, China, ² University of Birmingham, United Kingdom, ³ The Hong Kong Polytechnical University, China

* j.l.heng@outlook.com

Summary The novel concept of modular energy islands comes with novel challenges, i.e., the coupled corrosion fatigue (CF) deterioration of floating wind turbine towers (FOWTTs). This work proposes a digital twins-based assessment approach to elucidate the CF feature of FOWTTs under uncertainties, by integrating both the site loads, material data, deterioration model and numerical simulation. The output highlights the notable C-F issue in FOWTTs, and offers basis for condition-based management.

Introduction

The emerging climate challenges and energy crisis have imposed urgent and heavy demands for a green and sustainable world with renewable and reliable energy supplies. The concept of modular energy island (MEI) [1] has been proposed to fully exploit the abundant natural powers at deep-water oceans, including wind, tidal, solar and other energies. The novel application also leads to novel engineering challenges. Especially, the massive high-strength bolts in ring-flange connections of wind turbine towers become highly prone to deterioration under coupling effect of dynamic loads-induced fatigue and marine corrosion, i.e., corrosion-fatigue (CF) [2]. The work aims to offer novel insights into the C-F deterioration of bolts in floating wind turbine towers (FOWTTs) on the MEI, by integrating the material test data, site-specific condition, probabilistic CF (PCF) model and multi-physics simulation

Methodology

The wind-wave data measured from the Mexico Gulf [3] are incorporated into the multi-physics simulation tool OpenFAST [4] to derive fatigue stress spectra in bolts, see Fig. 1. The spectra and climate conditions are processed by a PCF model [5], by which the deterioration evolution is estimated.

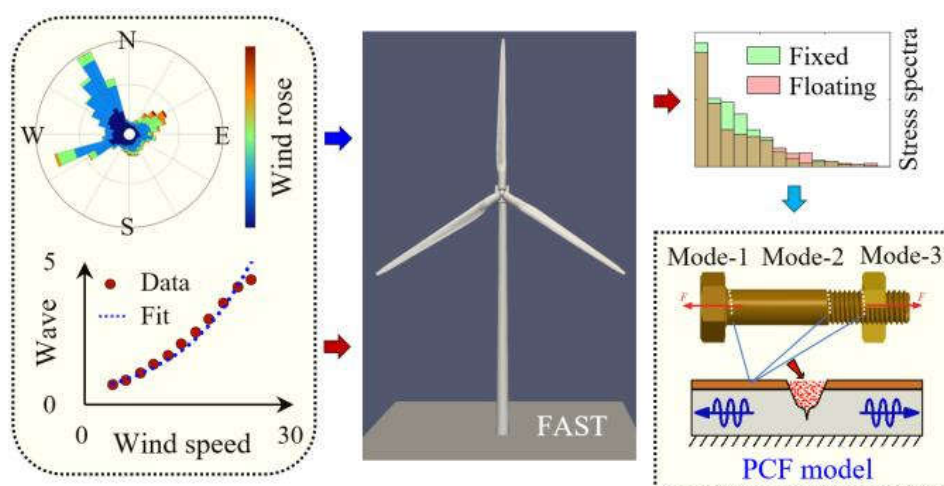


Fig. 1. Procedures for the probabilistic assessment of deterioration states using site data

Results

Fig. 2 shows the evolution of fatigue crack growth, and the failure mode of the most critical bolt at the bottom flange. The model-3 (first engaged threads) demonstrates a high priority while the other two modes also have considerable contributions to the failure of bolts.

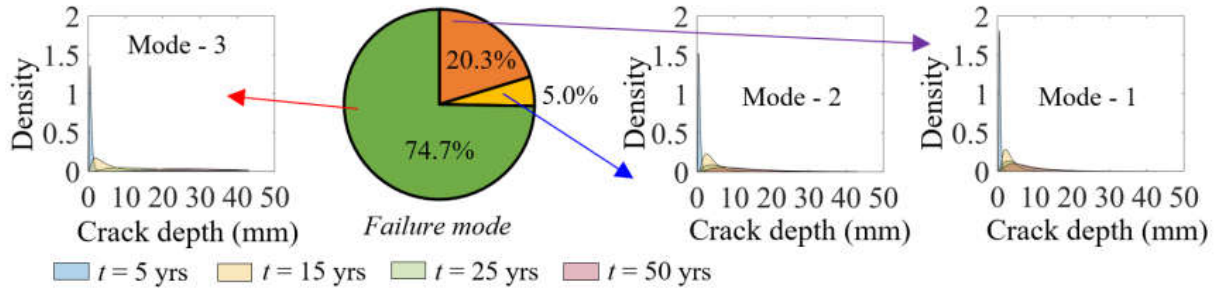


Fig. 2. Fatigue crack depth growth and failure modes of the most critical bolt in ring-flanges.

Fig. 3 shows the deterioration evolution of the above crucial bolts. The result suggests a premature failure risk (at 22 years) of bolts at the given marine condition under the target reliability of 1.7.

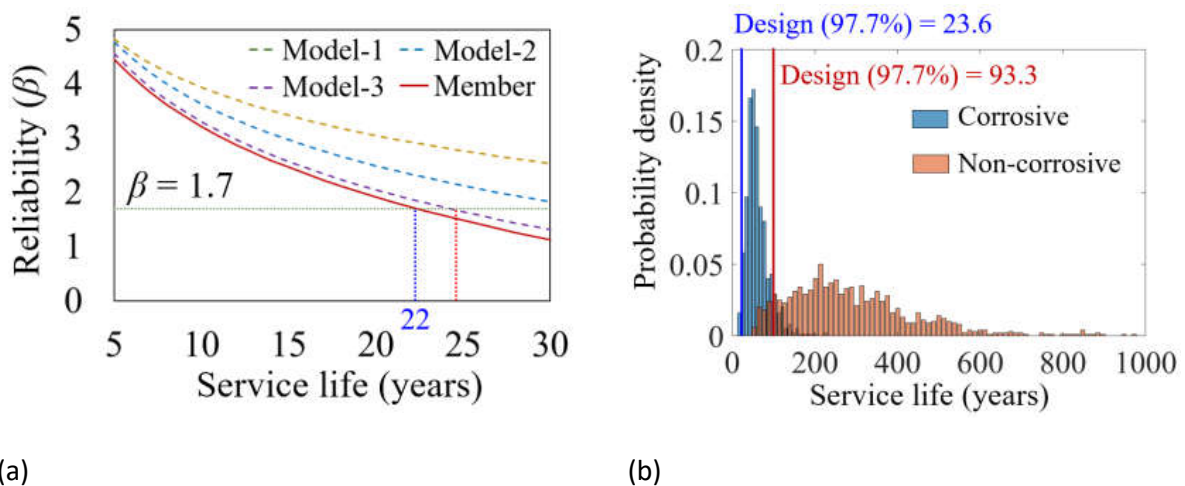


Fig. 3. Deterioration evolution of the most critical bolt: (a) Reliability; (b) Life distribution.

Conclusions

- (1) The high-strength bolt in ring-flanges of FOWTTs shows 3 major failure mode under CF, while the first engaged thread has the highest possibility. In both modes, the distribution of crack depth levels off and accumulates at the size threshold (i.e., 46.8 mm) with the service life.
- (2) The strong marine corrosion risks premature failure of bolts since it fails to meet the design reliability index of 1.7. Particular efforts are suggested for bolts in FOWTTs.

Acknowledgements

The COST Action MODENERLANDS (CA20109), MSCA Fellowship via URKI (EP/X022765/1) and National Natural Science Foundation of China (52208182) are greatly acknowledged by the



authors. The last author acknowledges with thanks ROYAL SOCIETY support to his research activities (IES\R1\221036)

References

- [1] Rebelo, C. & Baniotopoulos, C. (2022). Modular Energy Islands for Sustainability and Resilience Proceedings CESARE'22, 6-9 May, 2022, Irbid.
- [2] Adedipe, O., Brennan, F., & Kolios, A. (2016). Review of corrosion fatigue in offshore structures: Present status and challenges in the offshore wind sector. *Renewable and Sustainable Energy Reviews*, 61, 141-154.
- [3] National Data Buoy Center (NDBC), 2022. <https://www.ndbc.noaa.gov/obs.shtml>
- [4] National Renewable Energy Laboratory (NREL), 2022. OpenFAST – an open-source wind turbine simulation tool. <https://github.com/openfast>
- [5] Heng, J., Zhang, J., Dong, Y., et al. Corrosion fatigue prognosis of ring flange connections in floating offshore wind turbine towers considering multi-modes failure. (in preparation)

