

Project title:	Fatigue Life Enhancement through Residual Stress Management in Offshore Monopiles
Discipline	Materials Engineering
Key words:	Manufacturing; residual stress; renewable energy; monopile;
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Project Highlights:

- The research outputs will establish the knowledge base for improving the structural performance (fatigue life) of offshore wind turbine foundation monopiles.
- The residual stress engineering approach will be used to improve existing manufacturing procedures employed in the fabrication of offshore wind monopile foundations.
- This timely project is an excellent fit with the planned International Stress Engineering Centre (I-SEC) to be based at Harwell.
- Opportunity to use International Diffraction Facilities.

Project Description:

Offshore wind is a reliable source of renewable energy for meeting the UK's short- and long-term electricity needs and CO₂ reduction targets.

Over 75% of offshore wind turbine foundations are constructed using monopiles. These structures are fabricated from thick section plates joined by multi-pass welds. It is well known that multi-pass welding of thick plates introduces complex patterns of high magnitude residual stress.

During installation monopiles are “bedded in” by piling. The piling is expected to modify the residual stress distribution in the monopile. The few studies

published on the effect of piling on the fatigue life of welded monopiles are contradicting and inconclusive. Current Design Standards for monopiles fail to provide quantitative life assessment guidelines that account for residual stress and how it may evolve during the lifetime of a monopile. There is a wide knowledge gap here concerning the distribution of residual stress introduced into monopile structures during manufacture, how it is modified by installation pile driving and subsequent operational loads, and the influence of residual stress on the fatigue life of monopiles under harsh sea water environmental conditions.

The research hypothesis is that the lifetime of offshore wind monopiles can be extended through introducing beneficial “engineered” residual stresses at critical weld locations. Specific research objectives include the following.

1. To characterise the residual stress signature of the most critical monopile welded feature.
2. To investigate what effects installation piling and operational loading have on the residual stress signature of the most critical weldment and how this affects its predicted fatigue life.
3. To introduce beneficial “engineered” residual stresses into the critical welded feature and demonstrate how this enhances its fatigue life.

Research Methods:

A decommissioned Metrological Mast which has operated offshore for 8 years was donated to the University of Cranfield. A detailed post-mortem assessment of the decommissioned structure will be carried out focussing on mapping and understanding the state of residual stress in the vicinity of welds that are typical of those used in offshore wind monopiles.

Fatigue tests will be undertaken on coupons that have been extracted from the large-scale structures, some of which will have had beneficial residual stresses introduced.

Finite element analysis will be used to determine the installation and operational stress history in a typical monopile and a fatigue life analysis performed for various geometric features. The effect of residual stress will be investigated by introducing idealised stress profiles into the analysis.

Indication of project timeline:

Year 1: Residual stresses in the ex-service Metrological Mast and extracted coupons for fatigue testing will be measured using a number of residual stress measurement techniques including slitting, contour and diffraction methods.

Year 2: Fatigue crack growth (FCG) tests will be performed on full thickness cross-weld specimens extracted from the ex-service Metrological Mast. A numerical FE model simulating the FCG history for sample weldments will be developed and validated using the data obtained from the experiments. The effects of installation piling and operational loading on predicted fatigue life will be investigated.

Year 3: The efficacy of applying various post-weld fatigue life improvement will be assessed; for example local heat treatment and mechanical surface treatments like ultrasonic peening that can introduce deep compressive residual stresses.

Background reading:

- [1] Hosseinzadeh, F. et. al. (2014), Journal of Engineering.
- [2] Jacob A, et. al. (2018), Theoretical and Applied Fracture Mechanics, 96 (August) 418-427.
- [3] Jacob A, Mehmanparast A, D'Urzo R & Kelleher J (2019) International Journal of Fatigue, 128 (November) Article No. 105196.

Candidate Applications:

- An ideal candidate should have a strong background in Solid Mechanics or Materials Engineering, have experience of finite element simulations and enthusiasm for laboratory experimental work
- Experience of using diffraction facilities desirable but not essential.

Applications should include:

- A 1000 word cover letter outlining why the project is of interest to you and how your skills match those required
- An academic CV containing contact details of three academic references
- [Open University application form](#)
- Applicants will need to demonstrate good competence in the English language. To be eligible for a full award, a student must have no restrictions on how long they can stay in the UK and have been ordinarily resident in the UK for at least 3 years prior to the start of the studentship

Applications should be sent to STEM-EI-PhD@open.ac.uk by **31.03.20**