Engineering and Innovation Research Studentship
October 2021

Project title:	**Structural Integrity Assessment of Offshore Monopiles**
Discipline	Engineering
Key words:	Residual stress, structural integrity, Offshore wind, monopile
Supervisory team:	Foroogh Hosseinzadeh, Ali Mehmanparast (Cranfield University), Joe Kelleher (STFC Facility)
URL for lead supervisor's OU profile	http://www.open.ac.uk/people/fht7

Project Highlights:

- Reliable characterisation of residual stresses in large-scale welded monopile structures for offshore wind industry;
- Structural integrity assessment of offshore welded structures taking into account the effect of residual stress ;
- Strategic fit with the planned research agenda for the proposed National Stress Engineering Centre (N-SEC) to be built at the ISIS Facility.

Overview:

Offshore wind is a reliable source of renewable energy for meeting the UK's short- and long-term electricity needs and CO_2 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 [1,2].

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 [3,4]. 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.

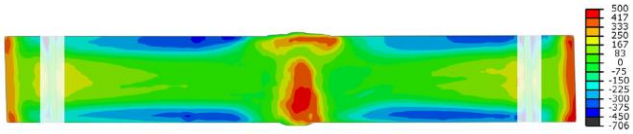

Figure 1. 2D map of longitudinal residual stress in a large welded mock-up measured using the contour method [2].

The aim of the proposed PhD research is to study the effect of residual stress on structural integrity assessment of welded monopiles for offshore wind industry.

Specific research objectives include:

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.
3. To take into account the effect of residual stress on fatigue life prediction of welded monopiles.

Methodology:

Centrica Renewable Energy Limited donated the University of Cranfield a decommissioned Metrological Mast which has operated offshore for 8 years. 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. A novel segmentation/reconstruction approach, using the contour method, will be applied to map multiple components of the stress tensor associated with critical welded features.

Fatigue tests will be undertaken on cross-weld coupons that have been extracted from the large-scale structures, some of which will have had full detailed residual stress characterisation using non-destructive techniques including neutron diffraction measurements. 2D map of residual stresses normal the crack plane of fatigue testing coupons will be measured using a hybrid method (combined slitting and contour method) which also provides a stress intensity factor profile that can be used directly in fatigue life assessments. Some fatigue tests will be interrupted to carry out neutron diffraction measurements in order to map redistribution of residual stresses at different stages of fatigue life.

A numerical Finite Element model simulating the fatigue crack growth history for sample weldments will be developed and validated using the data obtained from the experiments. Finite element analysis will be used to determine the installation and operational stress history in a typical monopile and a fatigue life analysis performed considering the influence of residual stress.

References & Further reading:

1. Francis, J.A. et. al., 2007, Welding residual stresses in ferritic power plant steels, Mater. Sci. Eng., 23: p.1009-1020.
2. Jacob, A. et. al., 2018, Residual stress measurements in offshore wind monopile weldments using neutron diffraction technique and contour method, Theor. Appl. Fract. Mec., 96: p. 418-427.
3. Lotsberg, I., et al., 2010, Recommended Design Fatigue Factors for Reassessment of Piles Subjected to Dynamic Actions From Driving, JOMAE, 132(4), p.041602-041602-7.
4. A Study of Pile Fatigue During Driving and In-Service and of Pile Tip Integrity, HSE Books, 2001

Further details:

Students should have a strong background in Solid Mechanics, Materials Engineeeing or Mechanical Engineering and enthusiasm for laboratory experimental work and competent programming and Finite Element Analysis skills. Please contact Dr Forooh Hosseinzadeh (foroogh.hosseinzadeh@open.ac.uk) for further information.

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
- an Open University application form, downloadable from: http://www.open.ac.uk/postgraduate/research-degrees/how-to-apply/mphil-and-phd-application-process
- IELTS test scores where English is an additional language

Applications should be sent to **STEM-EI-PhD@open.ac.uk by 05.03.2021.**