Material Pre-Straining Effects on Fatigue and Fracture Behaviour of Offshore Wind Monopile Structures

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Aims and Objectives

The aim of this project is to improve the current practices for the structural integrity of monopiles by considering material pre-straining effects. This project will determine the:

- Influence of material pre-straining on fracture toughness, fatigue crack initiation and growth behaviour
- Environmental effects of structural integrity assessment of pre-strained monopiles
- Development and validation of FEA models to predict fatigue and corrosion fatigue, crack initiation and growth

Key Methodologies

- Experiments will be run on samples pre-strained to different percentages
- A finite element model will be developed and validated using the experimental data
- The results of this project will be employed in the remaining life analysis of monopile structures in the offshore wind renewable energy industry

Fracture Toughness Test

- Measures resistance of a material to the presence of a flaw in terms of the load required to extend a crack

Fatigue Crack Growth

- In both air and seawater
- FCG data can be used for defect assessment and to predict the fatigue life of the material

Hole Drilling

- To determine the residual stresses locked in during the hot rolling process

1. Plates of S355 are hot rolled

2. S355 hot rolled plates undergo cold rolling to form cans

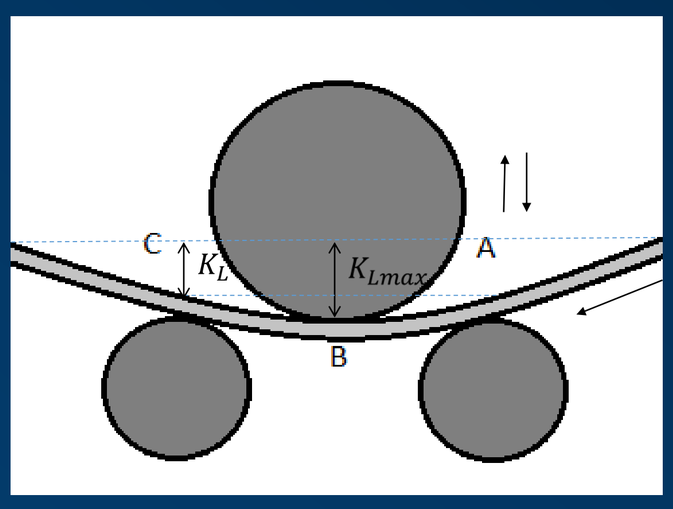
3. Cans are longitudinally welded

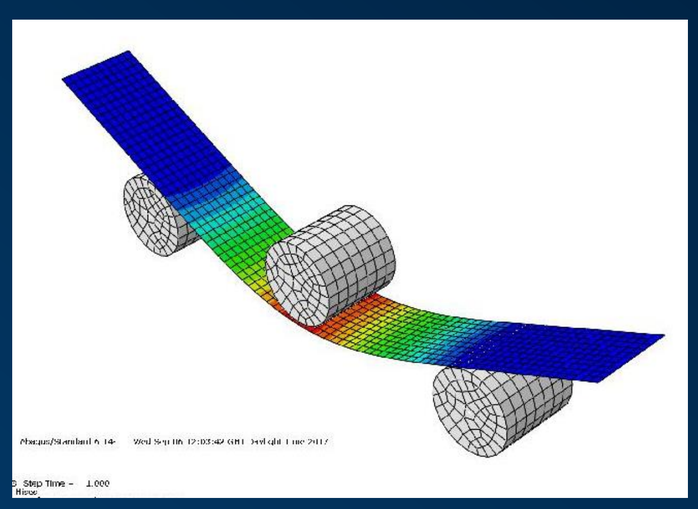
4. Cans are circumferentially welded

5. NDT inspection techniques are undertaken

6. Monopile is ready to go offshore

Analytical Equations for 3 Point Bending





At point A, the bending moment increases to its maximum. From point B to C, the curvature (K_{Lmax}) and bending moment decrease. At point C, the remaining plastic deformation after loading can be expressed by residual curvature (K_L^*). The max force required to bend the sheet at a specified curvature can be expressed as:

$$F = \left(\frac{(K_L^* - K_{Lmax}) * E' * I}{d}\right)$$

Project Summary

- Project will determine the effects of material pre-strain on the structural integrity of monopiles
- Fracture toughness, fatigue crack growth, and hole drilling will be carried out
- The results will be compared to those from analytical equations.
- An FEA model will be developed and validated from these results