Fatigue Life Extension of offshore Wind foundations (FlexWind)

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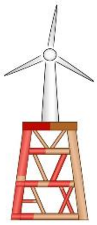

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MOTIVATION

Offshore wind turbines (OWTs) and their foundations are typically designed to have an operation lifetime of 20 years. The first Belgian offshore wind farm (the Thorntonbank wind farm of C-Power, Figure 1) was installed in the North Sea in 2008. The owners will soon face the decision of decommissioning or life extension based on technical and economical evaluations. Opting for the extension of existing assets is typically the most economical choice, if the costs related to prolonging the assets' life (turbine and structure) remain constrained.

Figure 1: Wind turbines D1 to D6 of Thorntonbank Wind Farm (C-Power).

Corrosion and fatigue damage play the most important role in the degradation of offshore steel structures. While corrosion damage can be assessed with existing tools, evaluating the fatigue damage proves challenging until a crack forms. These cracks are detectable only in the late stages of a structure's life due to the exponential nature of fatigue crack growth. Therefore, the task of life extension typically exists of demonstrating that the structure was designed overly conservative and the actual loads were lower than those anticipated during its design.

In the FlexWind project, UGent will develop an innovative approach to assess the current fatigue resistance of offshore wind turbine foundations based on their as-built condition rather than relying on as-designed inputs.

More specifically, UGent aims to enhance the analysis of local aspects, such as surface degradation and the as-built geometry of the welds, beyond current standard practices. Additionally, the project partners will explore the potential inclusion of remediation techniques (e.g. TIG dressing) to extend the fatigue life of specific parts or entire structures. The improved estimations of structural resistance will result from a combination of experimental and numerical investigations on small-scale and component-size specimens. The results will be integrated into a probabilistic framework for fatigue life estimation.

OBJECTIVES

The main objectives of UGent in the FlexWind project are:

1. The development of a numerical framework that is able to convert welded joint scanning data to highly detailed solid finite element models. The 3D scans are made with a handheld laser scanner, as shown in Figure 2.

Figure 2: Example of a handheld laser scanner to scan welds.

2. The development of a stress gradient-based method for fatigue analysis of long continuous welds based on surface scanned data.
3. Hindcasting the accumulated fatigue damage and forecasting the remaining fatigue life. Therefore, detailed submodels of the tubular joints will be

coupled with aero-hydro-elastic global models, as shown in Figure 3.

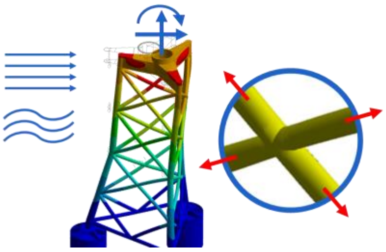

Figure 3: Local interface loads based on global loads on a jacket.

APPROACH

For the first objective, tubular joints of a decommissioned jacket from the North Sea will be scanned. The 3D scans serve as the basis for the development of the framework that allows for the construction of a finite element model mesh. 3D scans of full-scale joints inevitably contain missing or unscanned regions. These have to be filled, but care has to be taken that the as-built geometry is retained. Additionally, the inner surface of the joints will have to be constructed as this cannot be scanned. Attention will be paid to the weld root geometry, which is often neglected in literature. Using surface reconstruction, the point cloud from the scan can be converted into a finite element mesh.

The stress governing the fatigue damage accumulation will be calculated using a stress gradient method, developed in the second objective. The main advantage of the stress gradient method is that it is a non-local approach, eliminating the need to define the most critical location of the geometry upfront. Moreover, it can account for the effect of microstructural notch support and is thus well-suited to deal with stress singularities.

The calculation of stress concentration factors (SCFs) will allow to directly combine three determining factors for the fatigue life: the global weld geometry, the local weld profile and the geometry of corrosion pits. This is demonstrated with an example of a tubular joint in Figure 4.

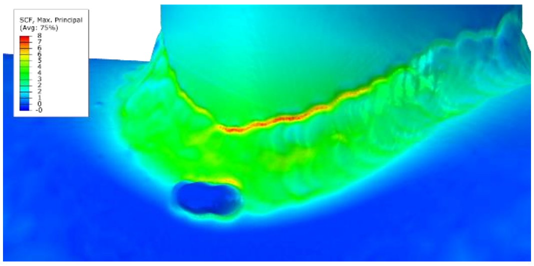

Figure 4: Stress concentration factor from FEA of real weld geometry.

For the last main objective, the detailed models of the joints developed with the numerical framework for meshing described above need to be coupled with global models of the structures. The environmental conditions such as wind, wave and current loads, as well as the loads due to the tower on top of the jacket are applied to the global model. To accomplish this, aero-hydro-elastic modelling software can be used. From the simulation of the global model, the joint interface loads can be extracted and used as boundary conditions for the high cost local models.

Based on hindcast and forecast load data for the site of the structure of interest, time domain simulations can be performed. The probabilistic nature of this will be tackled in collaboration with the University of Liège. These time domain simulations will provide a set of interface load spectra, which are used to calculate the accumulated fatigue damage and remaining life of the assessed welded joints.

OCAS and the Belgian Welding Institute will test both the joints of the decommissioned jacket described earlier and small-scale specimens. This will enable the verification of the numerical frameworks and methods developed at Ghent University.

Combining all of the building blocks described above, an improved fatigue lifetime extension approach can be proposed.

CONSORTIUM

The project is executed in collaboration with OCAS, the Belgian Welding Institute (BWI), and the University of Liège. Each partner contributes expertise in their respective field to achieve the best possible result. FlexWind is a fundamental research project with financial support of the Energy Transition Fund of the Federal Government of Belgium.

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