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The SLIC Project

Advancing Fatigue Design Guidance & Standards for Offshore Wind

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SLIC Structural Lifecycle Industry Collaboration

Abstract

SLIC – Structural Lifecycle Industry Collaboration is a Joint Industry Project with the participation of 10 Offshore Wind Operators, the UK Department for Energy and Climate Change and The Crown Estate. It has the technical support of Cranfield University, Siemens WP and all major Offshore Wind Class Societies DNV, Germanicher Lloyd and Lloyds Register.

The design of steel offshore foundation structures has been based largely on Oil & Gas standards and guidance which was migrated across, and served as the basis for the creation of offshore wind standards. Much of the original research is now several decades old, and was based on characteristics that were representative of typical Oil & Gas offshore structures, but differ fundamentally in terms of load regimes, structural characteristics and environment to typical offshore wind substructures.

In this intervening period materials, fabrication technologies, inspection and design techniques have evolved significantly and it is considered that fatigue tests on contemporary materials using representative manufacturing techniques, and exposed to relevant environments and loading would yield important information to support informed decisions concerning existing structures and future developments in terms of design savings, construction, and operation.

The need exists to re-address these issues in order to build a knowledge-base and methodologies that reflect the conditions in which current structures operate, and enable the design of new structures to be optimized accordingly.

Objectives

The SLIC programme of research and testing is intended primarily to develop a robust body of evidence, specifically appropriate for the load regime, materials, geometry and environmental conditions that apply to offshore wind turbine sub-structures addressing the current knowledge gap.

It aims to develop the currently available S/N curves reflecting the above parameters and expand the body of knowledge focussing on Offshore Wind monopile foundations but equally applicable to other structures or industries and contribute to reduce the LCoE of future projects. Additionally it is expected that the data developed by the SLIC will allow prolonged life extensions of existing structures.

The SLIC has completed the first two stages of the project, initial feasibility stage and the Pre-testing phase where tailored methodologies were developed through small scale testing programmes to define bespoke solutions to the complexities of the Main testing Phase which will be the third and final stage of the project. The Main testing phase is currently ongoing and final results are expected to be available by the end of 2015.

Methods

For girth welded joints, the S/N curves currently used have been developed from tests conducted on pipeline steels over several decades by different investigators on specimens derived from relatively small diameter, thin walled components with variable degrees of reporting and uncertain specimen and testing quality control[1]. All these test programmes were to satisfy concerns for Oil & Gas industry issues and to date no comprehensive fatigue test programme has been conducted for offshore wind monopile structures.

It is simply not practical to conduct full-scale fatigue tests on girth welded monopile sections due to the extremely large loads required. Instead, an approach was developed during the Pre-testing Phase to preserve the important characteristics of the components whilst at the same time testing under conditions that match those of the real structures as much as possible, reproducing the following characteristics:

-Material and Welding Procedure;
-Section Thickness and relative scale of tolerances;
-Environment;
-Loading Mode;
-Crack Characteristics (e.g. surface breaking).

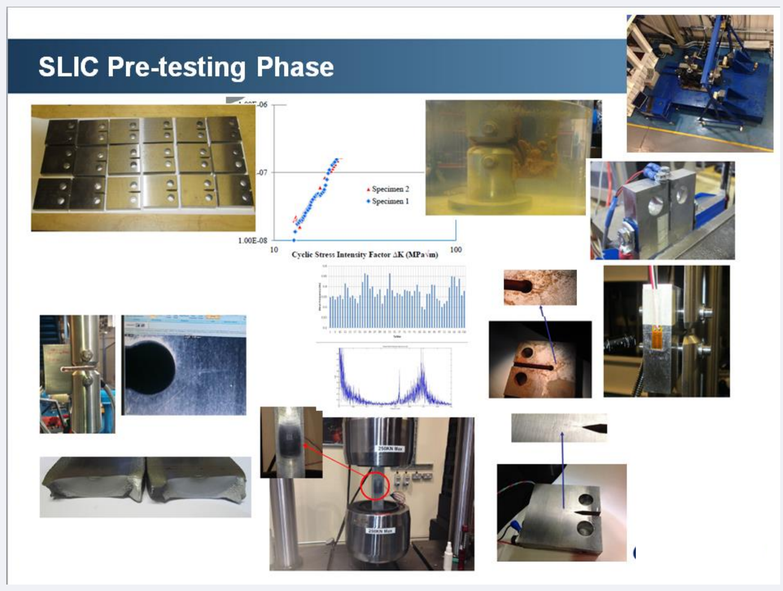

Figure 1 – Pre-testing Phase activities and methodology development

The Pre-testing Phase enabled the development of the techniques best suited to test the large scale specimens required to capture the characteristics seen as fundamentally representative. Figure 1 shows a number of the tests carried out to establish and optimize testing parameters, methodologies and test equipment.

In order to achieve the required specimen geometries and quality steel plate was obtained from the main offshore suppliers and fabricated using standard offshore wind methodologies by EEW, Bladt and SIF to ensure consistency with offshore fabrication standards.

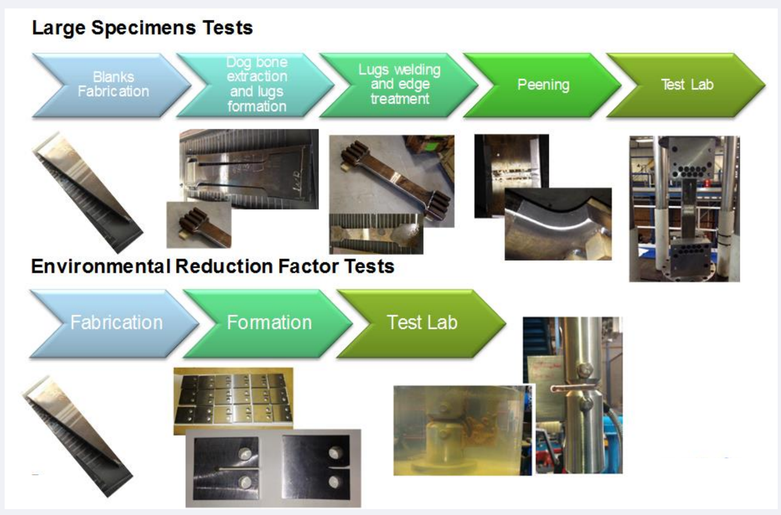

Figure 2– Specimen fabrication steps and test types

Results

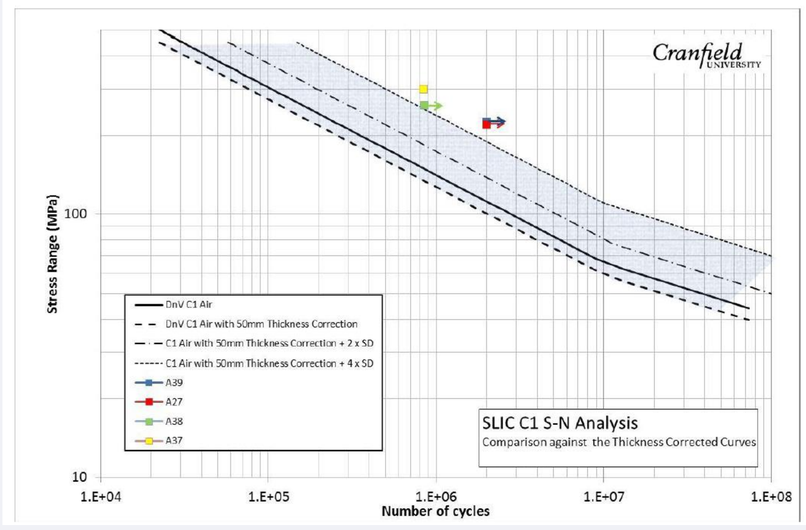

Figure 3– Plot showing ongoing tests with reference to existing curves

The Main-testing Phase is currently ongoing with full results expected towards the end of 2015.
Ongoing tests are shown in figure 3 with respect to the C1 existing curve and figure 4 shows figuratively what a full plot would look like once full testing is completed.
Once full results are obtained analysis will be carried out to obtain the respective standard deviation bands and establish S/N curves that would be representative of the offshore wind characteristics.

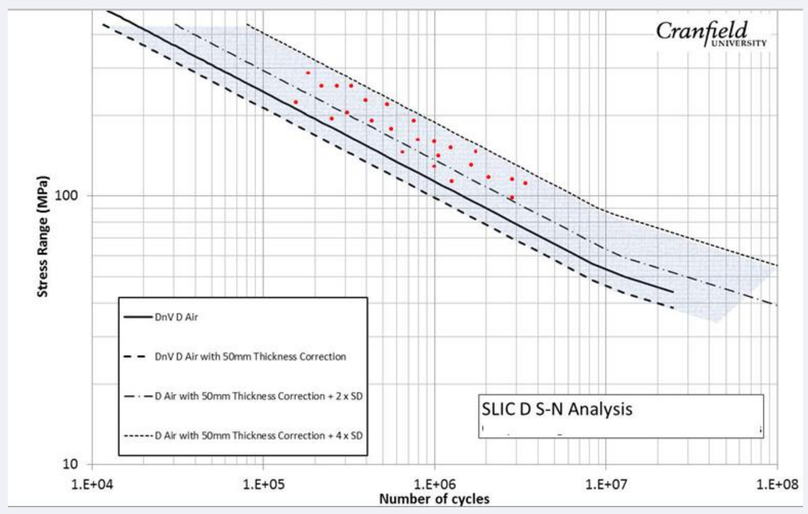

Figure 4– Illustration showing mean D curve and standard deviation bands for a figurative corresponding set of results

Conclusions

At this stage it is possible to establish that the work carried out during the Pre-testing Phase was successful in establishing methodologies that enable the testing of large scale specimens and crack initiation to occur at the test area to enable successful test results to be derived from representative specimens.

Currently it is expected the that full results will be available at the end of 2015 to complement the existing body of knowledge.

References

1. *Brennan and Tavares, "Fatigue design of offshore steel mono-pile wind substructures", Energy, Volume 167, Issue EN4, November 2014.*
2. SLIC Detailed Technical Scope, 2013.
3. T.R. Gurney, Fatigue design rules for welded steel joints, Welding Institute Research Bulletin, 17, pp. 115–124 (1976).
4. S.J. Maddox, International efforts on fatigue of welded constructions. A review of Commission XIII activities, Welding in the World, Pergamon Press Ltd, pp. 86-92. Vol. 31 (1993).
5. I. Lotsberg, and P.K. Larsen, Developments in Fatigue Design Standards for Offshore Structures, Stavenger, Norway, Proceedings of the Eleventh International Offshore and Polar Engineering Conference (2001).
6. Det Norske Veritas, Recommended Practice DNV-RP-C203, Fatigue Design of Offshore Steel Structures, (2011).
7. Health and Safety Executive, Background to new fatigue guidance for steel joints and connections in offshore structures, Offshore Technology Report - OTH 920390 (1999).
8. M.M. Salama, Fatigue design of girth welded pipes and the validity of using strips, St. Johns, Newfoundland, Canada, In the Proceedings of OMAE99, Paper No: Mat-2003 (1999).
9. I. Lotsberg, Stress concentrations due to misalignment at butt welds in plated structures and at girth welds in tubulars, International Journal of Fatigue 31 1337–1345 (2009).