Factors Affecting the Sour Corrosion Fatigue Behaviour of C-Mn steel Catenary Riser Welds

PUBLISHABLE SUMMARY

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Background

Carbon manganese steel is generally the most economic material for the construction of steel catenary risers, and offers other advantages such as ease of inspection. However, in sour service environments the fatigue resistance of welds is significantly degraded by comparison with air, and it becomes necessary to utilise an environmental reduction factor to account for the expected reduction in endurance.

This project aimed to provide guidance on how this reduction factor may be related to environmental conditions, by quantifying the effect of H_2S partial pressure on the observed endurance behaviour in a simulated service environment. It also aimed to examine the sour endurance behaviour of welds tested at low applied stress ranges, to determine whether the reduction factor may be lower under these conditions.

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Objectives

- To determine the effect of H_2S partial pressure on the observed endurance reduction factor for girth welded carbon steel riser material tested in a simulated sour service environment.
- To characterise the sour fatigue performance of girth welded carbon steel riser material at low applied stress ranges, to provide guidance on anticipated behaviour under these conditions.

Project Outcome

This project has demonstrated the following:

- Effect of sour environment, as defined by ISO 15156-2, on fatigue performance
- Effect of varying levels of partial pressure of H_2S on sour fatigue performance.
- Effect of cyclic loading frequency at both low (100MPa) and high (300MPa) stress ranges
- Relationship between the beneficial effect of an increase in pH from 3.5 to 4.9 and detrimental effect of an increase in H_2S partial pressure from 68mbar to 82mbar
- Worst case environmental conditions (in terms of pH and temperature)

Benefits

- Enhanced safety by reducing the risk of premature corrosion fatigue related failure through quantification and understanding of fatigue in sour environments.
- Significant cost savings by justifying the use of welded carbon steels in mildly sour environments, for which a CRA or clad product would otherwise be used.

Participants

The Sponsor Group Comprised:

- BHP Billiton Petroleum
- ENI SpA
- Saipem SpA
- Tubos de Acero de Mexico SA
- Chevron
- Petrobras
- Statoil
- Total

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Scope of Work

The pipe material used in this project was to API 5L grade X65 specification of nominal dimensions 406.4mm (16 inch) outside diameter and 25.4mm (1 inch) wall thickness. Eleven complete girth welds were manufactured using this pipe material. The procedure used an STT process for the root pass and GMAW for the fill and capping runs.

Fatigue endurance tests were carried out under direct axial loading using strip specimens machined from the girth welds. Specimens tested in air were loaded by friction grip of the specimen ends while those tested in a sour environment were pin loaded through slotted holes. A set of strain gauges was used to assess the local stress distribution in each sample. As the failure site of interest was the weld root, the cap was dressed prior to testing to prevent failure from this position. All tests were carried out in load control, using a constant amplitude stress range. A fixed maximum stress of 400MPa (approximately 90% of the specified minimum yield strength for X65 line pipe parent material) was used throughout, to simulate the presence of a high tensile residual stress. Test frequencies were between 2-5Hz in air, and 0.2Hz in sour environments. However, the loading frequency was increased to 1Hz for some of the sour tests. For tests carried out in sour environments, protective lacquer was used to prevent corrosive attack away from the site of interest (ie the weld root) and to minimise solution contamination. The entire specimen was coated except for a window on the root side surface extending to just beyond the parallel gauge length.

Project Budget

The project had a duration of 2 years and a budget of £640,000. It was funded by 8 Sponsors each making a contribution of £80,000. The fee for additional companies buying back into the project results is £80,000.

Further Information

For further information on how a Joint Industry Project (JIP) runs please visit:

http://www.twi.co.uk/services/research-and-consultancy/joint-industry-projects/

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