Establishing the Fatigue Behaviour and Optimising Inspection and ECA Procedures for Lined Pipes

PUBLISHABLE SUMMARY

21710

Background

In sour service environments, C-Mn steel pipe internally clad with a corrosion resistant alloy (CRA) has often been specified. Protecting the internal surface of the C-Mn steel pipe with CRA significantly improves the fatigue endurance of girth welds in sour environments compared to C-Mn steel. However, metallurgically clad pipe has a high cost and clad pipe can be subject to long lead times.

The alternative to clad pipe is pipe mechanically lined with CRA, which is cheaper than clad pipe and easier and quicker to manufacture. The liner is often secured in place using weld overlay cladding at the ends. Girth welds can then be produced between sections of lined pipe in the same way as clad pipe, as the weld bevel and subsequent weld are located in the weld overlaid region.

The fatigue strength of lined pipe for flowline and SCR applications is not well understood. In particular, there is a risk that the point at which the weld overlay interfaces with the liner (the 'weld overlay/ liner transition point') may be a fatigue critical detail.

Data on the fatigue strength of lined pipe with weld overlay is needed by designers during the FEED stage to allow them to specify lined pipe rather than clad pipe, and make the associated substantial savings in cost and lead time.

The ability to reliably inspect girth welds in lined pipe before installation would allow operators to have confidence in the safety of installed lined pipe, leading to increased safety and reliability of riser systems and reduced costs and lead times for sour fields.

TWI Ltd, Granta Park, Great Abington, Cambridge CB21 6AL, UK. Tel: +44 (0)1223 899000

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Objectives

- Produce an SN curve for lined pipe with weld overlay
- Optimise inspection procedures for inspecting the weld overlay / liner transition point in lined pipe with weld overlay
- Develop and optimise procedures for engineering critical assessment (ECA) of lined pipe with weld overlay
- Perform numerical modelling to establish the behaviour of lined pipe when subject to high strains

Scope of Work

To achieve the objectives, four work packages were carried out within the project:

- Full scale resonance fatigue testing
    - The resonance fatigue testing work package involved fatigue tests on 12 specimens of lined pipe, each containing a girth weld in the centre. The liner material in all cases was Alloy 625. Six of the specimens were 12.75in outer diameter, and six were 8.625in outer diameter (three of the 8.625 inch outer diameter specimens were simulated subjected to reeling before testing). Extensive sectioning was carried out on the failed specimens and a good understanding of the failure location of lined pipe was gained.
- Inspection procedure optimisation
    - The inspection work package used ultrasonic techniques to develop a method of detecting flaws at the weld overlay/ liner transition point from the outer wall of the pipe. Recommendations have been provided on the equipment and methods that can be used to detect flaws in this location from the outer wall of lined pipe.
- ECA procedure development
    - Specific stress intensity factor solutions have been generated for the lined pipe geometry which can be used in ECAs. Small scale mechanical tests (ie fracture toughness and tensile tests) have been carried out to determine mechanical properties and provide background data for the ECA. Fatigue crack growth rate tests on two liner materials (Alloy 625 and 316L stainless steel) were also performed at room temperature and 100°C.
- Numerical modelling
    - The numerical modelling work package was run by INTECSEA. Finite Element (FE) model(s) were developed to simulate the response of lined pipe in pure bending and work was carried out to determine the sensitivity of lined pipe under bending loads to liner wrinkling.

Project Outcome

- Recommended SN curve for lined pipe in air.
- Recommendations of best practice for detecting flaws at the weld overlay/ liner interface.
- Recommendations for how best to analyse cracks at the weld overlay/ liner transition region using ECA.
- Estimate of the strain for the onset of liner wrinkling and a parameterised finite element model of lined pipe.

Participants

The Sponsor Group comprised:

- Petrobras
- BG Group
- Tenaris Tamsa
- Saipem SA
- Cladtek
- Technip UK
- Heerema PTL

Project Budget

The project had a duration of two years. It was funded by four fee-paying Sponsors each making a contribution of £120,000 with in-kind contributions provided by three others. The fee for additional companies buying-back into the project results is £120,000.

Further Information

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

http://www.twi-global.com/services/research-and-consultancy/joint-industry-projects/

JIP Co-ordinator: Tracey Stocks **Ref:** 21710/10-1/14

Email: jip@twi.co.uk

Project Leader: Carol Johnston

Email: carol.johnston@twi.co.uk