Safe Specification and Operation of Plastically Strained C-Mn Steel Pipelines for Sour Service (phase 2)

PUBLISHABLE SUMMARY

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Background

Plastic straining occurs in pipe and pipelines during pipe reeling and laying operations, cold field bends, other installation operations and during service operation (buckling, upheaval). In particular, pipeline installation by reeling, a commonly used method of offshore pipe laying, subjects the pipe to repeated plastic straining. When C-Mn steels are subjected to plastic strain, this affects their mechanical properties, and may reduce their resistance to sulphide stress cracking (SSC) in sour service conditions, or in conditions that become sour.

Tests in Phase 1 of this programme of work (TWI Project 16071) on C-Mn steel girth welds subjected to plastic straining in the laboratory have confirmed that the effect of strain is significant with respect to the susceptibility to SSC, to the extent that failures were induced in specimens with hardness <250HV. It is important to clarify how the small-scale trials carried out in Phase 1 of this programme (TWI Report 16071/9-1/07) relate to full-scale samples, strained during laying or service. Of particular concern is pipe reeling, and there is some evidence (in-house from a client) that welds subjected to full-scale simulated reeling trials have suffered less severe degradation than the small-scale samples. It is important to understand this, so that representative small scale test methods can be developed and validated.

This programme was split into two parts. The main part covered plastic straining prior to environmental exposure. As an additional option, Sponsors of the main programme were able to join the second part of the project. This 'add-on' explored the effect of plastically straining material in the environment. This was a preliminary study of the effect of lateral buckling on sour pipelines in service. This document summarises both parts of the programme.

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Objectives

The main programme of work had the following objectives:

- Understand the distribution of strains involved in large-scale pipe bending, such as in reeling, and develop a small-scale technique to reproduce the same material condition.
- Demonstrate that such laboratory-based small-scale simulation of these strains can be used for specimens in SSC acceptance testing without excessive conservatism.

The additional part of the work programme had the following objective:

- Develop preliminary understanding of the effect of plastic strain which occurs during environmental exposure

Project Outcome

This project is now complete.

Benefits

- Improved requirements for weld procedure qualification of pipe laying/reeling operations intended for sour or mildly sour service.
- Improved confidence in the safety of pipelines installed with, or operating under, high plastic strain, for sour or mild sour service.

Participants

The Sponsor Group Comprised:

- Chevron Energy Technology Company
- PETROBRAS/CENPES/PDEP/TMEC
- Acergy Group
- Total

Scope of Work

An in-depth study of the strains involved in both full-scale and small-scale straining scenarios has been carried out, followed by SSC testing of specimens which have been subjected to large-scale straining, and specimens which have been subjected to small-scale straining, for comparison.

273.1mm OD, 18.3mm wt, SMLS 415 SFDP pipe was welded by Global Pipelines, overseen by Acergy, to produce six 1m long pipes, each with a centrally-located girth weld, and one 12m long pipe containing four girth welds 1m apart and centrally located. The six 1m long pipe joints were not strained, whilst the 12m long string was subjected to full-scale straining at Heriot-Watt University to generate data on local straining around the weld, and to provide SSC specimens. The pipe string was subjected to simulated reeling in accordance with the strains experienced on the Acergy Falcon vessel. The pipe was instrumented with 56 strain gauges, and it is believed that this represents the most extensively instrumented specimen that has been tested in this rig.

Residual stress measurements were made on the pipe external surface by the centre-hole drilling technique before and after straining.

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Finite element modelling work was undertaken to make predictions of the plastic straining in the full-scale tests and to theoretically develop small-scale testing methods that produce the same level of prior plastic straining. The three dimensional model took account of the shapes of the weld root, cap and fusion profile, the mechanical property distribution of the weld metal (WM), heat affected zone (HAZ) and parent material (PM), weld misalignment, and the residual stress profile. A pure non-linear kinematic hardening model based on monotonic tensile data measured on unstrained material was used.

In addition to tensile testing, samples were characterised by chemical analysis, metallography and hardness testing.

SSC tests were carried out on unstrained and strained welds, using four point bend constant load (dead weight) testing in a severely sour environment (NACE TM0177 solution A) at 24°C for 30 days. Strained material taken from the two most severely strained locations of the large scale simulation and from small scale simulations, designed using the modelling, was tested.

For the additional part of the programme, a test method was devised which allowed a full thickness axial strip specimen, machined from a pipe and containing a girth weld in the centre of the gauge length, to be strained whilst in a controlled sour environment. Tests were carried out in which straining to 0.4% total strain, achieved at a strain rate of about 10^{-6}/s, was followed by static (fixed load) testing. Test specimens were made from the same mechanised GMA girth weld as used for the main part of the programme. This work was restricted to initially unstrained welds. A number of test variables were identified which could be explored in future work

Price and Duration

The project had a duration of three years and a budget of £309,000. There were four Sponsors, each making a contribution of £60,000 per annum, with one Sponsor contributing £129,000 for supplementary work which was specific to their requirements.

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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