

Further Study of Fatigue Damage to Girth Welds from Low Stresses in the Loading Spectrum



PUBLISHABLE SUMMARY

18054

Background

Fatigue design of welded joints is based on data obtained under constant amplitude (CA) loading, used in conjunction with Miner's rule to estimate the damage introduced by cycles of various magnitudes in the service stress history. However, there is extensive evidence suggesting that Miner's rule can be unsafe (ie $\sum(n/N) < 1.0$ at failure) and that stresses below the CA fatigue limit (CAFL) are more damaging than currently assumed in design rules. These fundamental issues were addressed in the previous Group Sponsored Project (TWI Project 15216) in the specific context of girth welded pipes. A major problem found in that project was that the variable amplitude (VA) test results obtained from strip specimens extracted from the pipes were not directly applicable to the full-scale specimens. In particular, they gave much higher fatigue strength in the important long-life regime and a higher CAFL than the full-scale equivalent joints. This highlights the need for testing full-scale specimens under spectrum loading. Following preliminary experimental trials at TWI, this is now possible in the resonance test rigs used previously for the CA tests.

In consideration of the specific types of spectrum loading tests to be performed on full-scale pipes, review of the current status of research into the problems mentioned, including recent work undertaken as part of TWI's Core Research Project highlighted the importance of the nature of the stress cycles within the spectrum regardless of its shape. Cycling down from a constant tensile stress seems to be the most damaging type of loading while stress cycles with constant mean or minimum stress are the least damaging. Risers could experience either or both of these types of stress cycling and therefore both extremes need to be investigated, preferably with a suitable concave-up spectrum shape to ensure that low stresses make a significant contribution. However, the resonance rig is not suitable for cycling down from a constant tensile stress and therefore reliance must be placed on tests on strip specimens.

Thus, it is proposed to follow up to the previous project with spectrum loading tests under a concave-up shape of spectrum that is relevant to SCRs with the loading that cycles about a constant tensile mean stress applied to full-scale pipes and loading that cycles down from a constant tensile maximum stress applied to strip specimens. The main aim will be to establish the damaging effect of stresses below the CAFL for these conditions, but the results are also expected to throw light on the issue of doubts about the validity of Miner's rule.

Further Study of Fatigue Damage to Girth Welds from Low Stresses in the Loading Spectrum

Objectives

- Determine the damage due to stresses below the CAFL for girth welds under a concave-up loading spectrum representative of that experienced by SCRs with stresses cycling about a constant tensile mean stress, on the basis of tests on full-scale specimens.
- Determine the damage due to stresses below the CAFL for girth welds under the same concave-up loading spectrum but with stresses cycling down from a constant tensile stress, on the basis of tests on strip specimens.
- Confirm that VA fatigue tests performed on strip specimens are suitable for establishing safe values of the Miner's rule damage sum for full-scale girth welded pipes and hence confirm the validity of the tentative design approach proposed in the previous project for fatigue design under spectrum loading.
- Clarify the role of residual stresses on the VA fatigue behaviour of girth welds and the relative fatigue performance of full-scale and strip specimens.
- Provide design guidance on the influence of the type of loading spectrum and weld detail on the appropriate choice of Miner's rule damage sum and the method of accounting for the fatigue damage due to stresses below the CAFL. .

Benefits

- Enhanced safety by reducing the risk of underestimating the fatigue damage due to load spectra relevant to risers, from the viewpoints of the validity of both Miner's rule and current methods for treating stresses below the fatigue limit.
- Significant cost saving by using the appropriate design procedure developed from this project.
- Vital information urgently needed for the development and validation of the ISO and API fatigue design rules.

Participants

- BP
- Chevron
- ExxonMobil
- H&S Exec
- Heerema
- Petrobras
- Saipem
- Tenaris Tamsa

Further Study of Fatigue Damage to Girth Welds from Low Stresses in the Loading Spectrum

Scope of Work

- Fatigue tests under constant and VA loading on both full-scale girth-welded pipes and corresponding tests on strips cut from girth-welded pipes.
- Residual stress measurements before and after removing strip specimens from full-scale girth welded pipes.
- Fatigue crack growth measurements under constant and VA loading and associated fracture mechanics fatigue life calculations.
- Development of design recommendations with supporting evidence from the experimental results of the present and previous projects, and relevant published work.

Price and Duration

The project had a duration of 2 years and a budget of £750,000. It was funded by 8 Sponsors each making a contribution of £100,000. The fee for additional companies buying-back into the project results is £100,000

Further Information

For further information on Joint Industry Projects (JIP) and their operation, please visit:

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

JIP Co-ordinator: Tracey Stocks

Email: jip@twi.co.uk

Project Leader: Yanhui Zhang

Email: yanhui.zhang@twi.co.uk