**UKOPA Report**

University of Strathclyde Fatigue Study for the UKOPA Weld Quality Project

UKOPA/RP/006 Edition A

February 2023

**REPORT ISSUED BY UKOPA:**

Comments, questions and enquiries about this publication should be directed to:

**UK Onshore Pipeline Operators’ Association**

Pipeline Maintenance Centre

Ripley Road

Ambergate

Derbyshire

DE56 2FZ

**E-mail:** [**enquiries@ukopa.co.uk**](mailto:enquiries@ukopa.co.uk)

**Website:** [**www.UKOPA.co.uk**](http://www.UKOPA.co.uk)

**Disclaimer**

This document is protected by copyright and may not be reproduced in whole or in part, by any means without the prior approval in writing of UKOPA. The information contained in this document is provided as guidance only and while every reasonable care has been taken to ensure the accuracy of its contents, UKOPA cannot accept any responsibility for any action taken, or not taken, on the basis of this information. UKOPA shall not be liable to any person for any loss or damage which may arise from the use of any of the information contained in any of its publications. The document must be read in its entirety and is subject to any assumptions and qualifications expressed therein. UKOPA documents may contain detailed technical data which is intended for analysis only by persons possessing requisite expertise in its subject matter.

Copyright @2023, UKOPA. All rights reserved.

**Revision and change control history.**

**Planned revision: N/A**

|  |  |  |  |
| --- | --- | --- | --- |
| Edition | Date | No. of pages | Summary of changes |
| **A** |  |  |  |
| **B** |  |  |  |
| **C** |  |  |  |
| **1** |  |  |  |

Contents

[Executive Summary 1](#_Toc126674340)

[Conclusions 1](#_Toc126674341)

[1. Introduction 2](#_Toc126674342)

[1.1 Description of Experimental Studies 2](#_Toc126674343)

[2. Fatigue Test Results 4](#_Toc126674344)

[3. Conclusions 6](#_Toc126674345)

[4. References 7](#_Toc126674346)

[Appendix 1 Description of Fatigue Testing 8](#_Toc126674347)

[Appendix 2 Fatigue Test Results 9](#_Toc126674348)

# Executive Summary

UKOPA actioned two research projects to investigate the performance of girth welds in pipelines constructed before 1972:

1. Fatigue testing of 10 small scale specimens taken from the pipeline weld samples, and comparison of the results with published S-N Curves carried out by the University of Strathclyde, and
2. Comparison of the fatigue performance of old girth welds and equivalent current standard pipeline welds, and an investigation of the type and size of defect in old pipeline girth welds which may pose a threat to pipeline integrity carried out by Swansea University.

This report summarises the results of the fatigue study carried out by the University of Strathclyde.

## Conclusions

The University of Strathclyde fatigue study indicates that the fatigue performance of pre-1972 pipeline girth welds compares with current fatigue S-N design requirements as follows:

The fatigue lives compared with the mean E SN curve and fell within the mean and upper bound E SN curve, and above the lower bound E design SN Curve.

The fatigue lives compared with the upper bound F2 SN curve and fell between the mean and upper bound F2 SN curve.

The fatigue lives were typically two orders of magnitude above the IGEM/TD/1[1] SN design curve.

The fatigue test results obtained from both studies are conservative, as the specimens tested were taken from pipe-weld samples from pipelines which had been in operation for more than 40 years.

# Introduction

The University of Strathclyde undertook fatigue tests of small scale cross girth weld specimens taken from pre 1972 girth welds and compared the results with published fatigue SN design curves.

## Description of Experimental Studies

The work involved fatigue testing of standard small scale specimens cut and prepared from full scale 36” diameter x 16 mm wall thickness and 24” diameter x 12.7 mm wall thickness pipe-weld samples from the UKOPA weld quality project supplied to Strathclyde, see Figure 1.

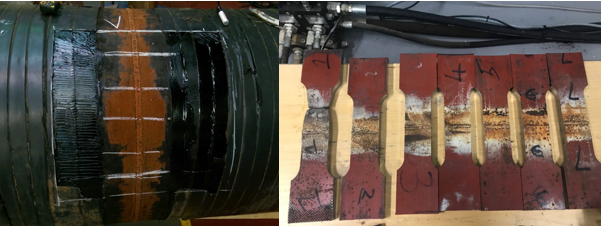


Figure 1 Small Scale Fatigue Specimens cut from 36” diameter x 16 mm wall thickness Pipe Weld Sample

An example of a failed specimen from a completed test is shown in Figure 2.

A picture containing text

Description automatically generated

Figure 2 Fatigue test of a 36” diameter x 16 mm Wall Thickness Specimen

Visual inspection indicated the fatigue crack initiated at the weld cap and propagated from one corner to the other.

A description of the fatigue testing is given in Appendix 1.

# Fatigue Test Results

The fatigue test results are given in Table 1 for the specimens taken from the 36” diameter x 16 mm wall thickness pipe weld sample, and Table 2 for the specimens taken from the 24” diameter x 12.1 mm wall thickness pipe weld sample.

The fatigue results are plotted and compared with the BS 7608 [2] F2 and E S-N curves in Figure 3 and Figure 4. These SN curves apply to transverse butt welds made from one side; the F2 curve applies when the welded root condition is not assessed directly by NDT and is typically used to assess the fatigue life of pipeline girth welds; the E curve applies when the weld root condition is assessed by appropriate NDT, and is typically used to assess the fatigue life of pipeline seam welds.

The fatigue test results are given in Appendix 2.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Pipe weld Sample** | | **36" dia x 16 mm wt** | | | |
| **Fatigue Specimen** | | **16 mm thick 50 mm width** | | | |
| **Test** | **Stress** | **%SMYS** | **Mean E Curve Fatigue Life** | **Experimental Fatigue Life** | **Comments** |
| **1** | 125 N/mm2 | 35 | 1.68x106 | 9000000 | No failure |
| **2** | 148.7 N/mm2 | 42 | 1.0 x106 | 1117048 |  |
| **3** |  |  |  | 602660 |  |
| **4** | 187.3 N/mm2 | 52 | 5.0x105 | 338163 |  |
| **5** |  |  |  | 397097 |  |

Table 1 36” Dia x 16 mm WT Pipe Weld Sample Fatigue Results

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Pipe weld Sample** | | **24" dia x 12.1 mm wt** | | | |
| **Fatigue Specimen** | | **12.1 mm thick 36.33 mm width** | | | |
| **Test** | **Stress** | **%SMYS** | **Mean E Curve Fatigue Life** | **Experimental Fatigue Life** | **Comments** |
| **1** | 187.3 N/mm2 | 52 | 1.68x106 | 1193262 |  |
| **2** |  |  |  | 947012 |  |
| **3** | 148.7 N/mm2 | 42 | 1.0 x106 | 741380 |  |
| **4** |  |  |  | 2000000 | No failure |
| **5** | 222 N/mm2 | 62 | 5.0x105 | 397097 |  |

Table 2 24” Dia x 12.1 mm WT Pipe Weld Sample Fatigue Results

Chart, scatter chart

Description automatically generated

Figure 3 Fatigue Results plotted on the F2 S-N Curve

Chart

Description automatically generated

Figure 4 Fatigue Results plotted on the E S-N Curve

# Conclusions

The University of Strathclyde fatigue study indicates that the fatigue performance of pre-1972 pipeline girth welds compares with current fatigue S-N design requirements as follows:

The fatigue lives compared with the mean E SN curve and fell within the mean and upper bound E SN curve, and above the lower bound E design SN Curve.

The fatigue lives compared with the upper bound F2 SN curve and fell between the mean and upper bound F2 SN curve.

The fatigue lives were typically two orders of magnitude above the IGEM/TD/1 [1] SN design curve.

The fatigue test results are conservative, as the specimens tested were taken from pipe-weld samples from pipelines which had been in operation for more than 40 years.

# References

|  |  |
| --- | --- |
| [1] | “IGEM/TD/1 Ed 6 Steel pipelines for high pressure gas transmission,” Institution of Gas Engineers and Managers, 2021. |
| [2] | “BS 7608 Guide to fatigue design and assessment of steel products,” British Standards Institution, 2014. |

# Appendix 1 Description of Fatigue Testing

The description of the fatigue testing carried out by the University of Strathclyde is given in the file below, which is provided as an attachment to this report.



# Appendix 2 Fatigue Test Results

The fatigue test results provided by the University of Strathclyde are given in the file below, which is provided as an attachment to this report.

