SINTEF

SINTEF Materials and Chemistry

Address: NO-7465 Trondheim NORWAY
Location: Richard Birkelands vei 2B
Telephone: +47 73 59 52 01
Fax: +47 73 59 29 31

Enterprise No.: NO 948 007 029 MVA

SINTEF REPORT

TITLE

SSC/SCC testing of GTAW welded lean duplex alloy UNS S32003.

AUTHOR(S)

André Mikkelsen and Tor Gunnar Eggen

CLIENT(S)

Allegheny Ludlum

REPORT NO.	CLASSIFICATION	CLIENTS REF.	
STF80 F04071	Confidential	John Dunn	
CLASS. THIS PAGE	ISBN	PROJECT NO.	NO. OF PAGES/APPENDICES
Confidential		243975.20	9/1
ELECTRONIC FILE CODE		PROJECT MANAGER (NAME, SIGN.)	CHECKED BY (NAME, SIGN.)
		Trond Rogne	Tor Gunnar Eggen
FILE CODE	DATE	APPROVED BY (NAME, POSITION, SIGN.)	
	2004-12-08	Jack Ødegård, Research Director	

ABSTRACT

The resistance towards sulphide stress cracking and stress corrosion cracking has been investigated in four point bend (FPB) for a GTAW welded UNS S32003, lean duplex stainless steel AL 2003, produced by Allegheny Ludlum. The testing was carried out at room temperature and at 160 °C in formation water with pH 5.8 simulating the conditions at the Kristin field in the North Sea. The test gas was 10 mbar H_2S with CO_2 as balance at a pressure of 7.4 bar. The test time was 720 hrs.

Conclusions

No cracking or pitting was observed in the FPB testing. This means that in formation water simulating "Kristin" conditions the tested welded lean duplex material is not sensitive to pitting and sulphide stress cracking.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	Materials technology	Materialteknologi
GROUP 2	Corrosion	Korrosjon
SELECTED BY AUTHOR	Sulphide stress cracking	Sulfidspennings korrosjon
	Stress corrosion cracking	Spennings korrosjon
	Lean duplex	Lean duplex

TABLE OF CONTENTS

1 Summary and conclusions 3

2 Experimental 4

2.1 Materials, welding and test pieces 4

2.2 Test procedure FPB 4

3 Results and discussion 6

Appendix 1. Deflection data FPB testing 8

1 Summary and conclusions

The resistance towards sulphide stress cracking and stress corrosion cracking has been investigated in four point bend (FPB) for a GTAW welded UNS S32003, lean duplex stainless steel AL 2003, produced by Allegheny Ludlum. The testing was carried out at room temperature and at 160 °C in formation water with pH 5.8 simulating the conditions at the Kristin field in the North Sea. The test gas was 10 mbar H_2S with CO_2 as balance at a pressure of 7.4 bar. The test time was 720 hrs.

Conclusions

No cracking or pitting was observed in the FPB testing. This means that in formation water simulating “Kristin” conditions the tested welded lean duplex material is not sensitive to pitting and sulphide stress cracking.

2 Experimental

2.1 Materials, welding and test pieces

The resistance towards sulphide stress cracking (SSC) and stress corrosion cracking (SCC) has been investigated in four point bend (FPB) for welded lean duplex material UNS S32003. The base material has a chemical composition as given in Table 1.

The dimensions of the test pieces are given in Figure 1. The test pieces were prepared by Allegheny Ludlum after specifications from SINTEF. All test pieces were taken from heat no. 511511. The welding consisted of root passes using GTAW and filler with SAW using 2209 wire.

Table 1 *AL-2003 chemical composition in wt% from heat no. 511511.*

C	Mn	P	S	Si	Cr	Ni	Mo	N	Fe
0.016	1.32	0.025	0.0002	0.38	21.6	3.8	1.8	0.18	Bal.

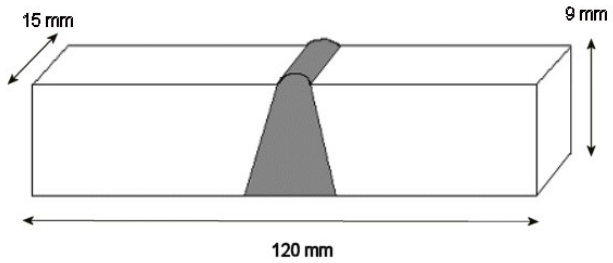

Figure 1 *Dimensions of a four point bend test piece.*

The four point bend testing was carried out at 160 °C and at room temperature in simulated formation water (FW) representing the conditions at Kristin field in the North Sea. The test conditions are given in Table 2.

Table 2 *FPB test conditions.*

Material	**parallels**	**Temperature**	**Pressure**	**Formation water (FW)**	**Load**
GTAW welded UNS S32003	3	Room temp	p_{CO2} = 7.4 bar, P_{H2S}=10mbar Ptot at 160°C = 13.5 bar*	87400 mg/l NaCl 1261 mg/l $NaHCO_3$	100% of the yield strength 534 MPa
	3	160 °C			

* (including water vapour pressure)

2.2 Test procedure FPB

The test was carried out in accordance with the EFC Document No. 17.
Prior to testing, the side edges of the test pieces were wet ground to 500 grit with silica paper. The thickness of the test pieces was measured at six different positions close to the weld root and the lowest value was used for calculations of the deflection. The deflection necessary to achieve 100% of the yield strength was calculated according to the ASTM G39 standard. The calculated deflection data are presented in Appendix 1. The deflection during loading was measured with a gauge having an accuracy of ± 0.001 mm.

The electrolytes were prepared in separate tanks and the pH of the electrolytes was measured at room temperature whilst purging CO_2 gas at 1 bar pressure.
Oxygen was then removed from the solutions according to the following procedure:

- The test pieces were placed in the test autoclaves which were sealed off and pressure-tested for leakage.
- The electrolytes and the autoclaves were separately purged with nitrogen for a minimum of 16 hours.
- Oxygen-free electrolyte was then transferred to the test autoclaves using nitrogen over-pressure.
- Test autoclaves loaded with electrolyte were purged with nitrogen for a minimum of 4 hours.

Prior to adding the test gas mixture the samples were pre-exposed in the electrolyte for 48 hours with continuous bubbling of CO_2 gas through the electrolyte. The temperature was then increased to the test temperature and the test gas mixture added and purged for 1 hour.

The test period was 720 hours. During the test period test gas was purged daily for 25 minutes.

After termination of the test, the weld area of test pieces were split in two across the middle, giving 2 surfaces for investigations in optical microscope. An illustration is given in Figure 2. The samples were sectioned in approximately equal sizes and referred to as sections S and M. S is the edge section and M is from the middle of the test piece. After sectioning, the specimens were wet ground, polished and electrolytical etched in NaOH for approx. 7 seconds. The investigation of the sectioned samples was performed at high magnification in an optical microscope.

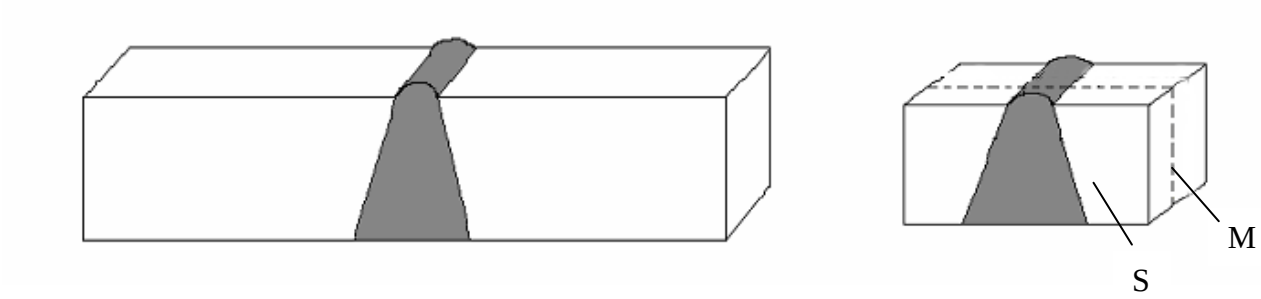

Figure 2 *Illustration of the sectioning of the test pieces giving two surfaces for investigation in optical microscope.*

3 Results and discussion

The results from the FPB testing at 160 °C and room temperature are presented in Table 3 and in Figures 3-5.

Table 3 *Results from the FPB testing.*

Test	Test piece	Result
Room temp	1	No cracking
	2	
	3	
160 °C	4	No cracking
	5	
	6	

Table 4 *pH measurements.*

Test	pH at start	pH at finish
Room temp	5.8	5.8
160 °C	5.8	5.7

As is seen in Table 3 and Figures 3-5 no cracking or pitting was observed in the FPB test. The material is therefore resistant towards SSC/SCC in the actual environments.

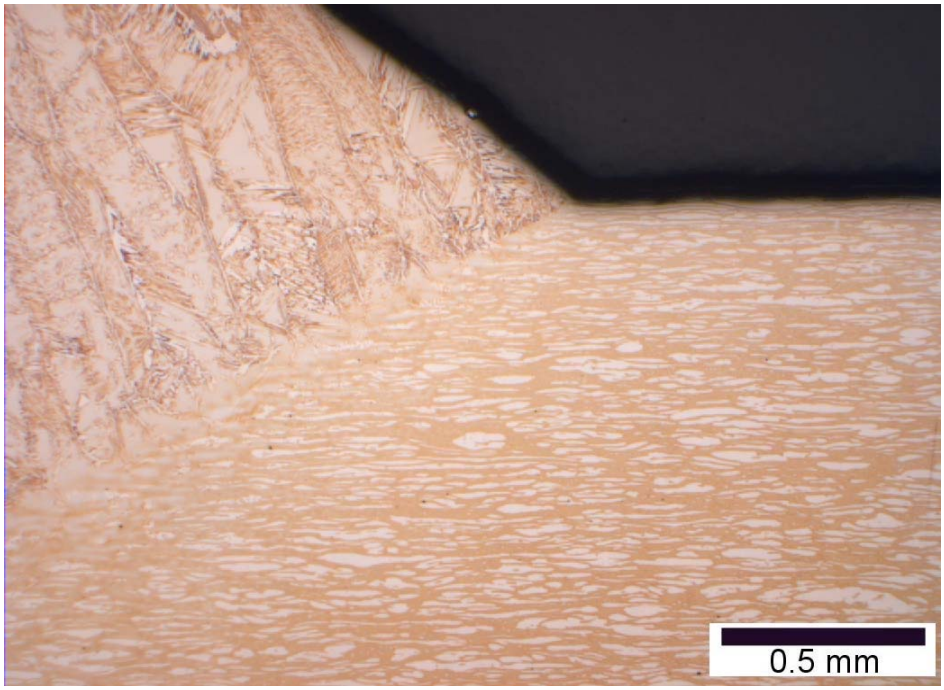

Figure 3. *Micrograph of sample 2 segment M tested at room temperature, no cracking is observed. Magnification 50X.*

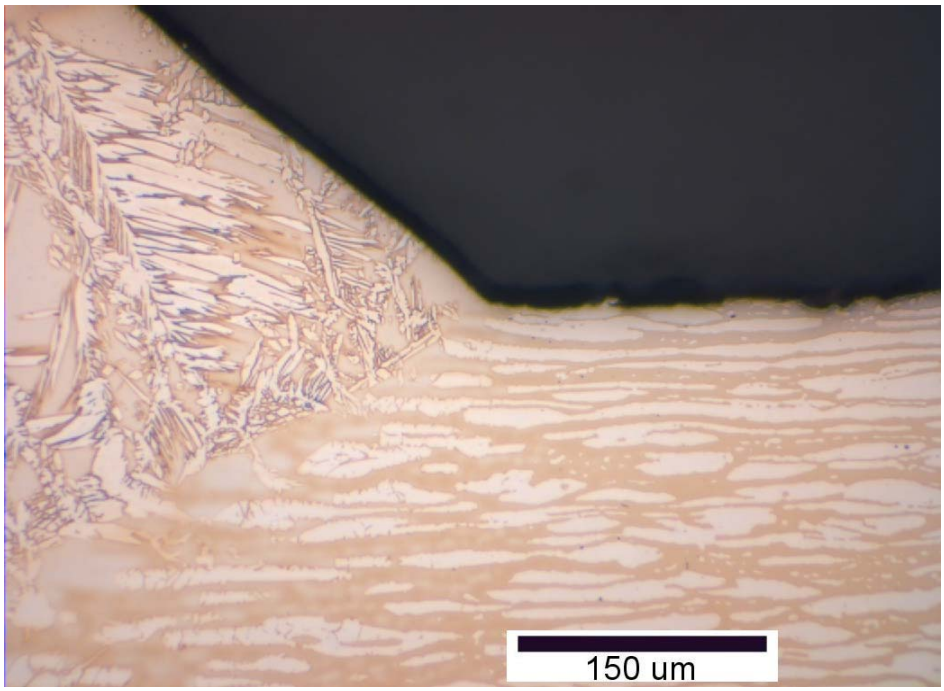

Figure 4. *Micrograph of sample 2 segment M tested at room temperature, no cracking is observed. Magnification 200X.*

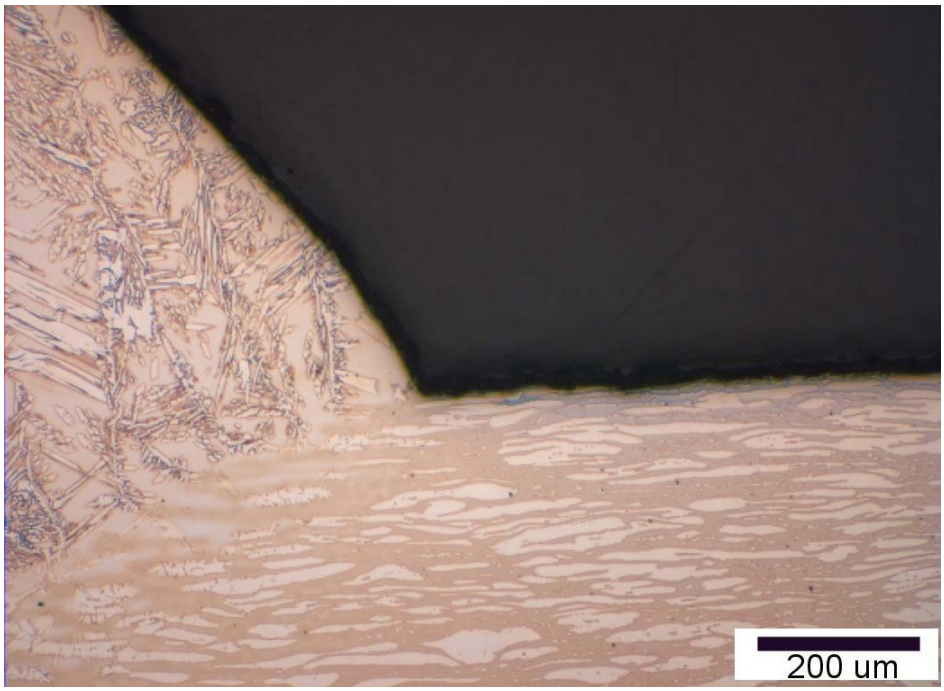

Figure 5. *Micrograph of sample 6 segment S tested at 160 °C, no cracking is observed. Magnification 100X.*

Appendix 1. Deflection data FPB testing

Table A1.1 *Deflection data*

Test	Sample	Thickness[mm]	Deflection[mm]
Romtemp	1	8,93	0,692
	2	8,89	0,696
	3	8,43	0,733
160 °C	4	8,90	0,695
	5	8,41	0,735
	6	8,30	0,745

For the calculation of deflection the E-module and yield strength used was 190 kN/mm^2 and 534 N/mm² respectively.

The distance between inner and outer jigg roller was 30 mm and the distance between the inner jigg rollers was 40 mm.

The 4-point bend specimens were loaded to 100% of actual yield strength in accordance with ASTM G39.