Appendix H: Mechanical Testing

1 Overview

Mechanical testing has been performed for two reasons: firstly, the aim to establish mechanical properties (tensile behaviour and fracture toughness) for the engineering critical assessment. The second objective is to compare the mechanical properties from two different tankers.

In the previous TWI project on the integrity of GRW circumferential seam welds, mechanical testing was undertaken on samples extracted from GRW tanker J3025. A series of tensile tests and fracture toughness tests were undertaken to obtain stress-strain curves for the tanker shell material and weld metal and to generate a tearing-resistance, J-R curve for the weld metal. A similar series of mechanical tests was undertaken in the present research project in order to obtain information about the scatter of tensile properties and fracture toughness. For the present work, the samples were obtained from a section removed from GRW tanker J3164.

2 Material Tested

TWI performed fracture toughness testing on single edge notched bend (SENB) specimens, extracted from a section taken from GRW tanker J3164. Testing was performed at the minimum design temperature stated in the ADR code: -20°C. Testing was performed to BS 7448:1997 Part 4, using the multi-specimen approach. Six specimens were notched through-thickness at the weld metal centre line to determine stable tearing resistance J R-curves.

In order to provide tensile properties for the fracture toughness testing and resulting four M4 round tensile specimens were machined. Two of these specimens were taken from the parent material (M01-01, M01-02) and two were taken from the welds (W01-07, W01-08). These specimens were tested at the minimum design temperature of -20°C in accordance with the latest version of BS EN ISO 6892-1. The test traces show 'serrated yielding' (the appearance of saw tooth-like features on the stress-strain trace) which is a relatively common occurrence in this grade of aluminium. The lower bound values were used for the fracture toughness testing and resulting.

3 Specimen Geometry

Six single edge notched bend (SENB) specimens (W01-01 to 06) were extracted from the circumferential seam weld, with a Bx3B cross section, in which B is as close to the shell plate thickness (5.2mm) as was practically achievable. Standard SENB specimens have a typical cross section of BxB or Bx2B. BS 7448:1997 part 4 allows up to Bx4B. The choice for Bx3B was made to increase the ligament in the specimen, allowing for more (stable) tearing to occur, but still limiting the risk of buckling instability which is likely in a Bx4B geometry.

The SENB specimen geometry gives high crack tip constraint, and can give over-conservative toughness results for material that is predominantly loaded in tension. However, given that present engineering critical assessment concerns load cases that involve significant through-wall bending stresses, the SENB specimen is appropriate. Additionally, a constraint-based analysis has been performed by analysing the T-stress to check the constraint in the test specimen is higher than in the structural component under consideration.

It should be noted that due to the small size of the specimen, the amount of stable tearing that could occur was very limited, which means that the J R-curve is truncated and does not show the material behaviour at greater levels of tearing. This again may lead to a conservative assessment.

4 Notch Location

The specimens were notched through-thickness at the weld metal centre line.

The SENB specimens were tested at the minimum design temperature of -20°C in accordance with Part 4 of BS 7448:1997, using the multi specimen approach.

5 Fracture Toughness Test Results

Tensile test results and fracture toughness test results are presented in Tables H1 and H2. The results do not strictly qualify to BS 7448:1997 Part 4. For this reason, the results should be viewed as indicative. The main causes for the non-compliances are the small specimen size and the low material strength. The tearing resistance J R-curve calculated from the test results is given in Figure H1. All specimens taken past maximum load failed in a ductile manner.

Table H1 Tensile test results

	Specimen ID	0.2% yield strength (MPa)	0.5% yield strength (MPa)	UTS (MPa)
Shell Plate	M01-01	150.9	167.1	304.5
	M01-02	154.5	170.3	308.0
Weld Metal	W01-07	166.6	184.6	284.3
	W01-08	185.2	202.3	283.7

Table H2 SENB toughness test summary. The specimens were loaded to different levels and their results used to determine the material tearing resistance curve (Figure 1)

Specimen	Specimen dimensions, mm			Load	Δa	J_{corr}	δ_{corr}	Qualified
number	W	B	ao	kN	mm	kJ/m²	mm	to standard
W01-01	14.910	5.000	7.759	0.99	0.84	53.825	0.228	No
W01-02	14.900	5.080	7.679	1.03	0.14	17.655	0.074	No
W01-03	14.940	4.970	7.669	0.98	0.34	27.338	0.122	No
W01-04	14.920	5.040	7.698	1.03	0.44	40.565	0.173	No
W01-05	14.920	5.000	7.896	0.90	0.54	40.425	0.181	No
W01-06	15.020	5.010	7.791	0.94	0.74	44.509	0.213	No

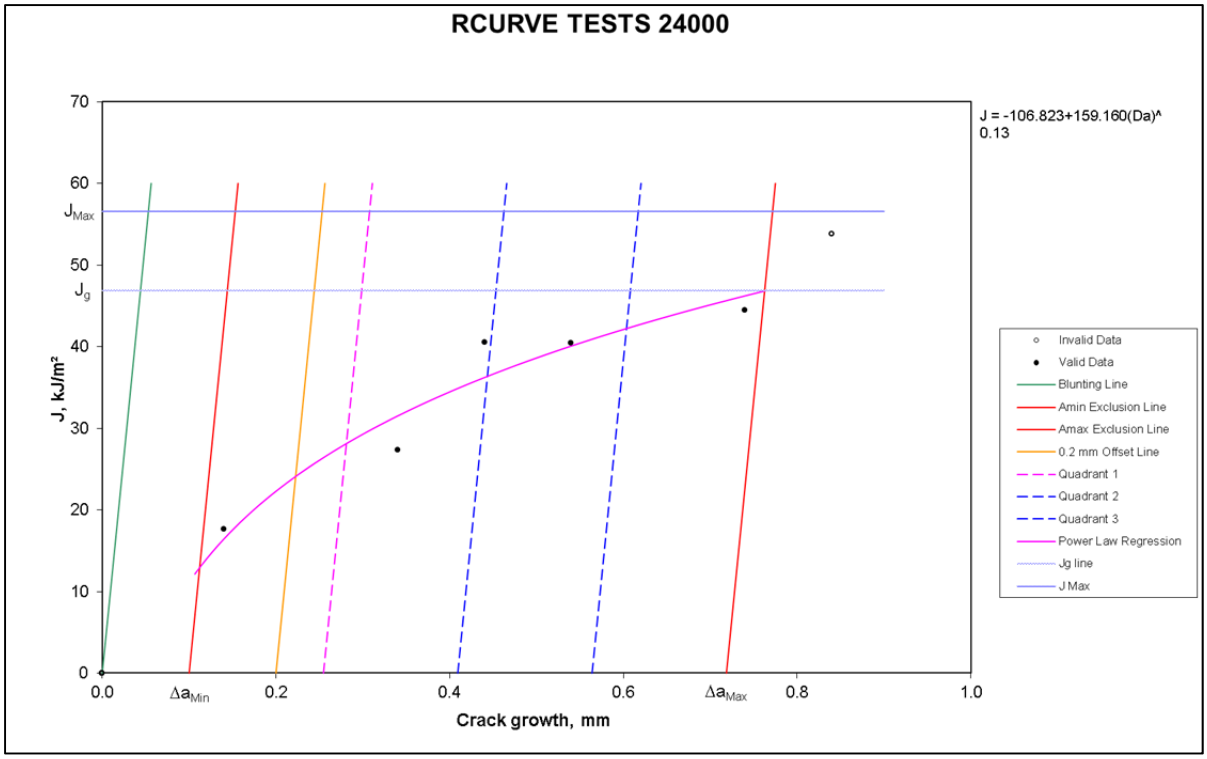

Figure H1 J R-Curve tearing resistance test result.