

Appendix I-3: Macro and Microscopic Examination of Samples from GRW Tanker J3564

1 Samples from J3564

1.1 Description of samples

Sections from the cradle position of bands C, D and G of GRW tanker J3564 were removed and sent to TWI. These samples are located in positions where the fatigue stresses are likely to be relatively high and therefore the main objective of the examination of these samples was to identify whether there was any evidence of fatigue crack growth. Additionally, the circumferential length of these specimens means that they could be subjected to impact under a roll over event. Each of the three sections was sectioned at approximately 100mm intervals and macros were prepared of the cross-section. Table I4 describes the positions of each of the macros that are presented. This table can be cross-referenced with Table I1 for reference to the specific band from which the section was obtained.

1.2 Sample J3564 W03-04 Band C

For this sample, W03 refers to the front-side weld (left hand side in the figures) and W04 refers to the rear-side weld (right hand side in the figures). All prepared macro samples are shown in Figures I30 to I50.

Figures I39 to I41 are of particular interest. Figure I39 shows an overall image of the cross-section. In Figure I40, the left hand side (front-side weld) is shown. In this image, a 2.19mm crack-like, surface-breaking defect is present. This is a significant defect and arises purely as a result of lack of fusion and not fatigue. The right hand side is shown in Figure I41 (rear-side weld). In this figure, a 1.62mm crack-like, surface-breaking flaw is present. Again, this defect arises purely as a result of lack of fusion and not fatigue.

In the context of previous analyses, both of these defects would be critical under a roll over event if the additional internal fillet weld was not present. However, for this specific macro, an internal fillet weld is present.

The defect is present in slice 4, and either side of this macro (slice 3 and slice 5), only a gas pore is present where the crack-like defect appears in slice 4. Further sectioning of the macros was undertaken and the results are shown in Figure I101. In this figure, it can be seen that, up to a 10mm resolution of the length, both flaws are at least 40mm in length and no more than 50mm in length. Additionally, the further sectioning revealed that on the side containing the 1.62mm deep flaw, there was a deeper point along the length, with the maximum observed depth equal to 2.04mm.

These crack-like defects are not located directly at the positioner lip, as was the defect that led to rupture in J2580.

1.3 Sample J3564 W05-06 Band D

For this sample, W05 refers to the front-side weld (right hand side in the figures) and W06 refers to the rear-side weld (left hand side in the figures). All prepared macros are shown in Figures I51 to I74.

The samples prepared from Band D did not contain any significant crack-like defects such as those found in the samples prepared from Band C. However, there are several lack of fusion, embedded-type defects and some significant

porosity. Although porosity is expected when welding the specific aluminium alloys in this joint, some of the gas pores have diameter nearly equal to the fillet weld throat thickness, which may negate the strengthening influence of the internal fillet weld under rollover.

1.4 Sample J3564 W07-08 Band G

For this sample, W07 refers to the front-side weld (left hand side in the figures) and W08 refers to the rear-side weld (right hand side in the figures). All prepared macros are shown in Figures I75 to I98.

The samples prepared from Band G did not contain any significant crack-like defects such as those found in the samples prepared from Band C. However, there are several lack of fusion, embedded-type defects and some significant porosity.

1.5 Conclusions from examination

The following conclusions were reached following analysis of the samples prepared from sections removed from J3564

- 1 One section exhibited crack-like, surface-breaking defects, 1.62mm and 2.19mm in height. Further sectioning revealed that the lengths of these defects was between 40mm and 50mm. The additional sectioning revealed that on the side containing the 1.62mm defect, there was a deeper point of the flaw, with the maximum observed depth equal to 2.04mm.
- 2 A significant number of samples exhibited significant porosity. The fillet weld joining the internal bulkhead to the extrusion band typically contained the largest gas pores. However, the internal fillet welds also contained large gas pores. In some cases, the diameter of the gas pores was nearly equal to the weld throat thickness. Such a pore could considerably weaken the beneficial influence of having the internal fillet weld present under rollover.
- 3 Only two surface flaws were observed; however, a large number of lack of side wall fusion flaws were also observed. These were either isolated lack of fusion, embedded-type defects or occurred in the vicinity of other lack of side wall fusion defects or gas pores.

2 Analysis of Weld Dimensions

The weld cap height and misalignment were measured on all macros prepared from J3564 and J3910. Additionally, HSL provided laser scan data for all bands (both offside and nearside) for J3910. A scatter data plot, showing the pairs of weld cap height and misalignment measurements is shown in Figure I99. There is no clear trend present in this figure. That is, there does not appear to be a strong relationship between weld cap height and misalignment. The non-dimensional geometry parameter, β , as described in the main report, is shown in Figure I100. This histogram was developed from the J3910 and J3564 measurements shown in Figure I98. There is a near-Gaussian type distribution of β -values, with approximately 40% of the values falling between 0.35 and 0.4. Using the fatigue life look-up table in the main report (and taking into consideration the built-in conservatism due to membrane-only loading), the estimated fatigue life would be in excess of 15 years.

Table I1 Samples received

TWI Sample ID	Tanker	Position	Weld length (mm)
W02	J3910	Band A O/S (impacted)	1450
W03	J3564	Band C O/S front weld	745
W04	J3564	Band C O/S rear weld	745
W05	J3564	Band D N/S front weld	840
W06	J3564	Band D N/S rear weld	840
W07	J3564	Band G O/S front weld	820
W08	J3564	Band G O/S rear weld	820
W09	J2580	Band H O/S (impacted)	1650
W10	J2580	Band H N/S	1660

Table I2 J3910 macro locations

Macro ID	Location (approx. distance from letter in mm)*
W02-01	Unimpacted area (100 from B, 100 from C)
W02-02	Impacted area (90 from C, 110 from D)
W02-03	Impacted area (90 from D, 100 from E)
W02-04	Impacted area (100 from E, 110 from F)
W02-05	Impacted area (100 from F, 90 from G)
W02-06	Unimpacted area (100 from G, 110 from H)

* letters refer to location marked during radiography.

Table I3 J3910 macro measurements (dimensions in mm)

	W02-01	W02-02	W02-03	W02-04	W02-05	W02-06
w	17.22	16.69	17.07	17.14	16.85	16.46
h	2.31	2.67	2.70	2.32	2.77	2.65
m1	0.72	1.70	1.14	0.50	1.49	0.66
m2	0.57	0.90	0.66	0.48	0.61	0.36
a	0.77	0.43	0.78	0.73	0.37	0.26

Table I4 J3564 macro slice positions

Macro	Location (approx. distance from top of sample in mm)
W03-01	50
W03-02	160
W03-03	250
W03-04	350
W03-05	450
W03-06	550
W03-07	650
W05-01	50
W05-02	150
W05-03	250
W05-04	350
W05-05	450
W05-06	550
W05-07	650
W05-08	750
W07-01	50
W07-02	150
W07-03	250
W07-04	350
W07-05	450
W07-06	550
W07-07	650
W07-08	750

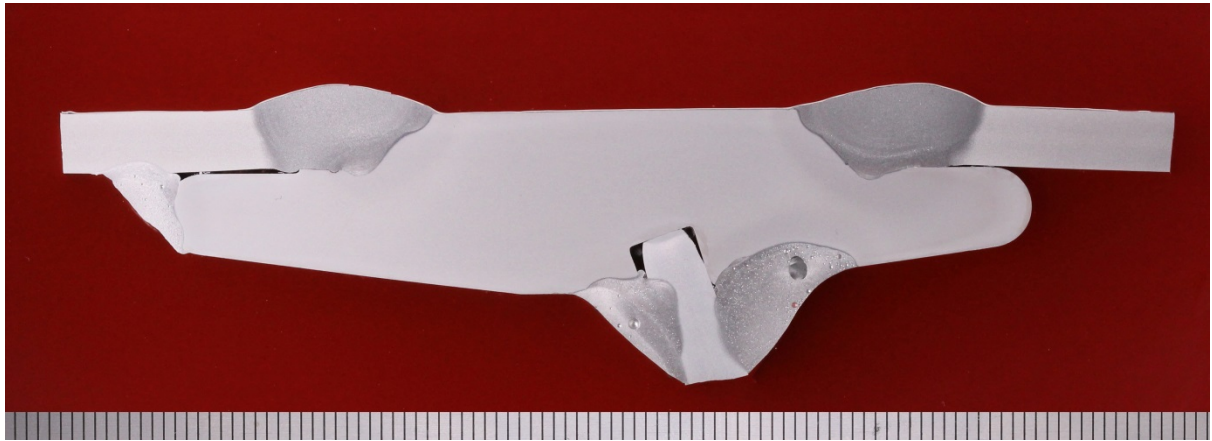


Figure I30 J3564 sample W03-04, slice 1.

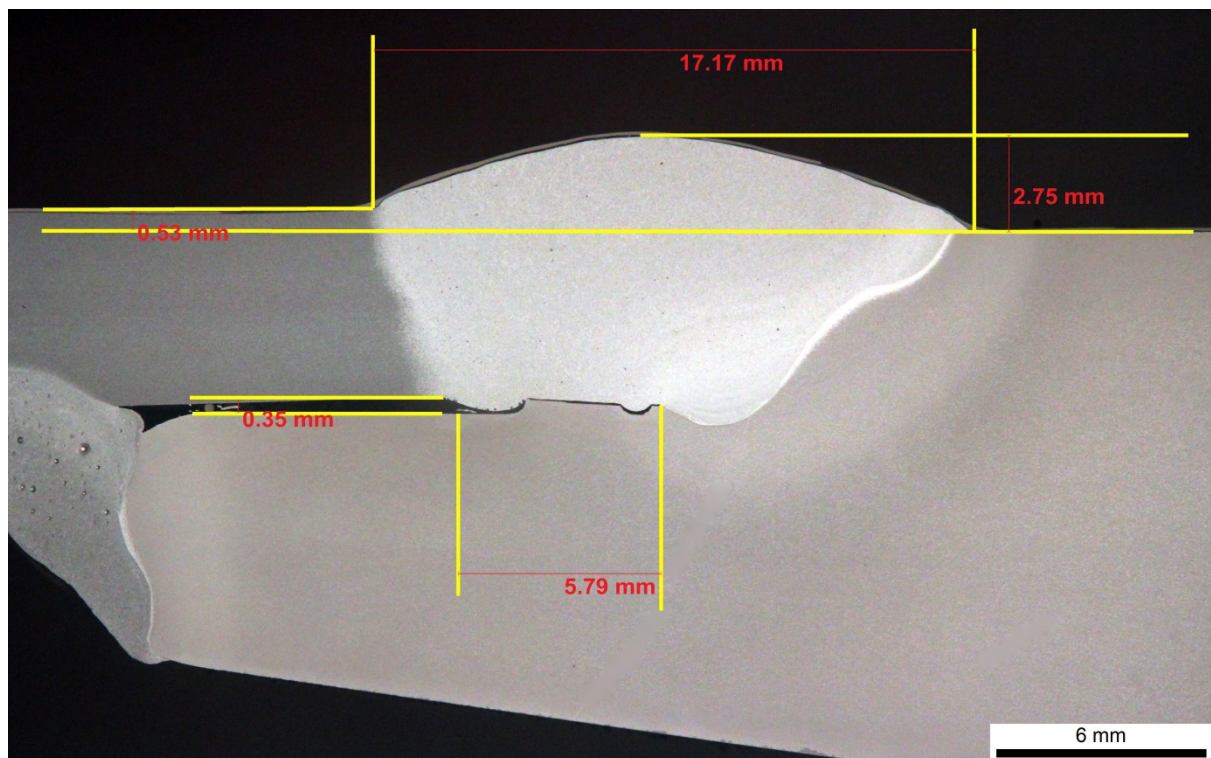


Figure I31 J3564 sample W03-04, slice 1, left side of Figure I30. No significant crack-like defect present.

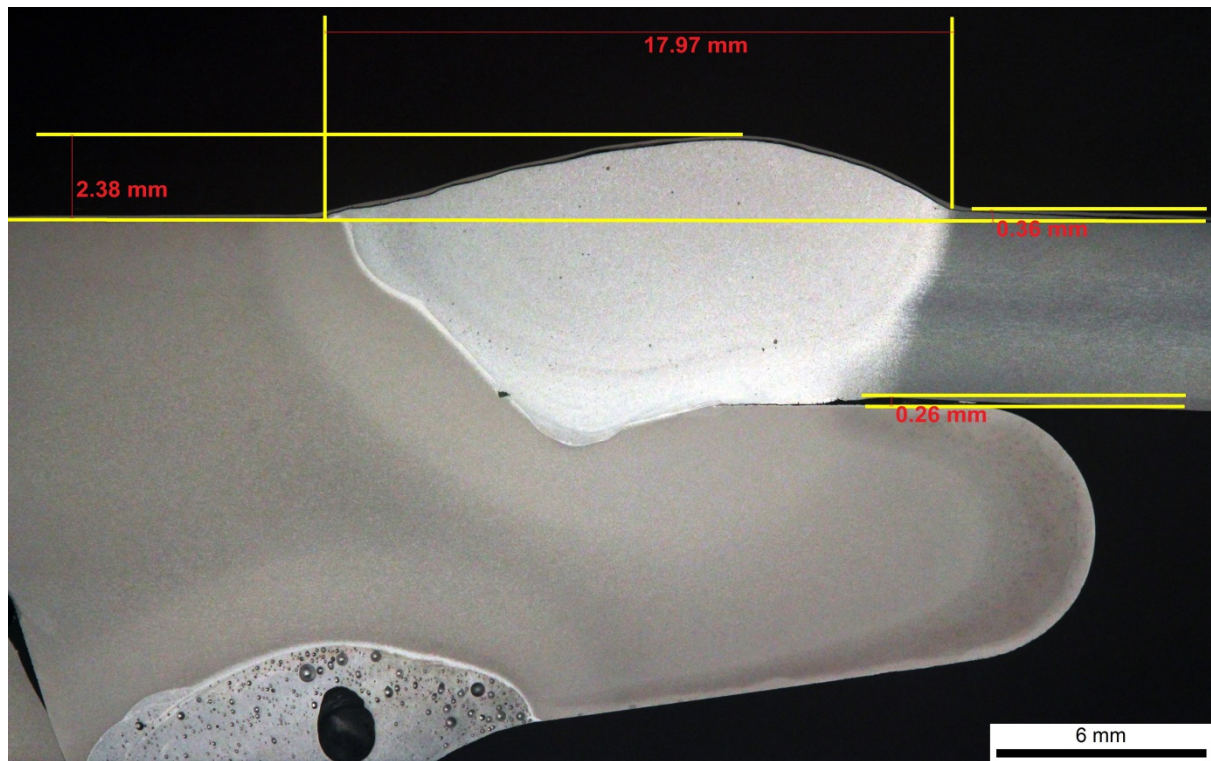


Figure I32 J3564 sample W03-04, slice 1, right side of Figure I30. Small lack of sidewall fusion defect present. Large gas pore in fillet weld between bulkhead and extrusion band.

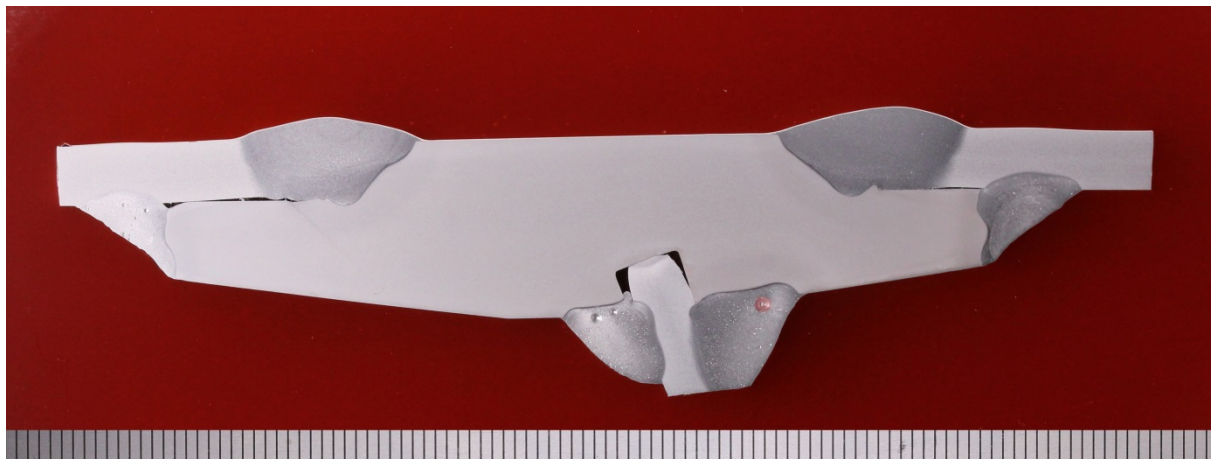


Figure I33 J3564 sample W03-04, slice 2.

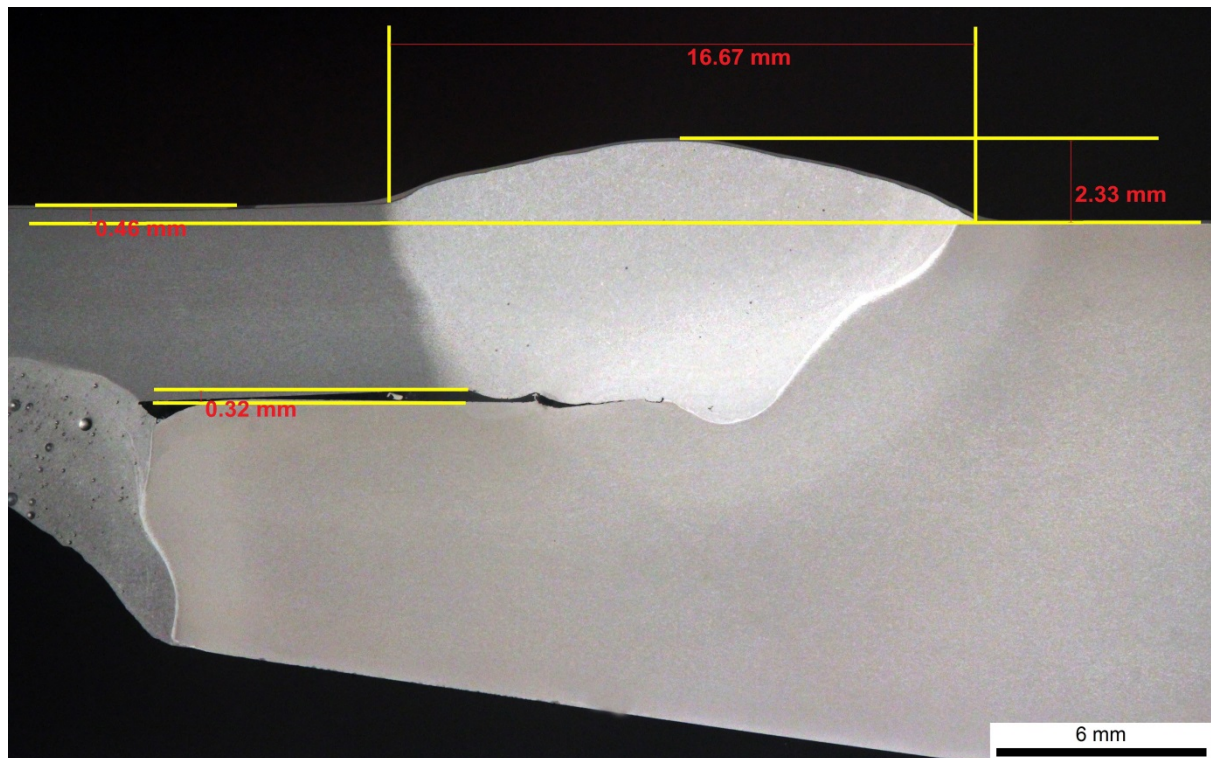


Figure I34 J3564 sample W03-04, slice 2, left side of Figure I33. No defect of note in the joint, scattered porosity in the internal fillet weld.

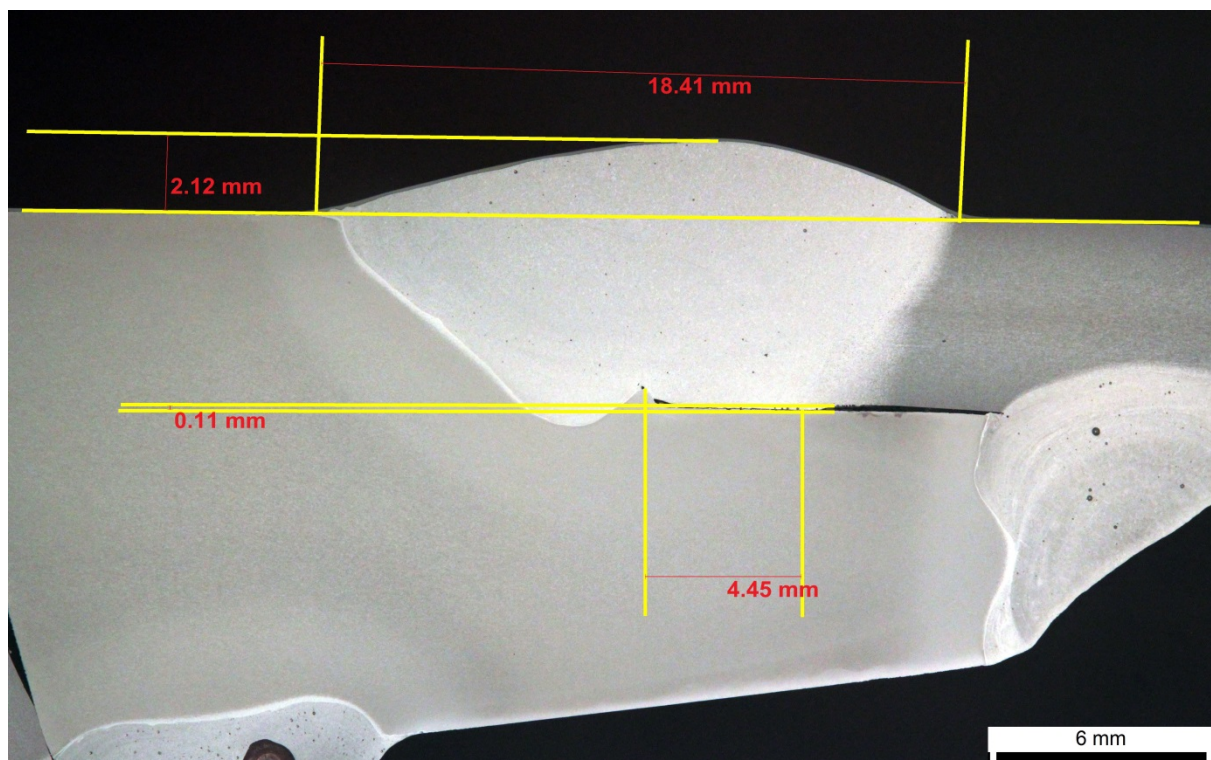


Figure I35 J3564 sample W03-04, slice 2, right side of Figure I33. Small pore above the positioner lip, and large gas pore in the fillet weld joining the bulkhead to extrusion band.

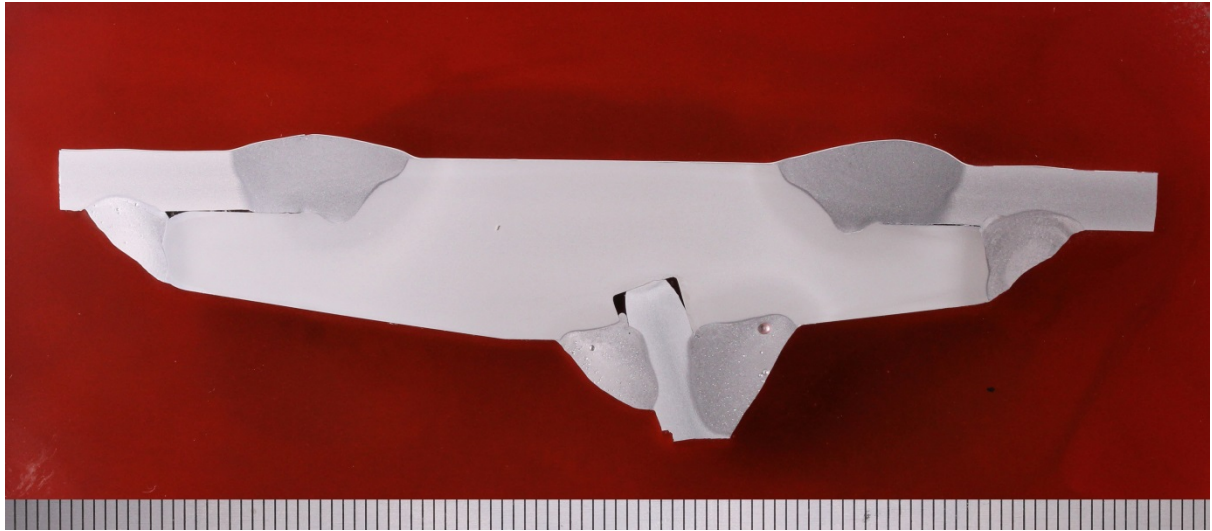


Figure I36 J3564 sample W03-04, slice 3.

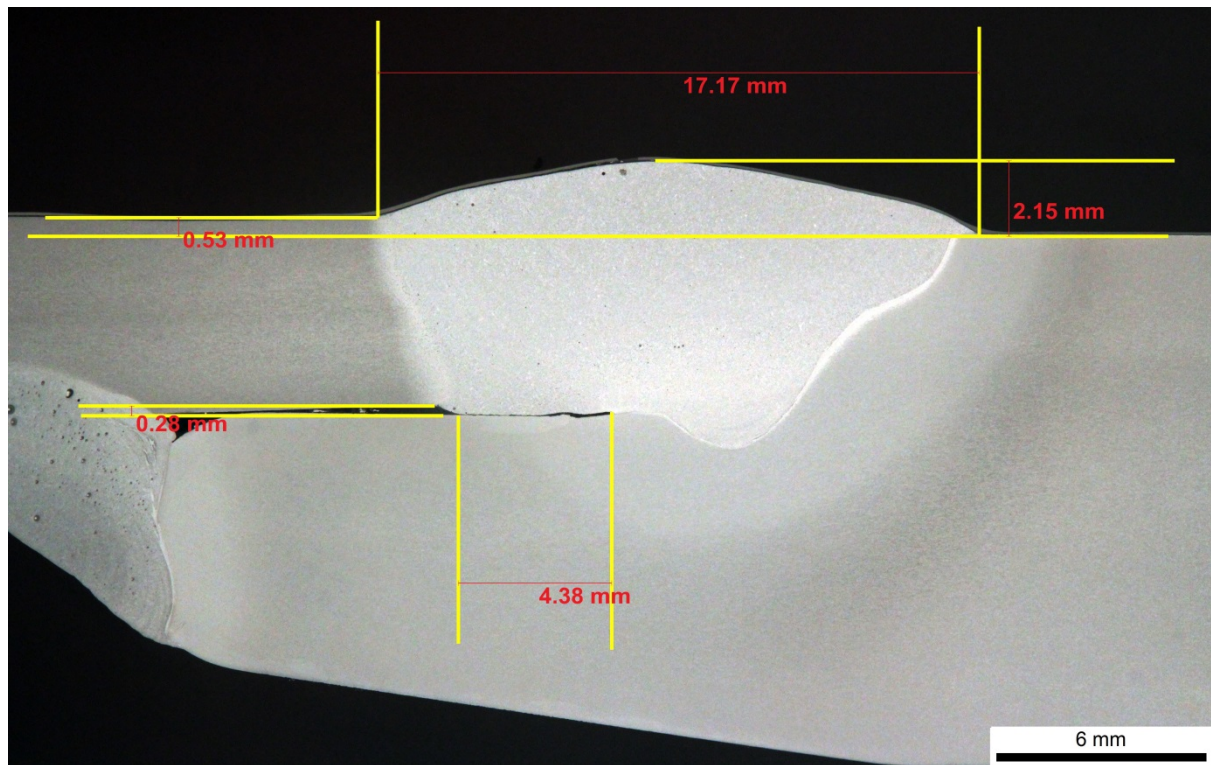


Figure I37 J3564 sample W03-04, slice 3, left side of Figure I36. No defect of note present.

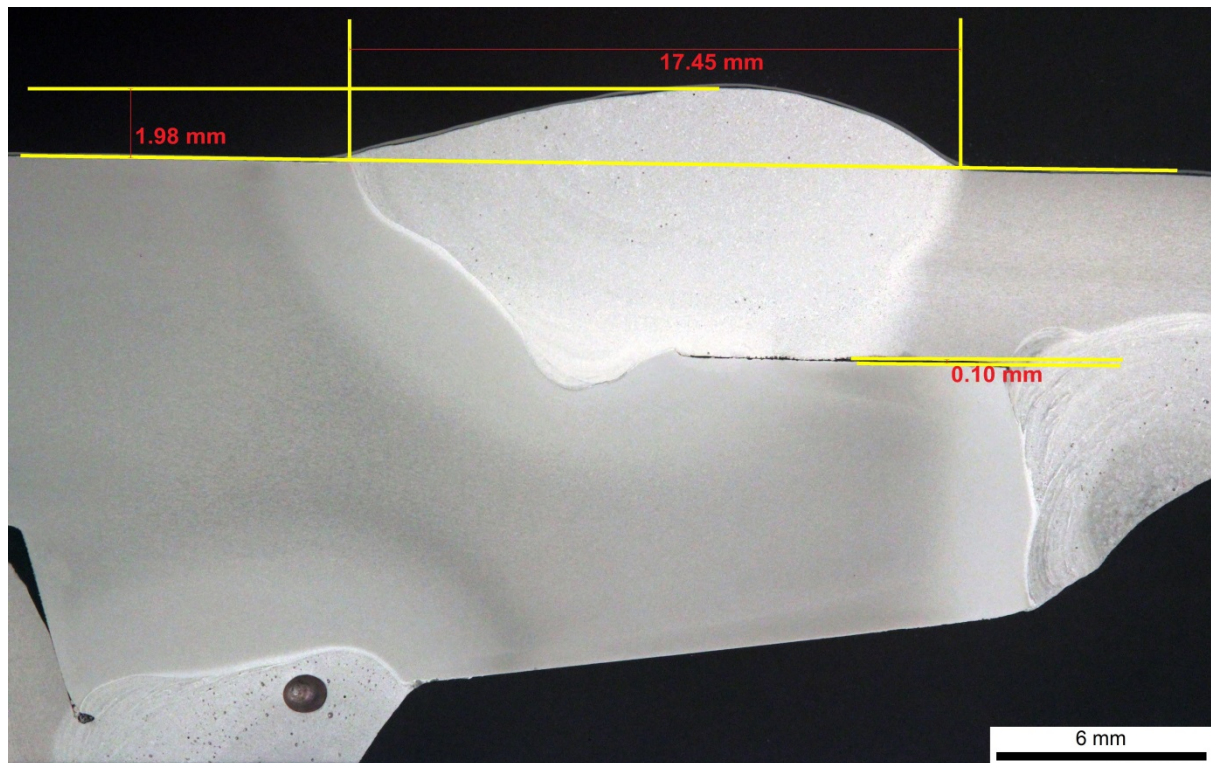


Figure I38 J3564 sample W03-04, slice 3, right side of Figure I36. No defect of note present in the joint. Large gas pore in the fillet weld joining the bulkhead to the extrusion band.

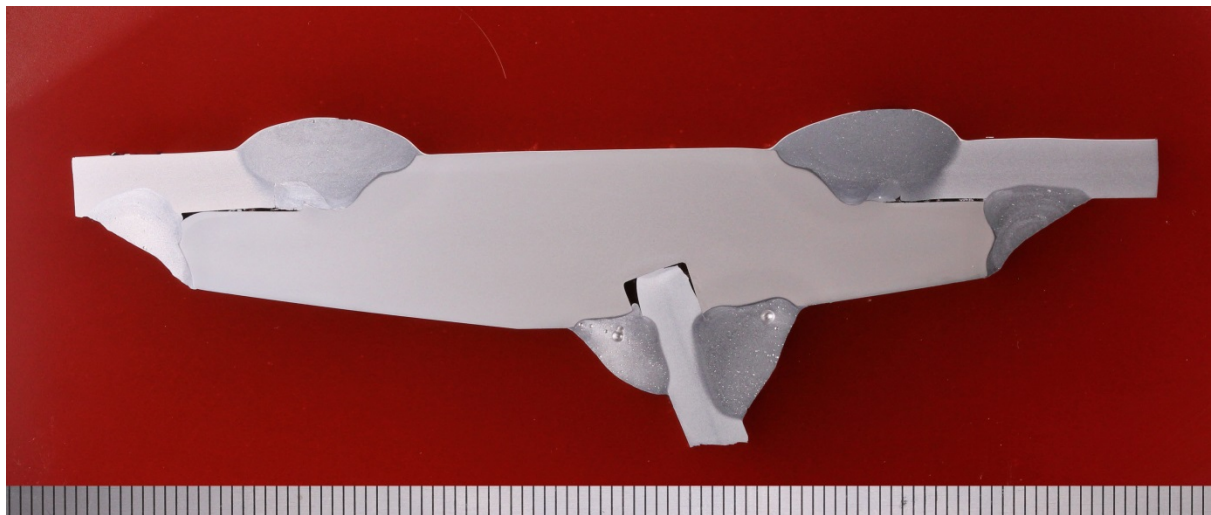


Figure I39 J3564 sample W03-04, slice 4.

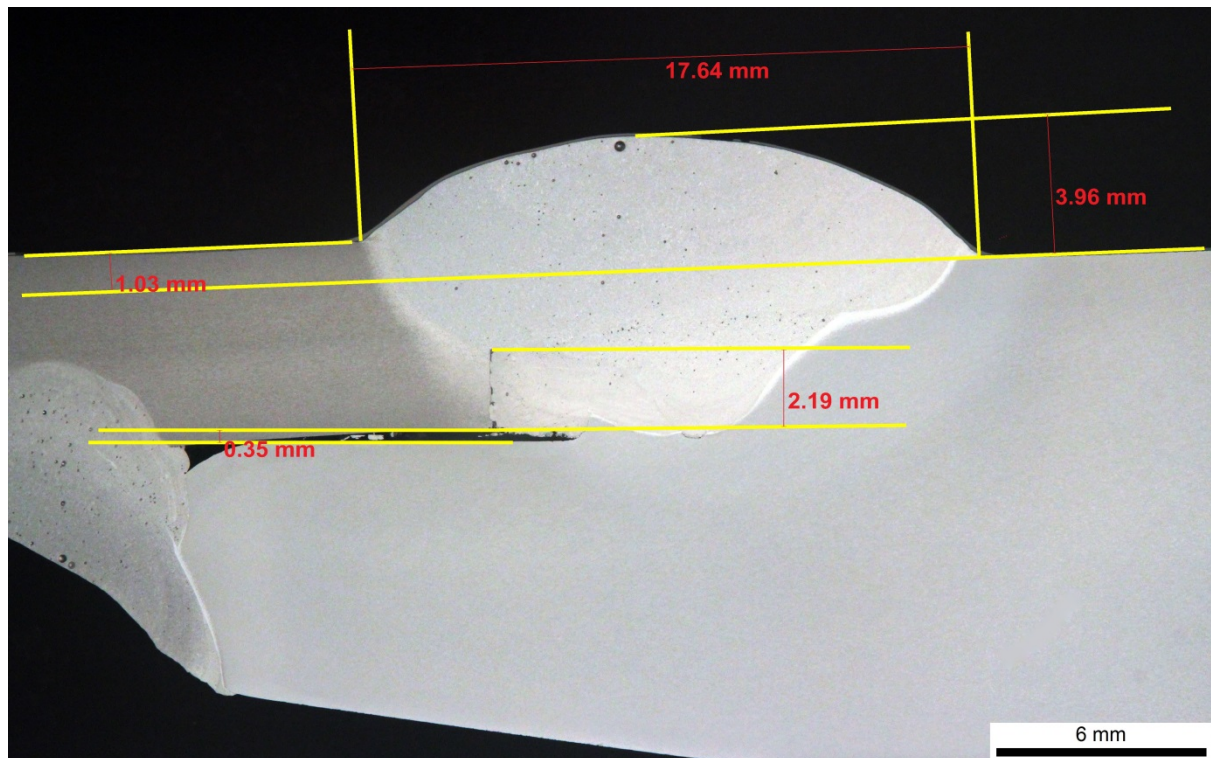


Figure I40 J3564 sample W03-04, slice 4, left side of Figure I39. A significant, 2.19mm high lack of fusion defect is present.

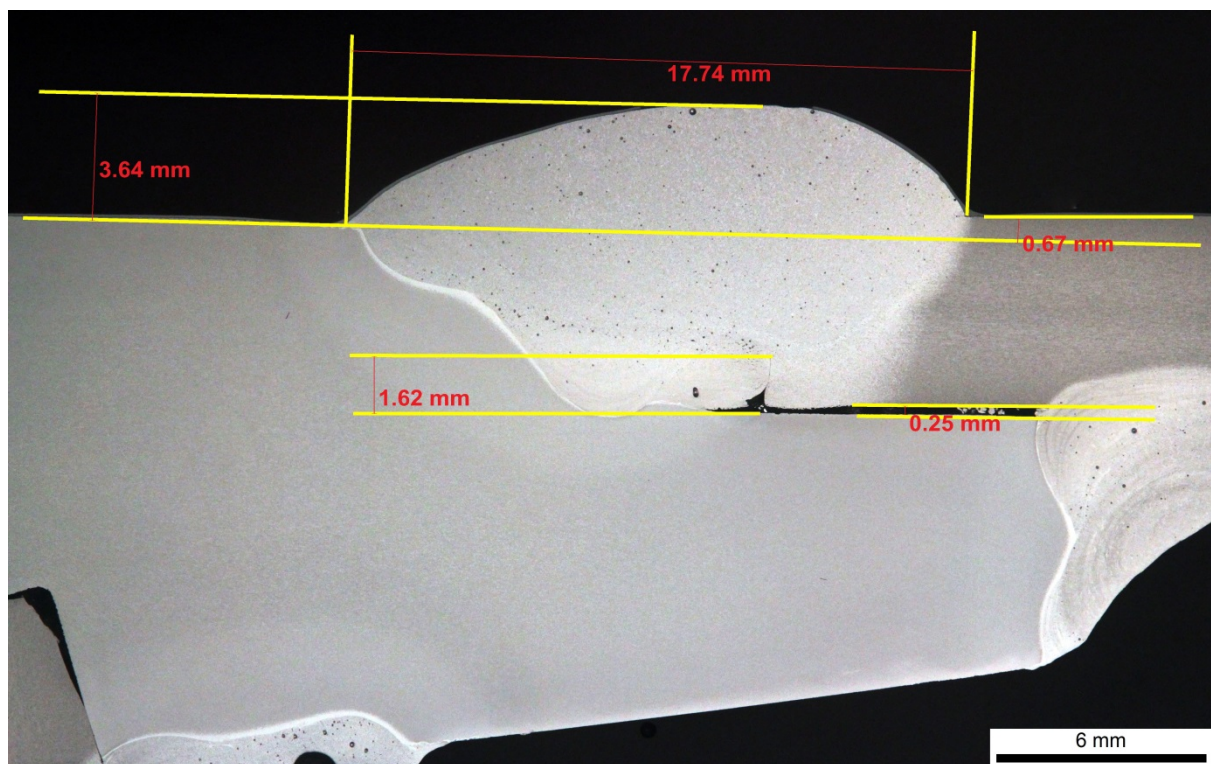


Figure I41 J3564 sample W03-04, slice 4, right side of Figure I39. A significant, 1.62mm high lack of fusion defect is present.

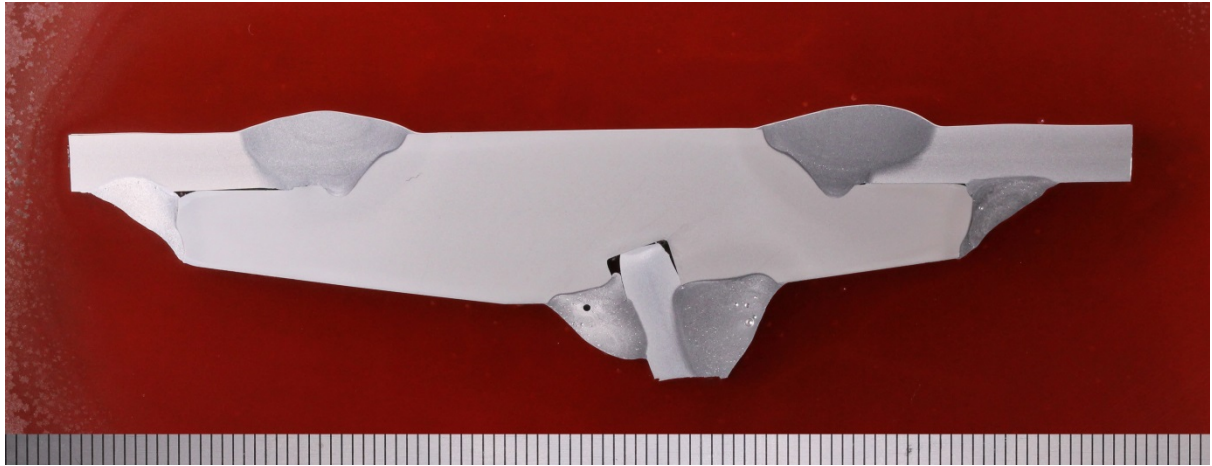


Figure I42 J3564 sample W03-04, slice 5.

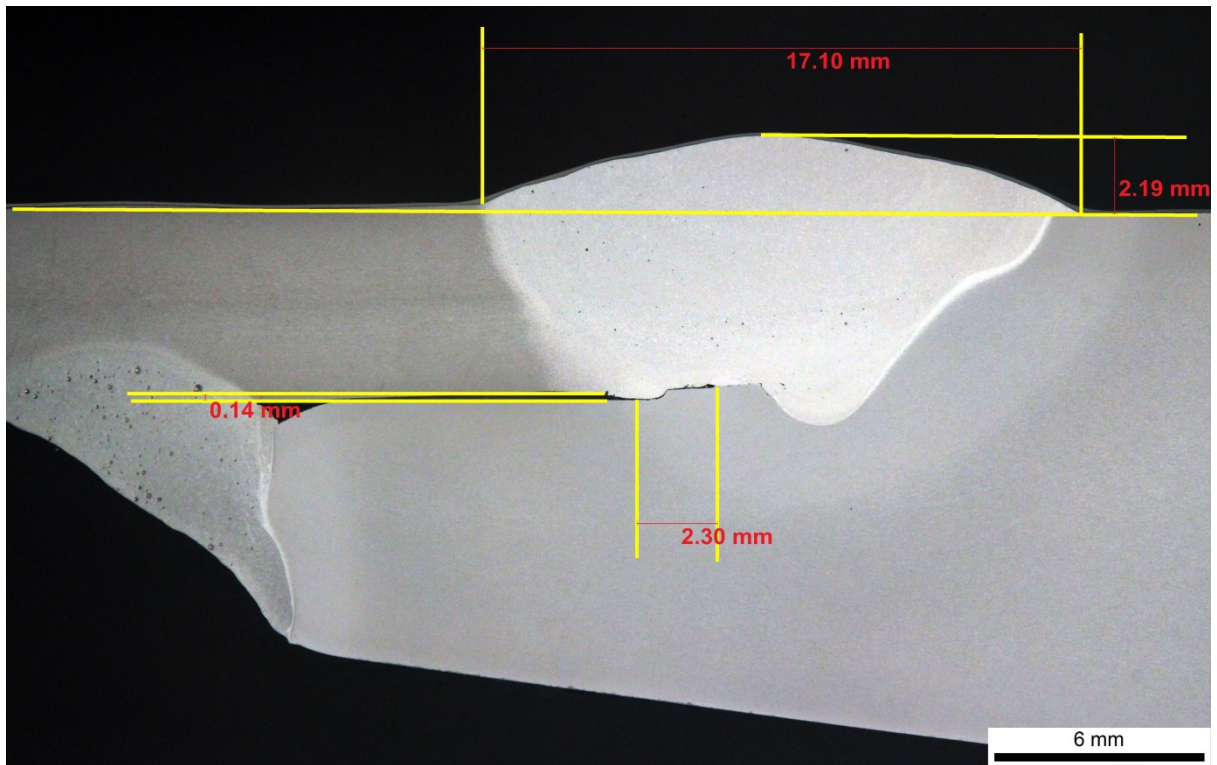


Figure I43 J3564 sample W03-04, slice 5, left side of Figure I42. No significant crack-like defect present.

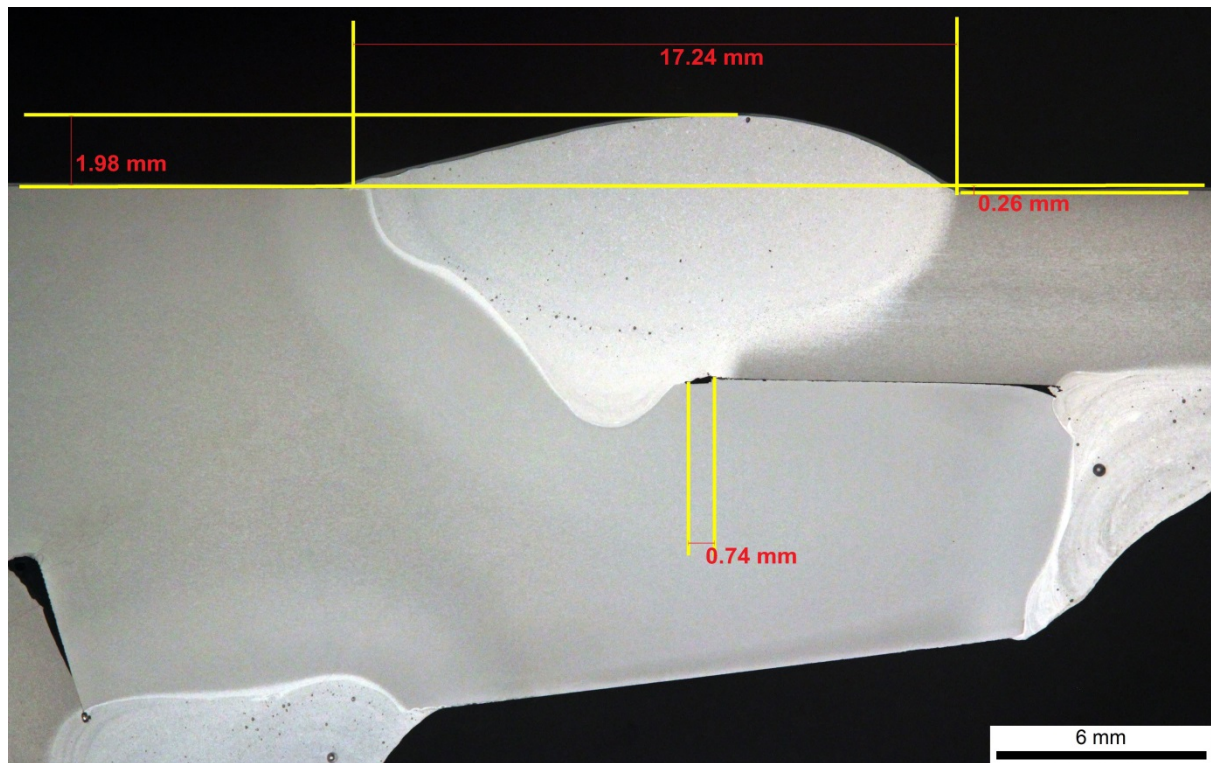


Figure I44 J3564 sample W03-04, slice 5, right side of Figure I42. No significant crack-like defect present.

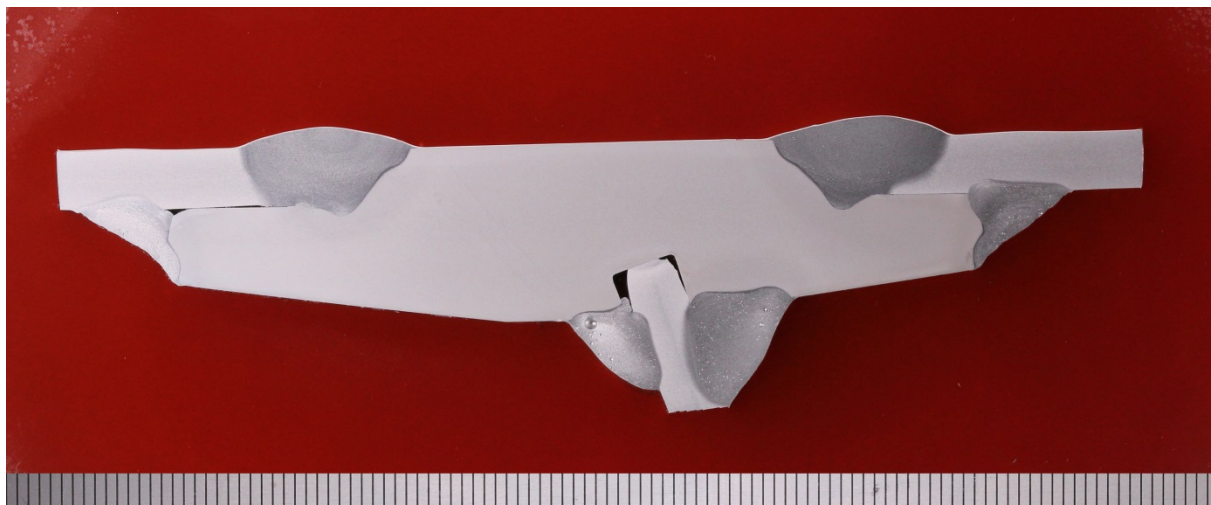


Figure I45 J3564 sample W03-04, slice 6.

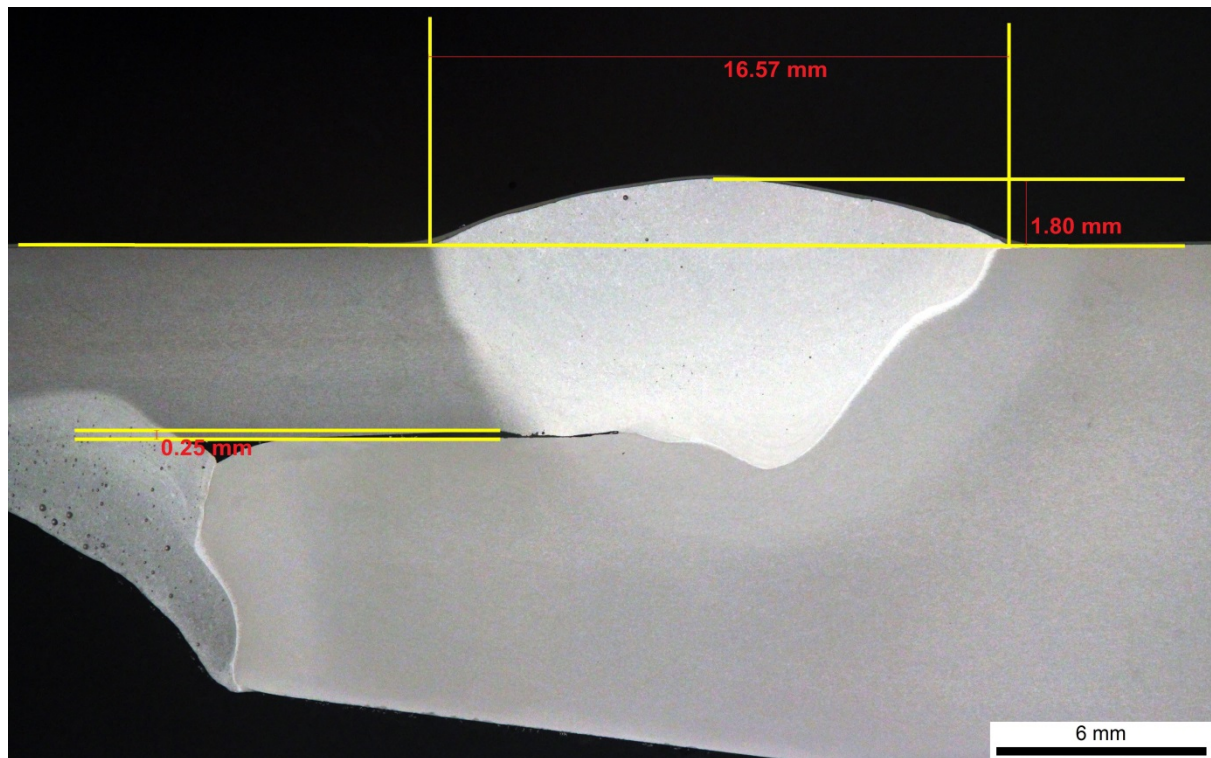


Figure I46 J3564 sample W03-04, slice 6, left side of Figure I45. No significant crack-like defect present.

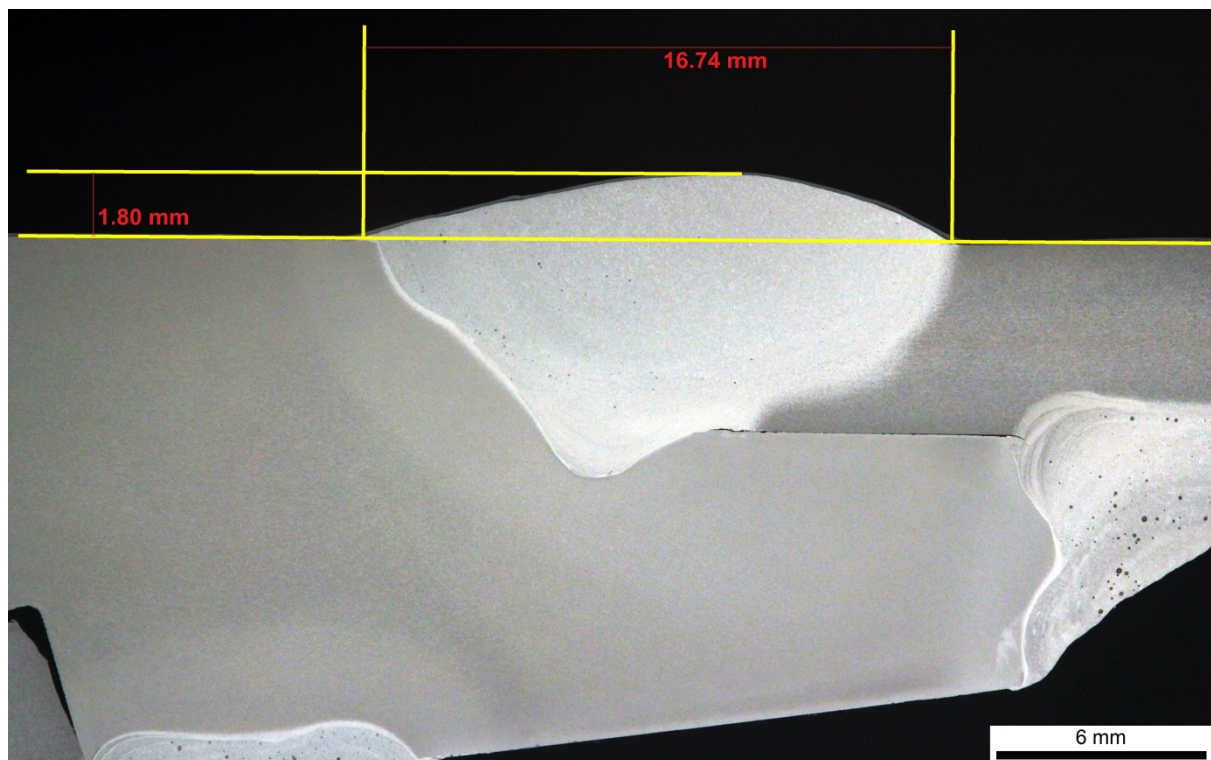


Figure I47 J3564 sample W03-04, slice 6, right side of Figure I42. No significant crack-like defect present.

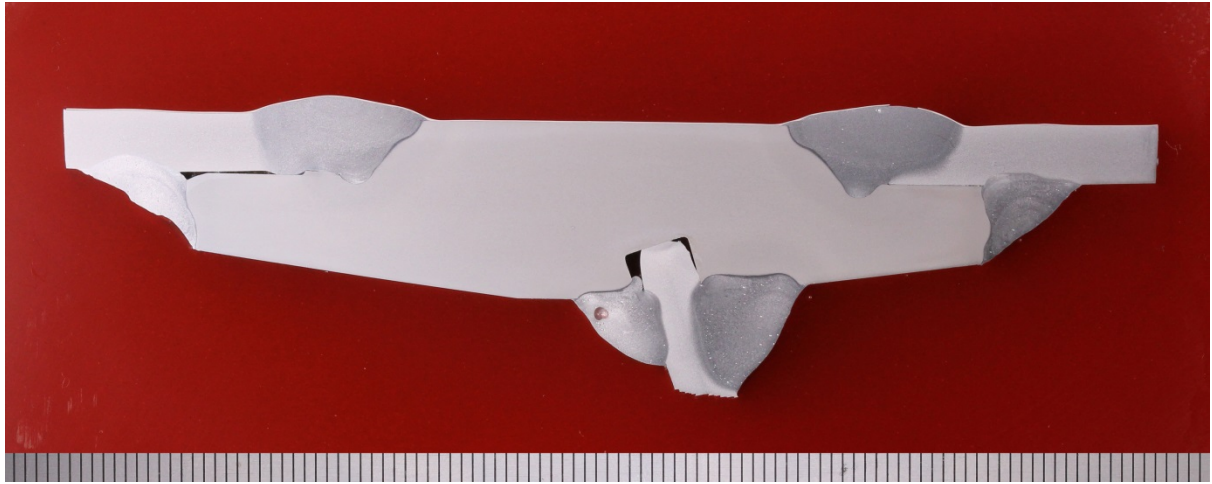


Figure I48 J3564 sample W03-04, slice 7.

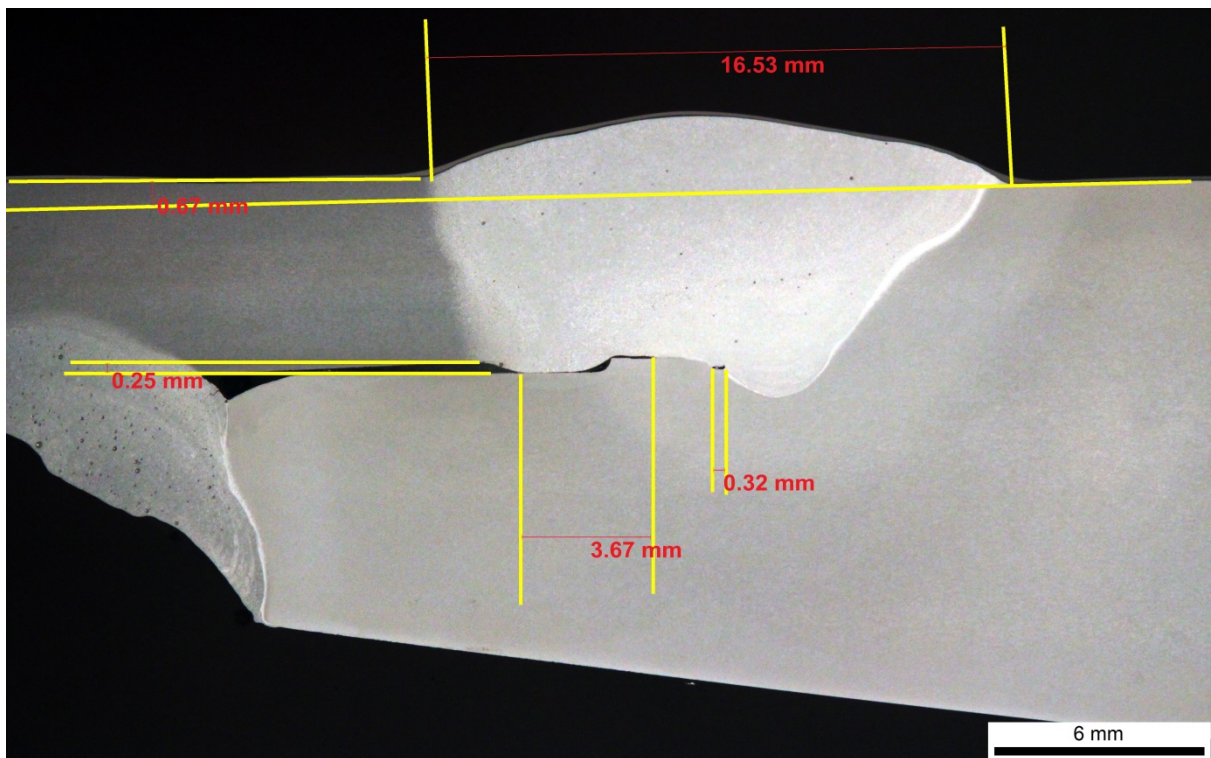


Figure I49 J3564 sample W03-04, slice 7, left side of Figure I48. Small volumetric defect present.

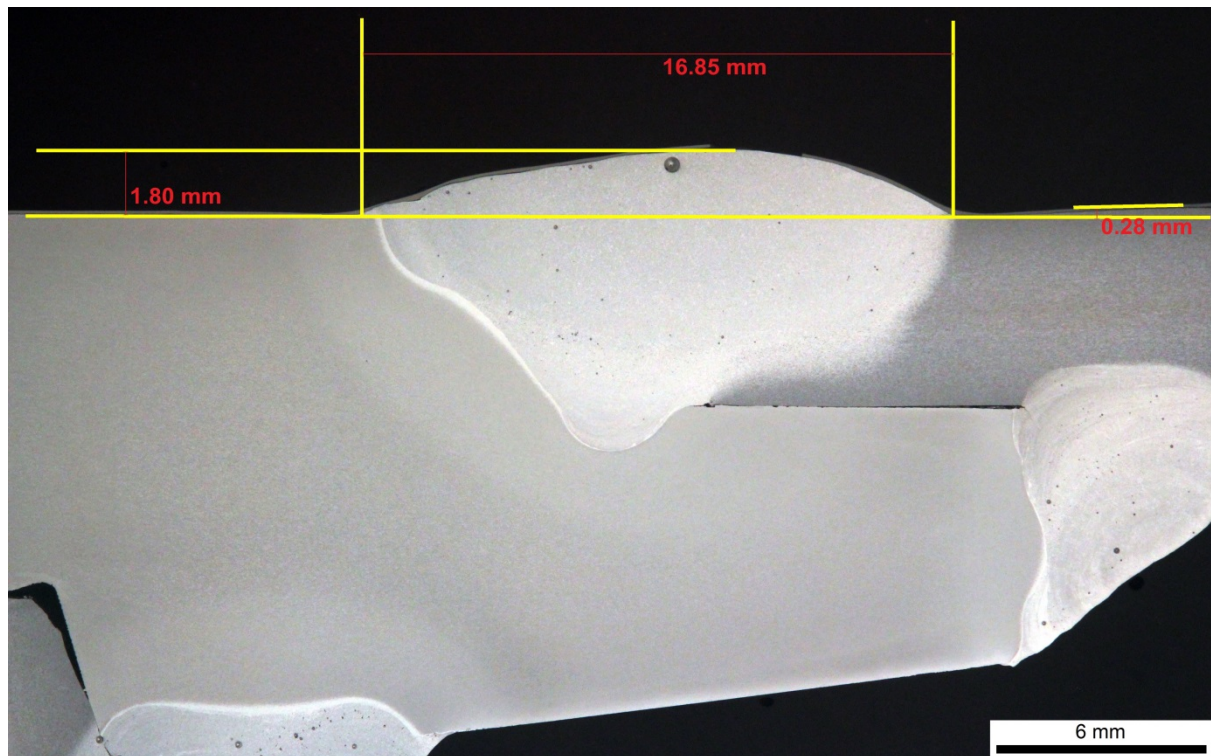


Figure I50 J3564 sample W03-04, slice 7, right side of Figure I48. No significant crack-like defect present.