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Evaluation of Internal Brushing on Pinch Weld Quality

By

P.S. Korinko

December 2005

Westinghouse Savannah River Company
Aiken, SC 29808

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Materials Compatibility and Welding Technology Group

ISSUED: December 2005

SRNL SAVANNAH RIVER NATIONAL LABORATORY, AIKEN, SC 29808
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Evaluation of Internal Brushing on Pinch Weld Quality

Abstract

Post machining operations such as borescope inspection can cause linear indications down the length of the bore of fill stems. Often these indications are removed or obscured using rotary wire brushing. This study evaluated the effect this mechanical operation may have on pinch weld quality when relatively cold welds were made. A total of four stems with two levels of brushing of both Type 304L and 21-6-9 stainless steels were tested. In addition, two each of the Type 304L stems were Nitradd cleaned and the other two were aqueously cleaned; all four 21-6-9 stems were aqueously cleaned. All of the brushed stem areas exhibited more surface anomalies based on borescope evaluation. On average, the bond rating was a higher value (worse) for the brushed areas than the unadulterated areas for both Type 304L and 21-6-9 stems. The test method used may have biased the results towards a lesser quality bond for the brushed areas so additional testing is recommended.

Background

Fill stems for tritium reservoirs have stringent scratch and internal bore inspection criteria. Occasionally, internal defects such as oxide discoloration, smeared metal, linear indications or other near surface anomalies are detected. These anomalies are removed using rotary wire brushing using a small stainless steel brush. The effect of this mechanical action and the resultant surface modification has been assumed to be benign, but no systematic evaluation has been reported. A scoping study was undertaken to evaluate the influence of brushing on the weld quality and in particular on the bond rating. Confined pinch welds using nominal weld conditions for both Type 304L and 21-6-9 stems were made. The stems were examined metallographically and bond rated. In some cases, the welds were examined at the center and other weld “elevations”.

Experimental

LF-7 (Type 304L Stainless Steel) type stems from the Fill Stem Manufacturing and Pinch Weld Processing ADAPT task and 1M (alloy 21-6-9) test stems from the Kansas City Plant (KCP) were mechanically brushed on the foot end of the stem at the KCP using the conditions listed in Table 1. Two cleaning conditions, aqueous cleaning using Oakite cleaner and Nitradd acid cleaning and passivating, and two brushing conditions were used. The fill nubbin end was left unaltered to be used for the baseline metallography.

Welds were made using the SRNL pinch welder at a force of 1250 lbs, a target current of 3650 A, in voltage control mode, and 12 cycles using a 3/16” radius electrode for the LF-7 (Type 304L stainless steel, Ref. 1) type samples and 1200 lbs, a target current of 3300A, 12 cycles, and a 3/32” radius electrode for the 1M (21-6-9) test stems (Ref. 2). These weld conditions represent cool weld conditions that are within the nominal weld parameters for these two alloys. These conditions were selected to exacerbate the effect and make any differences due to the brushing conditions more prominent.

Two welds were made on each stem due to the limited availability of assets; one weld was in the brushed area near the reclamation foot and the other was in the unaltered area near the fill nubbin. Due to fixturing differences in these areas, there are different levels of axial restraint for these welds. The second weld closest to fill nubbin exhibits virtually no restraint while the weld near the foot has typical restraint. The welds were made in the vertical orientation with a simulated or modified reservoir for the LF-7 and 1M stems, respectively for the brushed area. The welds were free to expand for the weld nearest the fill nubbin. The welds near the foot were made by introducing two atmospheres of nitrogen without evacuating the stems prior to introducing the N_2. The fill area of the stems were tested in an atmosphere of flowing nitrogen. The simulated reservoirs provided production-like restraint to the brushed area weld.

The samples were measured for thickness and width, radiographed for weld anomalies, closure length, and extrusion geometry, and examined metallographically for weld quality and bond rating.

Results

Forward-looking borescope images of the typical condition for the internal surfaces of the cleaned and brushed stems are shown in Figure 1. These images show more reflective spots with increased brushing for both Type 304L and 21-6-9 stems. In addition, the baseline areas show fewer spots in the acid cleaned stems compared to the aqueous cleaned stems from either alloy as shown in Figure 2.

The true color tube bore inspection system (TCTBIS) was used to examine “unwrapped” borescope images at the transition between the brushed and unadulterated areas, Figure 3. Based on these images, it is apparent, that brushing increases the number of reflective surface perturbations; these surface perturbations appear as white spots in the images. The transition between the brushed and unadulterated areas is very apparent for the acid cleaned LF-7 stems but less so for the aqueous cleaned stems.

The samples were welded using the conditions listed in Table 2. The weld voltage, current and force were close to the desired target values. All of the LF-7 samples were welded within about $\pm$15 ampere of the target with at range of 22A while the 1M stems were welded between 20 and 36 A lower than target, but within a range of 17 A. The net displacement for the foot welds of the LF-7 was a few mils less than the net displacement for the fill end, while the net displacement for the 1M stems exhibit the reverse trend. In this case, the net displacement at the fill end is a few miles less than the foot end. No conclusions can be drawn from this observation.

Further review of the weld data reveals that both the preweld resistance using a developmental method (Ref. 3) and the calculated post weld resistance values are higher for the brushed stems, simple statistical examination using the Student t-test indicates that the data do not exhibit the same mean (Ref. 4). These results for calculated resistance are supported by the measured weld voltages being higher for the brushed areas than for the unadulterated areas of the stems. The significance of this difference is not immediately apparent and may be attributable to fixturing differences, internal surface differences, or other process variations. It is interesting to note that the modified resistance test can detect set-up differences. Review of similarly fixtured fill stems indicates that the dynamic resistance for Type 304L SS welds should be in the range of 0.218 $\pm$ .005 mΩ, or within the reported range for the foot end welds.

Dimensional weld quality metrics, such as closure length and weld thickness, are presented in Table 3. The closure lengths and weld thickness are consistent with expectations for these weld conditions. Note that the closure length for the foot end is longer than for the fill end. This is likely due to the presence of restraint on the foot end and its absence on the fill end. The restraint is expected to increase the weld heat moderately but not allow as much free expansion which increases the weld length.

Typical film radiographs of selected welds are shown in Figure 4. The welds are clearly visible in the images, but little quality information is notable. As indicated by the data in Table 3, the 21-6-9 welds were relatively cold since they do not exhibit any extrusion, although they all pass the 10 mil ball test indicating that they are acceptable welds. Three of the four LF-7 foot end welds exhibited split extrusions. Split extrusions are typically associated with either hot welds or surface contamination that impedes bonding at the ends of the weld.

Metallographic examination of the transverse sections of the pinch welds was conducted for sections near the weld center. The bond rating data are provided in Table 3. The micrographs for the Type 304L stainless steel LF-7 stems are shown in Figures 5-12 for brushed and unadulterated and for aqueous and acid cleaned surfaces. Figures 5 and 6 show the lightly and heavily brushed aqueous cleaned stems, respectively. Neither of these stems have acceptable bond quality with ratings of 3 and 4. Figures 7 and 8 are images from the lightly and heavily brushed acid cleaned stems. Both these stems were rated 4. Contrary to plan, stem X0040 is not at the weld centerline and so the weld quality may be slightly biased and the welds tend to be slightly better near the center. Figures 9-12 show, contrary to expectation, that the acid cleaned stems exhibit a worse bond rating than the aqueous cleaned stems, with bond ratings of 3 and 2, respectively for the unadulterated areas.

The micrographs for the 1M style 21-6-9 stems are shown in Figures 13-20. All of these stems were aqueous cleaned only. The bond rating data are presented in Table 3. The bond ratings for the brushed areas are worse for two of the stems compared to the unadulterated areas and the other welds were rated the same for the brushed and unadulterated areas. Despite these minor variations stem to stem, the brushed areas exhibit more class 3 bonds than the unadulterated areas. The extent of brushing does not seem to adversely affect the bond rating since a heavily brushed area exhibits a class 2 bond compared to the class 3 for all the other brushed area welds.

Discussion

Considering all these results suggests that brushing may adversely affect the bond rating. However, there are some concerns that the method used to weld the stems may have biased the results for the worse. The lack of evacuation prior to backfilling with nitrogen may promote a heavier bond line while the continuous flow of nitrogen for the baseline welds may have provided a better purge. It has been recently shown as well as previously known, that the atmosphere between air and an inert gas can affect the bond rating by some amount (Ref. 3-5).

Summary

Brushing the fill stems increases that appearance of reflective spots visible in the borescope. The acid cleaned LF-7 stems were nearly free of these reflective spots. The reflective spot density increased with increased brushing for both LF-7 and 1M style stems. The aqueous cleaned stems exhibited a nearly uniform distribution of these spots.

The restrained welds on the foot of the fill stems had longer closure lengths than the welds near the fill nubbin that were largely unrestrained.

The combination of cleaning and brushing resulted in worse bond ratings for the welds made in the brushed areas than in the unadulterated areas for both Type 304L stainless steel and 21-6-9.

Due to less than ideal weld practices for the welds in the brush area, the influence of brushing on pinch welds can not be unequivocally stated. Additional testing is recommended with better controlled weld practice for the internal atmosphere to ascertain whether brushing is as damaging to pinch welds as suggested by this study.

Acknowledgements

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Table 1. Stem brushing condition

Matl	Condition	Brush Cycles	Brush Current	Brush Feed	Clean	S.N	Part no
304L	Light (L)	1	3600	50	Aq	X0045	PRJ706566-102
304L	Heavy (H)	5	3600	100	Aq	X0037	PRJ706566-102
304L	Light (L)	1	3200	100	Nit	X0048	PRJ706566-102
304L	Heavy (H)	5	3200	50	Nit	X0040	PRJ706566-102
21-6-9	Light (L)	1	3200	50	Aq	10012	7K0101-01
21-6-9	Light (L)	1	3200	100	Aq	10057	7K0101-00
21-6-9	Heavy (H)	5	3600	50	Aq	10008	7K0101-00
21-6-9	Heavy (H)	5	3600	100	Aq	10006	7K0101-00

Brush current is related to rotary speed, Aq is aqueous cleaned, Nit is nitradd cleaned.

Table 2. Weld Conditions and machine data

LF-7-Like Stems Type 304L												
ID	Loc.	Clean	Brush	Actual Voltage (V)	Actual Force (Lbs)	Pressure (psi)	Preweld Res. (mΩ)	Postweld Res. (mΩ)	Actual Current (A)	Energy (J)	Weld Voltage (V)	Net Displ. (in)
X0045	Foot	Aq	L	365.87	1256	108.83	0.276	0.216	3640.7	556.8	0.7900	0.0189
X0037	Foot	Aq	H	365.87	1255	108.80	0.271	0.217	3636.3	543.3	0.7900	0.0193
X0040	Foot	Nit	L	366.09	1254	108.70	0.267	0.215	3639.3	554.5	0.7800	0.0193
X0048	Foot	Nit	H	366.02	1253	108.65	0.271	0.217	3639.3	546.1	0.7900	0.0190
X0045	Fill	Aq	N	365.82	1254	108.80	0.239	0.204	3657.7	537.8	0.7500	0.0206
X0037	Fill	Aq	N	365.79	1255	108.88	0.244	0.204	3656.1	536.3	0.7500	0.0213
X0040	Fill	Nit	N	365.41	1255	108.89	0.243	0.205	3652.8	526.4	0.7500	0.0204
X0048	Fill	Nit	N	365.19	1254	108.76	0.240	0.205	3652.1	535.7	0.7500	0.0208
1M-Like stems 21-6-9												
ID	Location	Clean		Actual Voltage (V)	Actual Force (Lbs)	Pressure (psi)	Preweld Res. (mΩ)	Postweld Res. (mΩ)	Actual Current (A)	Energy (J)	Weld Voltage (V)	Net Displ. (in)
10012	Foot	Aq	L	333.12	1203	104.55	0.311	0.221	3264.3	452.3	0.72	0.0295
10057	Foot	Aq	L	333.18	1204	104.74	0.309	0.222	3266.5	455.9	0.73	0.0290
10006	Foot	Aq	H	333.23	1204	104.53	0.304	0.221	3268.4	454.5	0.72	0.0303
10008	Foot	Aq	H	332.99	1204	104.55	0.315	0.226	3267.2	454.3	0.74	0.0280
10012	Fill	Aq	N	332.79	1206	104.82	0.270	0.217	3276.2	457.3	0.71	0.0241
10057	Fill	Aq	N	332.70	1206	104.80	0.275	0.218	3268.1	443.6	0.71	0.0254
10006	Fill	Aq	N	332.70	1206	104.80	0.269	0.218	3268.5	429.2	0.71	0.0249
10008	Fill	Aq	N	333.09	1206	104.82	0.281	0.217	3280.9	457.4	0.71	0.0247

Target conditions: LF-7 type: 366 V, 3650 A, 12 cycles, 1250 lbs, 3/16" radius electrodes. 1M type: 333 V, 3300 A, 12 cycles, 1200 lbs, 3/32" electrodes. Aq is aqueous cleaned, Nit is nitradd cleaned, L is lightly brushed, H is heavily brushed, and N is not brushed (unadulterated)

Table 3. Weld quality information

LF-7-Like Stems Type 304L								
ID	Location, Clean, Brush	closure length	Max extr	10 mil ball	comments	Thickness	Bond rating	Comments
X0045	Foot, Aq, L	0.159	0.006	NA	Split	0.052	3	Thin cont. bond line
X0037	Foot, Aq, H	0.160	0.007	NA	Split	0.055	4	Thick cont. bond line
X0040	Foot, Nit, L	0.155	0.004	NA		0.054	4	Thick cont. bond line
X0048	Foot, Nit, H	0.156	0.007	NA	Split	0.053	4	Thick continuous bond line
X0037	Fill, Aq, N	0.151	0.001	NA		0.053	2	Discrete bond line
X0045	Fill, Aq, N	0.150	0	Y		0.052	2	Discrete bond line
X0040	Fill, Nit, N	0.150	0	Y		0.053	3	Thin cont. bond line
X0048	Fill, Nit, N	0.158	0.001	NA		0.053	3	Thin cont. bond line
1M-Like stems 21-6-9								
ID	Location, Clean, Brush	closure length	Max extr	10 mil ball	comments	Thickness	Bond rating	Comments
10012	Foot, Aq, L	0.128	0	Y		0.040	3	Thin cont bond line
10057	Foot, Aq, L	0.129	0	Y	Not at weld center	0.041	3	Thin cont. bond line
10057	Foot, Aq, L	0.129	0	Y	At weld center	0.041	2	Some breaks in bond line
10006	Foot, Aq, H	0.126	0	Y	Not at weld center	0.041	3	Thin cont. bond line
10006	Foot, Aq, H	0.126	0	Y	At weld center	0.041	3	Thin cont. bond line
10008	Foot, Aq, H	0.121	0	Y		0.042	2	Discrete bond line
10012	Fill, Aq, N	0.116	0	Y		0.040	2	Discrete bond line
10057	Fill, Aq, N	0.121	0	Y	Not at weld center	0.041	2	Discrete bond line
10006	Fill, Aq, N	0.123	0	Y		0.041	3	Discrete bond line
10008	Fill, Aq, N	0.113	0	Y		0.040	2	Discrete bond line

Aq is aqueous cleaned, Nit is nitradd cleaned, L is lightly brushed, H is heavily brushed, and N is not brushed (unadulterated), cont. is continuous none bond line, note 10057 at centerline is marginal for discontinuities in bond line.

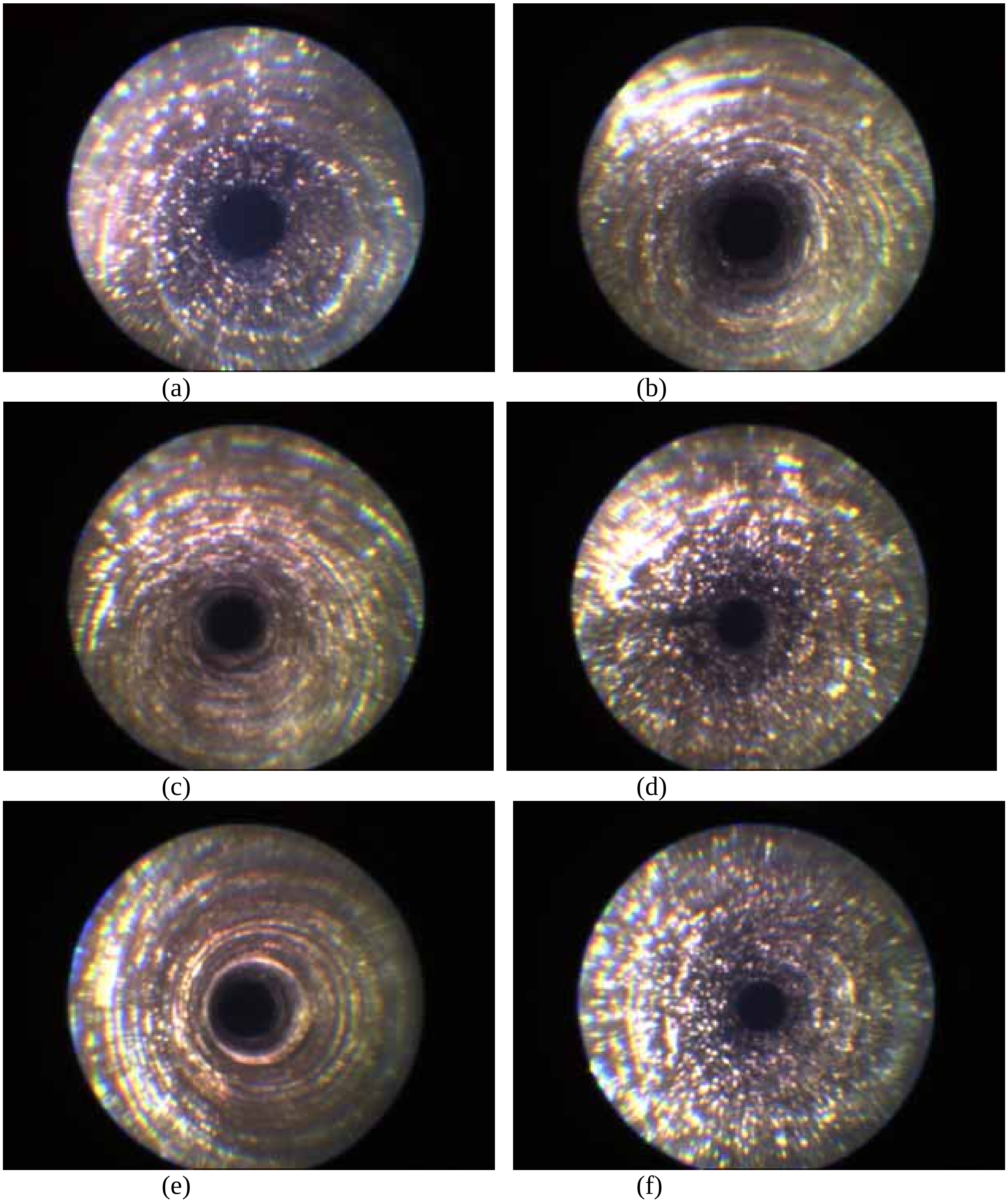
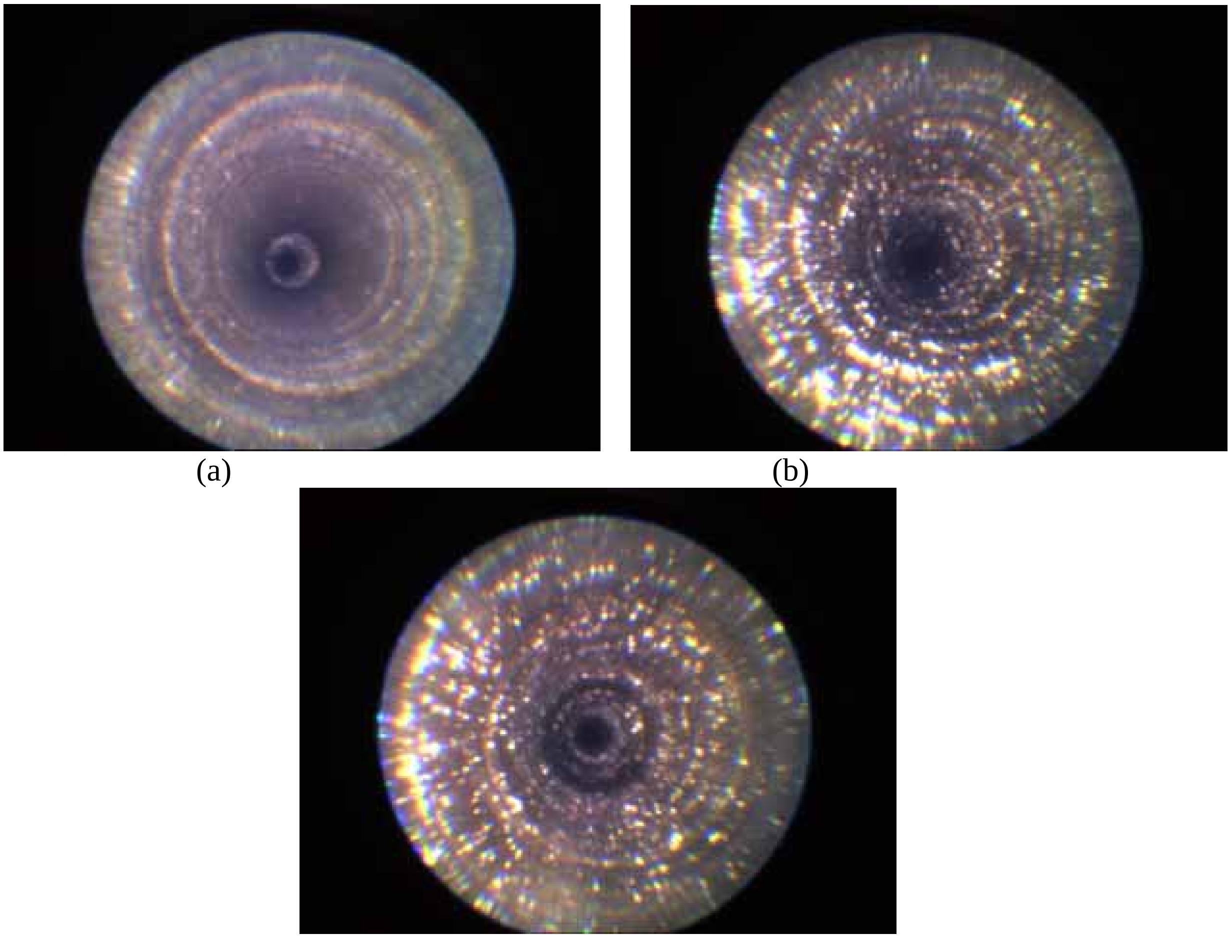
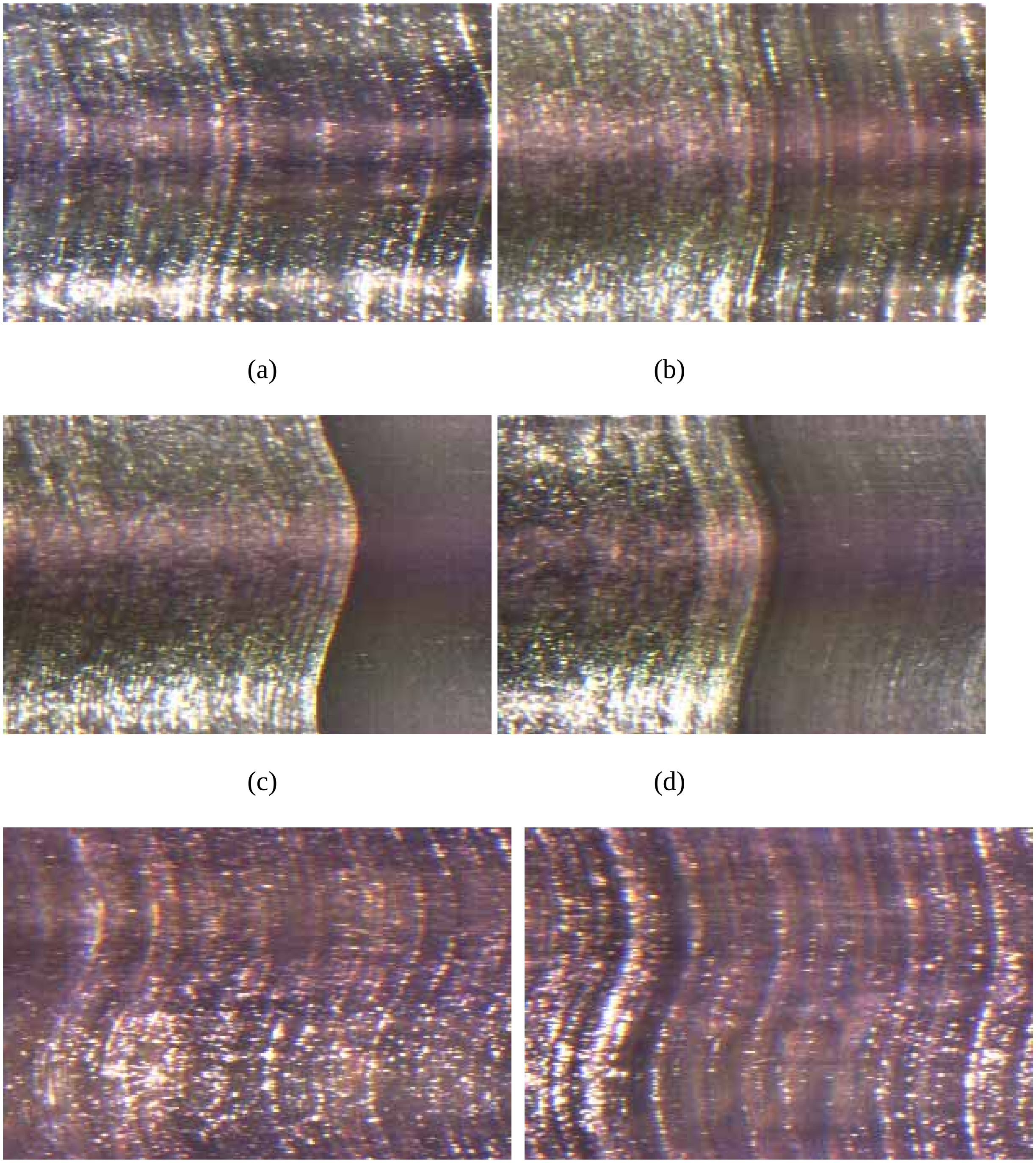


Figure 1. Forward looking borescope images typical of (a) aqueous cleaned, lightly brushed, X0045, Type 304L (b) aqueous cleaned heavily brushed, X0037, Type 304L, (c) acid etched, lightly brushed, X0048, Type 304L (d) acid etched heavy brushed X0040 LF-7 stems and (e) aqueous cleaned, lightly brushed, 10012 21-6-9 and (f) aqueous cleaned, heavily brushed, 10008 21-6-9 test stems.



(a) (b) (c)

Figure 2. Forward looking borescope images of (a) Nitradd cleaned (acid etched) LF-7, X0040, Type 304L (b) aqueous cleaned LF-7, X0045, Type 304L and (c) aqueous cleaned 1M, 10057, 21-6-9 stems in the unaffected zone.

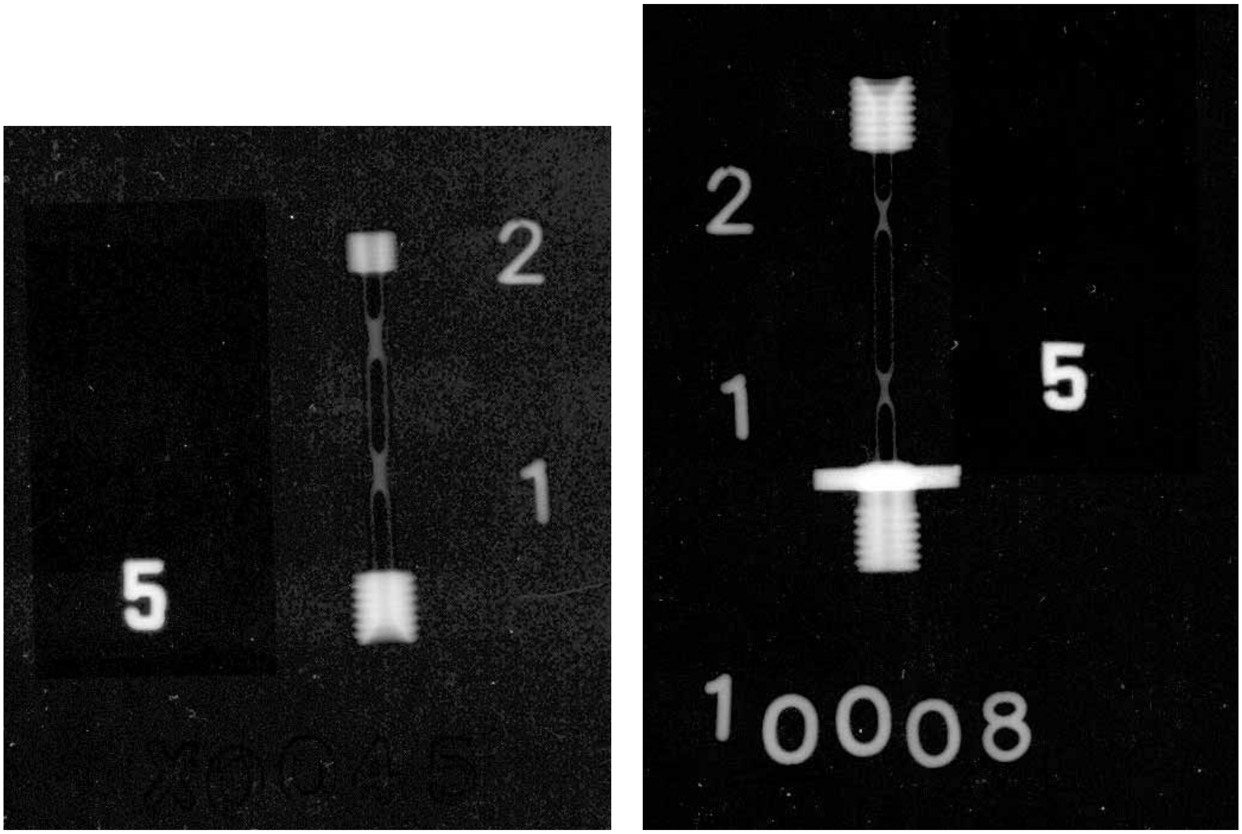


(a) (b)

(c) (d)

(e) (f)

Figure 3. Unwrapped borescope images typical of (a) aqueous cleaned lightly brushed stem X0045 (b) aqueous cleaned heavily brushed stem X0048 (c) Nitradd cleaned (acid etched) lightly brushed stem X0037 and (d) Nitradd cleaned (acid etched) heavily brushed stem X0040 for Type 304L LF-7 samples and (e) aqueous cleaned lightly brushed stem 10012 and (f) aqueous cleaned heavily brushed stem 10008 for 21-6-9 samples all near the transition zone.



(a) (b)

Figure 4. Film radiographs of the two stem types showing the relative placement of the welds, (a) X0045 and (b) 10008.

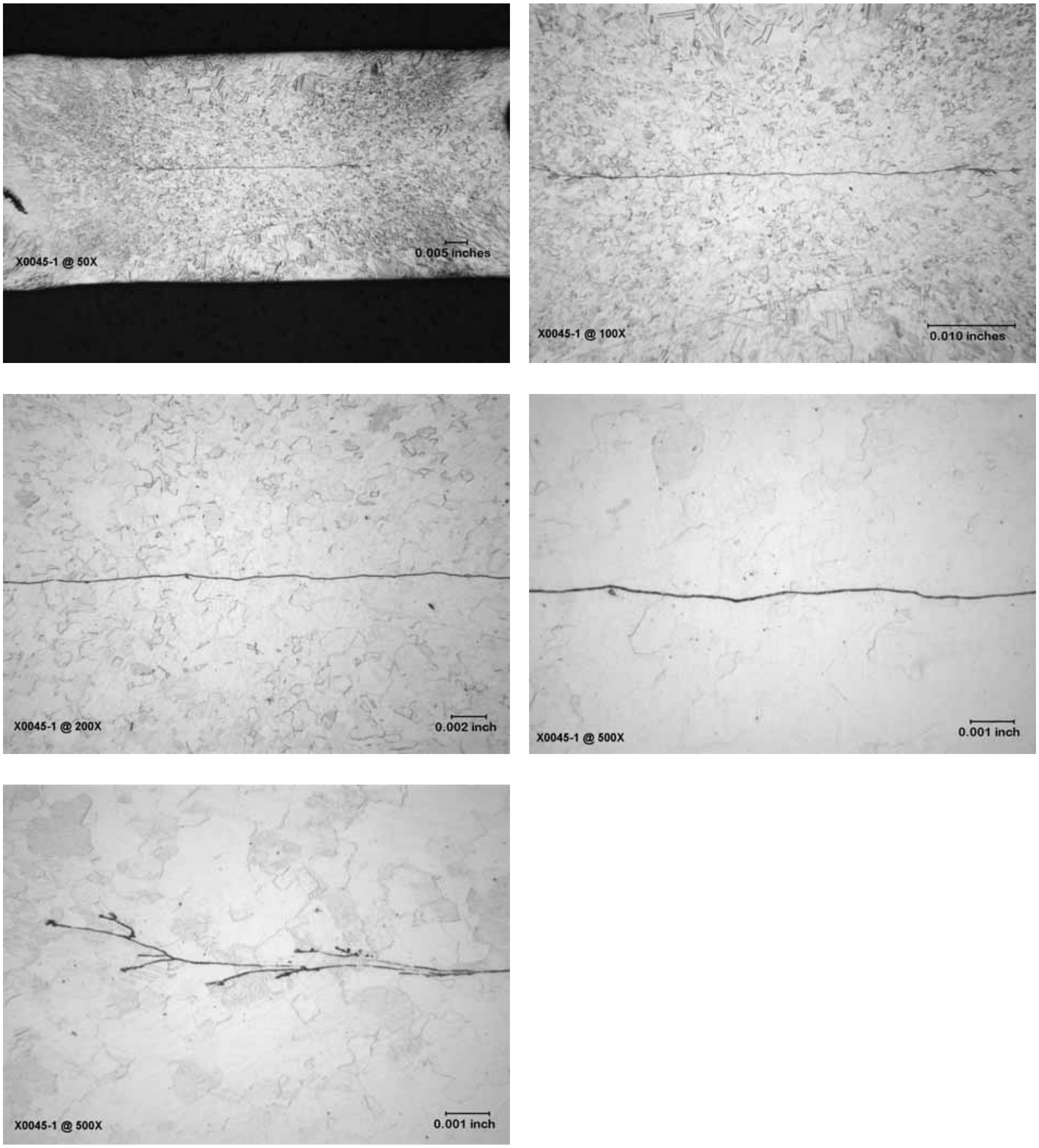


Figure 5. X0045, lightly brushed, aqueous cleaned, Type 304L SS, bond rating 3.

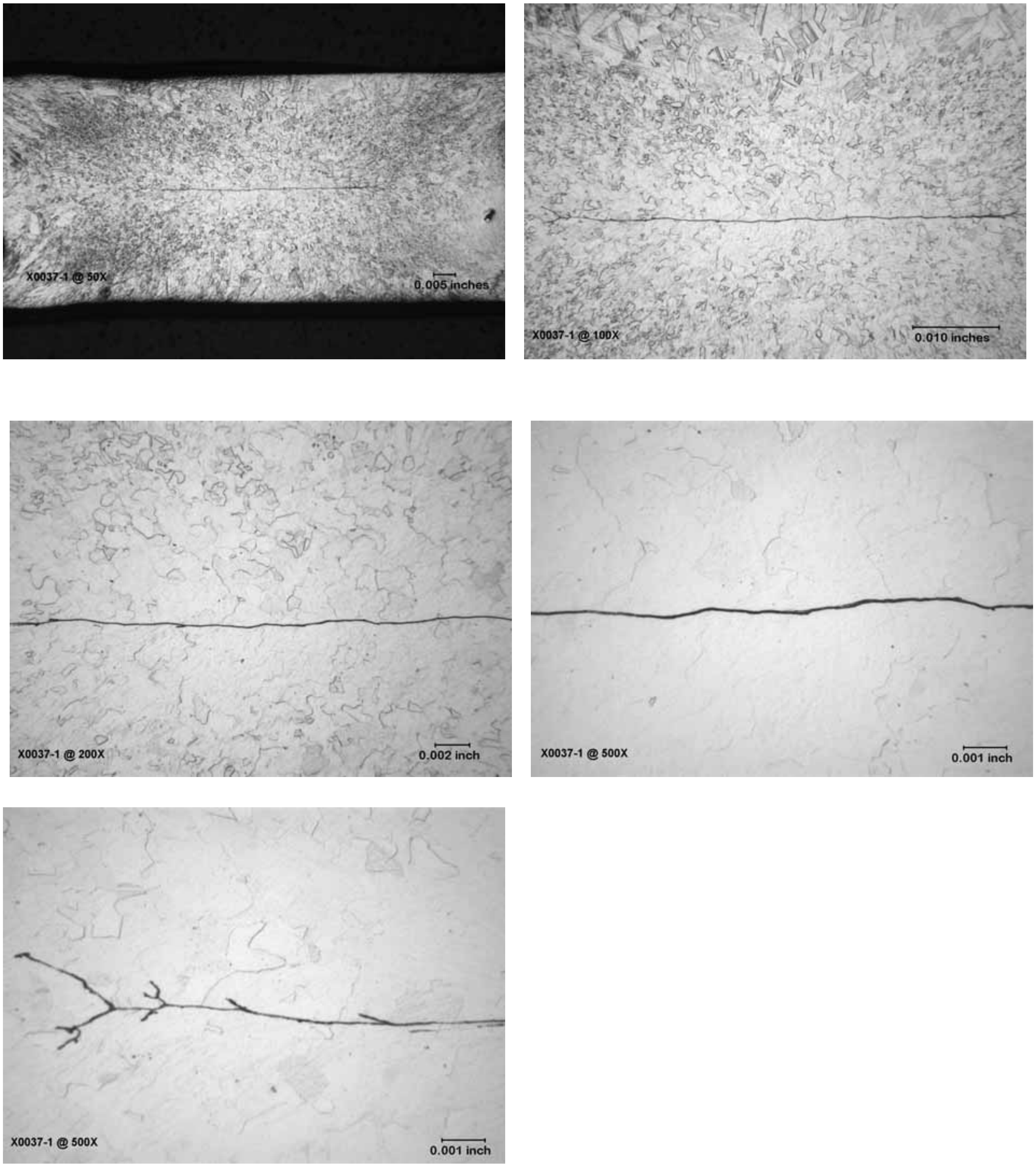


Figure 6. X0037, heavily brushed, aqueous cleaned, Type 304L SS, foot end, bond rating 4.

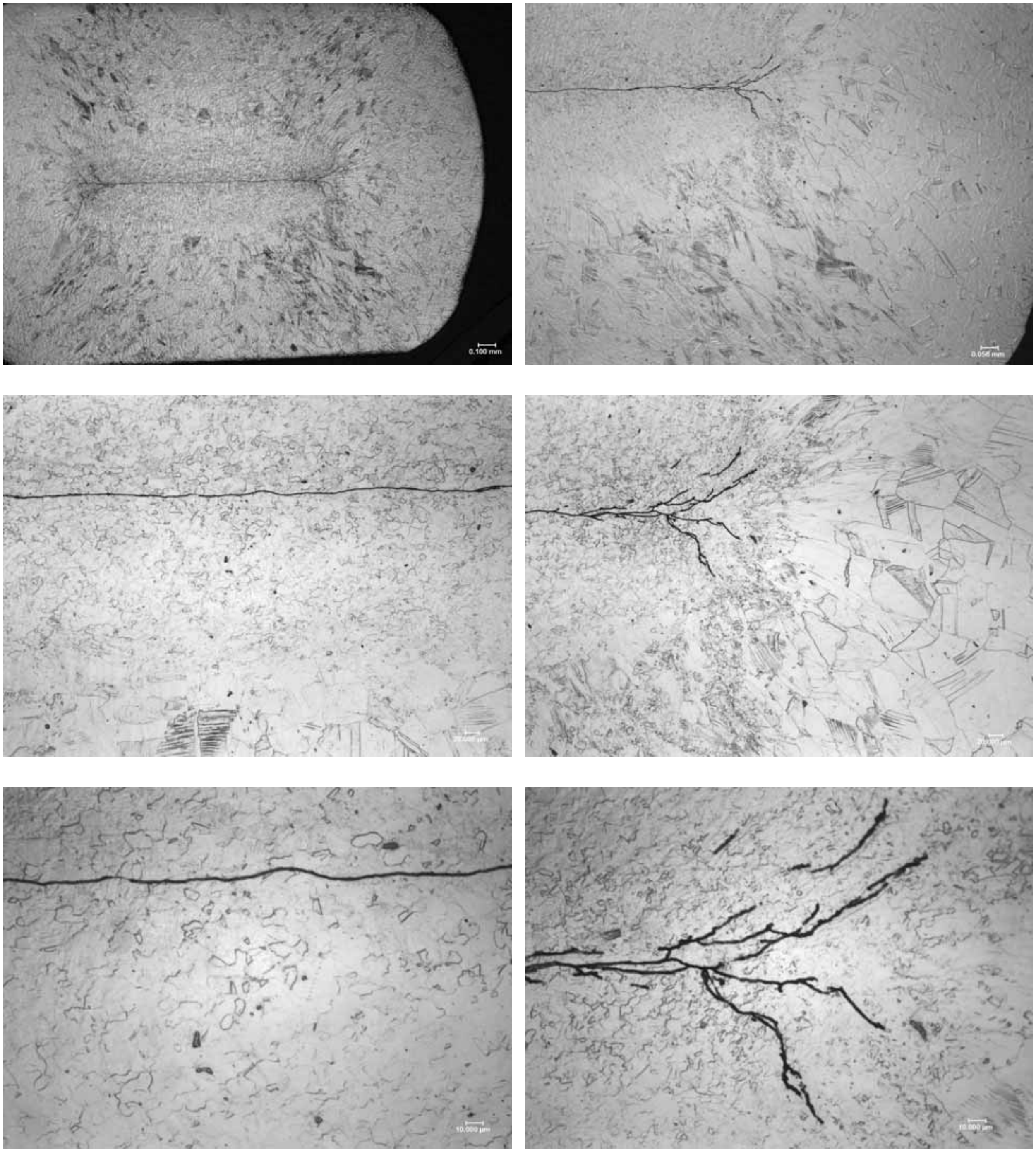


Figure 7. X0040, lightly brushed, Nitradd cleaned (acid etched), Type 304L, not in center of weld, foot end, bond rating 4.

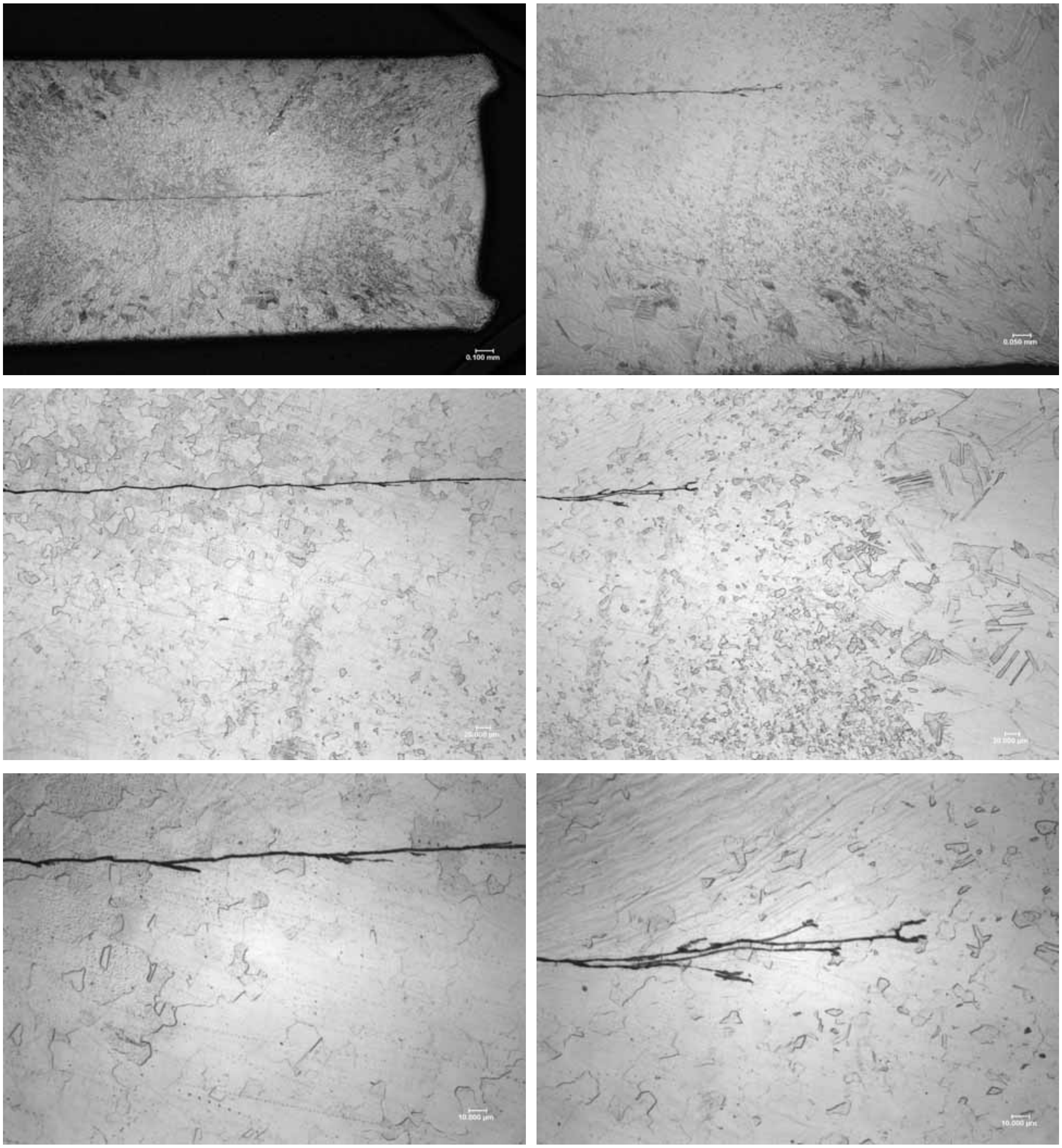


Figure 8. X0048, heavily brushed, Nitradd cleaned (acid etched), Type 304L, foot end, bond rating 4.

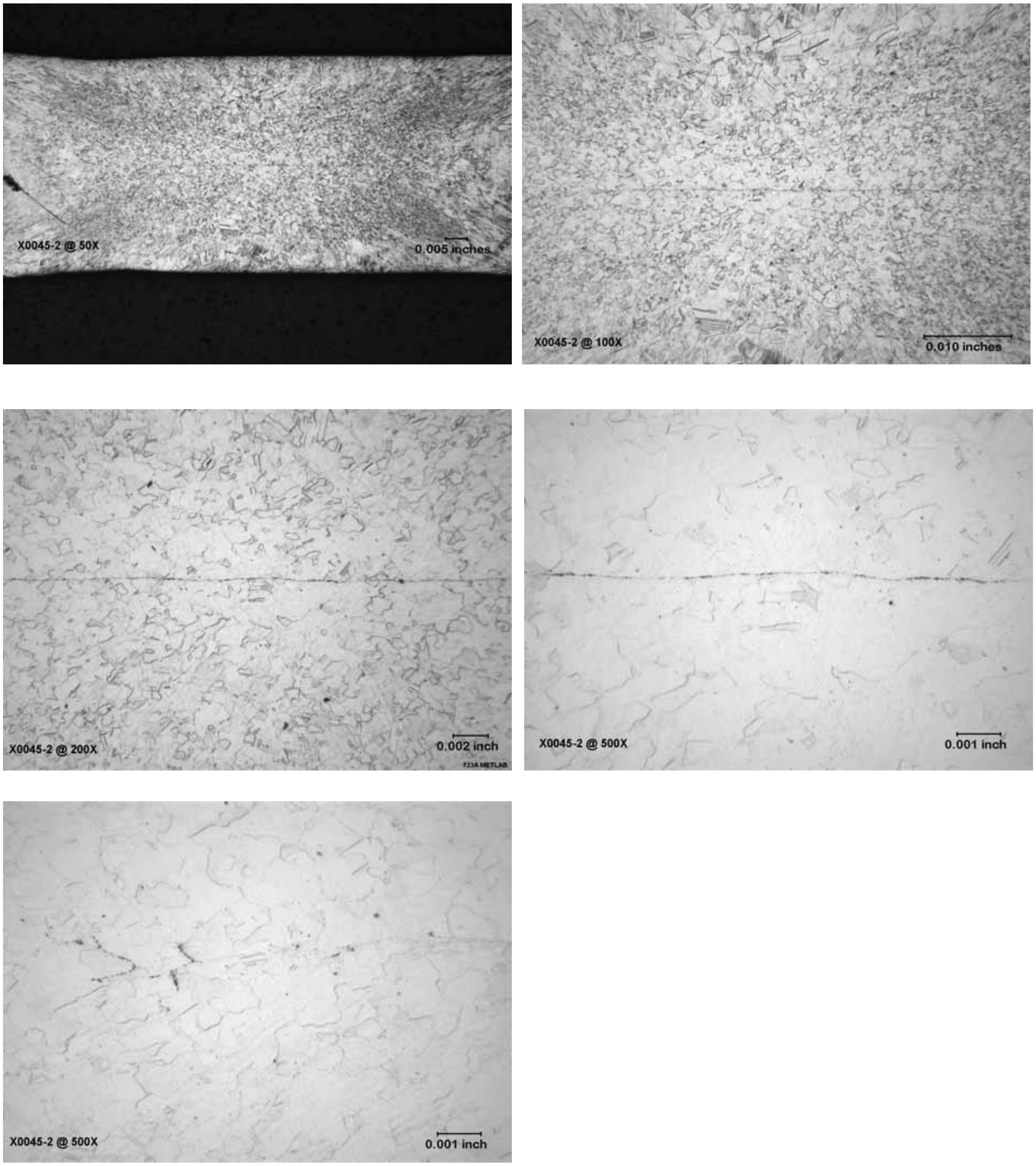


Figure 9. X0045, unadulterated area, aqueous cleaned, Type 304L SS, fill end, bond rating 2.

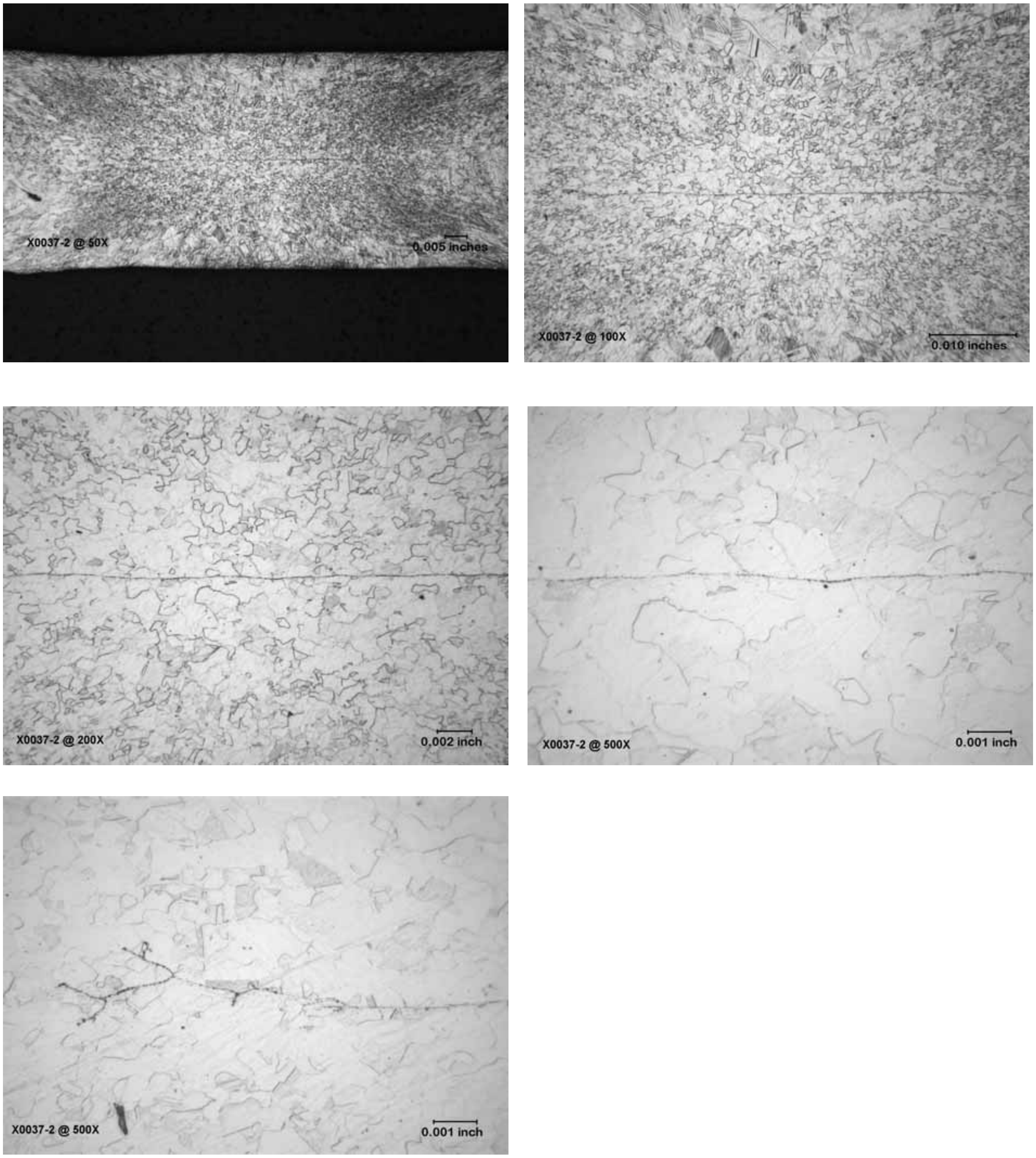


Figure 10. X0037, unadulterated area, aqueous cleaned, Type 304L SS, fill end, bond rating 2

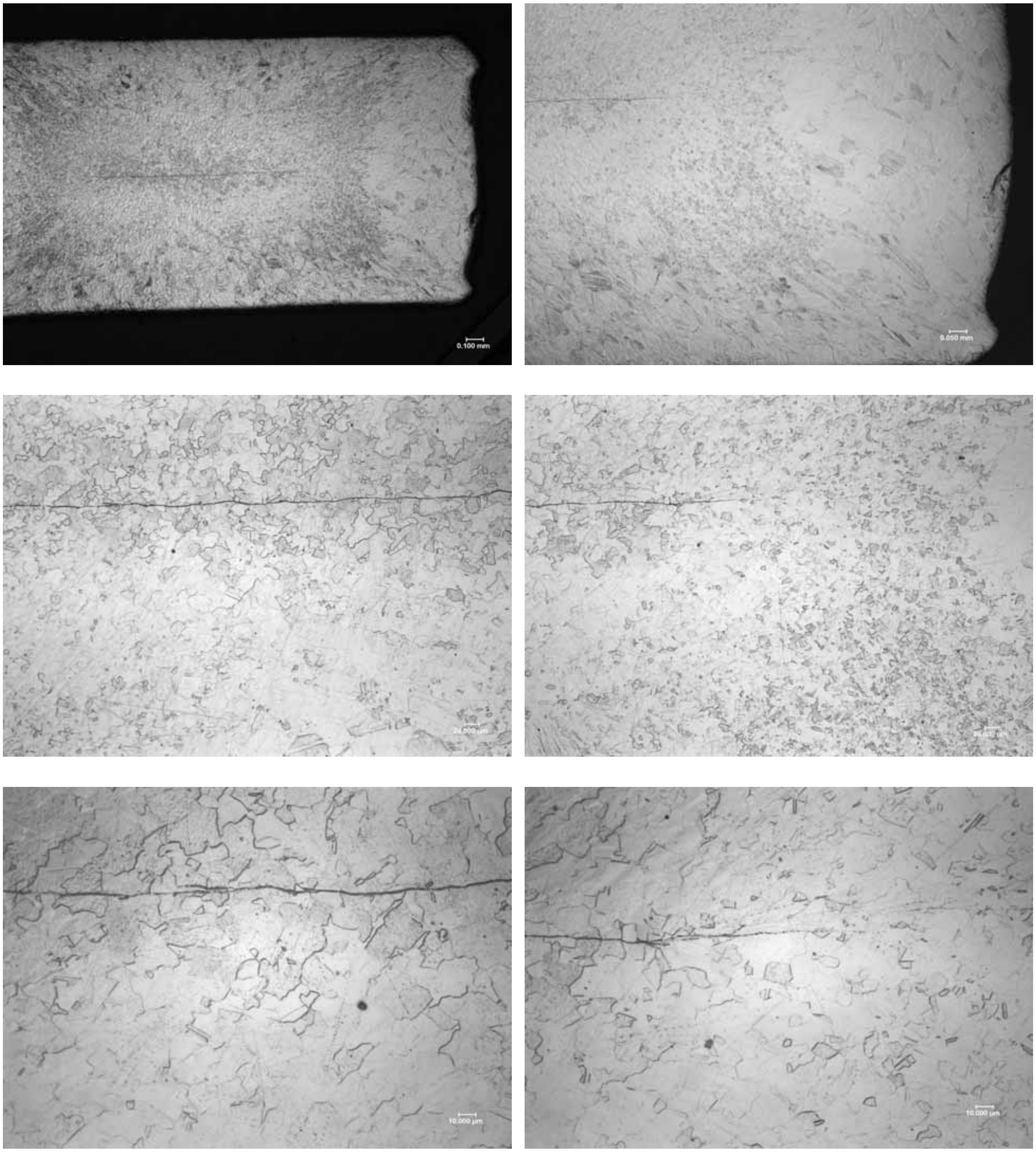


Figure 11. X0040, unadulterated area, Nitradd cleaned (acid etched), Type 304L, fill end, bond rating 3.

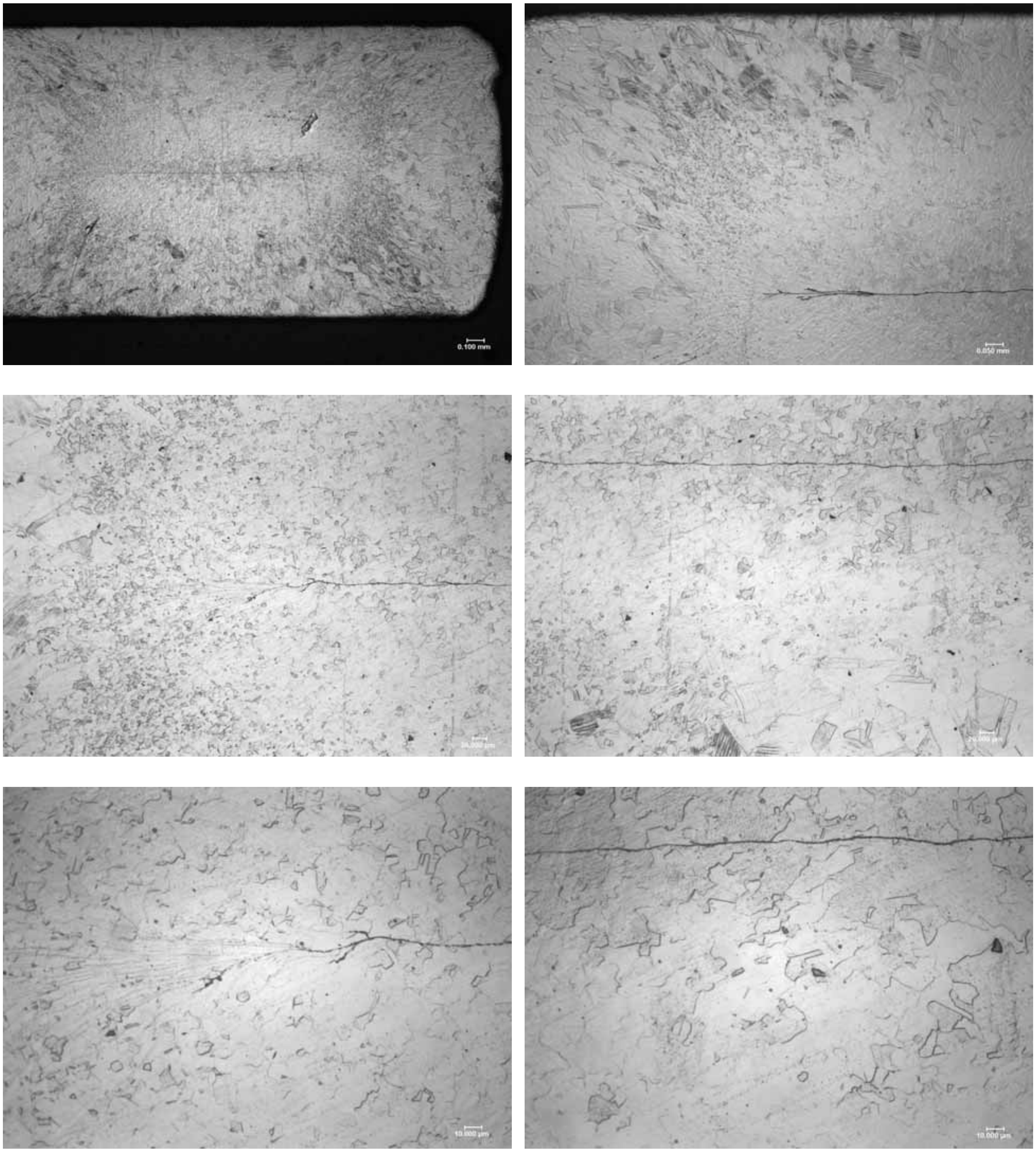


Figure 12. X0048, unadulterated area, Nitradd cleaned, Type 304L, fill end, bond rating 3.

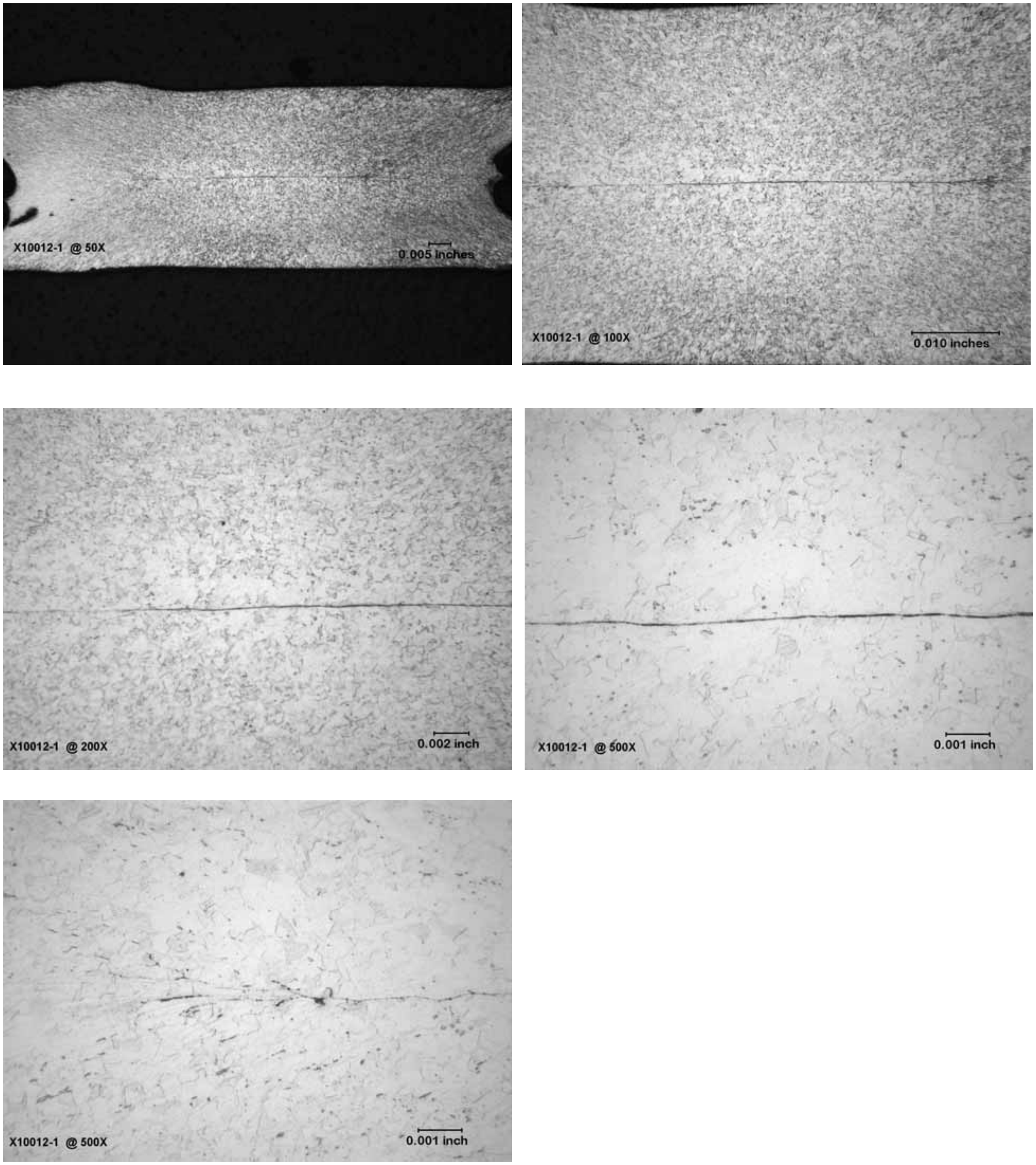


Figure 13. 10012, lightly brushed, aqueous cleaned, 21-6-9, foot end, bond rating 3.

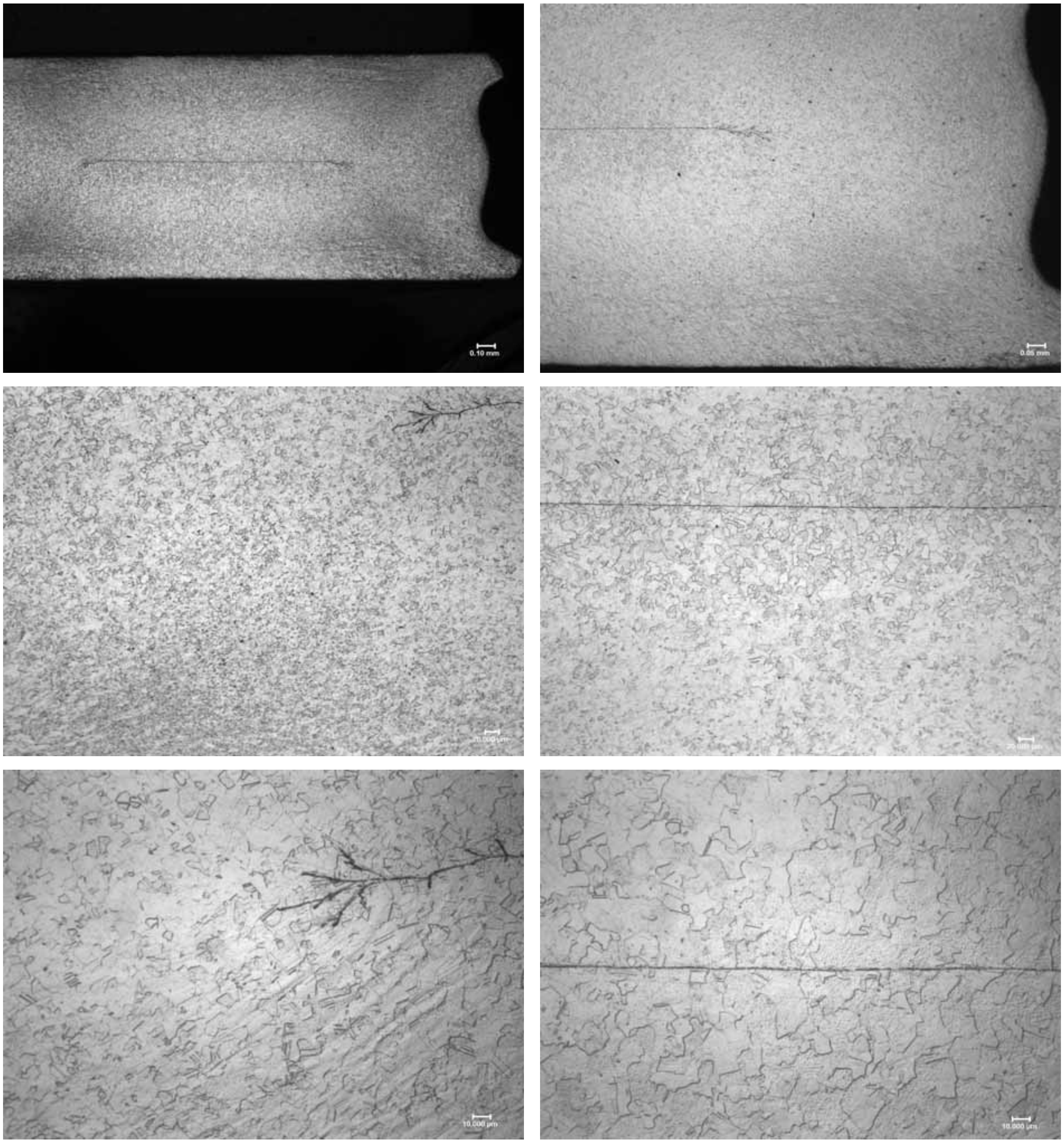


Figure 14. 10057, lightly brushed, aqueous cleaned, 21-6-9, foot end, bond rating 2.

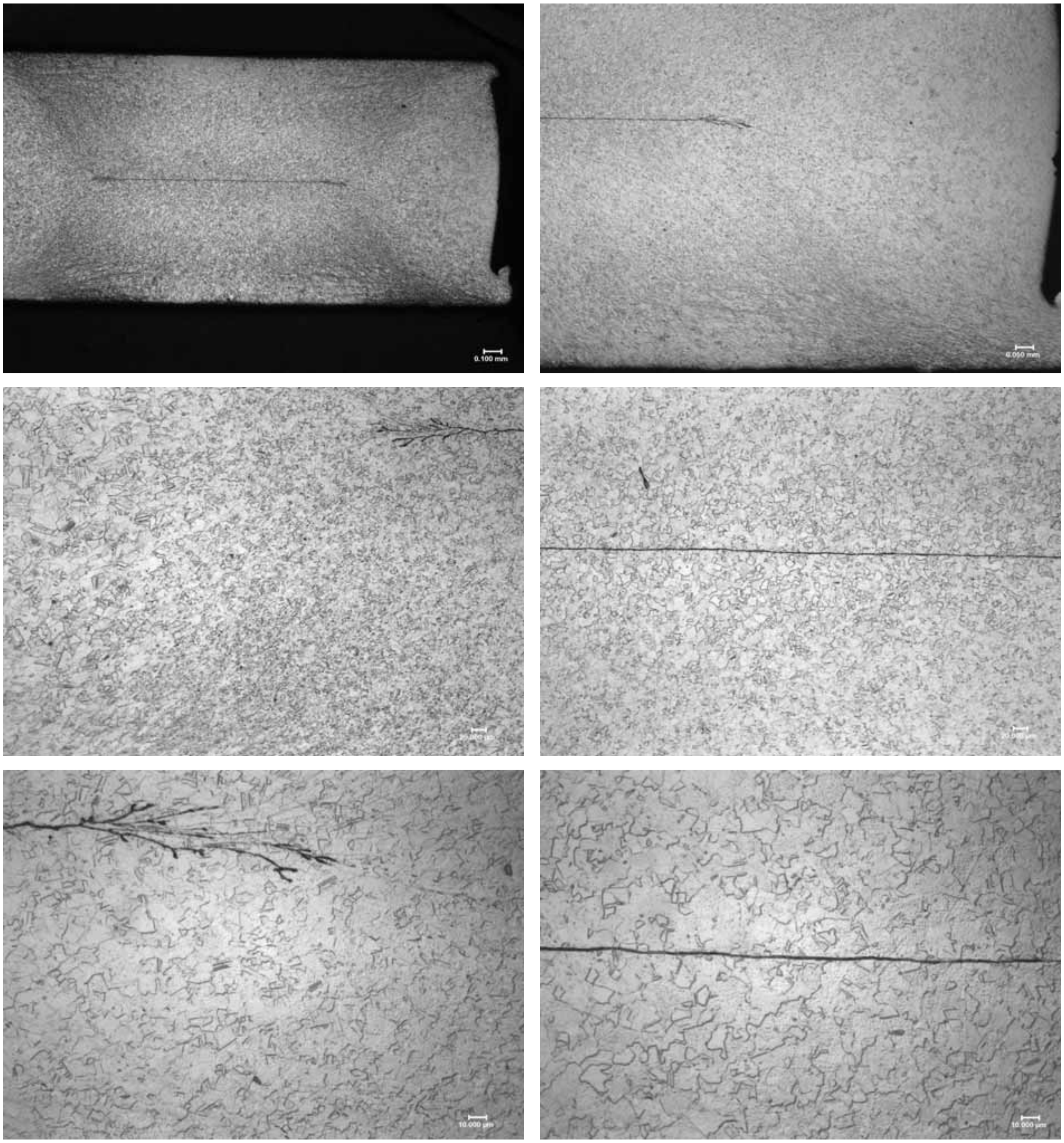


Figure 15. 10006 heavily brushed, aqueous cleaned, 21-6-9 foot end, bond rating 3.

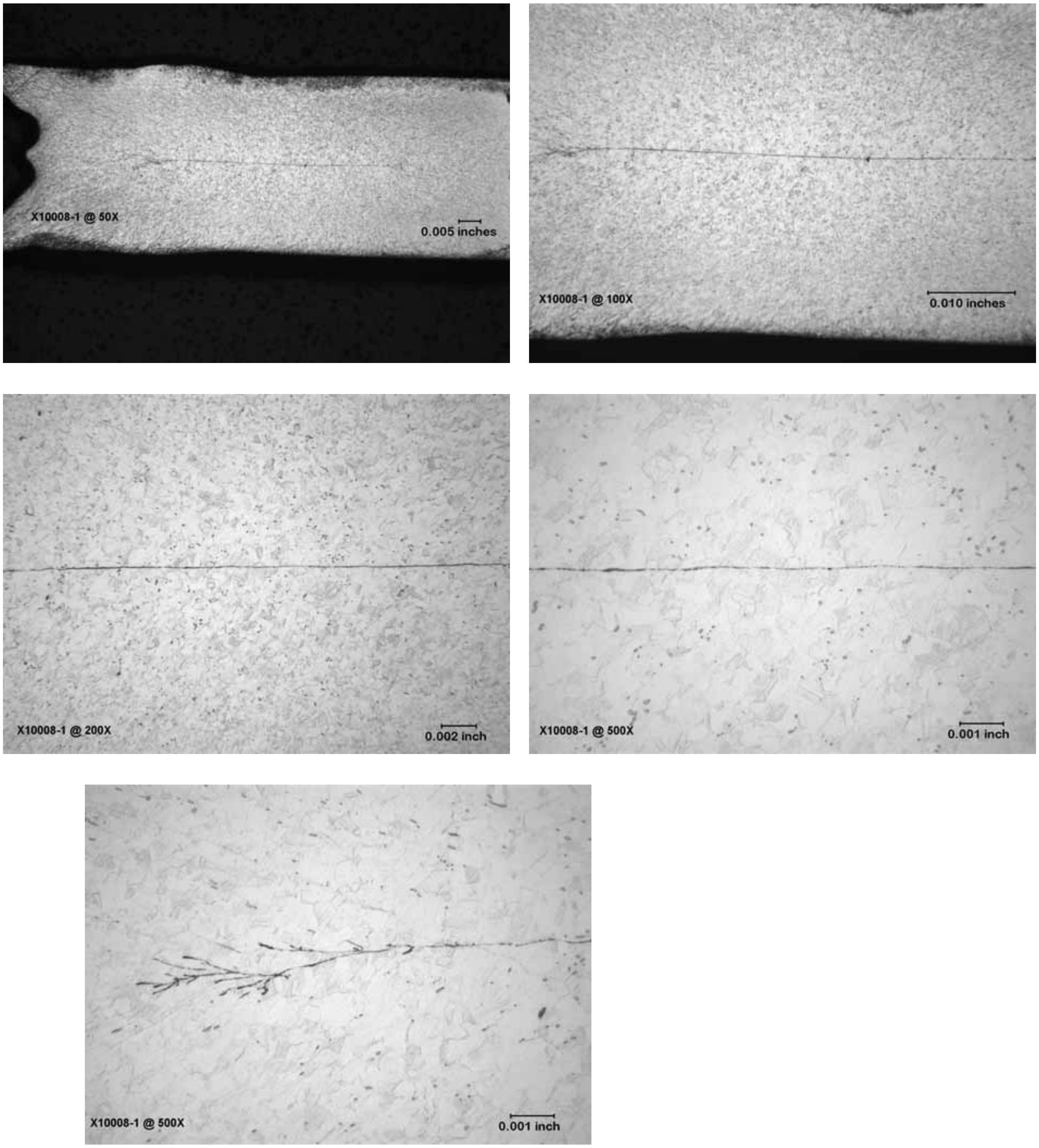


Figure 16. 10008, heavily brushed, aqueous cleaned, 21-6-9, foot end, bond rating 2.

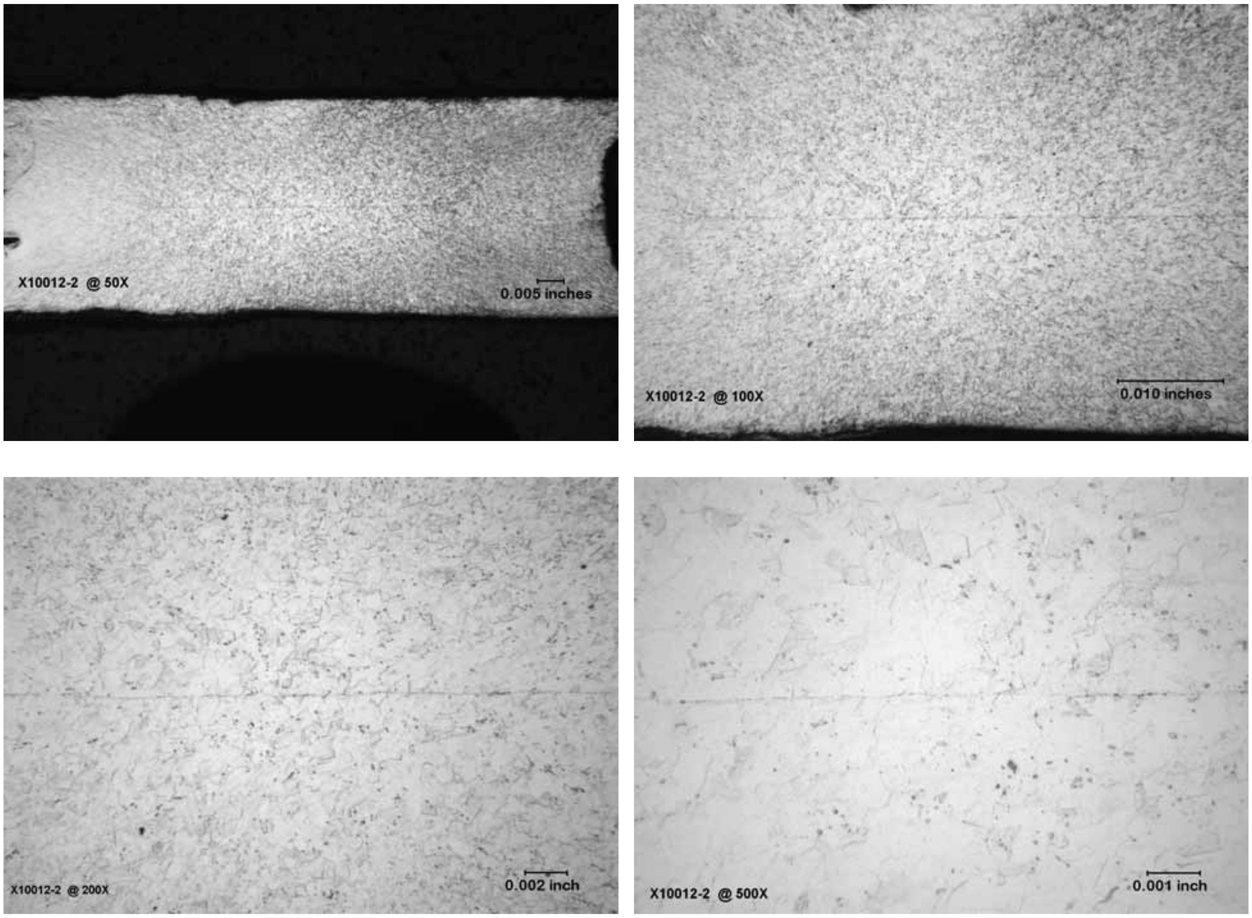


Figure 17. 10012, unadulterated area, aqueous cleaned, 21-6-9, fill end, bond rating 2.

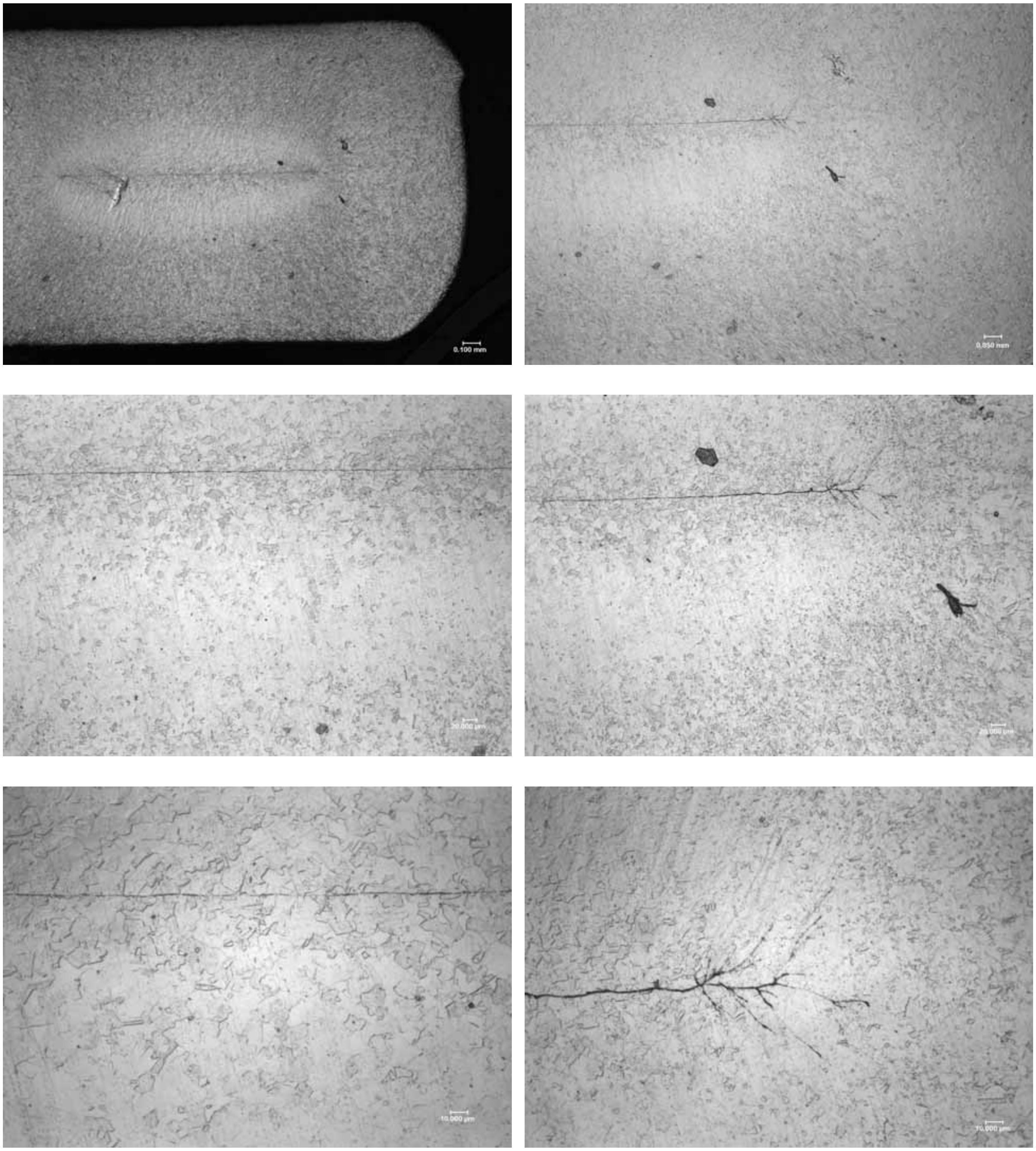


Figure 18. 10057, unadulterated area, aqueous cleaned, 21-6-9, not at weld center, fill end, bond rating 2.

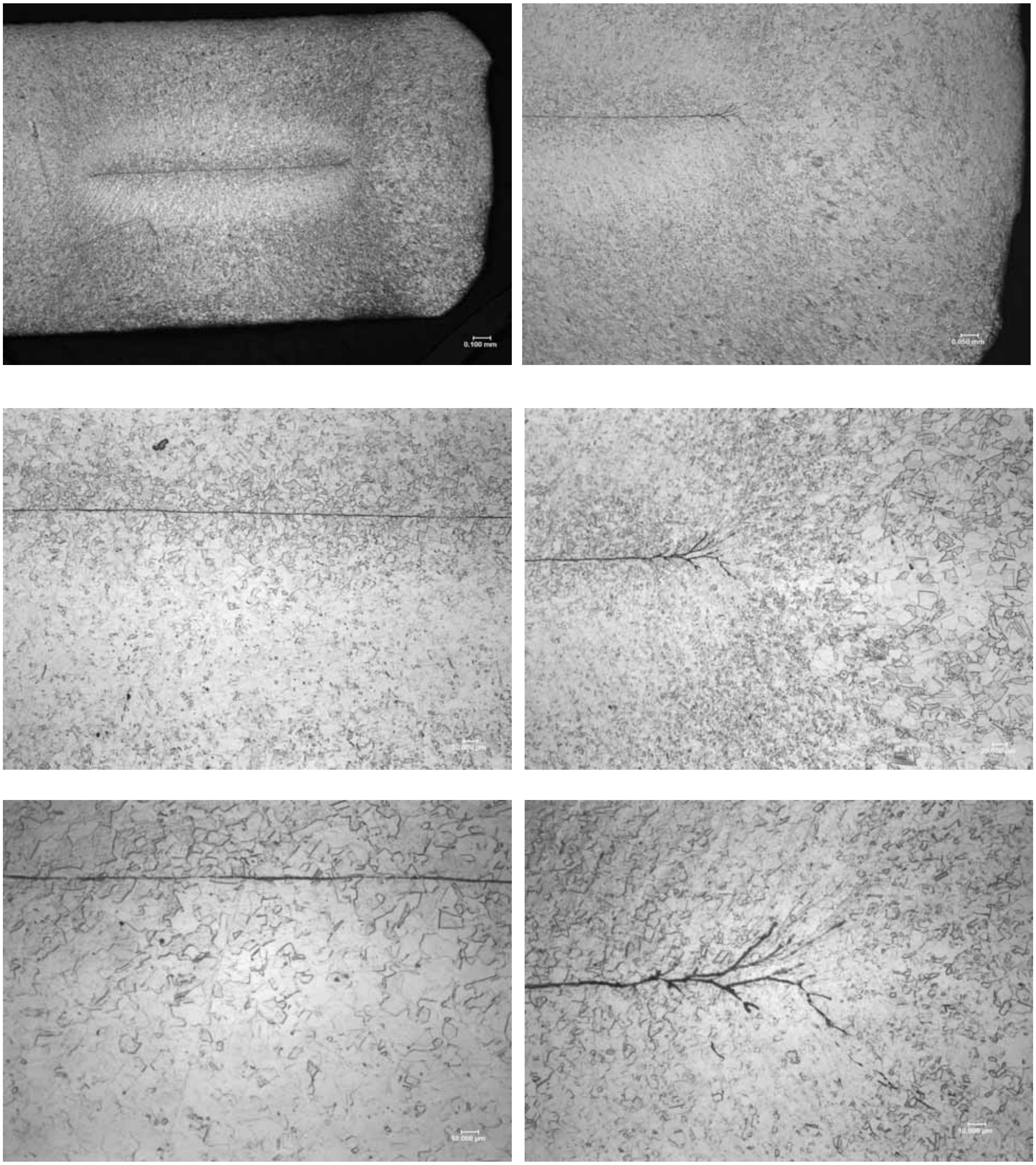


Figure 19. 10006, unadulterated area, aqueous cleaned, 21-6-9, fill end, bond rating 3.

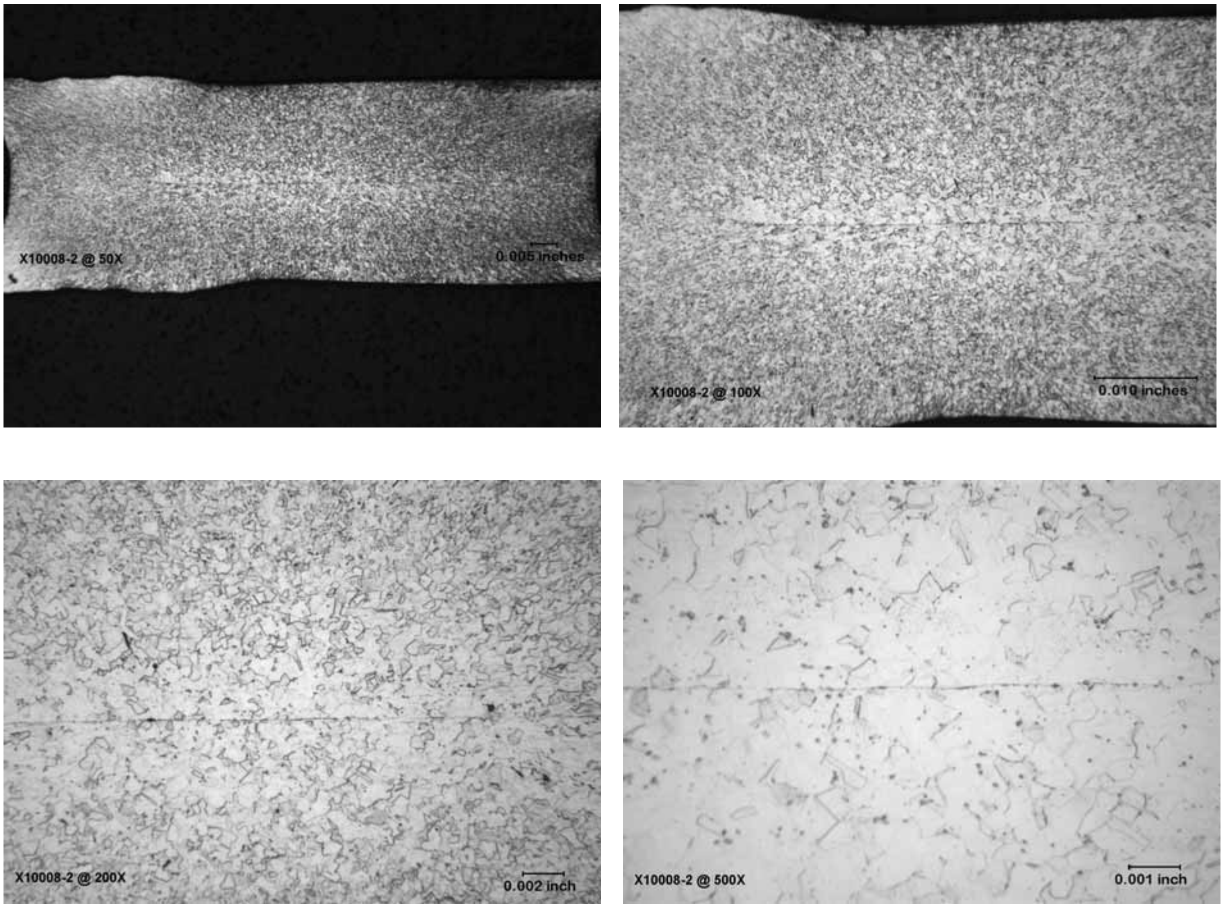


Figure 20. 10008, unadulterated area, aqueous cleaned, 21-6-9, fill end, bond rating 2.

Distribution

S.L. West SRNL
S. Mazurek SRS
K Arnold KCP
J. Samayoa KCP
E.A Clark SRNL
C. Pretzel SNL
K Hicken SNL
S. Robinson SNL
B. Wilkinson LANL
D Lohmeier LANL
P. Korinko SRNL
B. West SRS