

RTI PAST PERFORMANCE		
RTI Tracking Number:	1209991	Date:10/26/2012
Core Task:	Mechanical Testing, Chemical Analysis , Metallurgical Testing	
Analytical Techniques	Mechanical/Chem/Feature/Microhardness/ Photo	

**Metallographic observations:**

Two (2) samples (Sample #A – welded three strips of uncoated together 1.6mm to 1.0 mm to 1.6mm. and Sample #B – same sample was hot dip galvanized as-welded coil) were received for analysis (see fig.1 & fir. 2).

Both samples were tested at five (5) locations as follows:

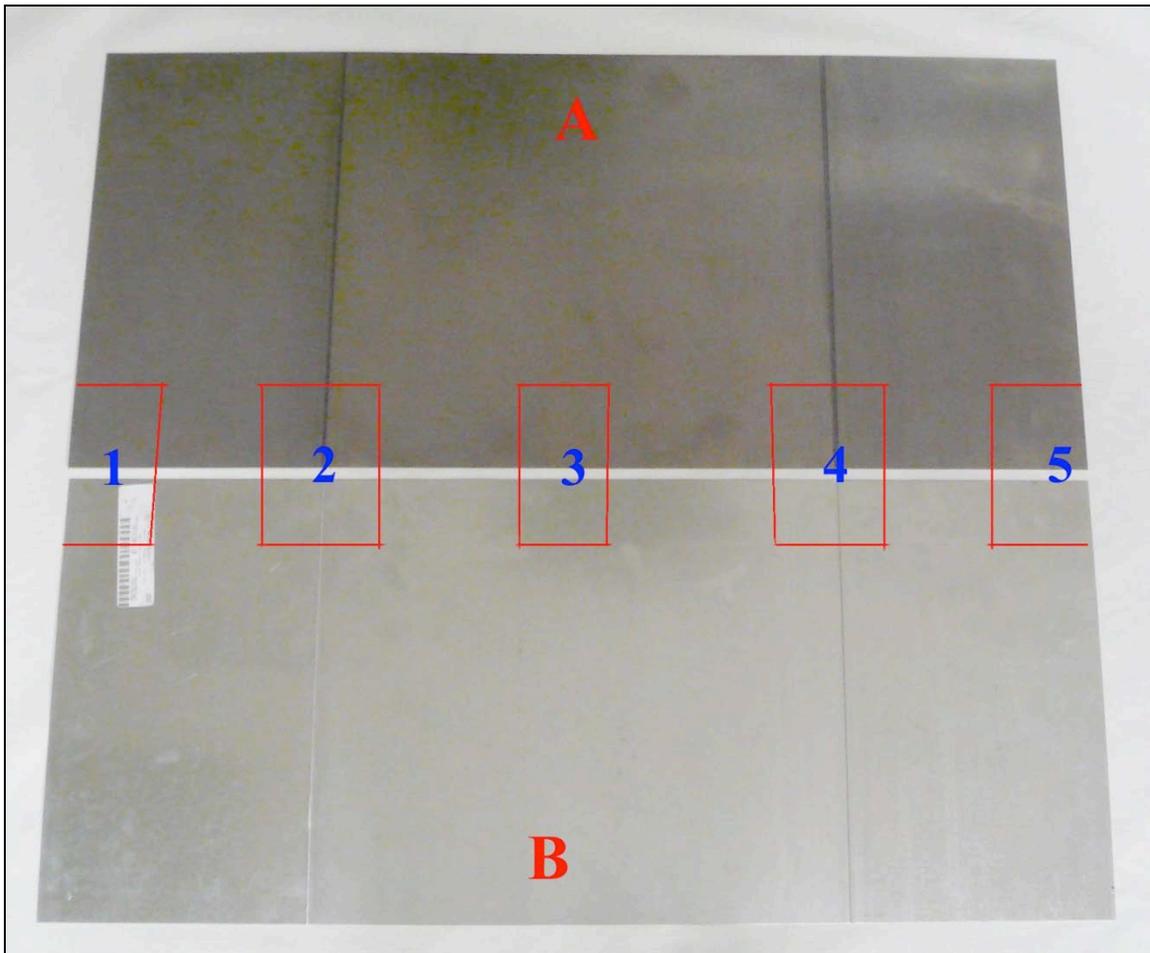
Location #1 – base metal of first strip 1.6 mm.

Location #2 – weld between first strip 1.6 mm and 1.0 mm. strip

Location#3 – base metal of strip 1.0 mm.

Location #4 - weld between strip 1.0 mm and second strip 1.6 mm.

Location #5 – base metal of second strip 1.6 mm.

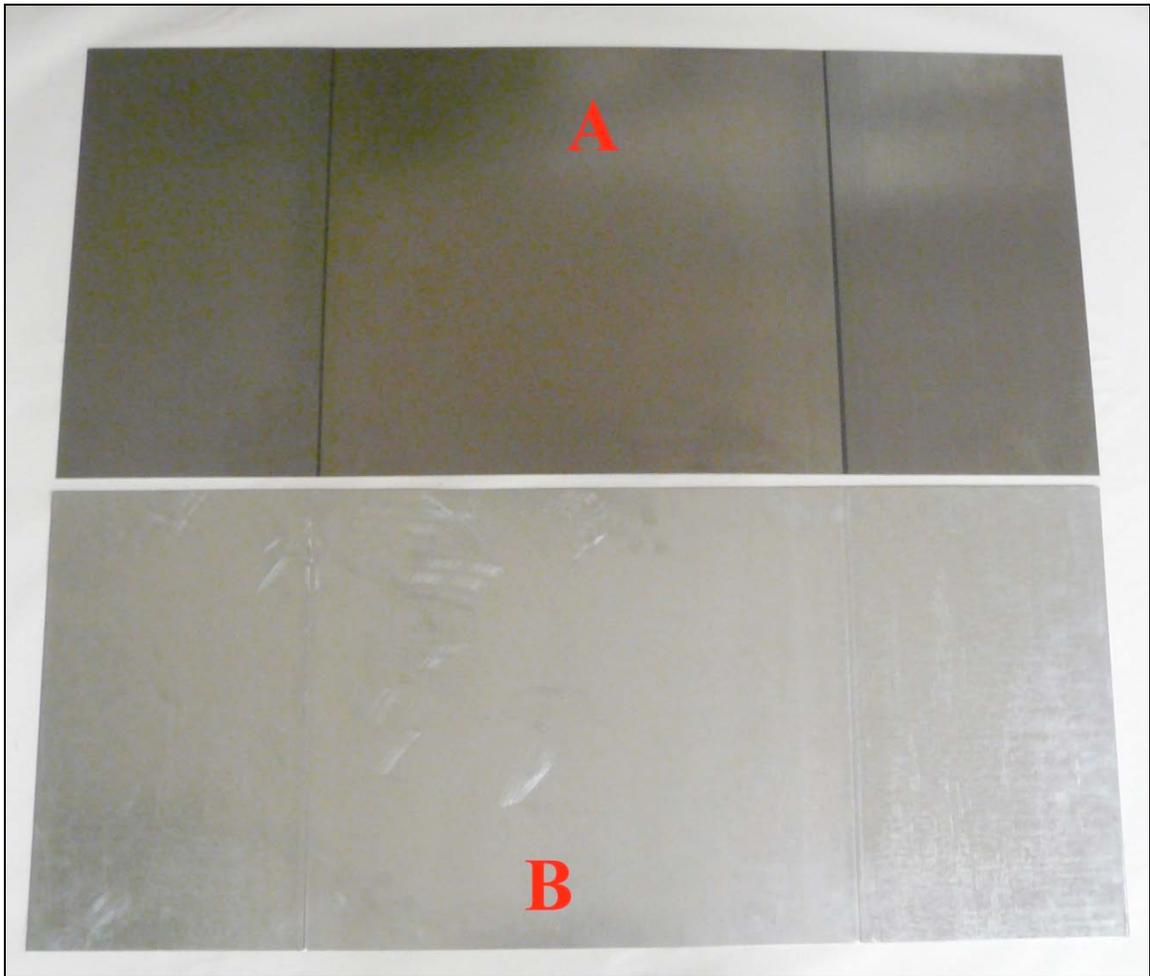


As-received for analysis.

Figure 1.

Reduced size.

Macro-image illustrates top view of the both samples A & B.



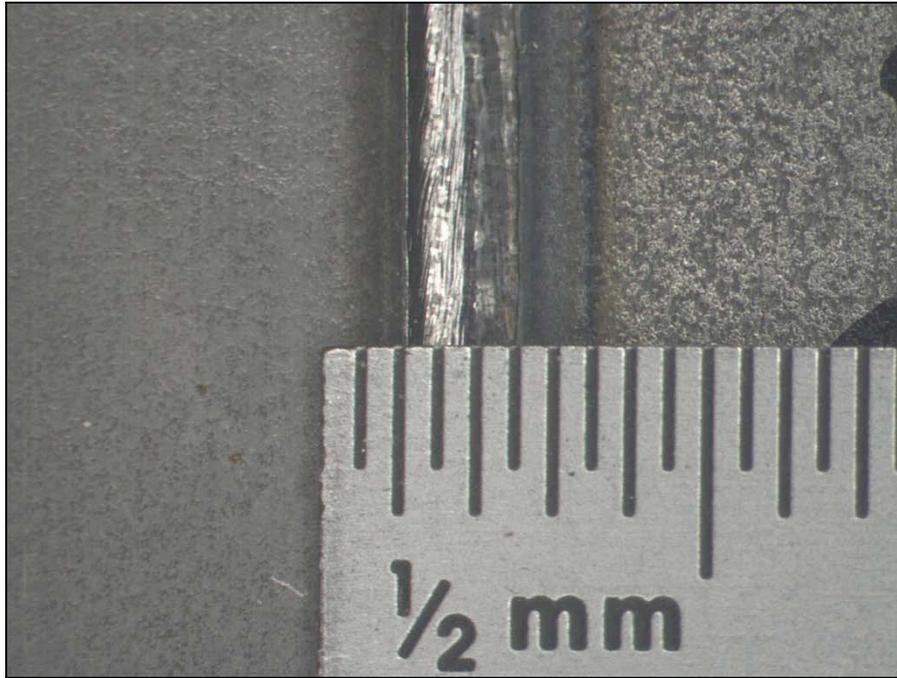
As-received for analysis.

Figure 2.

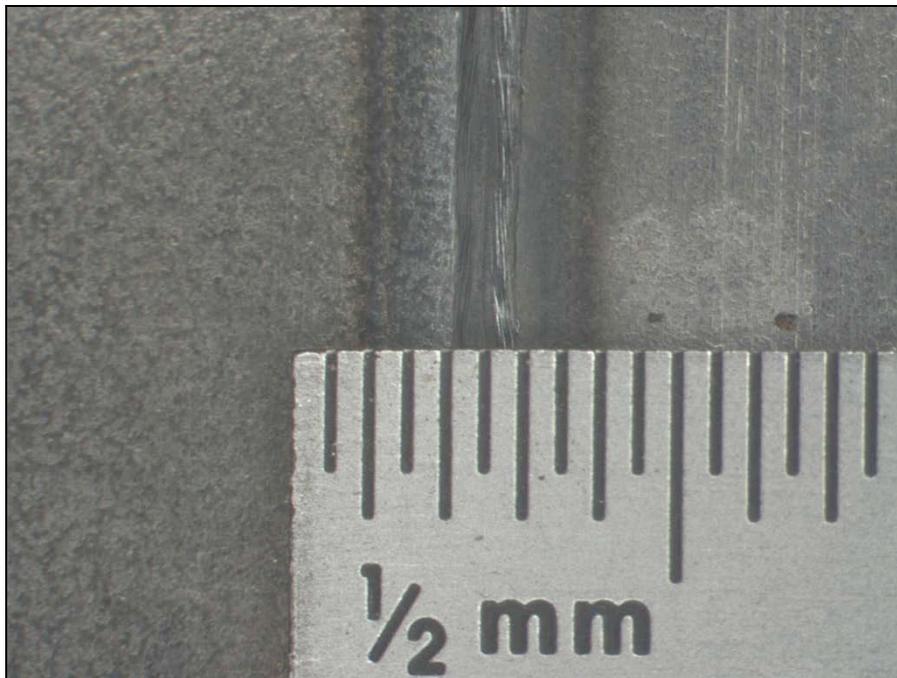
Reduced size.

Macro-image illustrates bottom view of the both samples A & B.

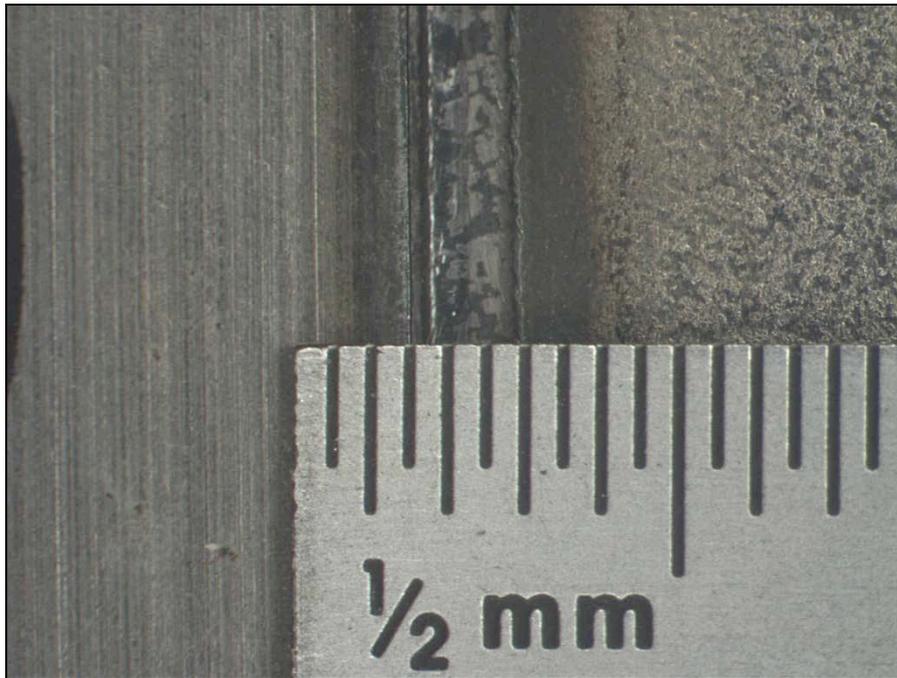
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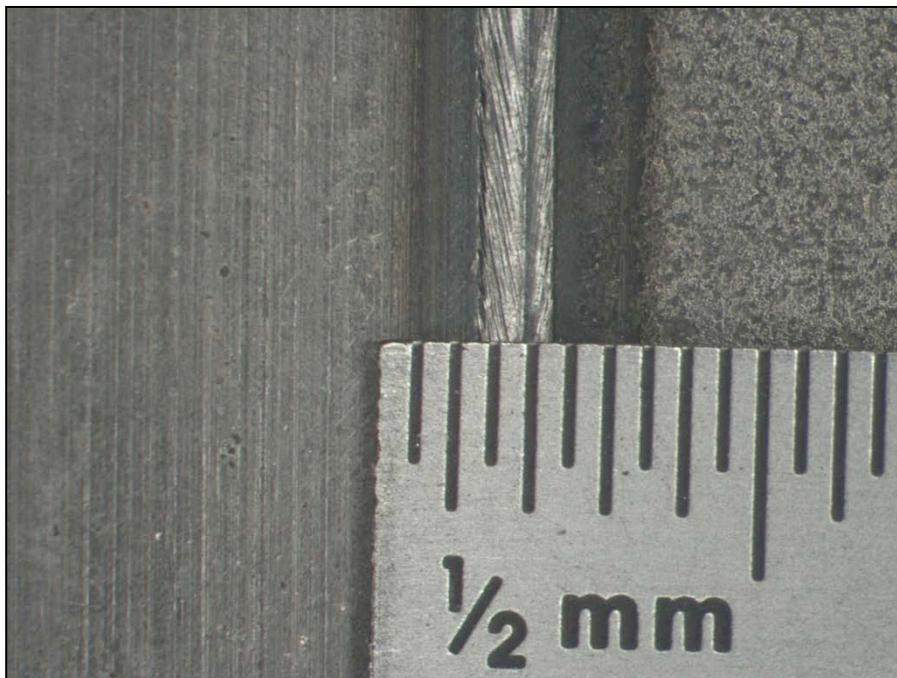
As-received for analysis. Figure 3. 10x.  
Sample #A, Location #2. Micro-image illustrates top view of the weld.



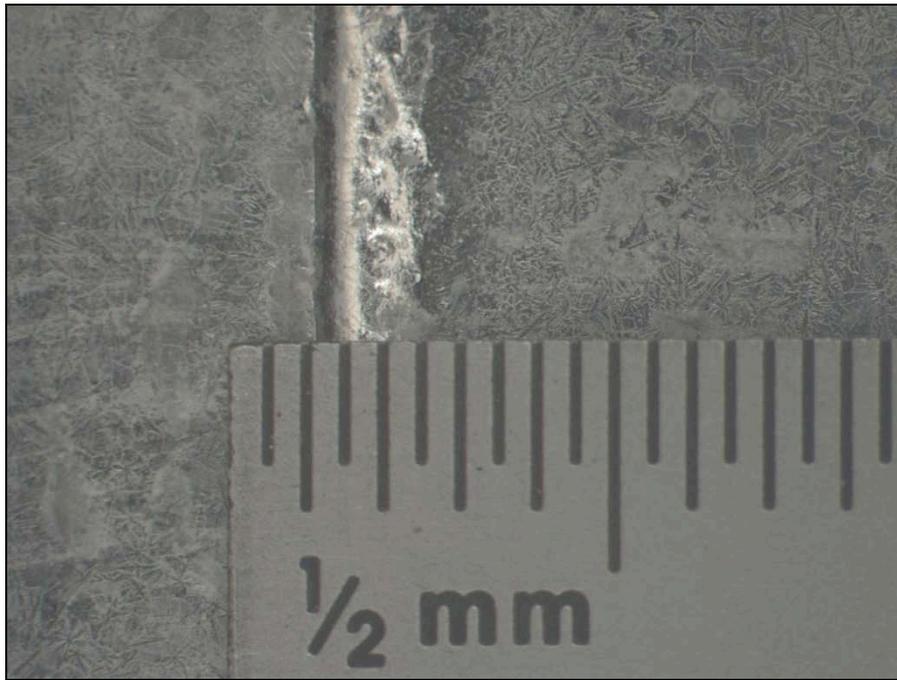
As-received for analysis. Figure 4. 10x.  
Sample #A, Location #2. Micro-image illustrates bottom view of the weld.



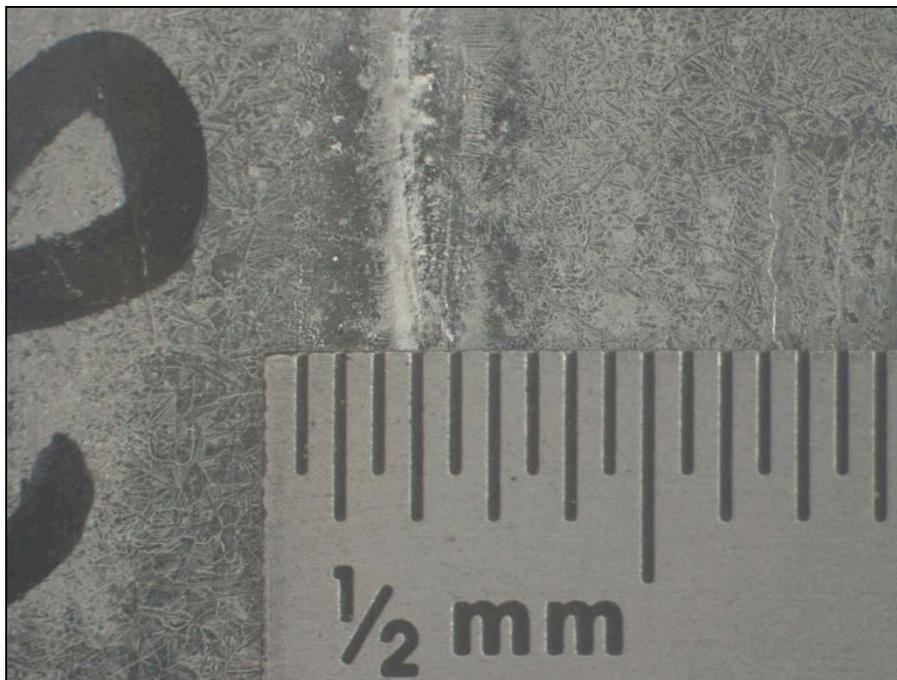
As-received for analysis. Figure 5. 10x.  
**Sample #A, Location #4.** Micro-image illustrates top view of the weld.



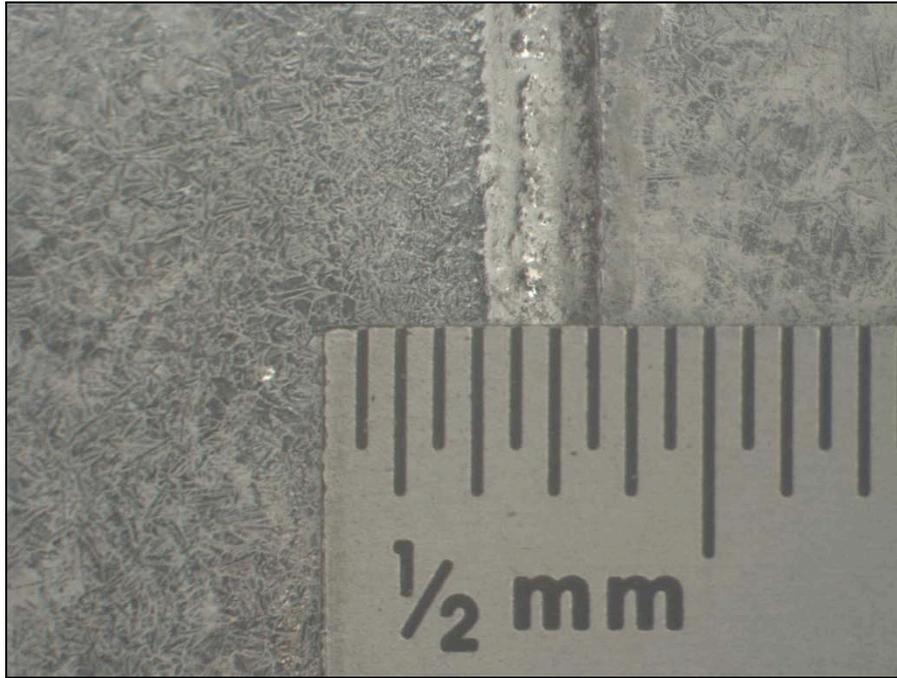
As-received for analysis. Figure 6. 10x.  
**Sample #A, Location #4.** Micro-image illustrates bottom view of the weld.



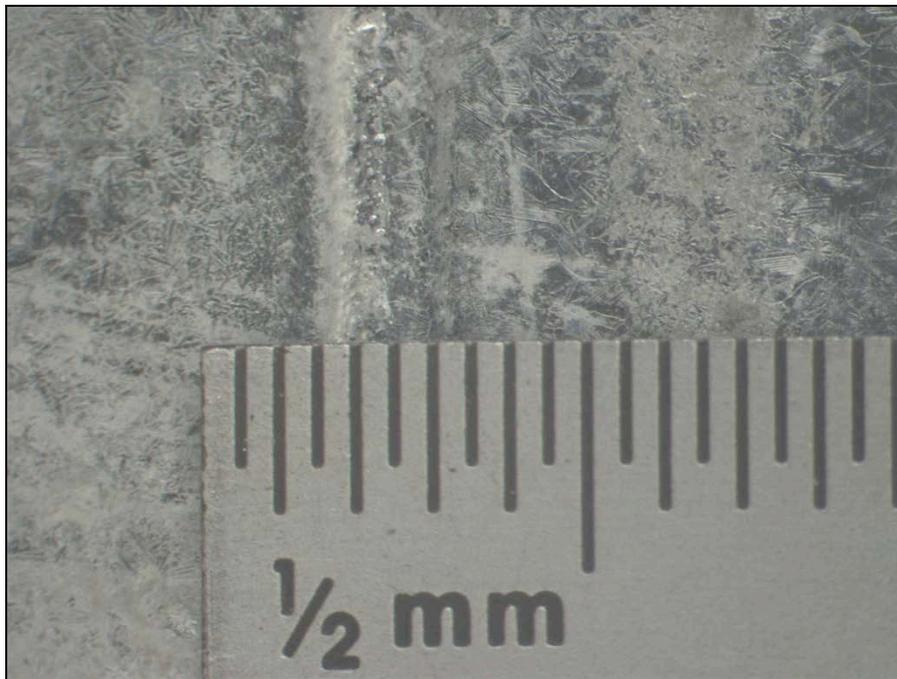
As-received for analysis. Figure 7. 10x.  
**Sample #B, Location #2.** Micro-image illustrates top view of the weld.



As-received for analysis. Figure 8. 10x.  
**Sample #B, Location #2.** Micro-image illustrates bottom view of the weld.



As-received for analysis. Figure 9. 10x.  
**Sample #B, Location #4.** Micro-image illustrates top view of the weld.



As-received for analysis. Figure 10. 10x.  
**Sample #B, Location #4.** Micro-image illustrates bottom view of the weld.



As-received for analysis.

Figure 11.

Reduced size.

Macro-image illustrates top view of the both samples A & B (Olsen cup test).



As-received for analysis.

Figure 12.

Enlarge size.

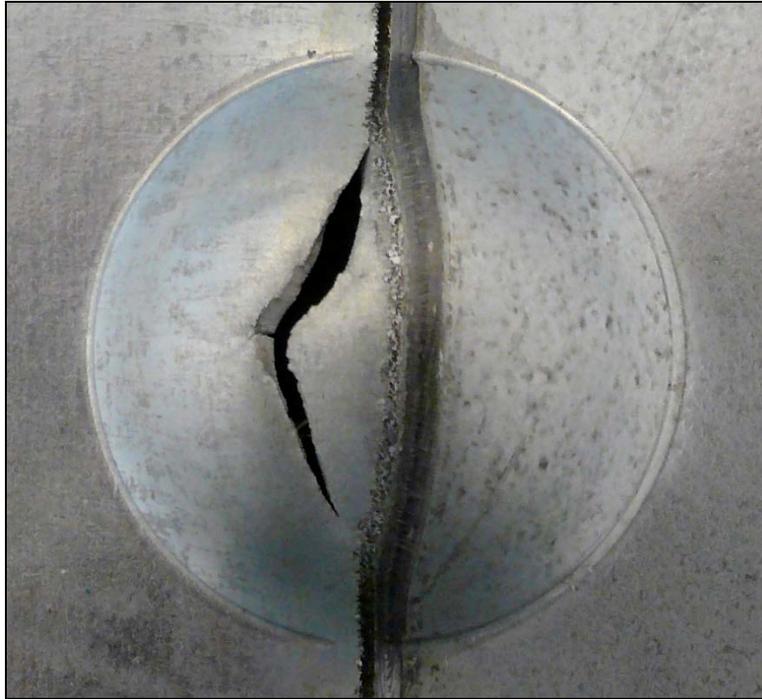
**Sample #A Location #1.** Macro-image illustrates top view.



As-received for analysis. Figure 13. Enlarge size.  
**Sample #A Location #2.** Macro-image illustrates top view.



As-received for analysis. Figure 14. Enlarge size.  
**Sample #A Location #3.** Macro-image illustrates top view.



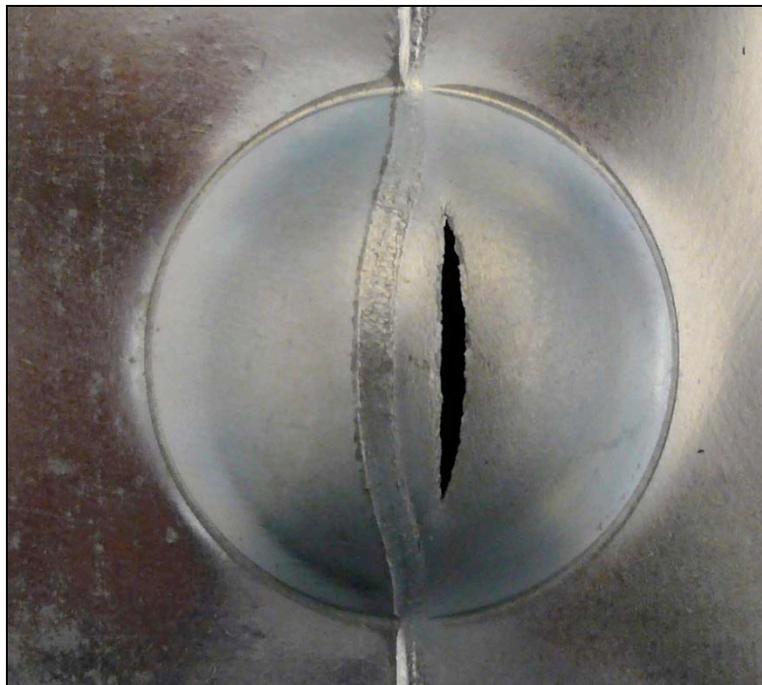
As-received for analysis. Figure 15. Enlarge size.  
**Sample #A Location #4.** Macro-image illustrates top view.



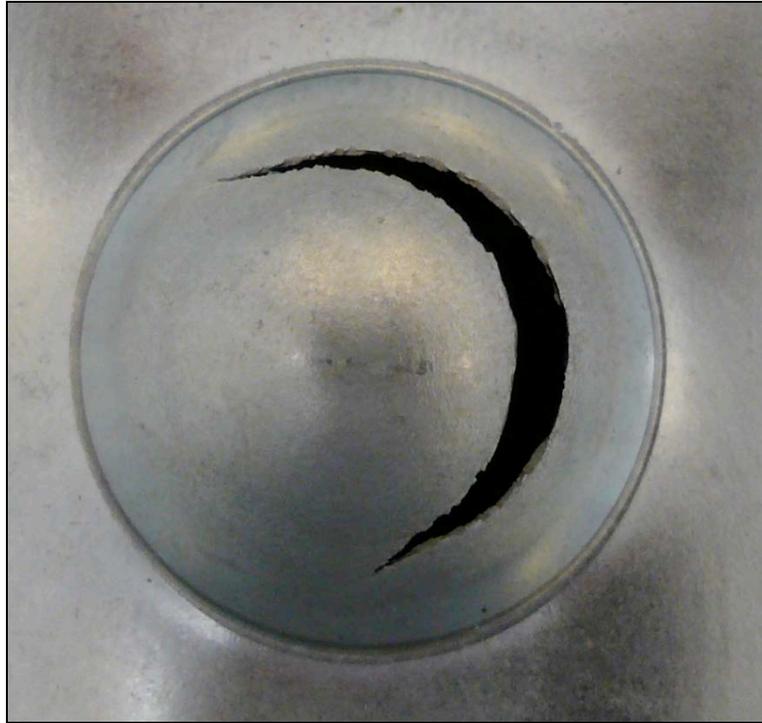
As-received for analysis. Figure 16. Enlarge size.  
**Sample #A Location #5.** Macro-image illustrates top view.



As-received for analysis. Figure 17. Enlarge size.  
**Sample #B Location #1.** Macro-image illustrates top view.



As-received for analysis. Figure 18. Enlarge size.  
**Sample #B Location #2.** Macro-image illustrates top view.



As-received for analysis. Figure 19. Enlarge size.  
**Sample #B Location #3.** Macro-image illustrates top view.



As-received for analysis. Figure 20. Enlarge size.  
**Sample #B Location #4.** Macro-image illustrates top view.



As-received for analysis. Figure 21. Enlarge size.  
**Sample #B Location #5.** Macro-image illustrates top view.

**Mechanical properties:**

Sample tested in accordance with the current revision of ASTM A370-11, E8/E8M-09

**Sample #A**

Locations	Mechanical properties and Results			
	Tensile Strength (ksi)	Yield Strength (0.2% offset) (ksi)	Uniform Elongation in. (%)	Total Elongation in 2.00" in. (%)
<b>1</b>	60.8	45.3	19.14	29.6
<b>2 Sample #1</b>	47.2	31.1	9.90	21.0
<b>2 Sample #2</b>	47.1	31.0	10.01	20.7
<b>2 Sample #3</b>	47.2	30.9	9.87	20.7
<b>3</b>	46.2	27.2	23.38	40.1
<b>4 Sample #1</b>	46.3	31.2	9.75	20.5
<b>4 Sample #2</b>	46.3	31.1	10.19	21.4
<b>4 Sample #3</b>	46.3	30.9	9.90	20.6
<b>5</b>	61.5	49.5	19.30	29.9



Sample #A. Macro-image illustrates locations of the fracture.

### Sample #B

Locations	Mechanical properties and Results			
	Tensile Strength (ksi)	Yield Strength (0.2% offset) (ksi)	Uniform Elongation in. (%)	Total Elongation in 2.00" in. (%)
<b>1</b>	59.9	44.8	19.33	30.6
<b>2 Sample #1</b>	48.9	36.8	9.75	19.3
<b>2 Sample #2</b>	49.3	38.4	9.92	19.6
<b>2 Sample #3</b>	48.9	37.8	10.42	19.8
<b>3</b>	48.9	35.0	23.7	36.9
<b>4 Sample #1</b>	49.2	33.5	10.08	19.3
<b>4 Sample #2</b>	49.5	34.3	9.69	19.8
<b>4 Sample #3</b>	48.9	34.1	9.63	19.3
<b>5</b>	60.3	47.4	18.64	30.2



Sample #B. Macro-image illustrates locations of the fracture.

### **Chemical Analysis:**

#### Analytical methods:

ASTM E1019-08: Determination of Carbon, Sulfur, Nitrogen and Oxygen in Steel and Iron, Nickel, and Cobalt Alloys.

Bulk chemical analysis by Glow Discharge- Optical Emission Spectrometry (GD-OES) in accordance with LECO GDS-850A Glow Discharge Spectrometer.

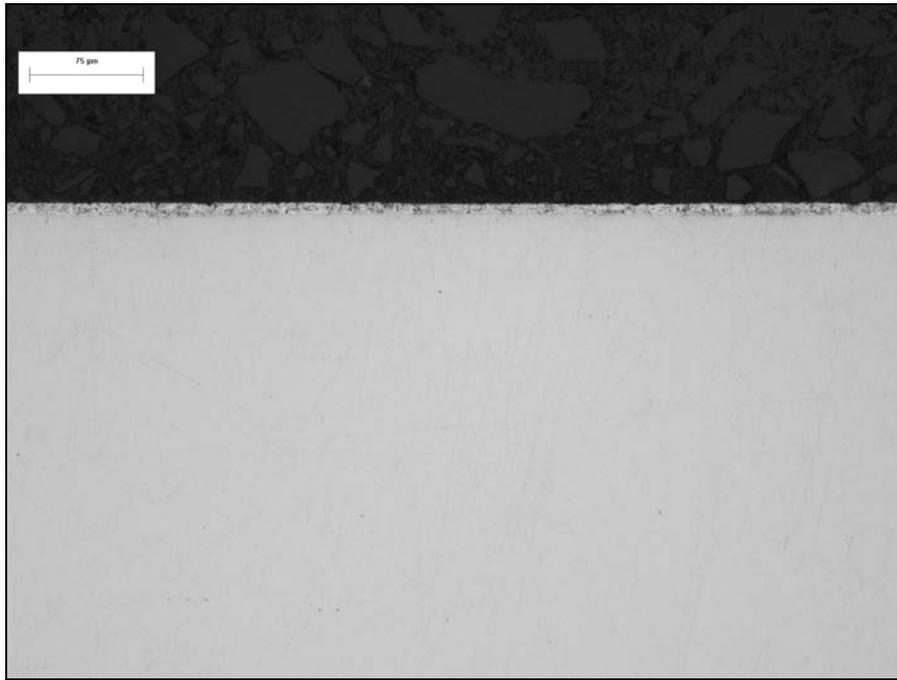
#### Sample #A

Locations	Elements (All units are % by wt.)												
	C	S	P	Si	N	Mn	Cr	Ni	Mo	Al	Cu	Ti	Nb
<b>1</b> (1.6 mm)	0.07	0.007	0.011	0.03	0.003	0.70	0.04	<0.02	<0.02	0.057	0.03	<0.008	0.021
<b>3</b> (1.0 mm)	0.04	0.007	0.014	<0.02	0.007	0.21	0.04	<0.02	<0.02	0.057	0.04	<0.008	<0.008

### **Microstructure evaluation:**

To further the investigation of the both samples (A & B) were sectioned transversally (perpendicular to the weld) at five (5) locations, metallographically prepared in accordance with ASTM E3-11, and microscopically examined in the as-polished and etched conditions.

Please see the results of the analysis and micro-images of a representative cross-sections and description below.

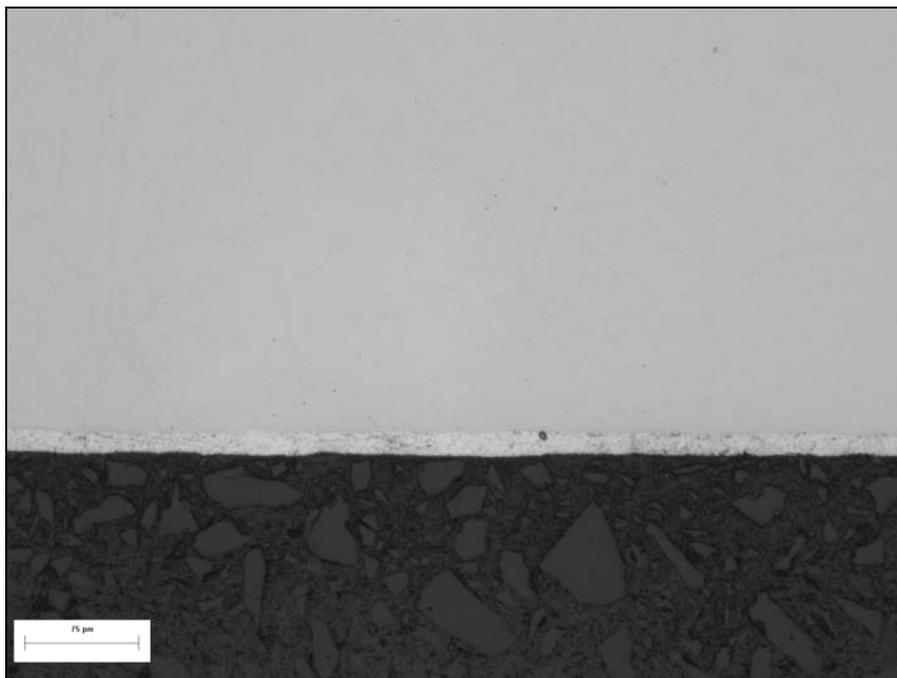


As-polished condition.

Figure 22 .

200x

**Sample #B Location #1.** Macro-image illustrates distribution of the coating on steel substrate. (Top)

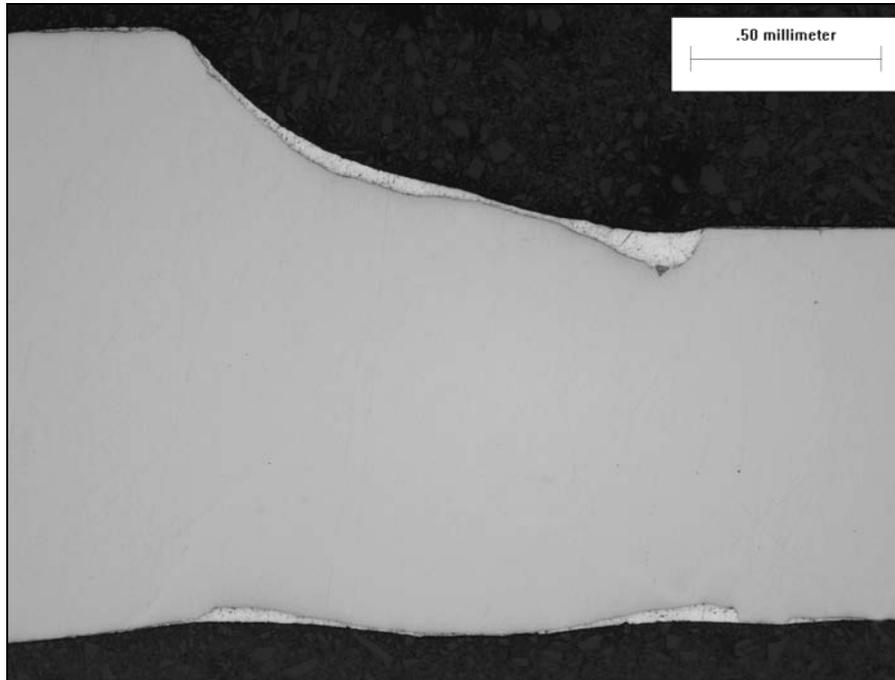


As-polished condition.

Figure 23 .

200x

**Sample #B Location #1.** Macro-image illustrates distribution of the coating on steel substrate.  
(Bottom)

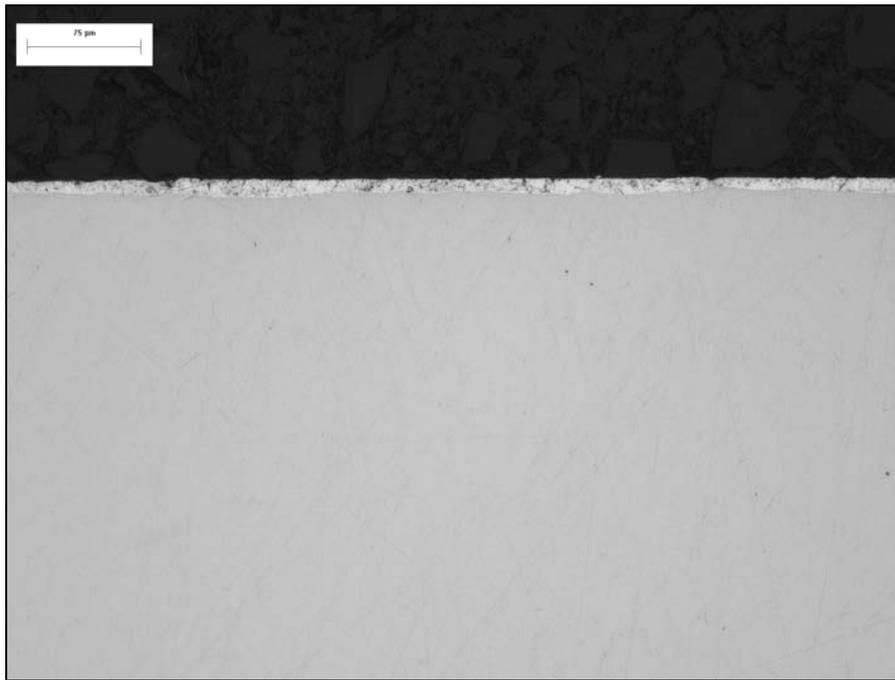


As-polished condition.

Figure 24.

50x

**Sample #B Location #2.** Macro-image illustrates distribution of the coating on steel substrate.

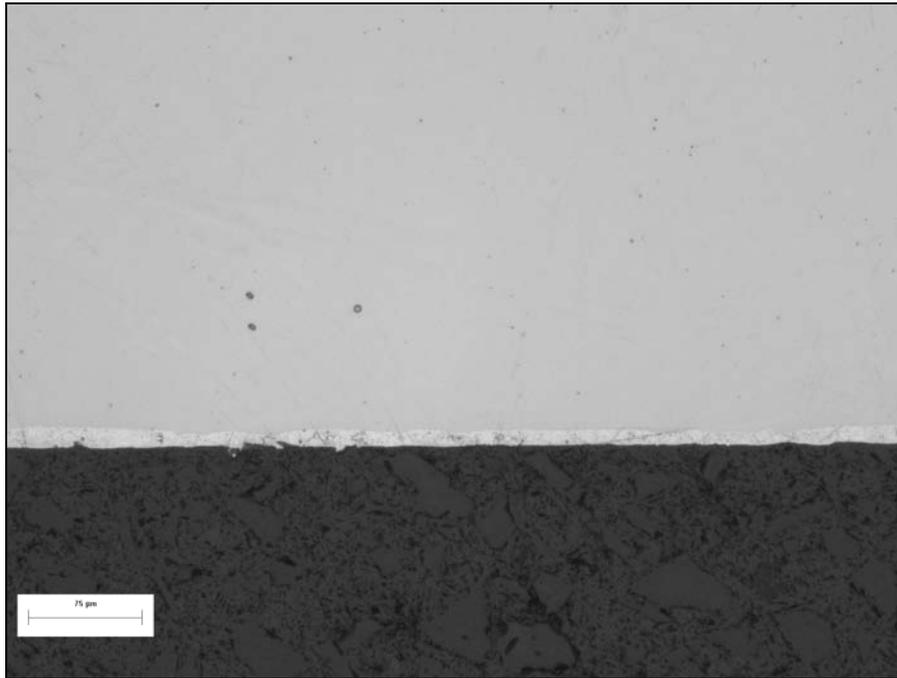


As-polished condition.

Figure 25.

200x

**Sample #B Location #3.** Macro-image illustrates distribution of the coating on steel substrate. (Top )

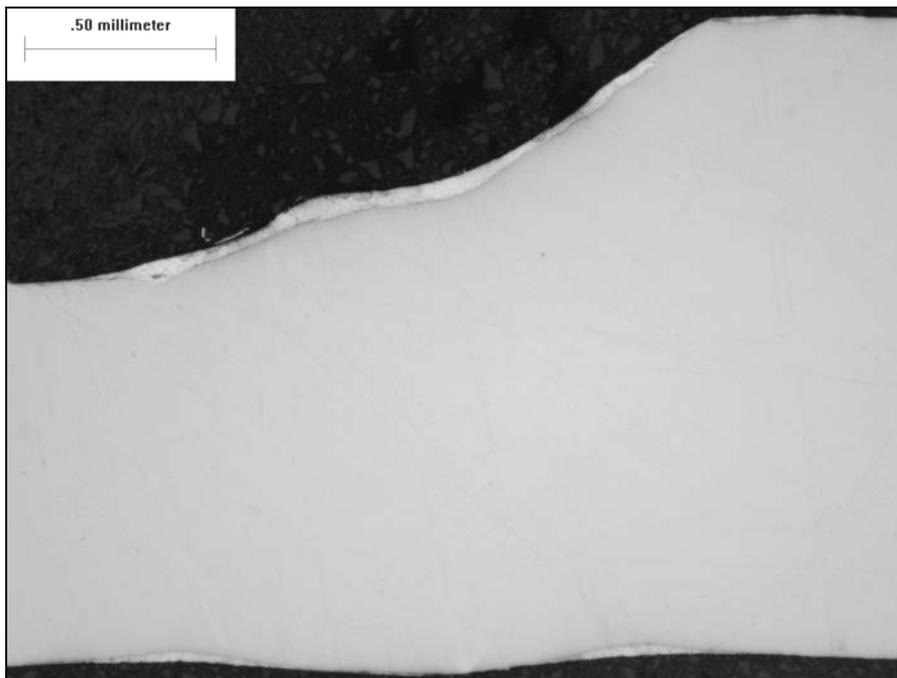


As-polished condition.

Figure 26.

200x

**Sample #B Location #3.** Macro-image illustrates distribution of the coating on steel substrate. (Bottom)

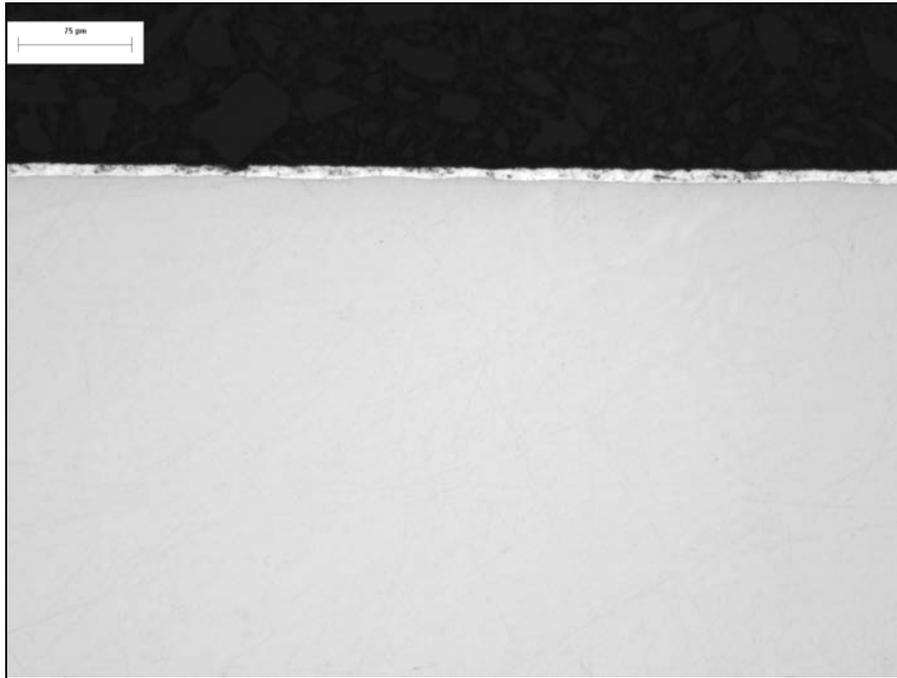


As-polished condition.

Figure 27.

50x

**Sample #B Location #4.** Macro-image illustrates distribution of the coating on steel substrate.

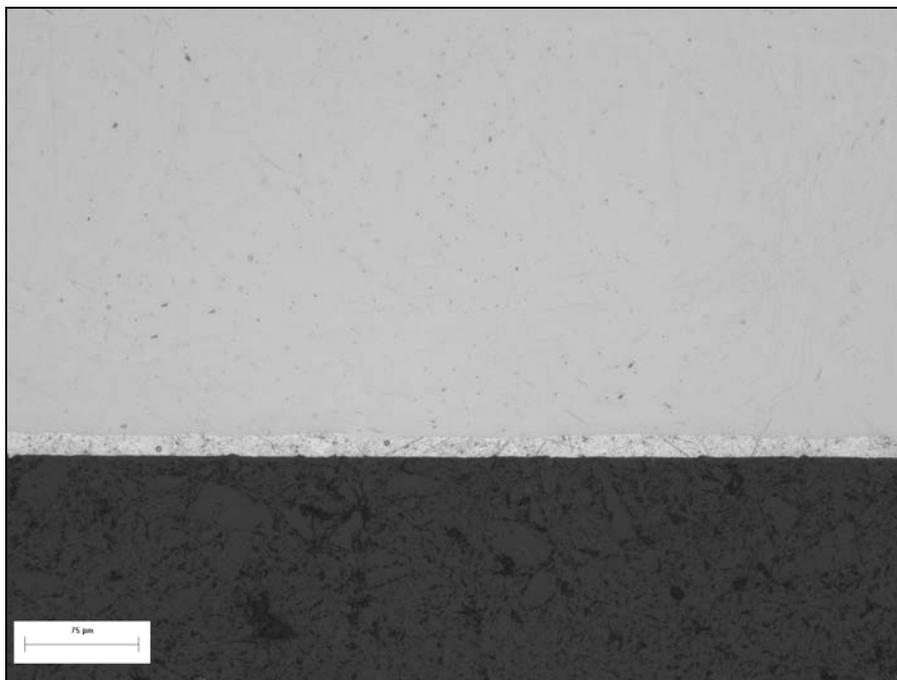


As-polished condition.

Figure 28.

200x

**Sample #B Location #5.** Macro-image illustrates distribution of the coating on steel substrate. (Top)

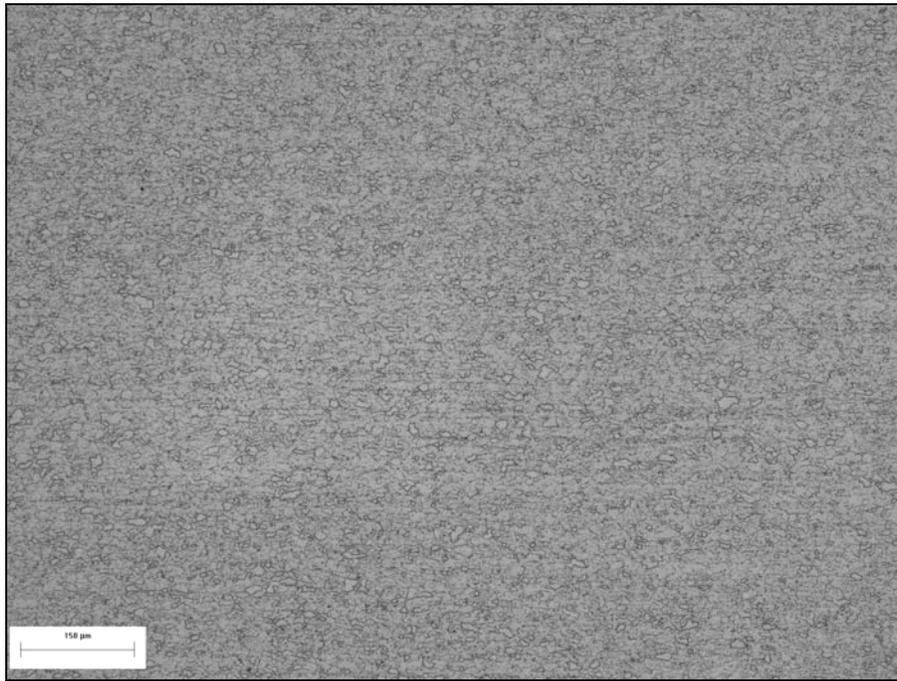


As-polished condition.

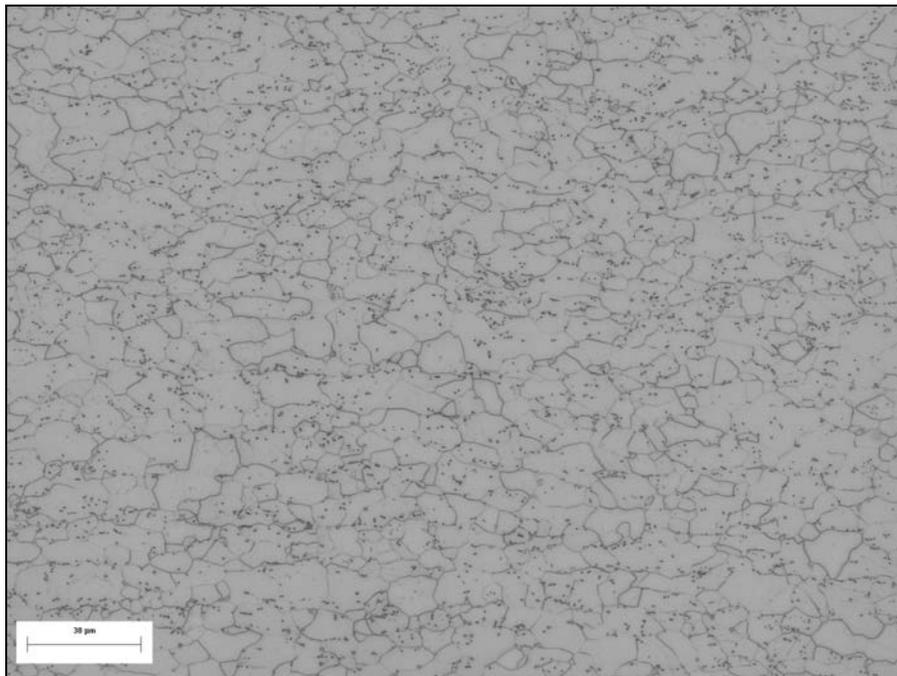
Figure 29.

200x

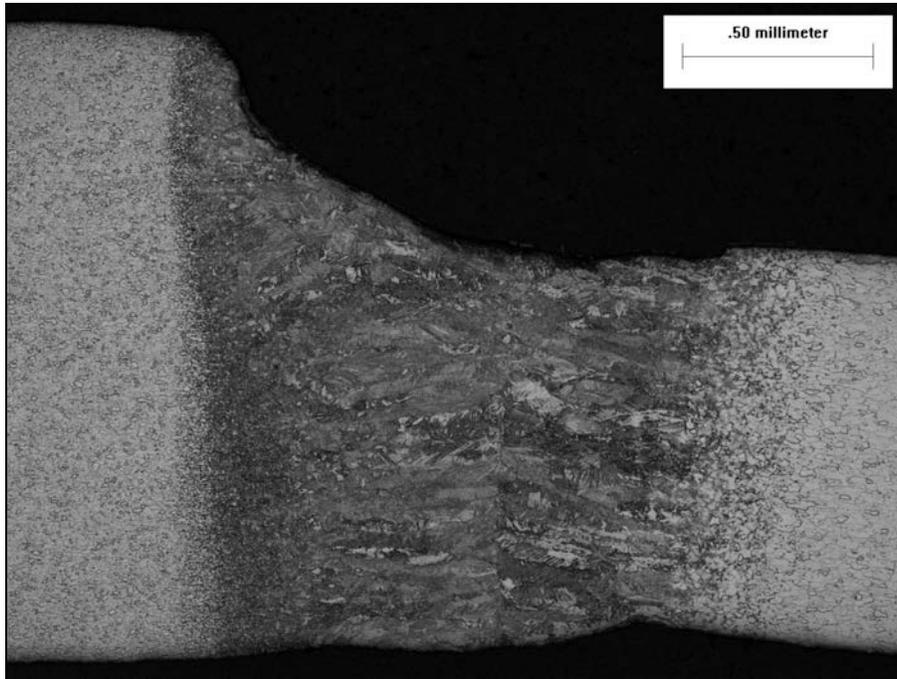
**Sample #B Location #5.** Macro-image illustrates distribution of the coating on steel substrate.  
(Bottom)



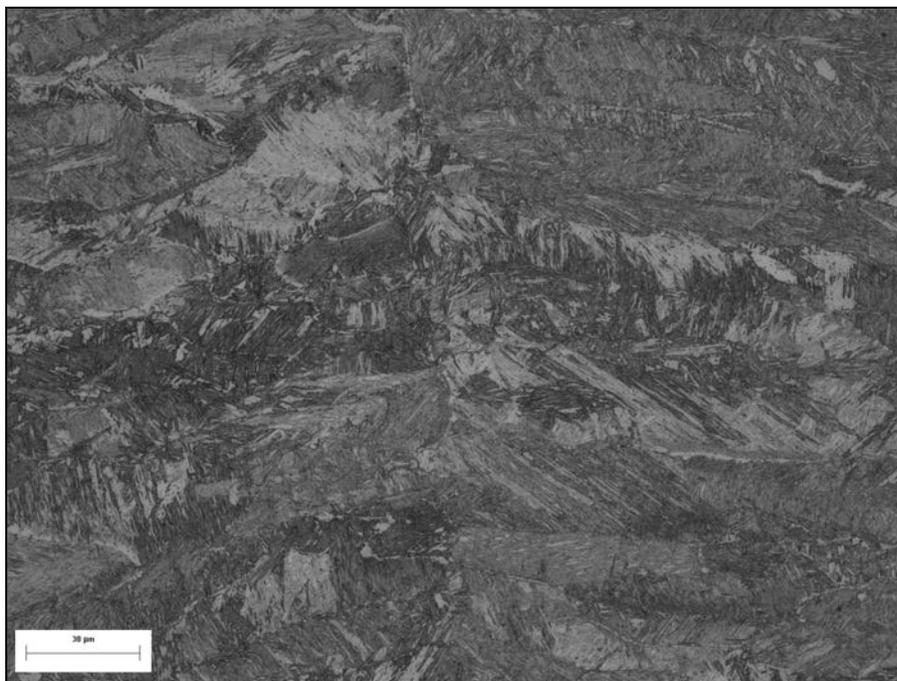
**Etched condition** **Figure 30** **100x**  
**Sample #A Location #1.** Micro-image of a representative structure.



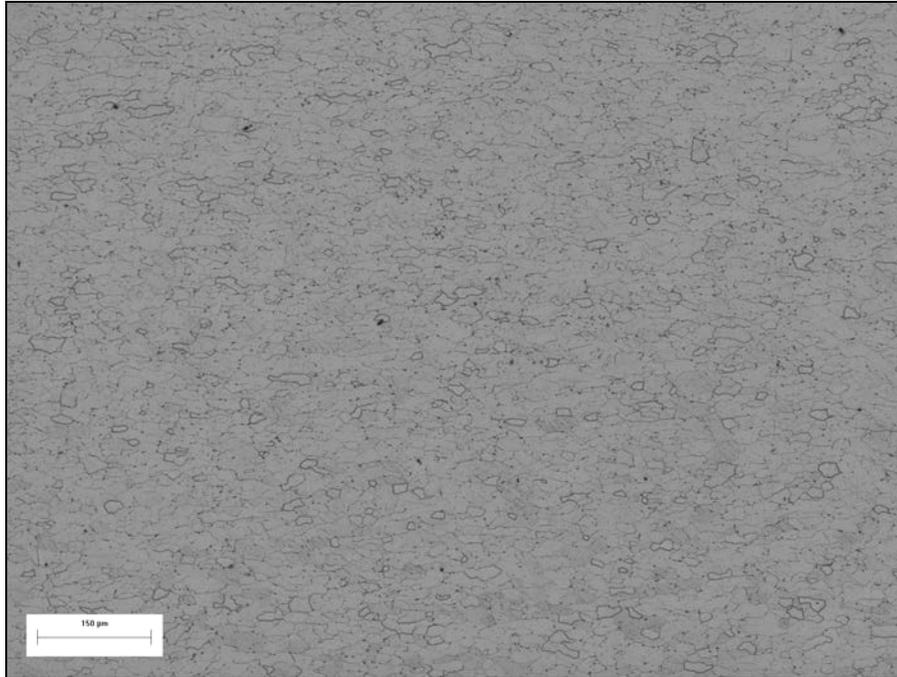
**Etched condition** **Figure 31.** **500x**  
**Sample #A Location #1.** Micro-image of a representative structure.



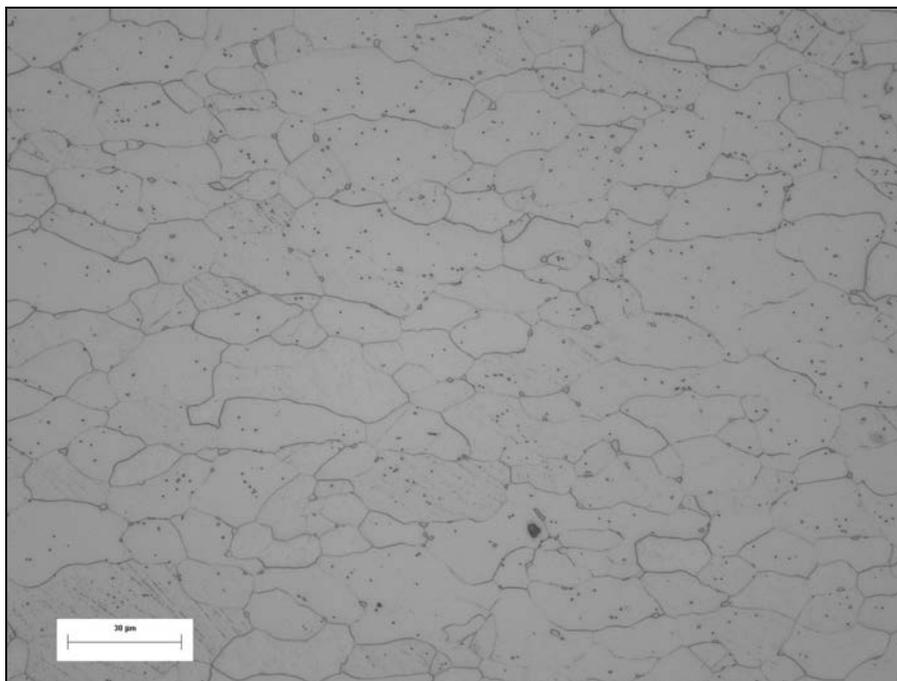
**Etched condition**                      **Figure 32**                      **50x**  
**Sample #A Location #2.** Micro-image microstructure of the weld.



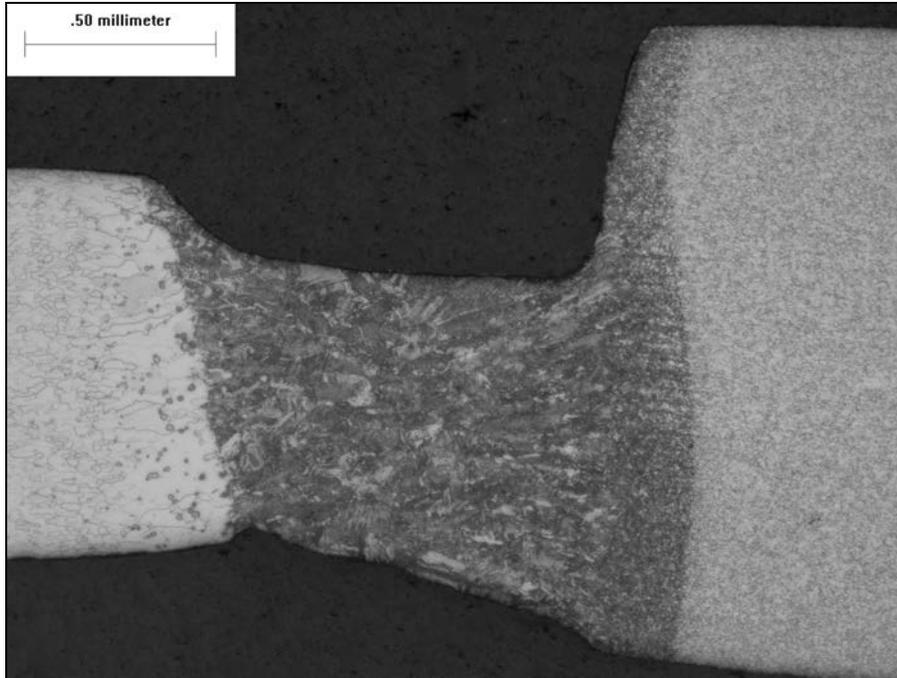
**Etched condition**                      **Figure 33**                      **500x**  
**Sample #A Location #2.** Micro-image of a representative structure.



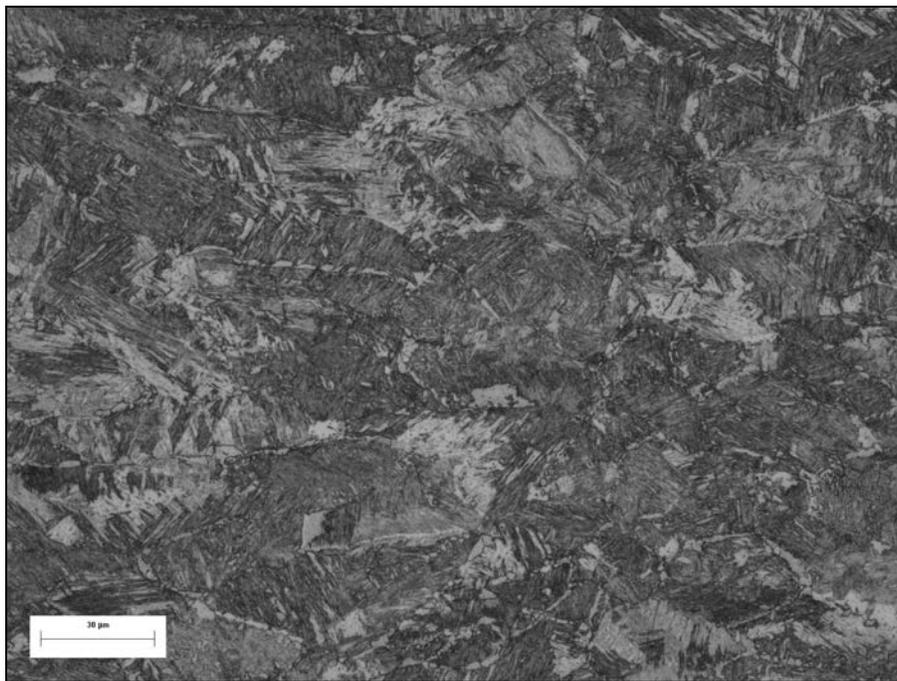
**Etched condition**                      **Figure 34**                      **100x**  
**Sample #A Location #3.** Micro-image of a representative structure.



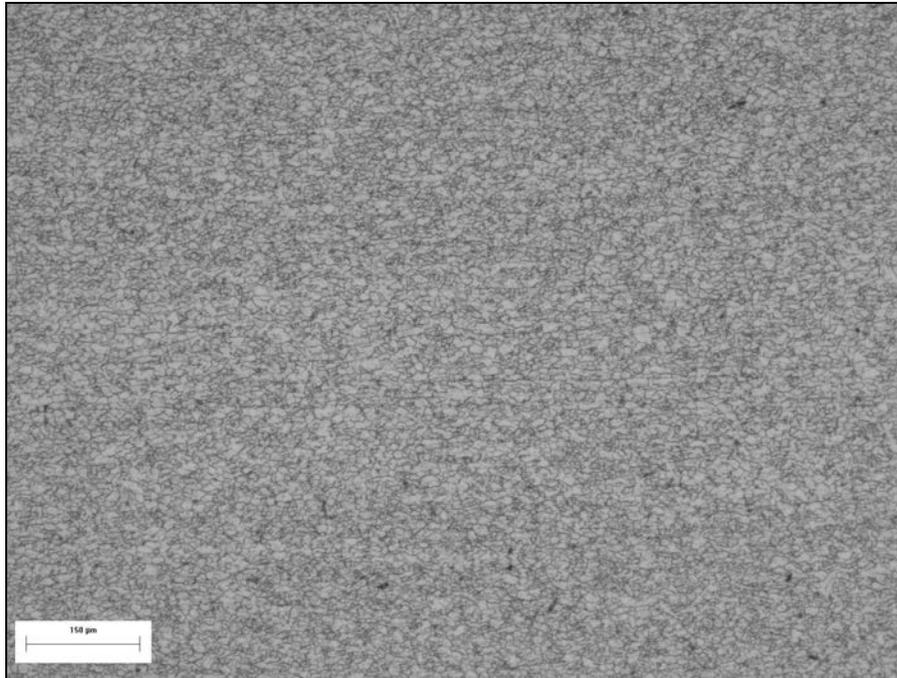
**Etched condition**                      **Figure 35**                      **500x**  
**Sample #A Location #3.** Micro-image of a representative structure.



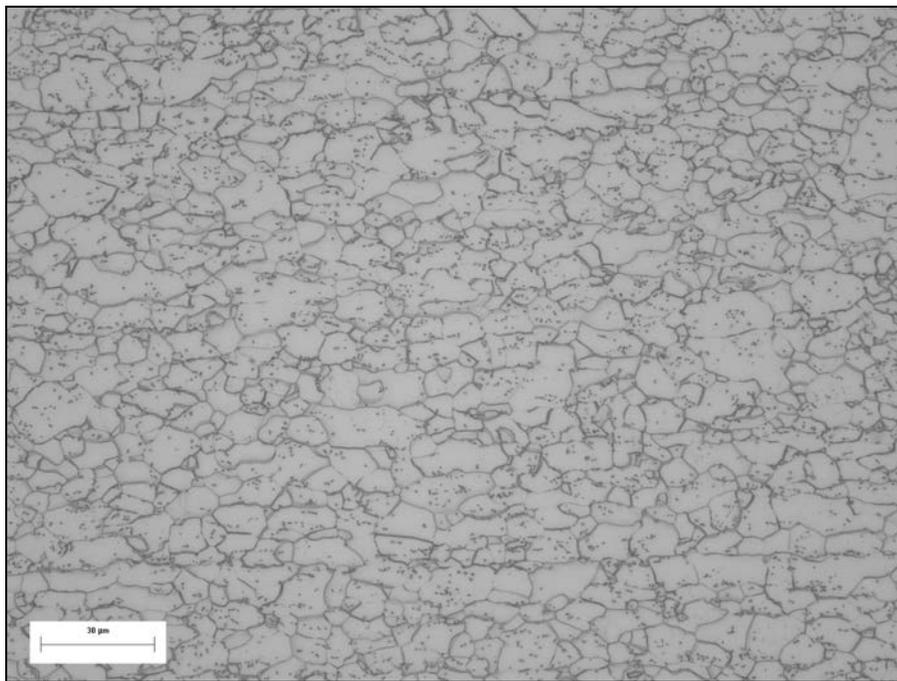
**Etched condition**                      **Figure 36**                      **50x**  
**Sample #A Location #4.** Micro-image microstructure of the weld.



**Etched condition**                      **Figure 37**                      **500x**  
**Sample #A Location #4.** Micro-image of a representative structure.

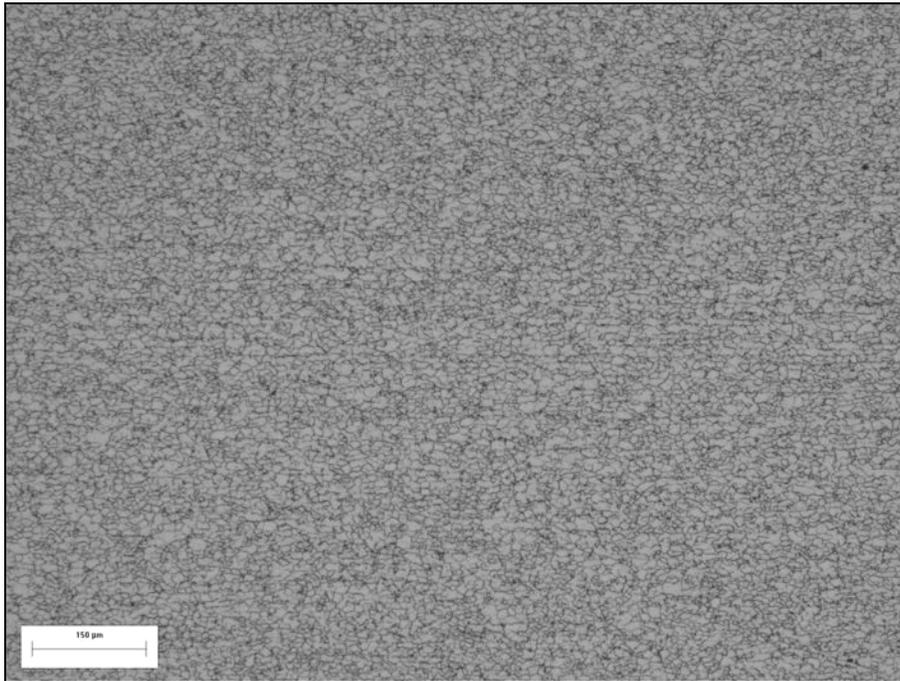


**Etched condition**                      **Figure 38**                      **100x**  
**Sample #A Location #5.** Micro-image of a representative structure.

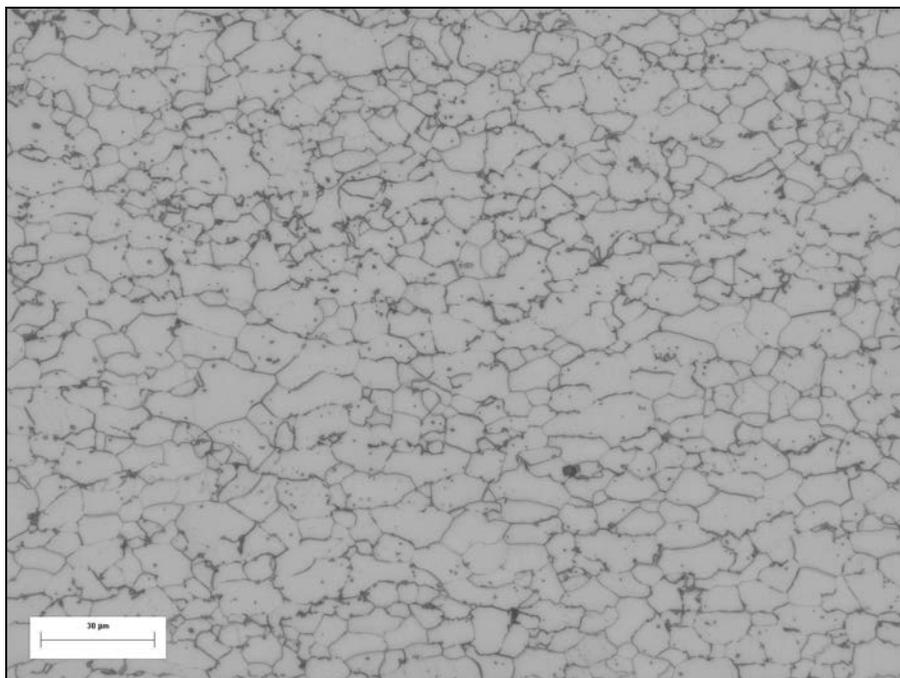


**Etched condition**                      **Figure 39**                      **500x**

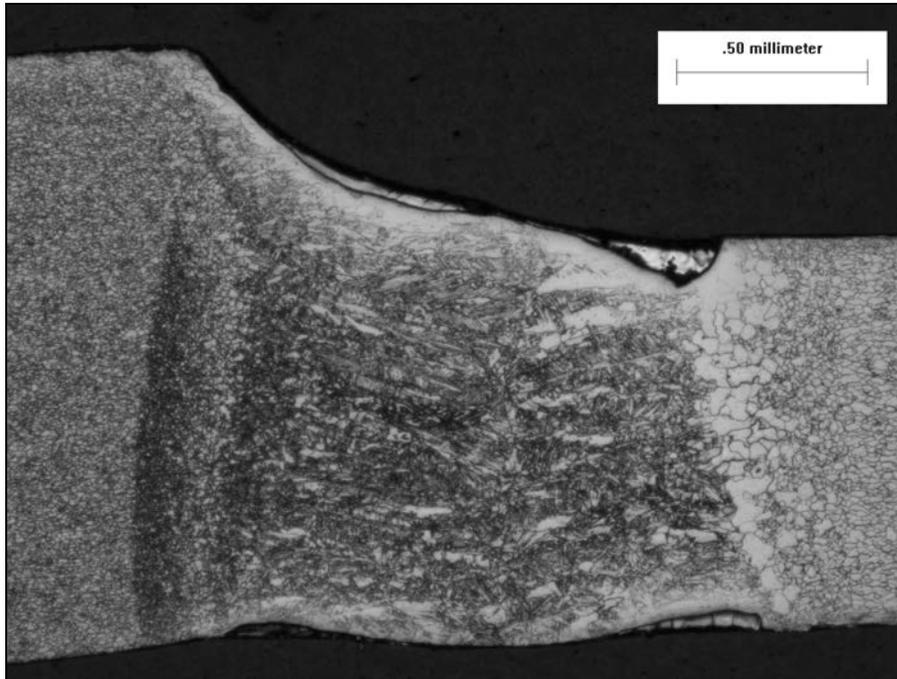
**Sample #A Location #5.** Micro-image of a representative structure.



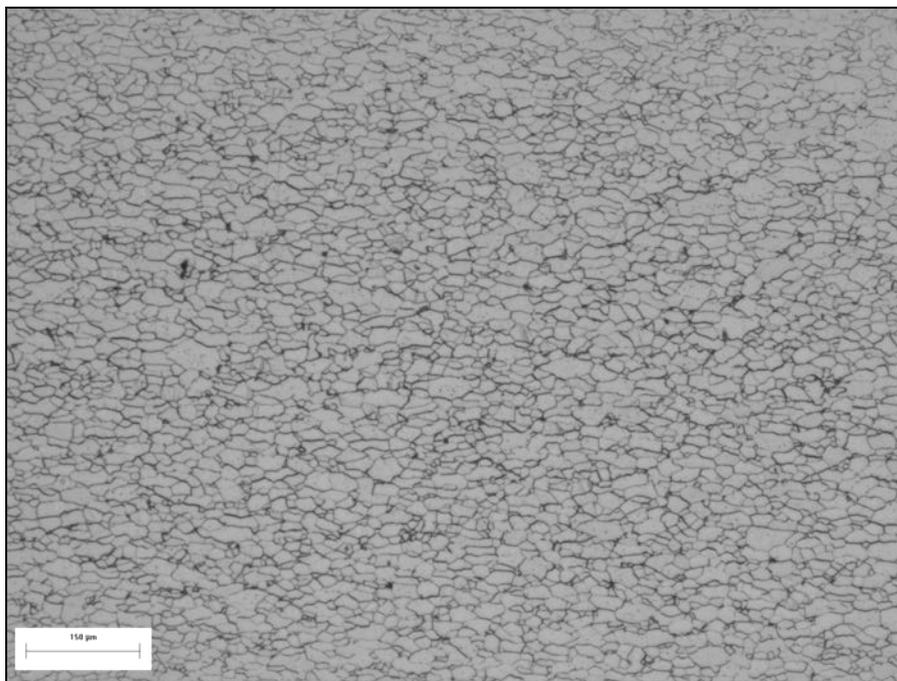
**Etched condition**                      **Figure 40**                      **100x**  
**Sample #B Location #1.** Micro-image of a representative structure.



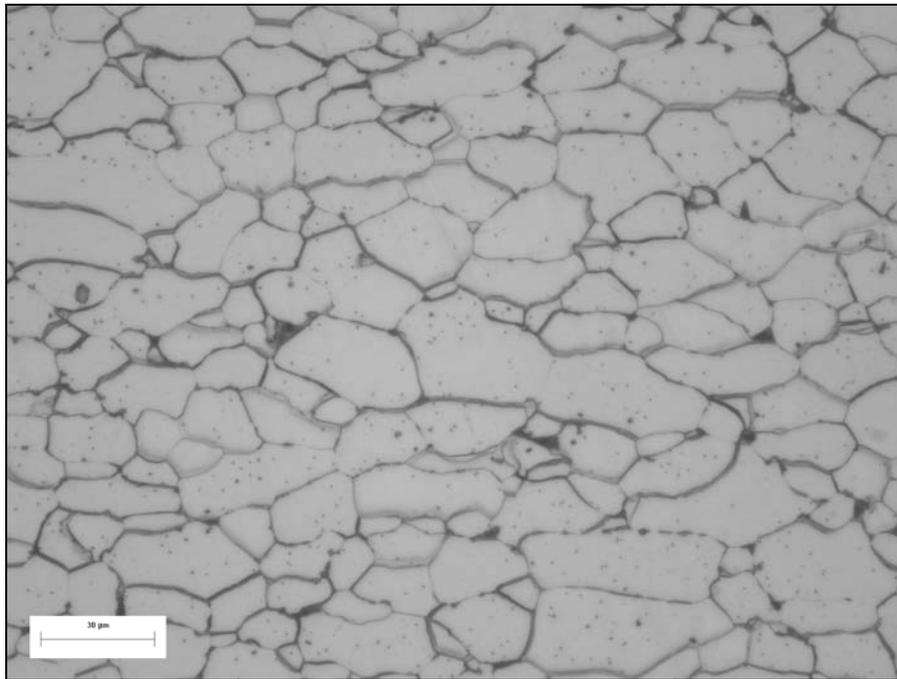
**Etched condition**                      **Figure 41**                      **500x**  
**Sample #B Location #1.** Micro-image of a representative structure.



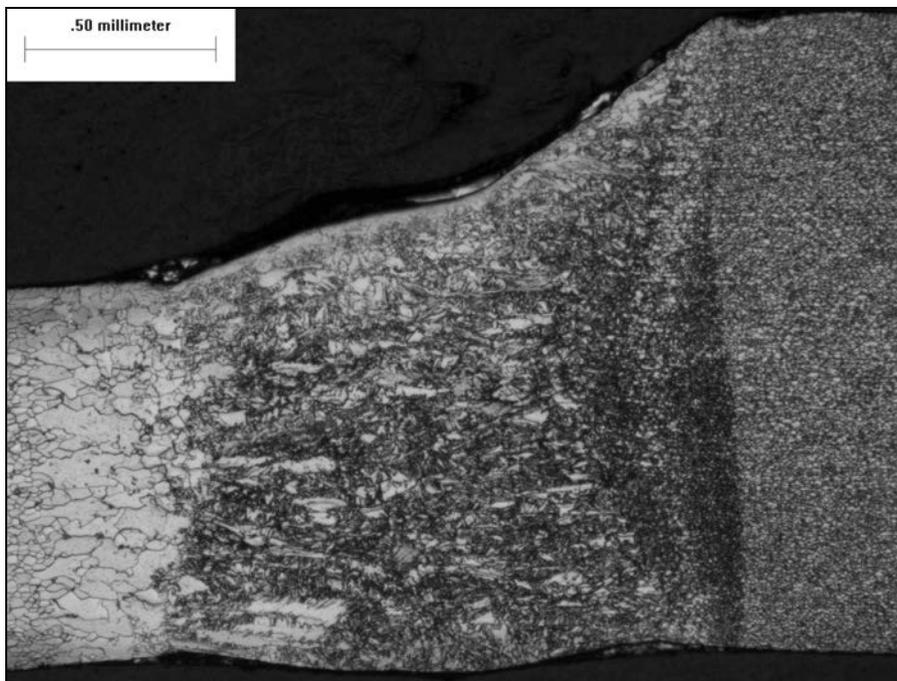
**Etched condition** **Figure 42** **50x**  
**Sample #B Location #2.** Micro-image microstructure of the weld.



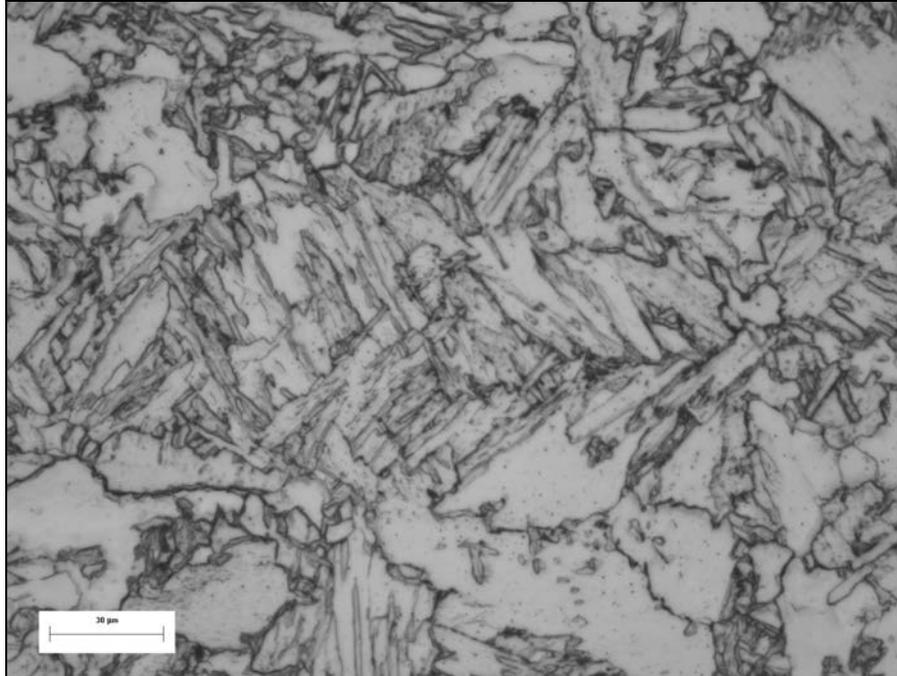
**Etched condition** **Figure 43** **100x**  
**Sample #B Location #3.** Micro-image of a representative structure.



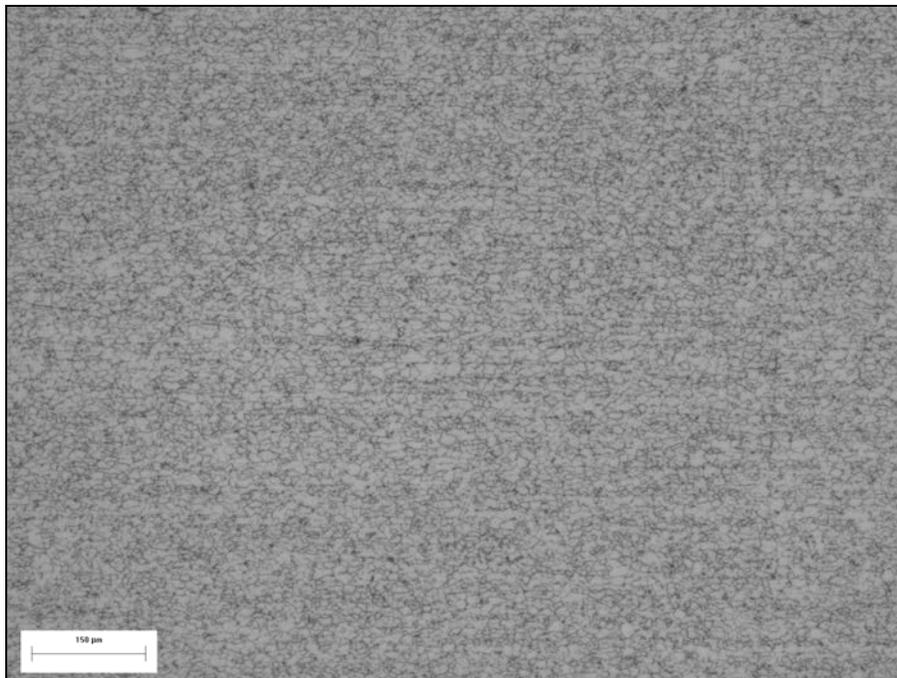
**Etched condition** **Figure 44** **500x**  
**Sample #B Location #3.** Micro-image of a representative structure.



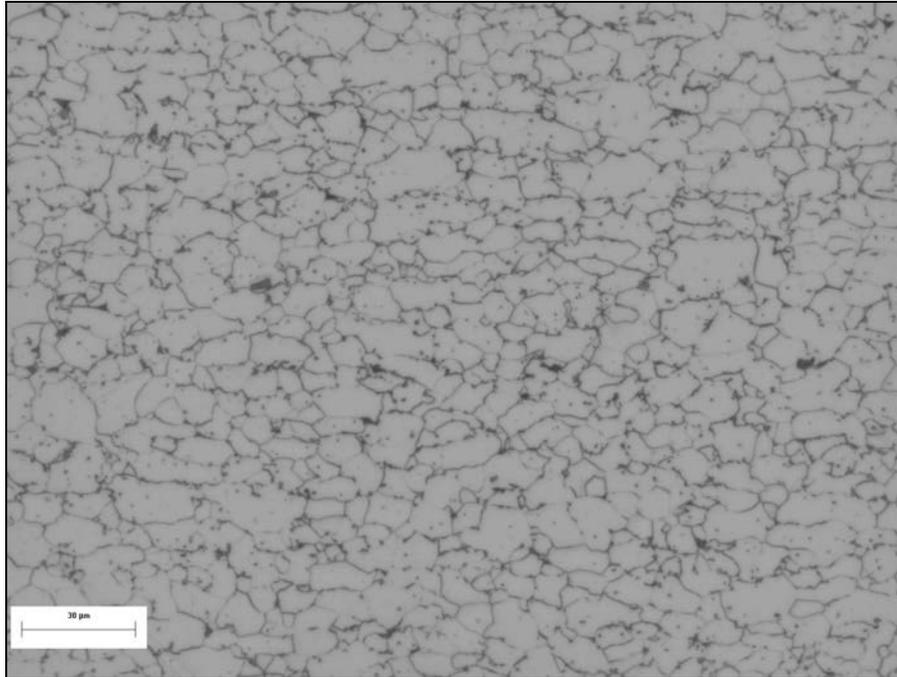
**Etched condition** **Figure 45** **50x**  
**Sample #B Location #4.** Micro-image microstructure of the weld.



**Etched condition**                      **Figure 46**                      **500x**  
**Sample #B Location #4.** Micro-image of a representative structure.



**Etched condition**                      **Figure 47**                      **100x**  
**Sample #B Location #5.** Micro-image of a representative structure.



**Etched condition**                      **Figure 48**                      **500x**  
**Sample #B Location #5.** Micro-image of a representative structure.

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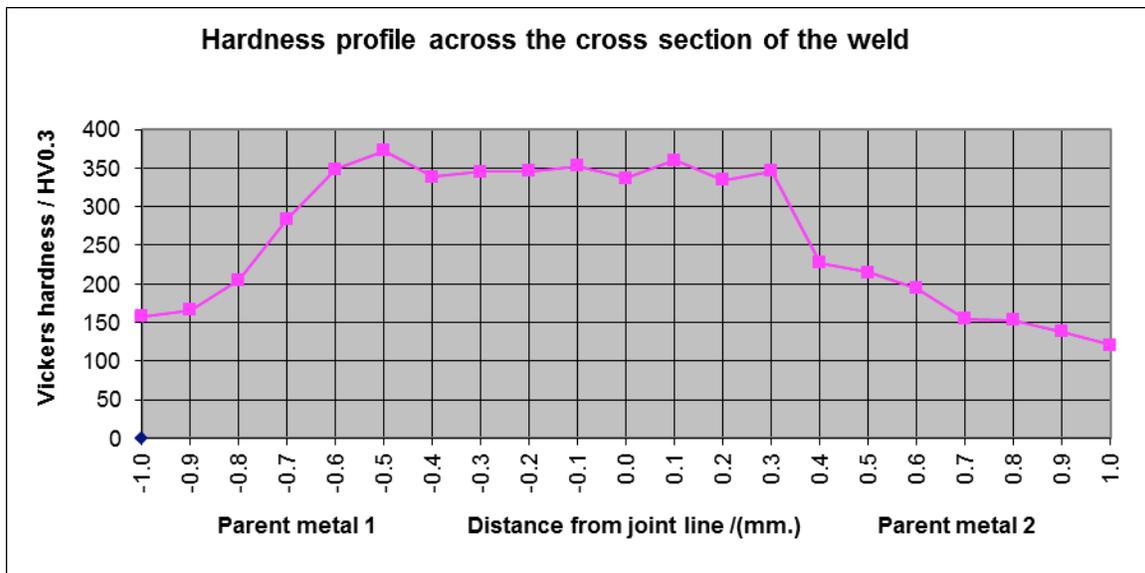
**Physical tests:** Analytical Method: ASTM E384-10<sup>1</sup>

Micro-hardness traverse readings were taken on the transversally sectioned and mounted sample from Parent metal side “A”, through welded region, to Parent metal side “B” using Vickers at 300 gram-force load.

**Sample A**

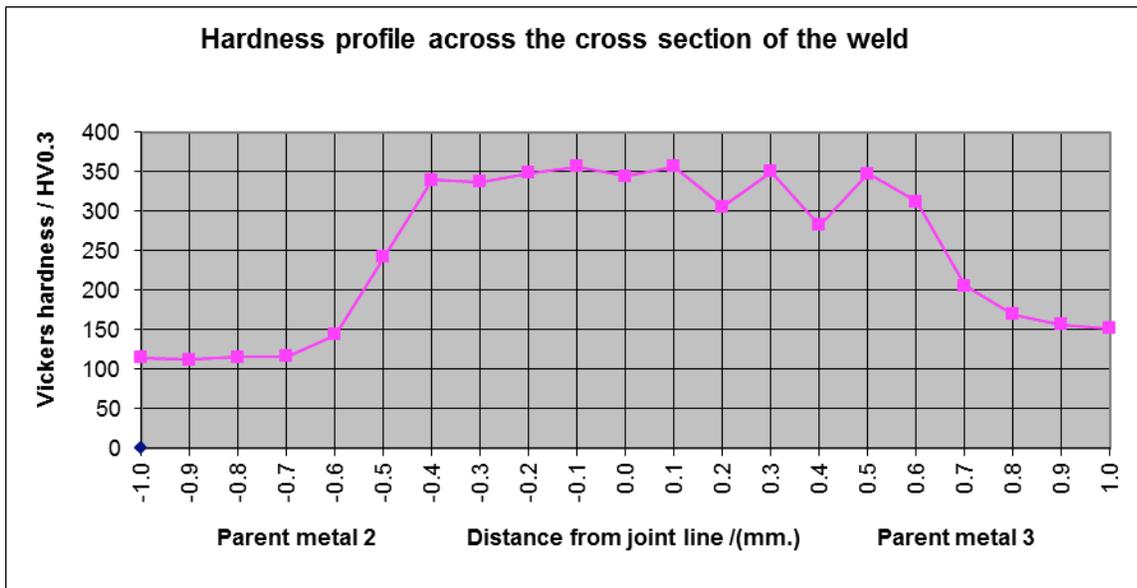
**Location 2**

Distance from joint line (mm.)	Vickers micro-hardness HV <sub>0.3</sub>	
	Parent metal “1”	Parent metal “2”
0.00	337	
±0.1	352	360
±0.2	346	335
±0.3	345	346
±0.4	339	277
±0.5	373	215
±0.6	349	194
±0.7	284	155
±0.8	205	153
±0.9	116	138
±1.0	158	120



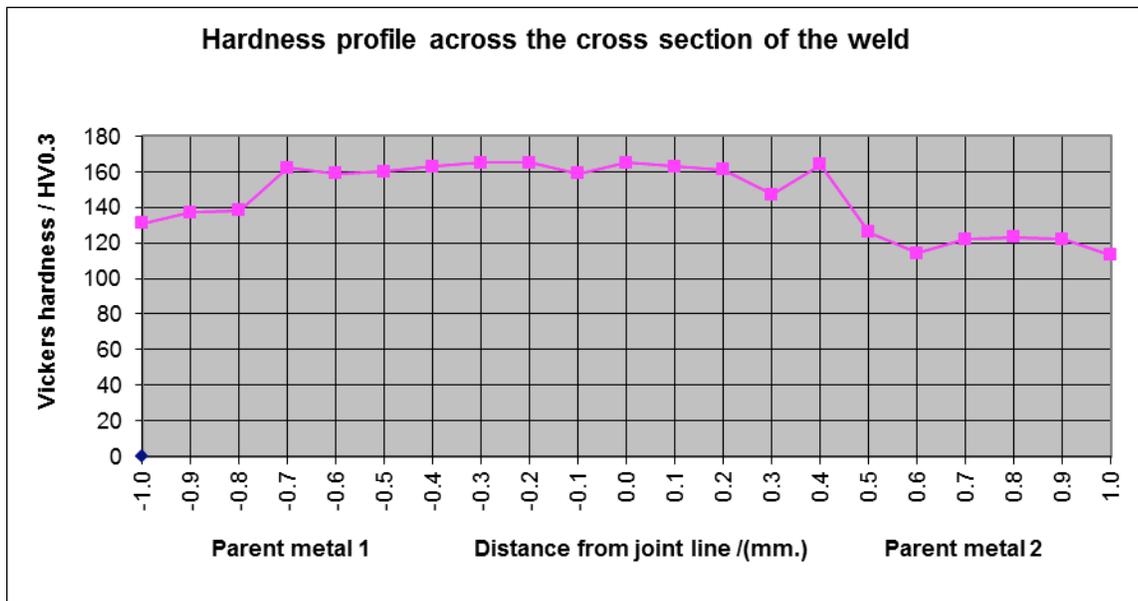
**Location 4**

Distance from joint line (mm.)	Vickers micro-hardness HV <sub>0.3</sub>	
	Parent metal "2"	Parent metal "3"
0.00	344	
±0.1	356	356
±0.2	348	305
±0.3	332	350
±0.4	339	282
±0.5	242	347
±0.6	143	313
±0.7	116	205
±0.8	115	169
±0.9	112	156
±1.0	114	151



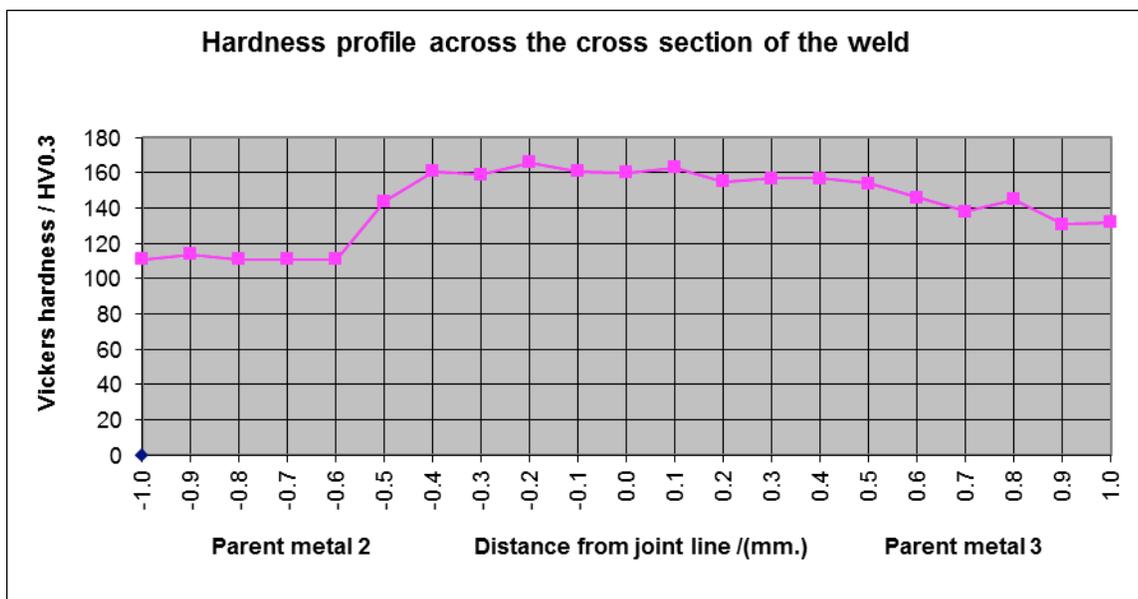
**Sample B****Location 2**

Distance from joint line (mm.)	Vickers micro-hardness HV <sub>0.3</sub>	
	Parent metal "1"	Parent metal "2"
0.00	165	
±0.1	159	163
±0.2	165	161
±0.3	165	147
±0.4	163	164
±0.5	160	126
±0.6	159	114
±0.7	162	122
±0.8	138	123
±0.9	137	122
±1.0	131	113



**Location 4**

Distance from joint line (mm.)	Vickers micro-hardness HV <sub>0.3</sub>	
	Parent metal "2"	Parent metal "3"
0.00	160	
±0.1	161	163
±0.2	166	155
±0.3	159	157
±0.4	161	157
±0.5	144	154
±0.6	111	146
±0.7	111	138
±0.8	111	145
±0.9	114	131
±1.0	111	132



In Summary:

A comprehensive inspection of materials physical and mechanical properties have been provided to support research and development into parameters defining welding between metals of dissimilar gauge.

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