M. E. Williams and Associates, Inc.

"Excellence in Metallurgical Engineering"

12825 385th Avenue
Waseca, MN 56093

Case Study: Robotic Welder Qualification

By

Merlin E. Williams, P.E.

Subject

Two square butt samples welded by a robotic welder were examined to determine their compliance with AWS D1.1. Both samples were rejected for lack of fusion at the root. The samples were examined by root Bend Testing, visual examination, and metallographic examination.

Visual Examination

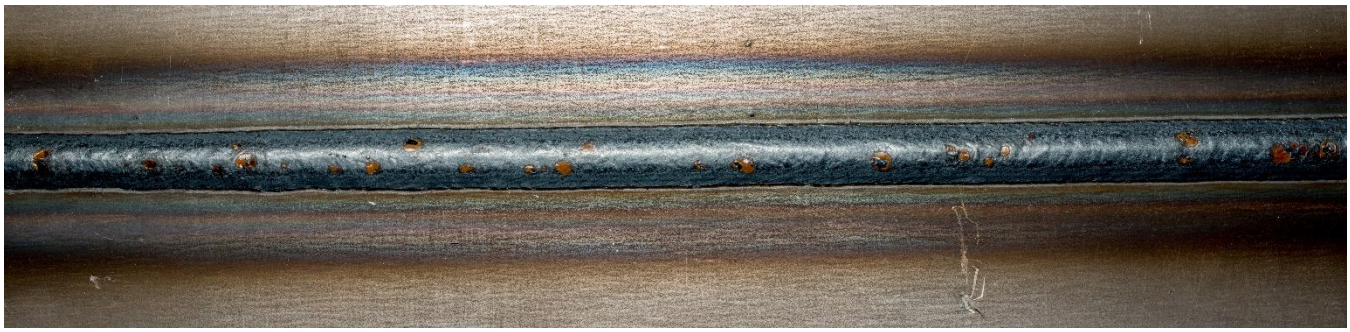

Figure 1 – Sample 1 CO_2 Cover Gas - Top Side

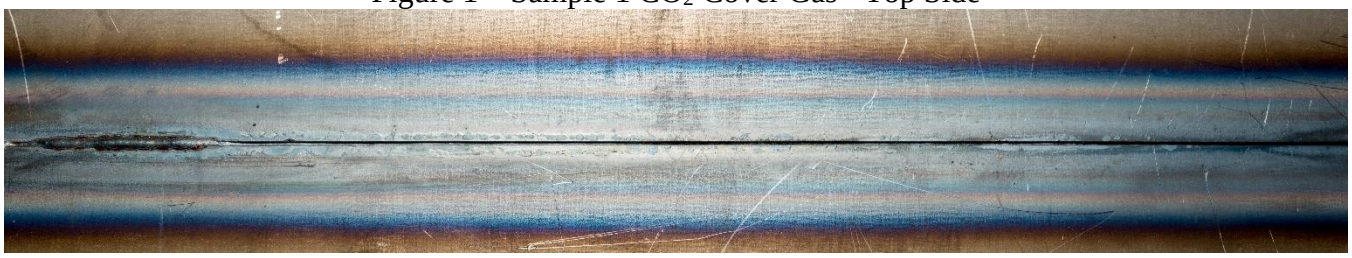

Figure 2 – Sample 1 CO_2 Cover Gas - Root Side

Figures 1 and 2 show Sample 1. The sample was identified as CO_2 Cover Gas. The cover gas was 90% Argon and 10% CO_2. The left side of Figure 2 shows where the root pass had full penetration. There was excellent root fusion in the full penetration section of the weld.

Phone (507) 835-2344 • FAX (507) 835-3412 • Twin Cities & Cell (612) 750-5578 • Toll Free (800) 854-6078

Email merlin@mewai.com – Web Site www.mewai.com

Figure 3 – Sample 2 Top Side

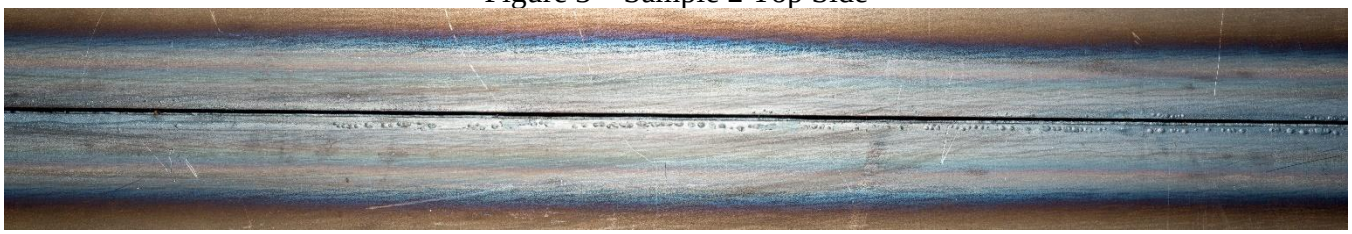

Figure 4 – Sample 2 Root Pass

The weld from Sample 2 is shown in Figures 3 and 4. There were no locations where the weld penetrated to the root. The cover gas used was not specified.

Root Bend Test

Figure 5 – Sample 1 Bend Test 1

Figure 6 – Sample 1 Bend Test 2

Figure 5 shows a crack that developed in the root of Bend Test 1. This sample was taken from an area where the weld had not penetrated to the root. Figure 6 shows Bend Test 2. There was a small crack near the location where full penetration had occurred.

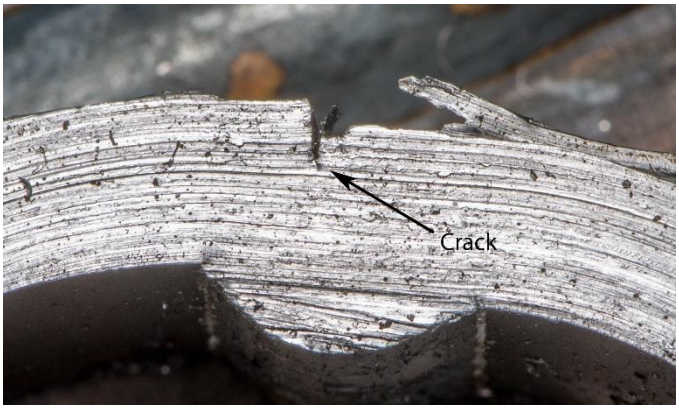

Figure 7 – Sample 2 Bend Test 1

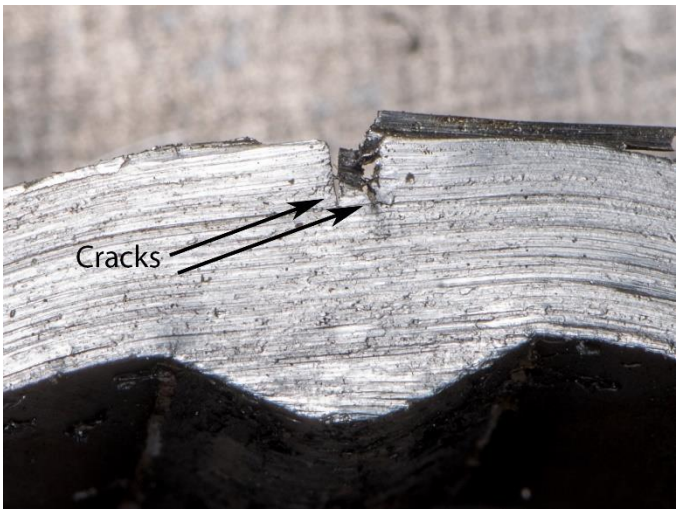

Figure 8 – Sample 2 Bend Test 2

Figure 7 shows a fine crack that developed at the root of the weld from Sample 2, Bend Test 1. Figure 8 shows lack of fusion at the root of the weld in Bend Test 2.

Metallographic Examination

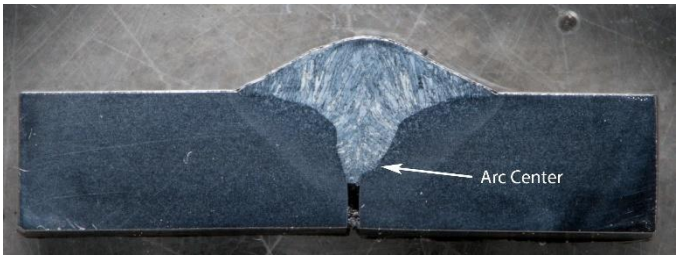

Figure 9 – Macro of Weld – Sample 1

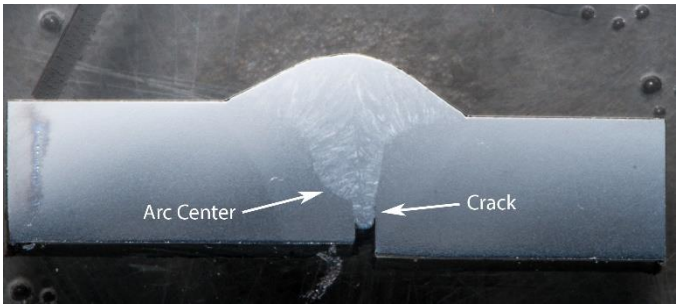

Figure 10 – Macro of Weld – Sample 2

Figure 9 shows the etched weld from Sample 1. The weld arc was not centered on the spacing between the two ¼ inch plates.

Figure 10 shows the etched weld from Sample 2. The weld arc was not centered on the spacing between the two ¼ inch plates, resulting in a visible crack at the root of the weld.

The lack of centering of the weld arc was the cause of failure of these two welds.

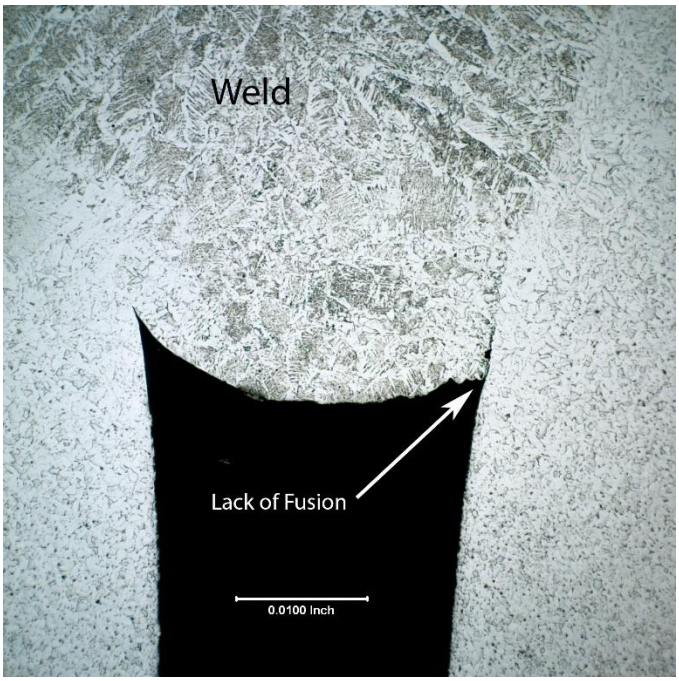

Figure 11 – 100X Lack of Fusion in Weld Root – Sample 1

Figure 12 – 100X Plate HAZ

The weld root in Sample 1 is shown in Figure 11. There was lack of fusion on the right side. The lack of fusion was caused by the off-centering of the welding arc. The plate heat affected zone, HAZ, is shown in Figure 12. The microstructure of the HAZ is a mixture of ferrite and acicular ferrite, which is excellent for the grade of steel used. There was no evidence of excessive grain growth and no evidence that "Carburization" had any effect on the weld quality.

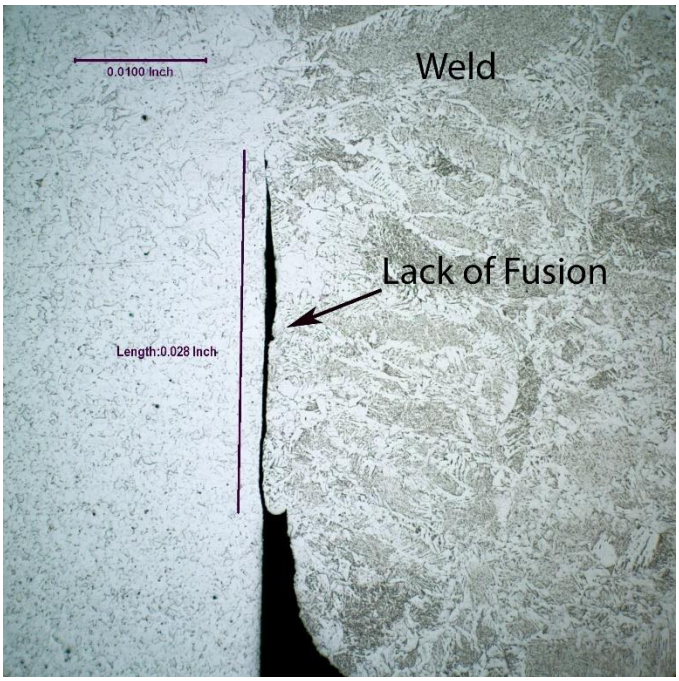

Figure 13 – 100X Lack of Fusion in Weld Root – Sample 2

Figure 14 – 100X Plate HAZ – Sample 2

There was a significant amount of lack of fusion at the root of Weld Sample 2, Figure 13. The lack of fusion was the result of the weld arc not being centered on the spacing between the ¼ inch plates. The amount of the lack of fusion shown would likely result in eventual failure of the part. The plate HAZ is shown in Figure 14. The microstructure of the HAZ was a mixture of ferrite and acicular ferrite, which is excellent. There was no evidence of excessive grain size.

Lack of fusion is not permitted for partial penetration welds under AWS D1.1.

Conclusions

1) The weld arc must be centered on the center line between the two plates to avoid lack of fusion in the weld root.

2) Robotic welders require very precise setup to produce quality welds.