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EVALUATION OF 3/32 IN. FILLET
WIRE-END CAP WELD

R. L. Myers

April 1970

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WIRE-END CAP WELD

by

R. L. Myers

FFTF Fuels Department
FFTF Division

April, 1970

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EVALUATION OF 3/32 in. FILLET
WIRE-END CAP WELD

R. L. Myers

ABSTRACT - 1332

A study of the 3/32 in. fillet wire-end cap weld was made to determine the characteristics of this welding technique. The test samples were similar to actual wire-end cap welds used on fuel pins. The welding parameters were controlled and recorded.

A visual examination revealed only minor dimensional variations in the length of the weld. Radiography showed that 3 of the 22 welds lacked penetration. When tensile tested, strength of the welds was found to be inversely proportional to the amount of penetration. All samples fractured on the wire side of the welds. Good resistance to corrosion was demonstrated in oxalic acid etch tests. Metallography confirmed previous radiography results and revealed that the amount of necking in the wire next to the weld increased as penetration increased.

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EXAMINATION OF 3/32 in. FILLET WIRE-END CAP WELD

R. L. Myers

INTRODUCTION

In a previous report, (1) a comparison of tensile strengths was given for five different wire wrap to end-cap weld designs. A further study has been made of the 3/32 in. fillet weld [called "small" weld in Reference (1)]. These weld samples were designed to simulate the wire to end-cap weld configuration. The fabrication and test procedure were done as outlined in Reference (2), with two exceptions: (1) a visual examination under a magnification of 10X was not done, and (2) tensile tests were conducted in addition to other test requirements.

SUMMARY AND CONCLUSION

The weakest link of the 3/32 in. fillet-type wire wrap-end cap joint is at the weld-wire interface and the adjoining wire. The joint strength is at least equal to or greater than the tensile strength of the annealed wire.

To reduce necking and the heat affect in the wire, a minimum amount of penetration is desirable, although it must be sufficient enough (as determined by radiography) to maintain confidence in the weld. The midtolerance penetration appears to satisfy these two conditions. However, the amount of necking that can be tolerated has not been determined.

The welding technique does not noticeably increase the susceptibility of the joint to intergranular attack and subsequent corrosion.

DISCUSSION

FABRICATION

Figure 1 shows the geometrical configuration of the weld samples. The rods were made of 316 SS, with the small diameter equal to the end cap diameter (0.187) and the large diameter equal to the tube diameter (0.230). The wire was 20% cold worked, 316 SS, 0.056 diam. A total of 22 weld samples were made according to Reference (2). Six welds were made with the weld parameters set to obtain the minimum acceptable penetration; these were labeled S-1 through S-6. Six welds made with the weld parameters set for maximum penetration were labeled L-1 through L-6. Ten welds made with the weld parameters set at mid-range values were labeled M-1 through M-10.

FIGURE 1. Tensile Test Samples

The weld parameters designated in Reference (2) are listed in Table 1. Only the current-time relationship was adjusted to obtain the different levels of penetration. The other parameters have less effect on penetration and are difficult to control when manual welding is used.

TABLE 1. Weld Parameters

Electrode	2% thoriated tungsten
Electrode Size	1/16 in.
Filler Metal	316 SS, 0.040 Diam. wire
Vertex angle of electrode tip at arc end	~30°

TABLE 1. (contd)

Distance of electrode extension beyond gas cup	1/8 - 1/4 in.
Gas Cup Size	No. 6 (HW20 torch)
Method of Arc Initiation	Foot control
Description of current slop control	Foot control
Nature of Current	d.c., straight polarity
Method of location and alignment of welding equip- ment with weld joint	Manual
Electrode tip to work distance	Varies
Current program: current- time relationship	Gradually increase to 8 A at ~10 sec; then drop to 0.
Voltage and points where voltage is measured	Controlled by foot lever
Method of establishing arc length	Manual
Welding Speed	None
Filler Wire Speed	As needed
Torch Angle: Axial, Lead	30°-40° and 0°
Gas Type	Argon
Gas Flow at Cup	15 ± 5 cfm
Fixtures, tack welds, etc. used for assembly of joint for welding	Hand Clamp

The maximum current and time of welding are recorded with other results in Table 2. The exact current-time relationship varies with each weld sample. However, the averages for each level of penetration show significant differences.

EXAMINATION

The length, height, and width of each weld was measured and is included in Table 2. The required visual examination

TABLE 2. Tensile Test Data and Results

Sample Number	Type	Length, in.	Width, in.	Height, in.	Current, A	Duration of Current, sec	Fracture Location (joint)	Maximum Load, lb	Strength, psi
S-1	Min. Penet.	0.12	0.103	0.085	7.2	10.0	1	234.0	95,100
S-2	Min. Penet.	0.10	0.094	0.075	7.2	9.0	2	214.0	86,900
S-3	Min. Penet.	0.09	0.097	0.076	7.1	11.0	6	>227.0	>92,200
S-4	Min. Penet.	0.10	0.098	0.080	7.2	11.0	1	>234.0	>95,100
S-5	Min. Penet.	0.10	0.099	0.084	7.2	10.0	2	>214.0	>86,900
S-6	Min. Penet.	0.10	0.106	0.076	7.3	11.0	6	227.0	92,200
Avg. S	Min. Penet.	0.102	0.100	0.079	7.2	10.3	-	225.0	91,400
M-1	Max. Penet.	0.14	0.110	0.078	8.1	10.0	1	218.0	88,600
M-2	Max. Penet.	0.12	0.096	0.078	7.9	8.0	2	224.0	91,000
M-3	Max. Penet.	0.10	0.090	0.078	7.5	10.0	8	>218.0	>88,600
M-4	Max. Penet.	0.11	0.106	0.075	8.0	11.0	4	198.0	80,400
M-5	Max. Penet.	0.14	0.116	0.086	8.0	10.0	5	227.0	92,200
M-6	Max. Penet.	0.14	0.107	0.078	7.6	12.0	1	>218.0	>86,600
M-7	Max. Penet.	0.14	0.091	0.079	7.8	8.0	2	>224.0	>91,000
M-8	Max. Penet.	0.12	0.088	0.081	7.9	9.0	8	218.0	88,600
M-9	Max. Penet.	0.12	0.087	0.071	7.9	10.0	4	>198.0	>80,400
M-10	Max. Penet.	0.10	0.105	0.077	7.9	8.0	5	>227.0	>92,200
Avg. M	Max. Penet.	0.12	0.100	0.078	7.9	9.6	-	217.0	88,160
L-1	Max. Penet.	0.12	0.099	0.074	7.9	6.0	1	215.0	87,400
L-2	Max. Penet.	0.16	0.123	0.086	8.0	8.0	5	>222.0	>90,200
L-3	Max. Penet.	0.15	0.123	0.074	8.0	6.0	3	204.0	82,800
L-4	Max. Penet.	0.15	0.132	0.075	8.0	8.0	1	>215.0	>87,400
L-5	Max. Penet.	0.14	0.104	0.079	8.1	7.0	5	222.0	90,200
L-6	Max. Penet.	0.12	0.118	0.075	8.0	6.0	3	>204.0	>82,800
Avg. L	Max. Penet.	0.14	0.116	0.077	8.0	7.0	-	213.7	86,800
Total Avg		0.122	0.104	0.078	7.72	9.0	-	218.3	88,630

at 10X magnification⁽²⁾ was not performed; however, photographs of 6X magnification were taken of each weld (Figures 2, 3, and 4).

TESTS

Radiography

The completed welds were radiographed as required.⁽²⁾ Two pictures were taken, one each at 0° (side view) and 90° (top view). All welds were acceptable in the 90° direction. In the 0° direction, three welds, one minimum penetration (S-4) and two midrange penetration (M-2 and M-3), were marginal, having some fusion but thin penetration.

Tensile Tests

Tensile tests were made as an addition to the requirements of A-0088-R for comparison with previous tests. As expected, the fracture in all cases occurred in the heat-affected zone of the wire next to the weld. The tests were performed at a strain rate of 0.05 in./min. The maximum load and corresponding strength are given in Table 2 for each weld.

Acid Etch Tests

Six welds, including two of each type, were oxalic acid-etch tested as required.⁽²⁾

Metallographic Tests

Those welds that were not acid-etch tested were metallographically examined. Half of the welds were cut axially along the length of the sample, and half were cut laterally through the weld. Photographs of each sample were taken at 10X magnification.

6X

Neg 069343-1

FIGURE 2. Small Penetration Weld Samples After Tensile Tests

Neg 0693463-2

6X

FIGURE 3. Large Penetration Weld Samples After Tensile Tests

Neg 0693463-3

6X

FIGURE 4. Medium Penetration Weld Samples After Tensile Tests

RESULTS

DIMENSIONS

If the specified weld has the normal tolerance limits of $\pm \frac{1}{64}$, the allowable weld size range would be 0.078 to 0.110. The length of the weld (along the base at the rod) exceeds the upper tolerance limit on the middle and large penetration welds (Table 2). Obtaining an acceptable weld is of more importance than maintaining the exact weld size. Therefore, the out-of-tolerance condition is permissible.

RADIOGRAPHY

An interesting observation is that all three welds not showing acceptable weld penetration had average or above average strengths when tensile tested. The fact that none of these welds broke in the weld emphasizes that the weakest link in the joint is not the weld itself. Instead, it is the weld-wire interface or the heat affected zone in the wire next to the weld.

TENSILE TESTS

Tensile Test results are given in Table 2, where the averages for each weld type are given along with the average for the entire sample. The fact that the average strength of the joint decreases as the amount of penetration increases is expected because the strongest joint is the one where the annealing of the wire in the heat-affected-zone is the least. This condition occurs in the small penetration welds. In the large penetration welds there is more heat, more annealing and, hence, lower strength. In all cases, the strength of the heat-affected zone of the wire is the weakest link in the entire weld joint.

ACID ETCH TEST

The step structure shown in Figure 5 is typical of all samples tested, and indicates acceptable resistance to intergranular attack.⁽³⁾

An interesting observation was made with Weld Number L-4. A fracture had started at this end of the test sample but the opposite end (Weld L-1) broke first. Had the fracture occurred in Weld L-4, it clearly would have been at the weld-wire interface (Figure 6). Every sample fractured in the vicinity of this interface, which is the weakest link in the weld joint.

METALLOGRAPHY

Figures 7, 8, 9, and 10 (10X) show the lateral and axial cuts on the weld samples with minimum acceptable penetration. The penetration shown in Figures 7 and 8 may be misleading because the exact location of the cut through the weld is not known. It is probable that the cut was made at the point of maximum weld height, which is not necessarily the point of maximum penetration. Thus, the penetration cannot be measured from photographs showing lateral cuts.

The axial cuts, showing the length of the weld, do show the amount of penetration accurately. The lack of penetration in Figure 9 confirms the radiographic results on Sample S-4.

Also observed in Figure 9 is what appears to be a shadow along the wire and weld. The "shadow" appears because the specimen was not cut through the exact center of the wire. The center of the wire, where the diameter is largest, shows up as a shadow in the photograph. Evident in many of the pictures, this shadow gives a misleading appearance of greater necking in the wire than actually exists. In Figure 10, the "shadow" is smaller and more even, and close examination is required to see the necking in the wire.

253X

FIGURE 5. Weld Sample S-3, Oxalic Acid Etch Test

100X

FIGURE 6. Weld Sample L-4, Oxalic Acid Etch Test

10X

FIGURE 7. Weld Sample S-2, Lateral Cut

10X

FIGURE 8. Weld Sample S-1, Lateral Cut

10x

FIGURE 9. Weld Sample S-4, Axial Cut

10X

FIGURE 10. Weld Sample S-5, Axial Cut

The medium penetration welds are shown in Figures 11, 12, 13, 14, 15, 16, 17, and 18 while the maximum acceptable penetration welds can be found in Figures 19 through 22. The same observations made from Figures 7 through 10 regarding "shadows" also apply to Figures 11 through 22. Comparing Figures 10, 11, and 19, where "shadow" appearance is minimum for each of the three weld types, the amount of necking in the wire is seen to increase with increased penetration.

10X

FIGURE 11. Weld Sample M-9, Axial Cut

10X

FIGURE 12. Weld Sample M-7, Axial Cut

10X

FIGURE 13. Weld Sample M-3, Axial Cut

10X

FIGURE 14. Weld Sample M-10, Axial Cut

10X

FIGURE 15. Weld Sample M-4, Lateral Cut

10X

FIGURE 16. Weld Sample M-5, Lateral Cut

10X

FIGURE 17. Weld Sample M-2, Lateral Cut

10X

FIGURE 18. Weld Sample M-8, Lateral Cut

10X

FIGURE 19. Weld Sample L-2, Axial Cut

10X

FIGURE 20. Weld Sample L-6, Axial Cut

10X

FIGURE 21. Weld Sample L-5, Lateral Cut

10X

FIGURE 22. Weld Sample L-3, Lateral Cut

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