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MASTER

RESISTANCE SPOT WELDING STAINLESS STEEL FOIL
BY THE EXPENDABLE-WIRE TECHNIQUE

C. L. Estes

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE Y-12 PLANT

operated for the **ATOMIC ENERGY COMMISSION** *under* **U. S. GOVERNMENT Contract W-7405 eng 26**

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CARBIDE**

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ABSTRACT

A spot welding method, which consists of placing an expendable copper wire between the workpiece and the electrode of the resistance spot welder, has been developed, demonstrated, and evaluated. This technique eliminates the need for electrode dressing, produces elongated spot welds that reduce the number of individual welds needed, and can be used at locations that are very close to the edges of the workpiece.

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SUMMARY

Electrolytic, tough-pitch, 0.300-inch-diameter copper wire in the annealed condition was used to produce consistent and uniform-resistance spot welds in 0.003-inch Type AISI 304 stainless steel foil.

The wire was placed in contact with the surface of the parts to be welded and the upper electrode lowered into contact with the wire. The elongated spot welds were approximately 0.010 inch wide by 0.070 inch long. The annealed copper wire provided a cushion between the surfaces being welded and the electrode, and it virtually eliminated dressing or replacing of the copper alloy electrode. Reliable and reproducible spots were obtained because the wire was discarded after each series of welds was completed.

The tensile-shear strength of the spots was 46.3 ± 6.8 pounds at the 95 percent confidence level, using an energy input of 35 watt seconds and an electrode-force setting of 30 pounds. Other important advantages realized by using the expendable-wire method for spot welding include: (1) more of the effective spot area can be located closer to part edges than with round spots, and (2) the number of spots required was reduced by 55 to 60 percent.

INTRODUCTION

A new method for producing resistance spot welds in thin materials has been under study. This technique involves the use of an expendable-wire electrode placed in contact with the parts to be welded.

STUDY OF THE WELDING METHOD

EQUIPMENT AND TECHNIQUE

Figure 1 presents an overall view of the equipment used in the welding operation. Included are a 200-watt second capacitor discharge power supply and a pressure-sensing head which has a force rating of 0 to 50 pounds. The Micarta^(a) specimen holder is shown in the welding position on the welding head. Figure 2 shows the assembly of jigs, expendable-wire electrode, and stainless steel test specimens in place for welding. The upper welding electrode is lowered successively into each hole in the upper section of the holder and contacts the expendable wire which is in contact with the surface of the parts to be welded.

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Figure 1. EQUIPMENT FOR WELDING THIN MATERIALS BY THE EXPENDABLE-WIRE METHOD.

(a) A product of the Westinghouse Electric Corporation.

Figure 2. EXPENDABLE-WIRE WELDING ASSEMBLY.

Figure 3 shows the Micarta specimen holder with the stainless steel discs and the expendable wire in position for welding. In Figure 4, the coupon holder, opened after welding, is presented. Figure 4(a) shows the top of the holder; the expendable wire in the welding position on the stainless specimen can be seen in Figure 4(b). The opened coupon holder with the expendable wire in the top section of the holder is seen in Figure 5(a). Figure 5(b) shows the elongated nature of the completed spot welds in a 0.003-inch-thick Type AISI 304 stainless steel test specimen.

A circular, welded coupon of 0.003-inch-thick stainless steel showing the location of the spot welds within approximately 0.010 inch of the edge of the specimen is shown in Figure 6. As can be seen, burn out at the edge is not a problem when utilizing the expendable-wire technique.

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Figure 3. TOP VIEW OF THE COUPON HOLDER WITH THE PARTS AND WIRE IN POSITION FOR WELDING.

(a) Top of Holder

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(b) Expendable Wire in Position on the Stainless Steel Coupon

Figure 4. COUPON HOLDER OPENED AFTER WELDING.

(a) Expendable Wire in Position

(b) Completed Spot Welds

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Figure 5. COUPON HOLDER OPENED AFTER WELDING SHOWING THE COMPLETED SPOT WELDS.

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Figure 6. ELONGATED SPOT WELDS IN A TYPE AISI 304 STAINLESS STEEL TEST COUPON. (Spots are Located within 0.010 Inch of the Edge of the Specimen)

WELD EVALUATION

Tensile-shear coupons were single spot welded with this technique and tested to determine spot efficiency. Optimum welding parameters are listed in Table 1 along with the tensile-shear test results. These parameters were used to make the spot weld shown in Figure 7. On testing, a hole was pulled in one of the coupons of

Table 1
WELDING PARAMETERS FOR EXPENDABLE-WIRE WELDING
0.003-INCH TYPE AISI 304 STAINLESS STEEL

Coupon Number ⁽¹⁾	Amperes	Volts	Time (msec)	Electrode Force (lbs)	Tensile Strength ⁽²⁾ (lbs)
1	35	1	5	30	49
2	35	1	5	30	47
3	35	1	5	30	43
4	35	1	5	30	46

(1) A hole was pulled in each coupon.

(2) Tensile-shear strength in pounds per spot.

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Figure 7. TENSILE-SHEAR TEST COUPON SHOWING A HOLE IN ONE SECTION OF THE SPECIMEN AFTER TESTING.

the test pair. Figure 8 shows that the material which was pulled from this hole is firmly joined to the mating coupon.

S-67-3178-1

Figure 8. TENSILE-SHEAR TEST COUPON SHOWING A NUGGET PULLED FROM THE COMPANION SECTION OF THE COUPON.

Figure 9 is a photomicrograph showing the cross section of a spot weld in 0.003-inch Type AISI 304 stainless steel; Figure 10 is a photomicrograph, taken at the same magnification, of the length of a companion weld. These photomicrographs show a length-to-width ratio of approximately 8.5 to 1. The time of energy flow during these welds is approximately five milliseconds. The absence of appreciable grain growth in the weld zone indicates a solid-state bond rather than a conventional resistance spot weld.

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Figure 9. PHOTOMICROGRAPH SHOWING THE WIDTH OF A SPOT WELD IN 0.003-INCH-THICK STAINLESS STEEL. (100X)

S-67-3178-6

Figure 10. PHOTOMICROGRAPH SHOWING THE LENGTH OF A SPOT WELD IN 0.003-INCH-THICK STAINLESS STEEL. (100X)

A dimensional comparison between conventional round spot welds and those produced by the new technique is presented in Figure 11. This comparison shows that eleven round spots are required for each 0.660 inch of weld specimen when the conventional method is used, whereas only six elongated spots are required for an equal length of weld surface when using the expendable-wire method.

DATA EVALUATION

Basically, the parameters for spot welding materials in the 0.003-inch-thickness range are: amperes, volts, electrode force, electrode tip configuration, contact resistance, and weld time. With a stored-energy power supply, voltage is related to amperes (an increase in energy setting produces a corresponding increase in voltage). Weld time is determined by the time required to discharge the capacitor,

Figure 11. SPACING AND PITCH RELATIONSHIP BETWEEN ROUND AND ELONGATED SPOT WELDS. (Scale: 10" = 1")

and with the expendable-wire technique, electrode configuration is always constant because the wire is discarded after each welding operation. Uniform contact resistance is maintained by a relatively simple cleaning procedure; therefore, essentially only two variables are present: (1) energy, expressed in watt seconds; (2) electrode force, expressed in pounds.

Data from an experiment designed to investigate the effects of the welding parameters on spot-weld strength have been analyzed. The spot-weld strength was determined by tensile-shear testing of spot-welded coupons. Table 2 lists the various combinations of force and energy used in the experiment.

Table 2
TENSILE STRENGTH TO BE EXPECTED FOR EACH PARAMETER
COMBINATION USING THE EXPENDABLE-WIRE TECHNIQUE

Energy (watt/sec)	Electrode Force (lbs)	Tensile Strength (lbs)	Deviation (lbs)
20	14	34.6	± 6.8
35	14	38.4	± 6.8
20	30	25.4	± 6.8
35	30	46.3	± 6.8

As can be seen, significantly stronger spots were obtained with a force of 30 pounds and an energy setting of 35 watt seconds than with any of the other parameter combinations. The tensile strength with these parameters was 46.3 ± 6.8 pounds (95% confidence). The tensile strength for each of the parameter combinations is listed in Table 3.

Table 3
VARIOUS COMBINATIONS OF FORCE AND ENERGY
FOR EXPENDABLE-WIRE WELDING 0.003-INCH FOIL

Coupon Number	Energy (watt/sec)	Electrode Force (lbs)	Tensile Strength (lbs)	Welding Sequence
1	35	30	49.0	1
2	35	30	47.0	5
3	35	30	43.0	9
4	35	30	46.0	13
5	20	30	27.5	2
6	20	30	25.5	6
7	20	30	27.0	10
8	20	30	21.5	14
9	35	14	40.5	3
10	35	14	36.0	7
11	35	14	38.0	11
12	35	14	39.0	15
13	20	14	32.0	4
14	20	14	38.0	8
15	20	14	34.5	12
16	20	14	34.0	16

At the 20-watt second energy setting, significantly stronger spot welds were obtained with a 14-pound force setting than with a 30-pound force setting. However, at the 35-watt second energy setting, significantly stronger spot welds were obtained with a 30-pound force setting than with a 14-pound force setting. These results are presented graphically in Figure 12.

Table 4 lists the parameters and tensile strengths for 0.020-inch-diameter, round spot welds in the same material that was used to make the elongated spots.

At the beginning of the expendable-wire welding development program, there seemed to be some indication that more uniform and higher-strength spot welds were obtained when welding with a continuous wire than with a noncontinuous wire.

Figure 12. INFLUENCE OF FORCE AND ENERGY ON SPOT-WELD STRENGTH IN 0.003-INCH TYPE AISI 304 STAINLESS STEEL.

Table 4

WELDING PARAMETERS AND TENSILE VALUES FOR ROUND SPOT WELDS IN 0.003-INCH TYPE AISI 304 STAINLESS STEEL

Coupon Number ⁽¹⁾	Energy (watt/sec)	Electrode Force (lbs)	Tensile Strength (lbs)
1	20	17	18.5
2	20	17	18.5
3	20	17	19.0
4	20	17	18.0
5	20	17	18.5
6	20	17	18.5
7	20	17	18.5
8	20	17	18.0
9	20	17	18.0
10	20	17	17.5

(1) Welds ranged from 0.020 to 0.025 inch in diameter.

(Continuous wire refers to wire which has been formed into a circle of the correct diameter and the ends welded to form a continuous energy path; noncontinuous wire is formed but not welded.) Data from an experiment designed to compare spot-weld strengths using a continuous wire with those obtained using a noncontinuous wire were evaluated. Ten coupons were single spot welded using each type of wire. All the welding parameters were held constant. The energy setting was 28 watt seconds; the electrode force was 20 pounds.

The results of the analysis show that there is no significant difference in either the mean tensile strength or variation in tensile strength for the two groups of spot welds. The mean tensile strength for spot welds made with the continuous wire was 40 ± 9.2 pounds; for the noncontinuous wire it was 40 ± 8.5 pounds per spot.

CONCLUSIONS

The expendable-wire technique of resistance spot welding is a reliable, reproducible method for welding thin stainless steel. Since more of the effective spot area can be located closer to the edges of the workpiece with this technique than with conventional spot welding, the number of spots required is 55 to 60 percent lower than the number normally needed.