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SPOT WELDING AND ITS APPLICATION TO AIRCRAFT STRUCTURE CORROSION-RESISTANT STEEL 18:8

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(MATÉRIEL BRANCH REPORT)

UNITED STATES
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SPOT WELDING AND ITS APPLICATION TO AIRCRAFT STRUCTURE CORROSION-RESISTANT STEEL 18:8

(Prepared by Charles L. Hibert, Materiel Division, Air Corps, Wright Field, Dayton, Ohio, Nov. 15, 1933)

OBJECT

The corrosion resistance and tensile strength of spot welds in relation to their visual appearance and microscopic structure.

CONCLUSIONS

NOTE A spot weld with adequate strength and ductility generally exhibits blow holes or gas holes in the fused zone, and splashes on the interior of the lap joint.

Carbide precipitation was not visible at 1,500 diameters in the microscopic examination of sheet with a carbon content of 0.08 percent and a period of current dwell equal to 0.133 second, which is beyond the time limit for successfully welding this material.

The material with a carbon content above 0.08 percent indicated corrosion embrittlement in the Strauss test. The intermittent corrosion test in sodium chloride solution showed no difference due to carbon content.

NOTE Visual examination is inadequate for judging the quality or strength of spot welds.

MATERIAL

Corrosion-resistant steel (18 : 8) in six gages, manufactured by the Allegheny Steel Co. The sheets were 0.005, 0.010, 0.015, 0.020, 0.026 and 0.040 inch in thickness.

All spot welding was done with the E. G. Budd "Shot Welder."

The physical and chemical properties of the sheet are given in Engineering Section Memorandum Report M-56-2504, addendum I.

PROCEDURE

The samples were all taken from specimens made in connection with the determination of the physical properties of spot-welded joints, covered by the report M-56-2504, addendum I.

The corrosion test consisted of a cycle of dipping the specimens into a 20-percent sodium-chloride solution for approximately 1 minute and drying for a period of 15 minutes. The specimens were removed for examination after exposure to this for 100, 360, and 720 hours. After the 720-hour period the specimens were tested in tension. A visual examination of the corrosion between the lap joint was made after this test.

A right-angle bend was made in a few specimens before immersion in the salt solution.

Spot-welded specimens for each sheet size were boiled in the Strauss solution for 100 hours. The specimens were tested by dropping to detect a loss of ring, and by a 180° bend test through the spot welds. Microphotographs were made of several sample spot welds.

Six specimens of 0.026-inch sheet, representing six different variations in timing, were given a 48-hour Strauss test and were examined microscopically. The 0.026-inch sheet material was selected because it had an average carbon content and represented a medium cold working. The current intensity was controlled for each speciment to produce a spot weld with a breaking strength of 650 pounds. This was to insure spot welds of like diameter and effect.

RESULTS

The specimens examined after 100 hours of the corrosion test showed no perceptible external corrosion of the sheet, nor did the spot welds appear to be affected. Rust streaks had run down from between the sheets of the lap joint. These rust stains appeared on all specimens. The spot welds were of a darker color than before the immersion test. No corrosion was noticeable at the right bend or along the sheared edges of the sheet.

The specimens were again examined after 360 hours exposure to the corrosion test. The appearance was similar to that at the end of the 100-hour period although the stains were more prominent.

The 720-hour exposure caused slight additional staining originating between the sheets in the lap joint. The tensile tests (table IV) indicate no noticeable reduction in the strength of spot welds after test from exposure to alternate wetting and drying.

The visual examination of the internal appearance after the tension test showed that the rust stains originated at the junction of the sheared edge of one sheet with the, polished surface of the other. The internal splashing of the welded material was but slightly corroded. The examination showed no corrosion of the spots.

No difference in rate or extent of staining was indicated by variations in the dwell of the current.

The results of the 100-hour Strauss test of the spot-welded specimens are given in table II. No perceptible difference in the ring of the material when dropped was found after the Strauss test. No carbide precipitation was detected from the microscopic examination. The results from the bend test varied according to the carbon content and previous cold working of the material of which the tensile strength was considered the criterion.

The results of the 48-hour Strauss test on the 0.026-inch thickness of sheet are shown in table III.

In figures 1 to 5, inclusive, are shown photomicrographs of typical spot welds. It will be noticed that all welds with normal strength show evidence of pipes or gas holes, and indicate splashes between the sheets. Figure 1 represents a structurally perfect spot weld with no evidence of gas holes or splashing between NOTE sheets. The breaking strength of this spot is too low for practical purposes. Neither was it ductile enough to be rotated through an angle of 60°.

Figure 2 shows the appearance of a practical weld encountered in spot welding of this corrosion-resistant steel. A gas hole is visible in the interior of the spot as shown on the cross section, but the external appearance is much the same as that of figure 1.

The coloration and depressions of these typical spots are much alike which indicates that spot welds cannot be judged by a visual examination of the exterior surface. The value of a microscopic surface examination is the detection of external splashes and determination of cast structure as a result of excessive time and current. The coloration around the indentation is no indication of a corona caused by precipitation of the carbides. A photomicrograph at high magnification is necessary for this purpose. No precipitated carbides were found with periods of current application of 0.133 second. A practical limit would be one-tenth of a second. These tests indicate that this period is too short for carbide precipitation to take place.

The views of the interior of the joint (figs. 1 and 2) present a different appearance but still do not give conclusive evidence as to the value of the respective spot welding. The spot weld free from defects shows a clean-cut appearance and outline with absence of splashes or gas holes, but lacks high tensile strength.

The photomicrographs of a vertical section through a spot weld give some indication of its relative strength. In figure 1, plate no. 4491–M, the spot weld free from blow holes shows a definite line of demarcation between the plane of the sheets. This indicates improper fusion between the sheets. Consequently the shear value is lower and the breaking strength of the joint is insufficient for practical purposes. Although in figure 2, plate no. 4439–M, there is evidence of a gas hole, no line of demarcation is noticeable, and fusion of the joint is good.

In figures 2 to 5 are shown typical spot welds for several gages of sheet. Figure 2, plate no. 4494–M, and figure 3, plate no. 4495–M, the photomicrographs show a shear failure of the spot weld. In figure 4, plate no. 4499–M, and figure 5, plate no. 4498–M, is shown a failure where the slug is pulled clear from one of the welded sheets. The type of spot failure is determined by the ratio of spot size to the thickness of the thinnest gage sheet welded. A spot of greater diameter than four times the sheet thickness will pull a slug clear of the sheet, while one of less diameter than four times the sheet thickness will shear between the sheets. The type of failure in the spot welds does not necessarily indicate the value of a spot-weld joint. If enough spots are welded in the joint the sheet will fail in tension.

The photomicrographs do not always represent a view across the true diameter of the spot.

NOTE The gas hole that occurred in all good fusion welds was located in a plane between the two sheets welded, but not necessarily in the center of the spot welds.

Referring to table II, it will be noticed that the table is divided into two sections; sheet 0.005 inch to 0.015 inch represent steels of high carbon content and are also drastically cold rolled. The high tensile strength and carbon content accounts for the failure in bend test for the sheet stock after boiling 100 hours in the Strauss solution. It appears that the high carbon content of the material effected a failure in the bend test of the spot welds.

The second group, 0.020 to 0.040 inch, represent steels of lower carbon content and are more acceptable when bending properties are desirable. The lower carbon content probably accounts for more satisfactory bend test through the spot welds. The time and current dwell of the second group was much longer, and it would be expected the longer time would result in carbide precipitation. No precipitation was found on the microscopic examination up to 1,500 magnification, but the corrosion and bend tests would indicate greater changes in the higher carbon material, which may be due to precipitation not resolved by the magnification used.

TABLE I.—*Chemical analysis and tensile strength of corrosion-resistant steel*

Sheet size	Carbon	Chromium	Nickel	Tensile strength
Inches	*Percent*	*Percent*	*Percent*	*Lb./sq. in.*
0.005	0.11 .11	17.53	8.78	198,000 199,150
0.010	.15 .14	17.10	7.97	187,910 189,000
0.015	.10 .11	18.31	9.96	192,470 192,230
0.020	.08 .08	18.11	9 20	119,500 119,600
0.026	.08 .09	16.80 16.82	9.02	161,400 163,200
0 040	.08 .08	18.42	9.20	166,100 166,000

TABLE II.—*Results of 100-hour Strauss test*

Sheet size	Ring of material	Result of bend test	Time of current, seconds	Current intensity	Carbon content, percent	Tensile strength, lb./sq. in.
0 005	O.K.	V.S C. in sheet. F. of spot welds.	0.050	C	0.11	198,000 199,150
.010	O.K.	do	.066	H	.15 .14	187,910 189,000
.015	O K.	S.C. in sheet C. in spots.	.083	G	.10 .11	192,470 192,230
.020	O.K.	O K. for sheet and spot welds.	.116	F	.08 .08	119,500 119,600
.026	O.K.	V.S.C. in sheet and spot welds.	133	I	.08 .09	161,400 163,200
040	O.K.	O.K. for sheet and spot welds.	.116	I	.08 .08	166,100 166,000

NOTES

F = failure.
C = large crack.
S.C. = slight crack.
V.S.C = very slight crack.
Current variable from A–K.
Microphotographs showed no intercrystalline corrosion.

Table III.—*Results of 48-hour Strauss Teet*

[Thickness sheet, 0 026 inch. Ult. tensile strength, 161,000 p.s.i.]

Sample no.	Ring of material	Time of current, seconds	Current intensity	Break load of spot, pounds	Carbon content, percent
11B...	O.K.	0.050	K	650	0.08 .09
21A.	O.K.	.066	J	644	.08 .09
30C	O.K.	.083	H	641	.08 09
40C.	O K.	.100	G	650	.08 .09
50B	O K	.116	F	665	.08 .09
60A	O.K.	.133	E	680	.08 .09

NOTES

Current variable from A-K.
Microphotographs showed no intercrystalline corrosion

Table IV.—*Results of 720-hour accelerated corrosion test in a 20 percent NaCl solution*

Sheet size	Sample no.	Machine settings			Average strength before test	Strength after corrosion test	Type and location failure
		Time, second	Current	Pressure, pounds			
0 005	925	0 050	C	75	600	560	Spots pulled out.
010	723	066	H	150	1,800	1,920	Do.
.015	635	083	G	150	2,350	2,380	Tension of sheet.
020	633	.116	F	125	2,570	2,550	Spots pulled, some sheared.
.026	724	.133	I	175	4,200	4,370	Shear of spots.
010	1,010	.116	I	200	......	6,880	Do.

NOTE

Sample number denotes spot arrangement, e.g., 925=9 spots in 2 rows, specimen no. 5.

PLATE 4492-M.—Surface view of a perfect spot weld. PLATE 4497-M.—Interior view of the same spot weld.

0.026 Allegheny sheet magnified 18×.

Welding conditions.— Die size, one-fourth inch; die pressure, 175 pounds, breaking strength, 360 pounds, time, 0.0833 second, current, C.

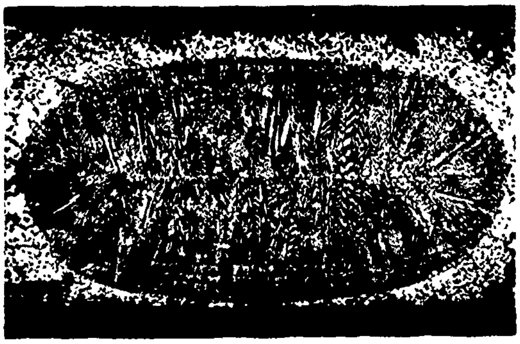

PLATE 4491-M.—Photomicrograph magnified 36×. Etch, glycerol.

FIGURE 1.

PLATE 4621-M.—Surface strength of good strength weld.

PLATE 4494-M.—Interior view of the same spot weld.

0.026 Allegheny sheet magnified 17×.

Welding conditions.—Die size, one-fourth inch, die pressure, 175 pounds, breaking strength, 884 pounds; time, 0 133 second; current, 1.

PLATE 4439-M.—Photomicrograph magnified 30×. Etch, glycerol.

FIGURE 2.

PLATE 4495-M.—Magnified 14× diameter. Etch, none. 0.020 Allegheny sheet. Condition of spot weld after shear failure at a breaking load of 550 pounds.

PLATE 4440-M.—Magnified 37× diameter. Etch, glycerol. Photomicrograph of a similar spot weld after 100 hours' Strauss test.

Welding conditions.—Die size, one-fourth inch; die pressure, 125 pounds; time, 0.116 second; current, F.

FIGURE 3.

PLATE 4499-M.—Magnified 14× diameter. Etch, none. 0.015 Allegheny sheet. Condition of spot weld after spot failure at a breaking load of 440 pounds.

PLATE 4477-M.—Magnified 30× diameter. Etch, chrome regia Photomicrograph of a similar spot weld after 100 hours' Strauss test.

Welding conditions.—Die size, three-sixteenths inch; die pressure, 150 pounds; time, 0.083 second; current, G.

FIGURE 4.

PLATE 4198-M.—Magnified 18× diameter. Etch, none. 0.005 Allegheny sheet. Condition of spot weld after spot failure at a breaking load of 77 pounds.

PLATE 4481-M.—Magnified 59× diameter. Etch, chrome regia. Photomicrograph of similar spot weld after 100 hours' Strauss test.

Welding conditions.—Die size, one-eighth inch, die pressure, 75 pounds; time, 0.050 second; current, C.

FIGURE 5.