NATIONAL BUREAU OF STANDARDS REPORT

9523

Stress Corrosion Behavior of Cadmium Plated 4130 Steel and Aluminum Metallized PH 15-7 Mo and 17-7 PH Stainless Steels In Marine Atmospheres

By

W. F. Gerhold

To

Materials Division
Air Systems Command
Department of the Navy
Project Number RRMA 2006

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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Reference: (a) Naval Air Systems Command (BUaer) letter AER-AE-417/209, dated 25 June 1957.

Introduction: High strength steel alloys are extensively used in the manufacture of Naval aircraft components. Often these components are located on aircraft, in areas which are not readily accessible for inspection. Since Naval aircraft operate in marine environments, the use of bare steel may lead to corrosion and stress corrosion which could ultimately result in failure of components and possible loss of the aircraft. Reference (a) requested that marine environmental tests be conducted on 4130, PH 15-7 Mo and 17-7 PH steels to determine the extent of protection from stress corrosion given by the subject coatings.

Materials: Materials used in this study were SAE 4130 steel alloy sheet and 17-7 PH and PH 15-7 Mo stainless steel alloy sheet. The as-received material conditions are given in Table 1.

Specimen Preparation: Initially oversized specimen blanks, 1.25 inches wide by 9 inches long, were sheared from the sheet material in a direction whose long dimension was transverse to the direction of rolling. The blanks were then machined to size, 1 inch ± 0.001 inch wide by 9 inches long for the stress corrosion specimens and 1 inch wide at the grip ends by 9 inches long with a 2 inch gage length and a reduced section 0.500 inch wide for specimens for mechanical properties determinations. Specimens were machined so that opposing sides and ends were parallel and squared. Then all of the specimens were cleaned by immersion for 10 minutes in dilute Oakite No. 33 (1 part Oakite No. 33 to 1 part distilled water), scrubbed, rinsed in distilled water and dried. During the wet operations, the specimens were handled with clean rubber gloves and when dried they were handled with white cotton gloves. These procedures were necessary to prevent the possibility of subsequent cracking from finger-print corrosion. The specimens were then heat treated in accordance with the procedures given in Table 1.

After heat treatment all specimens were wet grit blasted with a mixture of #100 pangbornite and #240 alumina to remove heat treating scale.

The specimens were machined to a suitable length for the stress corrosion tests. Details for the determination of the length of the specimens from each alloy are given in the paragraph on stress calibration.

All specimens except those used for mechanical properties determinations, stress calibrations and stress corrosion test control purposes were then metallic coated. The SAE 4130 steel alloy specimens were coated at NBS with electrodeposited cadmium, 2 mils thick. In order to determine if there was any influence on the stress corrosion behavior by hydrogen embrittlement, half of these specimens were baked for 3 hrs at 400° F to drive off hydrogen that may have been absorbed during the coating process and half were left unbaked. The PH 15-7 Mo and 17-7 PH stainless steel alloy specimens were metallized by METCO, Inc., Westbury, Long Island, New York with 1100 aluminum alloy, 2.5 mils thick.

Mechanical Properties: After heat treatment and wet grit blasting, mechanical properties were determined for each of the alloys. The results given in Table 1 are the average values obtained from 3 specimens from each alloy group.

Stress Calibration: Calibration curves for exposure stress determinations were obtained for each alloy as-heat treated. Uncoated specimens were machined to suitable lengths (greater than 7.000 inches) to fit a 7.000 inch Armco two point loading type stress corrosion jig. Strain gages were mounted at the mid area of each of the specimens. The specimens were then positioned in the jig as shown in the inset, Figure 1. The strain was then measured with an SR-4 strain indicator. The strain measurements which were obtained for each specimen were then plotted against the length of the specimen. A strain vs length of specimen curve was devised for each alloy. These curves are shown in Figure 1. A strain, equivalent to 75% of the alloy yield strength as determined by NBS, was calculated for each alloy. Points on the curves for each alloy, equivalent to the calculated strain, were then chosen to obtain the length of specimen required to give the desired exposure stress.

Exposure: All of the control (uncoated) and coated stress corrosion test specimens were exposed in the marine atmosphere test facilities of the International Nickel Company at Kure Beach, N. C. One set of specimens was exposed in the 80 foot lot and another in the 800 foot lot.

The distribution of the specimens exposed is given in Table 2. All specimens were stressed at 75% of alloy yield strength as determined by NBS. The specimens were stressed as noted in the previous discussion of stress calibration by utilizing Armco's two point loading system.

Results: The results obtained after exposure for 1477 days and 2142 days in the 80 foot and 800 foot lots respectively, at Kure Beach, N. C. are given in Table 3. There were no failures from corrosion or stress corrosion of any of the coated specimens exposed at either location.

The uncoated SAE 4130 steel specimens exposed in the 80 foot lot were severely rusted and had perforated at the ends where they were in contact with the stressing jig. These specimens were removed from test after 509 days exposure. The uncoated PH 15-7 Mo and 17-7 PH steel alloy specimens failed, after exposure periods of 4 to 16 days and 3 to 15 days, respectively, in the 80 foot lot. Both of these alloys failed after exposures from 18 to 22 days in the 800 foot lot.

Specimens exposed in the 800 foot that had not failed after the number of days shown in Table 3 were continued on exposure to obtain long term data.

<u>Conclusions</u>: Stress corrosion tests conducted in the marine atmosphere in the 80 foot and 800 foot lots at Kure Beach, N. C. indicated the following:

(1) There was no significant difference in attack on the cadmium plated, unbaked and cadmium plated, baked SAE 4130 steel specimens. There were no failures of specimens after exposure for 1477 days and 2142 days, in the 80 foot and 800 foot lots, respectively. Moreover, there were no stress corrosion failures of uncoated specimens at either site. Uncoated specimens were removed from exposure in the 80 foot lot after 509 days because of excessive corrosion at the ends of the specimens.

(2) That metallizing of 17-7 PH and PH 15-7 Mo alloy steels with 1100 aluminum alloy does inhibit stress corrosion cracking. Uncoated specimens of both alloys failed by stress cracking in less than 16 days, whereas coated specimens had not failed after exposures of 1477 days in the 80 foot lot and 2142 days in the 80 foot lot.

Table 1. As-received material conditions, subsequent heat treatment and mechanical properties of alloys evaluated in this investigation

Material and Condition	Heat Treatment	Mechanical Properties[1]		
		UTS, Ksi	YS Ksi	% Elongation in 2"
SAE 4130 steel alloy Aircraft quality - Annealed to 95 R_B max. Hot rolled sheet, 0.062 inches thick.	Austenitize at 1575° F (±25° F) for 30 minutes, air cool. Temper at 750° F for 1 hour, air cool.	206.7	187.8	3.7
PH 15-7 Mo stainless steel alloy Condition A, 0.050 inches thick.	RH 950 treatment Austenite conditioning - 1750° F (±15° F) for 10 minutes. Transformation cooling - at -100° F for 8 hrs. Precipitation hardening 950° F ± 10°F for 1 hr, air cool	244.0	212,000	6.0
PH 17-7 stainless steel alloy Condition A, 0.050 inches thick.	Same as PH 15-7 Mo above	227.0	214.0	7.2

(1) Average of 3 specimens for each alloy.

Table 2. Distribution of specimens exposed in the 80 ft and 800 ft lots at Kure Beach, N. C.

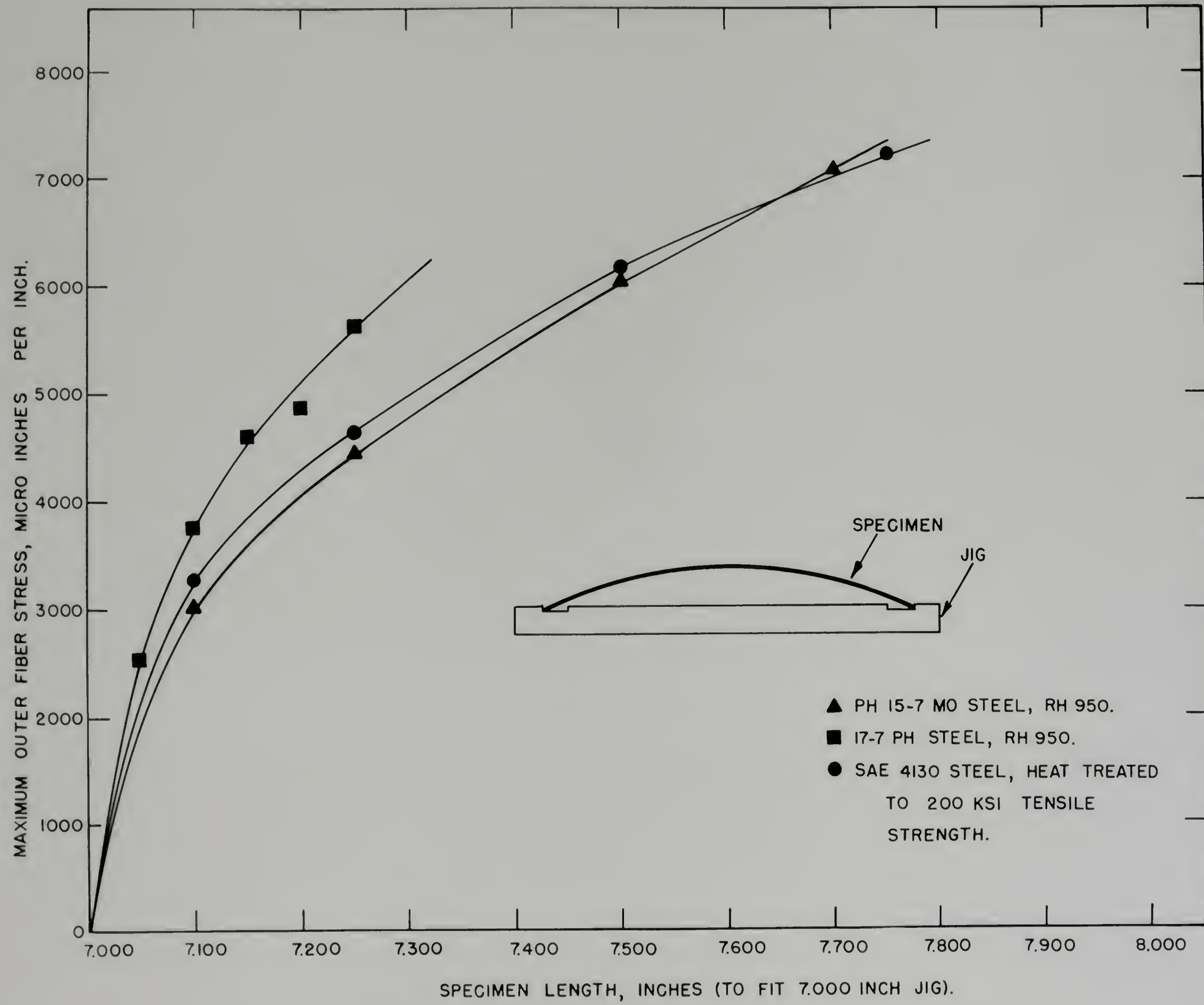
Alloy	No. of Specimens Exposed in Each Lot	Coating
SAE 4130	5	None
"	5	Electrodeposited cadmium
"	5	Electrodeposited cadmium + baked 3 hrs at 400° F.
PH 15-7 Mo	5	None
"	5	Metallized with 1100 aluminum alloy
17-7 PH	5	None
"	5	Metallized with 1100 aluminum alloy.

Table 3. Results obtained in stress corrosion tests conducted in the marine atmosphere at Kure Beach, N. C.

Exposure Site (1)	Exposed at Per cent of Yield Strength	SAE 4130 Steel Alloy: Exposure Stress, Ksi	SAE 4130: Days to Failure (2) Bare	SAE 4130: Days to Failure (2) Cadmium Coated (3)	SAE 4130: Days to Failure (2) Cadmium Coated & Baked (4)	PH 15-7 Mo Steel Alloy: Exposure Stress, Ksi	PH 15-7 Mo: Days to Failure (2) Bare	PH 15-7 Mo: Days to Failure (2) Aluminum Sprayed (5)	17-7 PH Steel Alloy: Exposure Stress, Ksi	17-7 PH: Days to Failure (2) Bare	17-7 PH: Days to Failure (2) Aluminum Sprayed (5)
A	75	140.9	509[6]	1477 NF	1477 NF	159.0	4	1477 NF	160.5	3	1477 NF
"	"	"	"	"	"	"	5	"	"	3	"
"	"	"	"	"	"	"	5	"	"	3	"
"	"	"	"	"	"	"	15	"	"	3	"
"	"	"	"	"	"	"	16	"	"	15	"
B	"	"	2142[7]	2142[7]	2142[7]	"	18	2142[7]	"	18	2142[7]
"	"	"	"	"	"	"	20	"	"	18	"
"	"	"	"	"	"	"	21	"	"	21	"
"	"	"	"	"	"	"	21	"	"	21	"
"	"	"	"	"	"	"	22	"	"	22	"

(1) A - 80 ft lot, Kure Beach, N. C.
B - 800 ft lot, Kure Beach, N. C.
(2) NF - Specimens did not fail after exposure for the number of days shown.
(3) Electrodeposited cadmium coating, 2 mils thick.
(4) Electrodeposited cadmium coating, 2 mils thick and baked 3 hrs at 400° F.
(5) Metal sprayed coating, 1100 aluminum, 2.5 mils thick.
(6) Ends severely rusted, perforated. Specimens did not crack.
(7) Specimens still on exposure. No failure after number of days shown.

Figure 1. Stress calibration curves for each of the alloys studied in this investigation. Inset shows Armco two point loading system used to obtain strain values. This system was also used to obtain the desired exposure stress for the stress corrosion tests.


MAXIMUM OUTER FIBER STRESS, MICRO INCHES PER INCH.
0
1000
2000
3000
4000
5000
6000
7000
8000
7.000
7.100
7.200
7.300
7.400
7.500
7.600
7.700
7.800
7.900
8.000
SPECIMEN LENGTH, INCHES (TO FIT 7.000 INCH JIG).
SPECIMEN
JIG
▲ PH 15-7 MO STEEL, RH 950.
■ 17-7 PH STEEL, RH 950.
● SAE 4130 STEEL, HEAT TREATED TO 200 KSI TENSILE STRENGTH.

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