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DEVELOPMENT OF INTENSIOSTATIC-GALVANIC
STRESS CORROSION TESTS FOR HIGH STRENGTH
ALUMINUM ALLOYS

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Frankford Arsenal
Philadelphia, Pennsylvania

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) An investigation was per- formed to identify improved methods for determining the stress corrosion resistance of strain hardenable 5083 alloy and heat-treatable high strength 7075 and 7050 alloys. An intensiostatic test method was investigated for strain hardenable 5083 alloy and the results showed that the test is capable of discrim- inating among conditions which have small differences in susceptibility to stress corrosion.		

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efficient inspection methods for materiel/materiel procured or maintained by AMC.

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The improvement in the sensitivity of the intensiostatic test as compared to the conventional alternate immersion test is shown to be significant. In addition, the test is more rapid than the conventional alternate immersion test.

A galvanic test method was investigated for two copper bearing high strength aluminum alloys, 7075 and 7050. The results showed that the galvanic test is capable of discriminating among various tempers of the alloys which possess a wide range of stress corrosion susceptibility. The test is also more rapid than the conventional alternate immersion test.

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INTRODUCTION

The work reported here was performed under the Materials Testing Technology (MTT) Program (PEMA 4931.0) for the purpose of investigating improved stress corrosion test methods for armament materiel. The methods investigated were the intensiostatic test for 5083 alloy and the galvanic test for alloys 7075 and 7050.

Under a previous MTT effort at Frankford Arsenal¹, preliminary work using the intensiostatic technique as a stress corrosion test was performed on 5083 alloy and the results compared quite favorably with those obtained from the conventional Alternate Immersion (A.I.) test. The results of that work showed that the intensiostatic test was more rapid than the A.I. test in achieving stress corrosion cracking and was capable also of discriminating among alloy conditions having large differences in stress corrosion susceptibility. Briefly, in the intensiostatic test the material is stressed and exposed to a constant anodic current while immersed in an electrolyte. The A.I. test consists of cyclically immersing a stressed specimen into a 3-1/2 percent sodium chloride solution for a 10-minute period followed by 50 minutes of air drying per cycle. A more complete description of both test methods is described elsewhere.^{2,3,4}

On the basis of the previous work, it was concluded that the results were significant to justify that additional intensiostatic tests be performed on measuring the stress corrosion characteristics of borderline material. Borderline material is defined as that material whose stress corrosion characteristics are such that when tested by the A. I. Technique, stress corrosion cracking (SCC) is difficult to detect with failure occurring generally within 60 to 90 days. It was believed that a consideration of incorporating the intensiostatic test into military specifications should require that the test be able to discriminate among materials which have a relatively high resistance to SCC. Thus, the first phase of the present effort was directed toward determining the sensitivity of the intensiostatic technique as applied to borderline material.

¹J. J. Gordon and J. V. Rinnovatore, "Development of an Intensiostatic Stress Corrosion Test for Strain Hardenable Alloys", Frankford Arsenal Report M72-4-1, March 72.

²H. Rosenthal and H. R. Pritchard, "A Quantitative Stress Corrosion Test for Al-Zn-Mg Alloy Plate", Stress Corrosion Testing, ASTM STP 425, American Society of Testing Materials, 1967, p. 165.

³A. Prati, "Test Methods for the Study of Stress Corrosion of Al-Mg Alloys. Comparison Between the Anodic Method and Other Methods", Istituto Sperimentale dei Metalli Leggeri, for the Department of the Army, Report 12.727/6309.070, 1968.

⁴F. F. Booth and H. P. Godard, "An Anodic Stress Corrosion Test for Al-Mg Alloy", International Congress on Metallic Corrosion, London, 1961.

The second phase of the present effort was concerned with developing a more rapid stress corrosion test for solution heat treatable, copper bearing, high strength aluminum alloys. Previous studies⁵ involved with developing more efficient stress corrosion tests for copper bearing aluminum alloys have been unsuccessful. In general, the previous techniques have consisted of applying a stress to a suitable specimen continuously immersed in various chemical media. A limited amount of work using the intensiostatic test on copper bearing aluminum alloys has also proved to be unsuccessful.

In the present study, the technique of galvanic coupling, which was investigated previously by Brown et al,⁶ for magnesium alloys, was used in combination with an applied stress. Briefly, the technique consists of electrically coupling a stressed specimen to another dissimilar metal while immersed in a suitable electrolyte with no applied potential. The results of the study by Brown et al on magnesium alloys suggested that galvanic coupling might be applied successfully to copper bearing aluminum alloys such as 7075 and 7050.

EXPERIMENTAL PROCEDURE

Intensiostatic Test

All tests were performed on 3/4 inch outside diameter (O.D.) C-rings fabricated from 1-1/2 and 1-3/4 inch 5083 alloy plate material, supplied by Dow Chemical Company and Reynolds Metals Company in the H131 temper. The alloy was tested in the as-received temper and in three heat-treated conditions. The purpose of the heat treatments was to produce different levels of stress corrosion susceptibility within the alloy which would range from highly susceptible to borderline in terms of failure times induced by the 90 day A. I. test.

The chemical composition of each lot of 5083 alloy is shown in Table I. The mechanical properties of the alloy in the various conditions are shown in Table II.

⁵H. B. Romans, "Stress Corrosion Test Environments and Test Duration", Stress Corrosion Testing, ASM, STP 425, p. 188, 1967

⁶R. H. Brown, R. B. Mears, E. H. Dix, Jr., "A Generalized Theory of Stress Corrosion of Alloys", Symposium on Stress Corrosion Cracking of Metals - published jointly by ASTM and AIME, 1944, pp 333-336

TABLE I
Chemical Composition of 5083 Alloy

Supplier	% Alloying Element ^a							
	Mg	Mn	Fe	Cu	Si	Zn	Ti	Cr
Dow	4.33/4.34	0.63	0.15/0.35	0.03	0.05/0.15	0.04	<0.05	0.05/0.15
Reynolds	4.94/5.00	0.63	0.1/0.30	0.06	0.05/0.15	0.07	<0.05	0.05/0.15

^aAluminum and impurities constitute the remainder.

TABLE II
Mechanical Properties of 5083 Alloy

Supplier	Thermal Condition	Longitudinal Strength		% Elongation
		Yield (ksi)	Tensile (ksi)	
Dow	5083-H131 ^a , As Received	37.5	48.1	17.0
	5083-H131 + 2 days @ 200°F	36.4	48.2	17.5
	5083-H131 + 4 days @ 200°F	36.0	47.8	16.0
	5083-H131 + 8 days @ 200°F	36.3	48.1	17.5
Reynolds	5083-H131, As Received	40.0	50.3	17.0
	5083-H131 + 1 day @ 200°F	38.4	49.6	15.0
	5083-H131 + 2 days @ 200°F	37.6	49.9	17.3
	5083-H131 + 4 days @ 200°F	37.3	49.6	17.0

^aH131 represents a strain hardenable temper designating about 30 percent cold rolling in the plate material.

The intensiostatic test consisted of applying a constant anodic current to a C-ring specimen stressed to 75 percent of the longitudinal yield strength while exposed to a solution of sodium chloride. The charging current density was maintained at a constant value of 40 ma/in². The cathode consisted of identical 5083 material in the form of 4-1/2" x 1-1/4" x 1/4" thick rectangular plate. Tests were performed on both lots of 5083 material using a 1N sodium chloride solution buffered to a pH range of 5.0 to 5.6 by additions of 0.5 N HAc and 0.5 N NaAc solutions. The solution was stirred during the test.

Galvanic Test

All galvanic tests were performed on 3/4" O. D. C-rings fabricated from commercial 7075 and 7050 alloy one inch plate. Both alloys were tested in tempers which provided a wide range of susceptibility to stress corrosion. The chemical compositions and mechanical properties of these alloys are listed in Tables III and IV.

Cathodes were taken from commercial 7075 and 7050 in the form of 6" x 3-1/2" x 1/16" rectangular sheet. The cathodes were heat treated to provide electrical conductivities which would be below that of the C-rings.

C-rings were tested in the critical short transverse direction, stressed at 25, 35, and 50 ksi. Tests were performed in a solution of 4M sodium chloride, 0.5 M potassium nitrate, and hydrochloric acid. The solution was stirred during the test.

Specimens were exposed for two hours in the intensiostatic test and six hours in the galvanic test. These times were considered adequate so that a discrimination could be made among the alloys with different degrees of stress corrosion susceptibility.

During the intensiostatic and galvanic tests, specimens were continuously examined for stress corrosion by low power microscopy (10X). At the termination of the tests, selected specimens were examined metallographically in order to confirm the presence or absence of SCC.

TABLE III

Chemical Composition of 7075 and 7050 Alloys

Alloy	% Alloying Element ^a									
	Zn	Mg	Cu	Fe	Si	Mn	Cr	Ti	Zr	Ni
7075	5.70	2.43	1.79	0.1/0.2	0.5/.15	.05	.18/.25	<0.05	0.00	<.01
7050	5.89	2.16	2.53	0.07	0.06	0.02	0.00	0.04	0.11	0.00

^a Aluminum and impurities constitute the remainder

TABLE IV

Mechanical and Electrical Conductivity Properties of 7075 and 7050 Alloys

Alloy	Temper	% Electrical Conductivity	Longitudinal Strength (ksi)		Results	
			Yield	Tensile		
7075	T651	31.5	80.3	88.5	9.5	As Received (AR)
7075	T76	37.5	71.1	80.8	10.0	AR + 16 hrs @ 325°F
7075	T73	39.3	65.6	76.4	10.0	AR + 32 hrs @ 325°F
7050	T6X1	35.1	80.5	86.2	13.8	2 hrs @ 875°F, cold water quench, 5 days natural age at room temperature, 4 hrs @ 250°F + 4 hrs @ 335°F
7050	T7X1	37.0	80.2	85.4	14.3	2 hrs @ 875°F, cold water quench, 5 days natural age at room temperature, 24 hrs @ 250°F + 12 hrs @ 325°F
7050	T73	39.0	72.6	80.2	16.0	2 hrs @ 875°F, cold water quench, 5 days natural age at room temperature, 24 hrs @ 250°F + 24 hrs @ 325°F

RESULTS AND DISCUSSION

Intensiostatic Tests

The results of the intensiostatic and the A.I. tests performed on 5083 alloy are shown in Table V. The data indicate that the aging treatments applied to the as received cold rolled material promoted stress corrosion cracking within the alloy, with the susceptibility increasing with increasing thermal treatment. This is evidenced by the results obtained from both the A.I. and the intensiostatic tests. The significant result is that the intensiostatic test showed good discrimination between conditions which have small differences in stress corrosion susceptibility. This is shown, for example, by comparing the results from tests on Dow material aged 2 days versus 4 days at 200°F. In addition, the test achieved end points in significantly shorter time periods than the A.I. test. For all conditions where failure was observed in the A.I. test, failure was also observed in the intensiostatic tests; and where no failure was observed in the A.I. tests on the as-received material, a similar result was obtained from the intensiostatic tests. These results were observed from tests on both materials (Dow and Reynolds).

On comparing the results obtained from the two tests, it can be seen that for borderline as well as for highly susceptible conditions, the intensiostatic test is more sensitive than the A.I. This is an important result since for some conditions the A.I. test would not provide conclusive results whereas the intensiostatic test would more than likely give a clear indication concerning the stress corrosion characteristics of the alloy.

Galvanic Tests

The results of the galvanic and A.I. tests performed on 7075 and 7050 alloys are shown in Table VI. These data show that, in general, the galvanic test is capable of providing good discrimination among conditions of the alloys which have large differences in resistance to SCC, such as the T6 and T73 tempers. The galvanic test data also show that within the intermediate resistant temper, T76 or T7X, some discrimination resulted with stress as a variable. That is, no SCC was induced in the intermediate resistant alloys at the minimum stress of 25ksi, whereas SCC was induced at the maximum stress of 50ksi. It is also seen from these data that for the most susceptible and least susceptible tempers of each alloy, there is a good correlation between the galvanic and the A.I. tests. For example, the results from tests on

TABLE V

Results of Intensitostatic Tests and Alternate-Immersion Tests on 5083 Alloy

Supplier	Thermal Treatment	3.5% NaCl Alternate-Immersion Test				1N NaCl Intensitostatic Test			
		Visual Examination		Metallographic Exam.		Visual Examination		Metallographic Exam.	
		F/N ^a	Days to Failure ^b	F/N	Days to Failure	F/N Minutes to Failure	F/N Minutes to Failure	F/N Minutes to Failure	F/N Minutes to Failure
Dow	5083-H131, As Received	0/5	20K90, 30K90	0/5	5 OK 90	0/5	20K120, 30K120	0/5	5 OK 120
Dow	5083-H131 + 2 days @ 200°F	1/5	69, 20K90, 20K90	1/5	69, 4 OK 90	5/5	59, 61, 66, 69, 70	5/5	59, 61, 66, 69, 70
Dow	5083-H131 + 4 days @ 200°F	3/5	49, 51, 66, 20K90	4/5	49, 51, 66, 90, 10K90	5/5	25, 33, 33, 37, 40	5/5	25, 25, 23, 33, 37 40
Dow	5083-H131 + 8 Days @ 200°F	5/5	2, 3, 3, 7, 28	5/5	2, 3, 3, 7, 28	5/5	17, 21, 21, 27, 30	5/5	17, 21, 21, 22, 30
Reynolds	5083-H131, As Received	0/5	20K90, 30K90	0/5	5 OK 90	0/5	20K120, 30K120	0/5	5 OK 120
Reynolds	5083-H131 + 1 day @ 200°F	2/5	48, 20K90, 20K90	1/5	48, 40K90	5/5	40, 45, 46, 48, 48	5/5	40, 45, 46, 48, 48
Reynolds	5083-H131 + 2 days @ 200°F	4/5	13, 13, 14, 20, 10K90	5/5	13, 13, 14, 20, 90	5/5	38, 38, 38, 41, 43	5/5	38, 38, 38, 41, 43
Reynolds	5083-H131 + 4 days @ 200°F	5/5	3, 3, 6, 6, 7	5/5	3, 3, 6, 6, 7	5/5	22, 22, 24, 28, 29	5/5	22, 22, 24, 28, 29

^a F/N = Number of failures/Number of specimens tested.^b A line placed above failure(s) indicates that metallographic examination was performed on the specimen after removal from test.

TABLE VI

Results of Galvanic Tests and Alternate-Immersion Tests on 7075 and 7050 Alloys

Alloy - Temper	Stress Level	3.5% NaCl Alternate Immersion Test				NaCl-KNO ₃ Galvanic Test			
		Visual Examination		Metallographic Exam.		Visual Examination		Metallographic Exam.	
		F/N ^a	Days to Failure	b	F/N	F/N	Hours to Failure	F/N	Hours to Failure
7075-T651	25	5/5	2,2,2,2,2		5/5	2,2,2,2,2	5/5 4.0,3.0,2.6,2.6,2.4	5/5	4.0,3.0,2.6,2.6,2.4
7075-T7651	25	0/5	20K90, 30K90		2/5	90,90,30K90	0/5 20K6.0, 30K6.0	0/5	5 OK 6.0
	35	1/5	3, 40K90		2/5	3,90,30K90	0/5 20K6.0, 30K6.0	0/5	5 OK 6.0
	50	2/5	3,3, 30K90		3/5	3,3,90,90,10K90	5/5 4.0,3.9,3.8,3.7,3.7	5/5	4.0,3.9,3.8,3.7,3.7
7075-T7351	50	0/5	20K90, 30K90		0/5	5 OK 90	0/5 20K6.0, 30K6.0	0/5	5 OK 6.0
7050-T6X1	25	3/5	5,11,15,20K90		3/5	5,11,15,20K90	1/5 0.5, 40K6.0	5/5	0.5,6.0,6.0,6.0,6.0
7050-T7X1	25	3/5	5,20,26,20K90		4/5	5,20,26,90,10K90	0/5 20K6.0, 30K6.0	0/5	5 OK 6.0
	35	5/5	5,5,11,11,11		5/5	5,5,11,11,11	2/5 2.2,2.7,20K6.0,10K6.0	3/5	2.2,2.7,6.0,20K6.0
	50	5/5	5,5,5,7,12		5/5	5,5,5,7,12	4/5 1.7,2.6,2.7,3.2,10K6.0	4/5	1.7,2.7,3.2, 10K2.6, 10K6.0
7050-T73	50	0/5	30K90, 20K90		3/5	90,90,90,20K90	0/5 20K6.0, 30K6.0	0/5	5 OK 6.0

^aF/N = Number of failures/Number of specimens tested.^bA line placed above failure(s) indicates that metallographic examination was performed on the specimen after removal from test.

alloys 7075 and 7050 in the highly susceptible temper (T6) show that both methods induced SCC within a short time. It should be noted, however, that metallographic examination was necessary in order to detect SCC in alloy 7075 - T6X1. In regard to the most resistant temper (T73), no SCC was induced by either the galvanic or the A.I. test. The correlation between the two tests is not as good when a comparison of results is made for the intermediate resistant material. That is, 7075 - T7651 material stressed at 25 and 35ksi did not exhibit SCC during the galvanic test whereas failure did occur during the A.I. test. A similar discrepancy was noted for 7050 - T7X1 stressed to 25ksi.

The fact that a one-to-one correlation between the galvanic and the A.I. tests for all tempers of alloy 7075 was not achieved in this work does not necessarily detract from the use of the galvanic test as a potential quality assurance test method for a particular temper. At present, the military specification, QQ-A-250/12E, for alloy 7075 - T73, requires that the alloy exhibit no SCC after 30 days in the A.I. test while stressed to 75 percent of the yield strength. Since the results from the 6-hour galvanic tests on 7075 - T73 in this study show that SCC did not occur, it is possible that this test might be used in place of the current A.I. test as a quality assurance method.

With regard to the more recently developed alloy 7050, no military stress corrosion specifications have been formulated as yet. Therefore, no statement can be made relative to the use of the galvanic test in a specification on this alloy until stress corrosion criteria are established.

CONCLUSIONS

1. The intensiostatic technique is more sensitive than the alternate immersion test for the detection of small differences in susceptibility to stress corrosion cracking in 5083 alloy. In addition, the test is more rapid than the alternate immersion test.
2. The intensiostatic test represents a good technique which could be incorporated into military specifications concerned with the stress corrosion requirements of 5083 alloy.
3. The galvanic test is a potential quality assurance method for evaluating 7075 alloy in the highly resistant (T7351) temper. However, additional testing should be performed before any final assessment of this method is made.

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