AD 422105

AZUSA PLANT

STRUCTURAL MATERIALS DIVISION

STRESS-CORROSION CRACKING OF HIGH-STRENGTH ALLOYS

Contract DA-04-495-ORD-3069

A Report To

U.S. ARMY ORDNANCE CORPS
FRANKFORD ARSENAL

Report No. 0414-02-1 (Quarterly) / October 1963 / Copy No. 7

AEROJET
GENERAL TIRE
GENERAL

This is the tenth in a series of quarterly progress reports submitted in partial fulfillment of the contract. It constitutes the first quarterly progress report for the second 1-year continuation of the original 2-year program.

This report covers the period 1 July through 30 September 1963. It was written by R. B. Setterlund, who was supervised by A. Rubin.

W. L. Bruckart, Head
Metallics and Refractories Department
Structural Materials Division

CONTENTS

I. OBJECTIVES

The objectives of the program are outlined below.

A. To study the stress-corrosion characteristics of 18% nickel maraging steel with respect to compositional variation.

B. To study the effect of environmental temperature on the rate of stress-corrosion cracking in three alloys: 18%-nickel maraging steel, a low-alloy martensitic steel, and a hot-worked die steel.

C. To study the electropotential changes occurring in 18%-nickel maraging steel during stress-corrosion exposure and the effect of applied potential.

D. To evaluate the effectiveness and applicability of surface protection on 18%-nickel maraging steel in preventing stress-corrosion cracking.

II. WORK PROGRESS

A. BACKGROUND

The present program is the second 1-year extension of the original 2-year program on stress-corrosion cracking of high-strength alloys. During the first 2-year study, six alloys were evaluated: (1) Ladish D6AC steel, (2) Type 300 M steel, (3) Vascojet 1000 steel, (4) AM 355 cold-worked PH steel, (5) precipitation-hardening 15-7Mo stainless steel, and (6) B120VAC titanium. Significant failures were found to occur with the D6AC, 300 M, and Vascojet 1000 steels in tap, distilled, and salt water, as well as in high-humidity environments. The time-to-failure was found to decrease with increasing strength level for each of the three steels.

During the first 1-year continuation program, attention was focused on three new high-strength steels plus one high-strength titanium alloy. These alloys are (1) 20%-nickel maraging steel, (2) 18%-nickel maraging steel, (3) 9% Ni-4%Co vacuum-melted steel, and (4) 6Al-4V titanium. The titanium alloy showed complete immunity to stress-corrosion failure under test conditions. Limited susceptibility was noted with the 9 Ni-4 Co alloy. High susceptibility was noted with both the 20%- and 18%-nickel maraging steels. While the failures of the 20%-nickel grade material had been somewhat expected, the failures of the 18% grade was not. Tests made by the developers of this material show a high degree of resistance to stress-corrosion cracking for 18% nickel maraging steel. The present program will therefore be directed exclusively to the study of the stress-corrosion behavior of this one alloy.

This present program has three general aims: (1) to determine the extent of the problem by testing four additional heats of 18%-nickel maraging steel, (2) to compare the susceptibility of maraging steel with conventional ultra-high-strength steels, and (3) to determine, if possible, the cause of failure of 18%-nickel maraging steel.

B. TEST PROCEDURES

1. Bent-Beam Test

The bent-beam test is the primary test method used in the program. Figure 1 shows an insulated bent-beam fixture with test samples mounted. Polycarbonate blocks 7.000 ±0.001 in. apart, attached to a stainless-steel holder, support the test specimen and insulate it from the holder. Specimens are cut to exact length to give a maximum outer fiber stress of 75% of the 0.2% offset yield strength. The length-stress relationship is shown in Figure 2.

2. U-Bend Test

Figure 3 shows a U-bend test sample. This test is designed to show the effect of elastic stress superimposed on plastic deformation. A bend fixture has been machined that will permit samples to be bent to a 1-in. radius. Plans are to bend samples after maraging, if possible.

3. Center Notch Test

Figure 4 shows the test specimen configuration used in the accelerated center-notch test. The configuration consists of a 1-3/4- by 8-in.

tensile specimen containing a central notch. This notch is produced by a two-step process. First, a 0.06- by 0.57-in. slot is Elox machined and extended at each end by very narrow Elox machined notches of 0.001-in. root radii. Second, an extension of these notches is produced by fatigue-cycling to obtain fatigue cracks of controlled dimensions.

These center-notched specimens are tested in Baldwin creep-test machines. The desired loads are obtained by dead weight loading applied to a 20 to 1 lever arm. These specimens are well adapted to stress-corrosion studies in that crack growth rate, corrosion potential, or corrosion current may be measured.

C. PROGRAM STATUS

1. Compositional Variation

The first objective is to study the effect of compositional variation on the stress-corrosion characteristics of 18%-nickel maraging steel. Both U-bend and bent-beam tests will be conducted in aerated distilled water, aerated 3%-NaCl solution, 140°F water-saturated air, and natural seacoast environments. These environments were found to be the most severe in the previous year's program.

Four heats of 18%-nickel maraging steel will be tested in triplicate in each environment. These heats are now on hand and mechanical evaluation is under way. Table 1 lists the chemical analysis of the four heats as well as the chemical analysis of the four heats of 18%-nickel maraged material tested in the previous program. The titanium content of the heats to be evaluated ranges from 0.23 to 0.55%. This range is of more current interest than the 0.50 to 1.00% evaluated in the previous program. In addition to the U-bend and bent-beam testing, plans are being made to conduct center-notched specimen tests at various loads in salt water with each heat of material.

2. Environmental Temperature

The second objective is to study the effect of environmental temperature on the rate of stress-corrosion cracking in three alloys: 18%-nickel maraging steel, a low-alloy martensitic steel, and a hot-worked die steel. Bent-beam and U-bend tests will be conducted in distilled water at three temperatures, ambient, 120°F, and 160°F. The chemical analysis of the low-alloy martensitic steel and the die steel are shown in Table 1. These two alloys are also in the process of mechanical evaluation.

3. Electrochemical Measurements

The third objective of the program is to measure the electrochemical changes occurring in 18%-nickel maraging steel during stress-corrosion exposure and to determine the effect of applied potential on failure time. A preliminary test has been conducted using a salt bridge to connect the crack tip of the center notch specimen of Figure 4 to a saturated calomel electrode. A linear relationship was found between stress and the anodic potential of the specimen in salt water. However, the test was stopped when KCl leakage from the salt bridge into the crack tip of the specimen was observed. This experiment will be repeated using a redesigned salt bridge.

It is hoped by means of this method that the stress-corrosion cracking process can be studied to learn some of the following characteristics: (a) effect of stress on potential, (b) duration of incubation period before crack initiation, (c) effect of exposure time on potential, and (d) effect of applied potential on failure time.

4. Surface Protection

The fourth objective of the present program is to evaluate the effectiveness and applicability of surface protection on 18%-nickel maraging steel in preventing stress-corrosion cracking. The two protective coatings found to be most effective in preventing stress corrosion of H-11 steel will be tested on 18%-nickel maraging steel. The coatings selected, based on the previous year's work are CAT-A-LAC 454-1-1 (a chromate-inhibited epoxy), and Magna Laminar X-500 (a polyurethane-type coating). Test environments will be aerated 3% NaCl solution, 140°F water saturated air, and outdoor seacoast exposure.

D. TEST RESULTS TO DATE

Work to date has consisted on machining specimens and test fixtures and determining mechanical properties of materials. No environmental test exposures have yet been started, but some of these data will be available for the next quarterly report.

Preliminary tests have been conducted as a check on techniques for measurement of potential of center notch specimens and applied current density on bent-beam specimens. Based on these preliminary runs, no difficulty is anticipated with these experiments. These test data will be presented in the next quarterly report.

E. FUTURE WORK

Now that material is on hand, environmental tests will be started to fulfill the objectives of the program. No delays or technical difficulties are anticipated.

TABLE 1

MILL-CERTIFIED CHEMICAL ANALYSIS OF PROGRAM MATERIALS

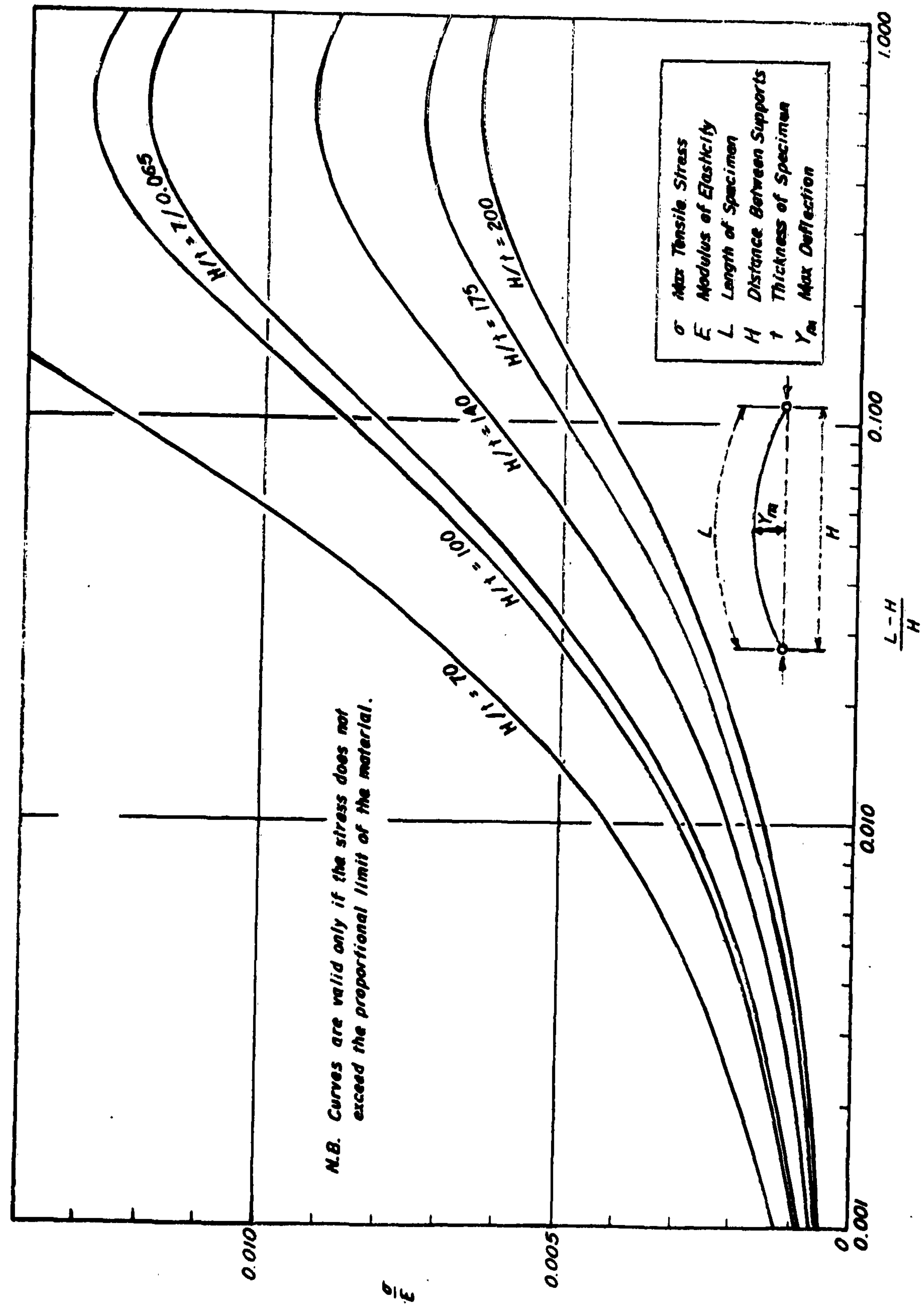
			Composition, %														
Trade Name	Supplier	Heat No.	C	Mn	P	S	Si	Ni	Co	Mo	Al	Cr	Zr	Ti	Ca	B	V
*(a) Maraging Steel from Previous Program																	
RSM 250	Republic Steel	3960502	0.02	0.08	0.007	0.006	0.15	18.48	7.00	4.84	0.21	0.10	0.035	0.50	--	0.0036	
--	Allegheny-Ludlum	448	0.029	0.002	0.004	0.008	0.009	18.51	8.48	4.92	0.089	--	--	0.52	--	--	
Almar 18	Allegheny-Ludlum	W-24178	0.012	0.01	0.003	0.005	0.01	18.69	8.90	4.92	0.029	--	0.003	0.62	0.006	0.002	
--	Allegheny-Ludlum	476	0.02	0.08	0.006	0.005	0.014	18.60	9.05	4.90	0.078	--	--	1.00	--	--	
(b) Maraging Steel for Present Program																	
RSM 200	Republic Steel	3960523	0.029	0.06	0.005	0.006	0.05	17.79	8.50	3.48	0.13	--	--	0.23	--	--	
Vascomax 250	Vanadium Alloys	07868	0.02	0.09	0.004	0.005	0.10	17.75	7.60	4.60	0.08	--	0.017	0.52	0.05	0.004	
Marvac 18	Latrobe Steel	C56858	0.03	0.03	0.004	0.008	0.05	18.34	8.00	4.75	0.11	--	0.03	0.49	--	0.004	
Vascomax 300	Vanadium Alloys	07268	0.03	0.05	0.004	0.006	0.04	18.54	9.06	4.88	0.09	--	0.088	0.55	0.02	0.003	
(c) Conventional High-Strength Steels																	
Vascojet 1000	Vanadium Alloys	07914	0.38	0.21	0.010	0.008	0.92	--	--	1.33	--	4.75	--	--	--	--	0.51
Ladish D6AC	Allegheny-Ludlum	W-23217	0.495	0.62	0.009	0.003	0.20	0.57	--	0.94	--	1.00	--	--	--	--	0.05

*Some material from previous program will be used to obtain supplementary data.

1062-616

Bent-Beam Test Specimens

Figure 1

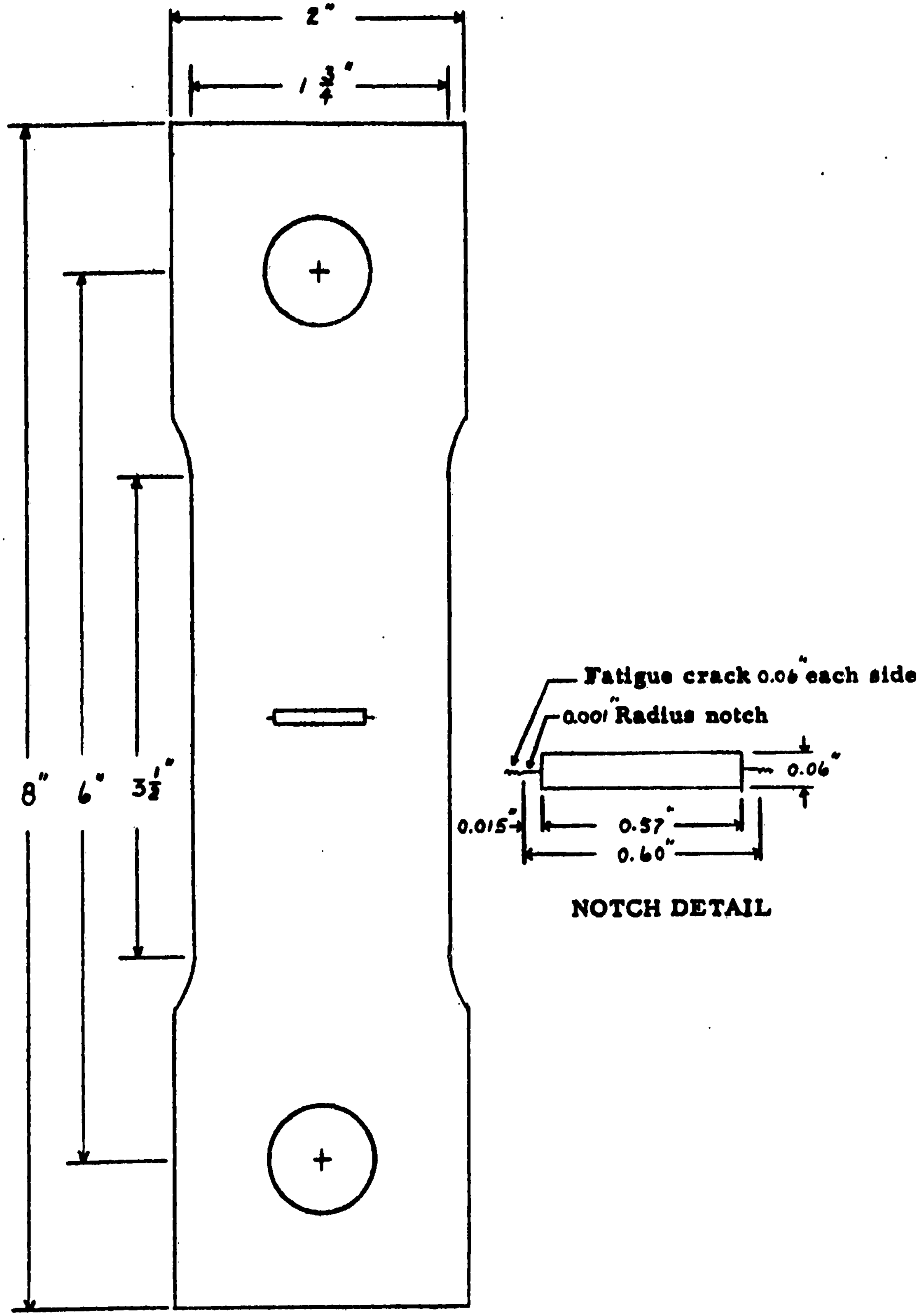


Beam Length-Stress Relationship

Figure 2

U-Bend Test Specimen

Figure 3



Center-Notch Specimen Configuration

Figure 4