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OF
TITANIUM STRESS CORROSION CRACKING

Lab. Project 6377-6, Progress Report 3
SF 020-01-01, Task 0723

I. GELD
S.H. DAVANG

5 JUN 1967

TECHNICAL REPORT

U.S. NAVAL APPLIED SCIENCE LABORATORY

NAVAL BASE
BROOKLYN 1, NEW YORK

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PHYSICAL SCIENCES DIVISION
J.M. McGreevy, Head

Approved: E.J. JAHLE
Technical Director

Approved: T.T. McGILLICUDDY, CAPTAIN USN
Commanding Officer & Director

U.S. NAVAL APPLIED SCIENCE LABORATORY
FLUSHING AND WASHINGTON AVENUES
BROOKLYN, NEW YORK 11251

ABSTRACT

Studies were conducted to determine whether shot peening and abrasive blasting reduced susceptibility to stress corrosion cracking (SCC) of titanium-721 alloy in sea water using V-notched bar specimens and a constant-strain rate, three-point bending device. Steel shot peening significantly reduced sea water SCC of test specimens containing no precrack, but had no effect on precracked specimens. Abrasive blasting had no significant effect.

SUMMARY

Coatings to be studied for prevention of titanium stress corrosion cracking (SCC) require pretreatment of the metal surface by abrasive blasting or shot peening to help insure good adhesion. Previous investigators found that such treatments reduced SCC susceptibility, but no information was available on effects on titanium alloys in sea water. Studies were therefore undertaken to determine whether shot peening and abrasive blasting reduced susceptibility to SCC of titanium-721 in sea water. Tests were conducted with V-notched bar specimens, using a constant-strain rate, three-point bending device. Steel shot peening significantly reduced sea water SCC susceptibility of the notched bar specimens containing no precrack, but had no effect on precracked specimens. Abrasive blasting had no significant effect.

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ADMINISTRATIVE INFORMATION

Ref: (a) NASL Program Summary of 1 May 1967, SF 020-01-01, Task 0723
(b) NASL Project 6377-6, Technical Memorandum 1 of 5 Aug 1966
(c) NASL Project 6377-6, Progress Report 2 of 9 May 1967
(d) Military Specification MIL-S-13165A, "Shot Peening of Ferrous Metal Parts" dated 26 Mar 1956

1. In accordance with objectives set forth in reference (a), the Naval Applied Science Laboratory is conducting research and development of advanced technologies for the fabrication of high strength titanium alloys into pressure hulls of deep diving submersibles. Previous NASL reports on prevention of stress corrosion cracking (SCC), conducted under Lab. Project 6377-6, included:

a. Reference (b), which reported results of a state-of-the-art survey on sea water SCC prevention, and preliminary data on protective coatings and electrochemical potentials of titanium-721, and

b. Reference (c), which reported results of studies on SCC effects of rolling direction and water immersion.

2. The present report provides information on effects of shot peening and abrasive blasting.

ACKNOWLEDGMENTS

3. The investigation was conducted under the supervision of W. L. Miller, Head, Inorganic Chemistry Branch, Physical Sciences Division. The NASL titanium development program is under the direction of R.J. Wolfe, Head, Titanium Program, Material Sciences Division. The Program Manager is B.B. Rosenbaum, NAVSHIPS (03422) and the Project Engineer is T. Dawson NAVSEC (6101D).

BACKGROUND

4. The Naval Applied Science Laboratory is studying protective measures to prevent SCC of titanium alloys in sea water. One promising approach, cited in reference (b), is use of a treatment system consisting of abrasive blasting and/or shot peening, coating application, and cathodic protection.

5. The first of these treatments, i.e., shot peening and abrasive blasting, are known to reduce SCC. Davis[1] found that shot peening and grit blasting of

high-strength steels improved SCC resistance, both by compressive stresses and by causing metal surface flow. NASL has observed that titanium also exhibits surface flow when peened. Sandblasting increased SCC failure time of H-11 steel in aerated 3% NaCl from 1.6 to 18.5 hours[2]. Specific information was considered needed on effects of these treatments on titanium alloys in sea water at ambient temperatures.

OBJECTIVE

6. Objective of the work reported herein is to determine whether shot peening and abrasive blasting reduce susceptibility to SCC of titanium alloys in sea water.

APPARATUS AND MATERIAL

7. The SCC equipment consisted of a Manlabs fatigue precrack machine and a Manlabs three-point loading, constant deflection rate, slow bend machine. The specimens were 0.5 in. by 0.5 in. by 6.0 in. titanium-721 bars, containing a central 0.010-inch root radius notch, machined with the longitudinal axes parallel to the direction of rolling. Details on the specimens, and construction and operation of the equipment were provided in reference (c).

PROCEDURE

8. Specimens were treated as follows:

a. One set of nine specimens was shot peened on all surfaces, including the notches, with No. 70 steel shot (0.005 in. to 0.014 in. diameter) to a peening intensity of 0.007A (reference (d) designation) relative to a standard Almen test strip, and a surface roughness of 60 microinches. Shot peening was conducted in accordance with the requirements of reference (d).

b. Another set of nine specimens was similarly shot peened, but with 0.004 in. to 0.008 in. diameter glass beads, to a test strip intensity of 0.011N2 (Grumman Aircraft designation), and a surface roughness of 73 microinches.

c. A third set of twelve specimens was blasted at 90 psi with 8-20 mesh flint abrasive, to a surface roughness of 140 microinches; the blasting nozzle was normal to and 1 to 2 inches from the specimen surface. (Appearance of the surfaces is shown in Figure I).

9. Approximately half of each set of the above-treated specimens was precracked subsequent to shot peening and prior to SCC; the other specimens were not precracked. The SCC studies were conducted at room temperature in air and natural sea water, using the Manlabs equipment cited in paragraph 7 above.

10. Stress intensity values were obtained using the following equation from Kies et al[3]:

$$K_I = \frac{2.06\ PL_1\left(\frac{1}{\alpha^3} - \alpha^3\right)^{1/2}}{BD^{3/2} \times 1000}$$

where K_I is the stress intensity factor in units of kilopounds per inch $^{3/2}$ or KSI $\sqrt{in.}$; P is the maximum applied load in pounds; L_1 is the distance between the outer and inner load points (2.5 in.); $\alpha = 1 - \frac{a}{D}$; a is the depth of the V notch (.080 in.) plus maximum depth of precrack in inches (a is the depth of the V notch only, in the absence of a precrack); D is the depth of the specimen (0.5 in.); and B is the width of the specimen (0.5 in.). Determination of precrack depth was described in reference (c). Percent SCC susceptibility, with respect to control specimens, was calculated using the formula:

$$S = \left[1 - \frac{K_{I_{SCC}}}{\left(K_{I_{XC'}} \text{ or } K_{I_{XC''}}\right)}\right] 100$$

where S is the percent susceptibility, $K_{I_{SCC}}$ is the stress intensity factor in sea water, and $K_{I_{XC'}}$ and $K_{I_{XC''}}$ are the stress intensity factors of the control specimens (not shot peened or abrasive blasted) in air, with and without precracks, respectively.

RESULTS

11. Effects of shot peening and abrasive blasting on SCC susceptibility of specimens with and without precracks are provided in Table 1.

ANALYSIS AND DISCUSSION

12. Titanium-721 is being used in these and future studies principally as a sensitive indicator of SCC. It is assumed that protective measures effective for this alloy will also be beneficial for other, less susceptible titanium alloys.

13. The data listed in Table 1 indicate the following:

a. Steel or glass peening did not significantly affect SCC susceptibility of precracked specimens. Evidently, the compressive stresses produced did not reach below the roots of the precracks.

b. Precracks were not necessary to induce SCC susceptibility in titanium-721, but the degree of susceptibility in the absence of a precrack was considerably lower.

c. SCC susceptibility of specimens without precracks was reduced about one third by glass peening, and reached the air value of the control specimen by steel shot peening. The superiority of the latter process may be attributed, in part, to the higher kinetic energy which induces increased compressive stresses to greater depths.

d. Abrasive blasting had no significant effect on reduction of SCC susceptibility, whether the specimens were precracked or not.

CONCLUSIONS

14. It was found that steel shot peening significantly reduced sea water SCC susceptibility of notched bar, titanium-721 specimens, containing no precrack; this effect was not observed with precracked specimens. The results indicate that benefits may be achieved by shot peening SCC susceptible areas in titanium alloy structures. Such surfaces, residually stressed in compression, are also inherently resistant to fatigue crack formation. Abrasive blasting had no significant effect on SCC susceptibility.

FUTURE WORK

15. The next phase of this work, to be initiated 1 July 1967, will cover studies of the effectiveness of coatings in reducing the susceptibility of stress corrosion sensitive titanium alloys to SCC.

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2. Setterlund, R.B., "Stress Corrosion Cracking of High-Strength Alloy", U.S. Army Ordnance Report No. 2684 (Final), Contract DA-04-495-ORD-3069, September 1963.

3. Kies, J.A.; Smith, H.L.; Romine, H.E.; and Bernstein, H., "Fracture Testing of Weldments", Fracture Toughness Testing and Its Applications, ASTM STP 381, Am. Soc. Testing Mats., 1965.

SURFACE TREATMENT	SURFACE ROUGHNESS (MICROINCHES)
GROUND (CONTROL)	12–14
GLASS PEENED	73
STEEL SHOT PEENED	60
ABRASIVE BLASTED	140

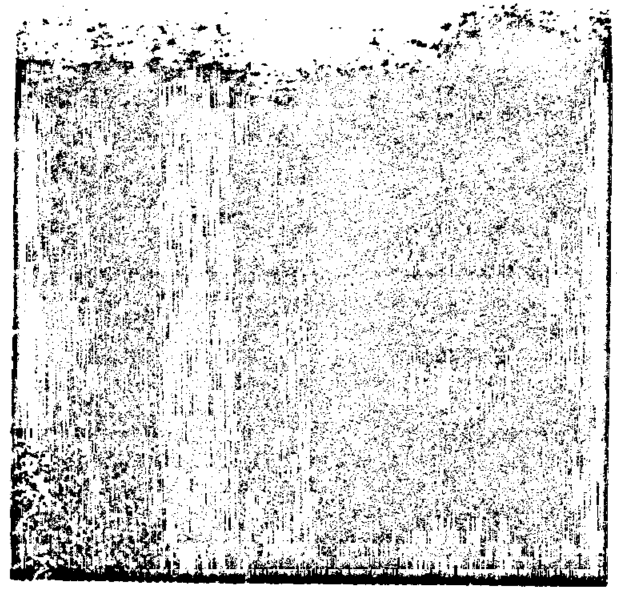

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FIGURE 1 - APPEARANCE OF TREATED SURFACES

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Table 1

EFFECT OF SURFACE TREATMENT ON SCC OF TITANIUM-721

Surface Treatment	K_{I_X} (KSI $\sqrt{in}$)	Standard Deviation	$K_{I_{SCC}}$ (KSI $\sqrt{in}$)	Standard Deviation	SCC Susceptibility (%) $\left[1 - \frac{K_{I_{SCC}}}{(K_{I_{XC'}} \text{ or } K_{I_{XC''}})}\right]100$
			Precrack		
Ground (Control)	85.8	2.95	48.6	4.60	43.4
Glass Peened	88.2*	1.80	45.8*	0.16	46.6
Steel Shot Peened	83.0*	1.00	50.4*	2.35	41.3
Abrasive Blasted	88.3	2.76	52.8	1.66	38.5
			No Precrack		
Ground (Control)	77.3	1.95	62.8	2.00	18.8
Glass Peened	80.4	0.58	68.0*	3.00	12.0
Steel Shot Peened	81.6	0.28	77.3*	1.50	0.0
Abrasive Blasted	88.7	0.28	63.4	2.99	18.0

Notes:
1. KSI denotes kilopounds per square inch.
2. $K_{I_{XC'}}$ and $K_{I_{XC''}}$ are the stress intensity factors of the control specimens in air, with and without precracks, respectively.
3. Results are averages of triplicate specimens, except where indicated by an asterisk; these values are averages of duplicate specimens.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Titanium-721 alloy, stress corrosion cracking, pretreatment of surfaces, abrasive blasting, steel shot peening, glass peening, fatigue - crack, V - notch bar specimens, constant strain rate, three-point bending, sea water.						

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