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THE STRESS-CORROSION CRACKING OF
UNDERAGED AND OVERAGED U-2.3 wt% Nb IN AN
AQUEOUS CHLORIDE ENVIRONMENT

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THE STRESS-CORROSION CRACKING OF UNDERAGED AND OVERAGED U-2.3 wt% Nb IN AN AQUEOUS CHLORIDE ENVIRONMENT

James M. Macki and Robert L. Kochen

Abstract. The stress-corrosion cracking (SCC) behaviors of the U-2.3 wt% Nb alloy aged 24 hours at 230°C (underaged) and 24 hours at 430°C (overaged) have been studied. The SCC test utilized smooth, dead-weight loaded, static tensile specimens which were exposed to oxygen-saturated water containing 50 ppm chloride ions.

The tests showed that the underaged material is more susceptible to SCC than the overaged material. SCC in the underaged material appears to proceed by a transgranular fracture mode. The overaged material might not fracture by a SCC mode; but rather, it might fracture by a mechanical mode after corrosion has reduced the cross-sectional areas of the specimens.

INTRODUCTION

This report summarizes the results of stress-corrosion cracking (SCC) tests on specimens of the U-2.3 wt% Nb alloy aged for 24 hours at 230°C and 430°C.

The terms "underaged" and "overaged" are explained in Figure 1 which was taken from a report by Jackson and Boland.¹ In Figure 1, the yield strength (0.2% offset) is plotted as a function of aging temperature for 24-hour aging times. A 135 ksi yield strength was required. This 135-ksi yield strength can be obtained by aging at 230°C or 430°C. The material aged at 230°C is called "underaged,"

Figure 1. The Yield Strength (0.2% offset) of Solution Quenched U-2.3 wt% Nb as a Function of Aging Temperature.

and the material aged at 430°C is called "overaged." The 230°C aging produces the single phase, α -uranium microstructure; the 430°C aging yields a two-phase microstructure of α uranium and the niobium-rich γ_2 phase (with the possibility of some retained alpha).^{1,2}

EXPERIMENTAL

Smooth, static tensile SCC tests were used to compare the SCC behaviors after these two aging treatments. Smooth specimen SCC tests involve stressing the specimen in a test environment and recording the time-to-failure (TTF). This TTF is the sum of the nucleation time and the propagation time. The SCC specimens were elongated, pin-loaded tensile test type specimens with a rectangular cross section of 125 mils by 200 mils (0.025 square inch).

Each specimen was mounted in an environmental chamber of Pyrex glass as shown in Figure 2; the chamber was

Figure 2. Stress-Corrosion Cracking Specimen and Environmental Chamber.

filled with water containing 50-ppm chloride ions; oxygen was bubbled through the aqueous solution; and the specimen was stressed to 40 ksi.

The U-Nb binary alloys have been shown to be susceptible to SCC in this aqueous test environment.³

RESULTS AND DISCUSSION

After completion of the SCC tests, the Analytical Laboratory examined samples from two overaged and two underaged SCC specimens. The results are shown in Table 1.

Table 1. Results of Laboratory Analyses on U-2.3 wt% Nb Specimens (ppm).

Sample	C	N	O	H	Nb (wt%)
Underaged	40	43	197	7	2.11
Underaged	20	37	59	4	2.16
Overaged	20	44	600	10	2.16
Overaged	10	27	176	4	2.18

The results of the SCC tests on the aged U-2.3 wt% Nb alloy are summarized in Table 2.

Table 2. The SCC of U-2.3 wt% Nb Aged 24 Hours.

Aging Temperature (°C)	Time-to-Failure (hours)
230	183
230	190
230	392
430	1286
430	1922
430	2856

These results show that the underaged, single phase material is more susceptible to SCC in the test environment than the overaged, two-phase material.

The microstructures and the fracture surfaces of the U-2.3 wt% Nb alloy specimens are shown in Figures 3 through 6. The fracture edge of the underaged material shown in Figure 5 could not be resolved when the metallographic specimen was etched (Figure 3). However, neither the fracture surface nor the secondary cracks shown in Figure 5 appear to follow grain boundaries of the type shown in Figure 3. Therefore, the underaged material must fracture by a transgranular SCC mode.

Figure 3. The Microstructure of the Underaged (230°C) U-2.3 wt% Nb Alloy. 100X.

Figure 4. The Microstructure of the Overaged (430°C) U-2.3 wt% Nb Alloy. 100X.

Figure 5. The Fracture Edge of the Underaged Material. Note that neither the fracture nor the secondary cracks appear to follow the grain boundaries. 100X.

Figure 6. Fracture Surface of the Overaged Material Showing Corrosion Penetration Which Reduces the Cross-sectional Area of the Specimen.

The fracture surface of the overaged material shown in Figure 6 has a large corrosion pit along one end (dark region) and general corrosion penetration around the perimeter of the fracture surface. This corrosion penetration reduces the cross-sectional area of the specimen which could lead to mechanical fracture. Therefore, the overaged material may fail by corrosion penetration that leads to mechanical failure.

CONCLUSIONS

1. The underaged, single phase U-2.3 wt% Nb alloy is more susceptible to SCC in the test environment than the overaged, two-phase material.
2. The SCC in the underaged material proceeds by a transgranular fracture mode.

3. The overaged material might not fracture by an SCC mode; but rather, by a mechanical mode after corrosion has reduced the cross-sectional areas of the specimens.

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