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Corrosion Rate of Alloy 22 as a Function of Immersion Time

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Abstract

Alloy 22 (N06022) is a nickel (Ni) based alloy containing nominally 22% Chromium (Cr), 13% Molybdenum (Mo) and 3% tungsten (W). Alloy 22 is highly resistant to general and localized corrosion such as pitting corrosion and stress corrosion cracking. Due to the formation of a stable passive film, when Alloy 22 is immersed in certain electrolytes, its corrosion potential (E_{corr}) increases and its corrosion rate (CR) decreases as a function of the immersion time. This paper discusses the evolution of E_{corr} and corrosion rate (CR) of creviced Alloy 22 specimens in six different mixtures of sodium chloride (NaCl) and potassium nitrate (KNO_3) at 100°C. Two types of specimens were used, polished as-welded (ASW) and as-welded solution plus heat-treated (ASW+SHT). The latter contained the black annealing oxide film on the surface. Results show that, for the two type of materials, as the immersion time increases, E_{corr} increased and the CR decreased. Even for concentrated brine solutions at 100°C the CR was < 50 nm/year after more than 100 days immersion.

Experimental

The specimens of Alloy 22 were machined from welded 1.25-inch thick plates (~32 mm). Details of chemical composition of the plate and weld wire, specimen configuration and many other experimental details are given elsewhere [1]. All the specimens had a weld seam through the center of the cross section. There are two types of specimens mentioned in this work: (1) The as-welded (ASW) which were as-received welded specimens and (2) the as-welded plus solution heat treated (ASW + SHT) which were annealed in air for 20 min at 1121°C and then water quenched. The latter specimens were finished with 600-grit paper before the heat treatment but the final oxide formed as a consequence of annealing and water quenching was not disturbed prior to testing. For each surface and metallurgical condition (ASW and ASW + SHT) there were four PCA specimens of Alloy 22 in each cell (electrolyte). The E_{corr} of all eight Alloy 22 specimens were monitored continuously.

Table I shows the composition of the six test solutions expressed in molality (*m*), which represents moles of the salt per kilogram of the solvent (water). The solutions were prepared using sodium chloride (NaCl), potassium nitrate (KNO_3) and de-ionized water. The volume of the electrolyte solution in each cell was 2 liters (2 L). The testing temperature was 100°C. The electrolyte solutions were naturally aerated; that is, the solutions were not purged, but a stream of air was circulated above the level of the solution. The E_{corr} was monitored using saturated silver chloride electrodes [SSC] through a Luggin capillary. For E_{corr} data see Ref. 1.

At the same time that E_{corr} was being monitored for all eight Alloy 22 specimens, the polarization resistance (PR) of two specimens was also monitored as a function of time using the ASTM G 59 and G 102 technique [2]. The resistance to polarization was generally measured at 24 h of first immersion, at 7 days, at 28 days and monthly after that. The polarization resistance values ($\Omega.cm^2$) were later converted to corrosion rates (µm/year). To measure the polarization resistance, an initial potential of 20 mV below the corrosion potential (E_{corr}) was ramped to a final potential of 20 mV above E_{corr} at a rate of 0.167 mV/s. Linear fits were constrained to the potential range of 10 mV below E_{corr} to 10 mV above E_{corr}. The Tafel constants, b_a and b_c, were assumed to be $\pm$ 0.12 V/decade. Corrosion rates were calculated using equations from [2] assuming an equivalent weight for Alloy 22 of 23.28 g.

Results

Figure 1 shows the corrosion rate of Alloy 22 specimens as a function of immersion time in 6 m NaCl + 0.9 m KNO3 at 100°C. As the immersion time increased the corrosion rate decreased. This was the trend observed for all the six reported concentrations in Table 1. Figure 1 shows that in the first month of immersion, the corrosion rate of the ASW + SHT specimen (KE0190) was higher than the ASW specimen (KE0125). However, for longer immersion times, the trend was reversed. The final measured corrosion rate for both specimens approached 0.03 µm/year or 30 nm/year.

Figure 2 shows the long-term corrosion rates for both types of Alloy 22 specimens (ASW and ASW + SHT) as a function of the amount of nitrate in the solutions (from Table 1). The data in Figure 2 represents the average values at times higher than 100 days for the six different solutions listed in Table 1. For clarity, only the standard deviation of the ASW specimens is given. The behavior of the corrosion rates of the ASW + SHT specimens was somewhat erratic, but for the ASW specimens it is apparent that the corrosion rate slightly decreased as the nitrate concentration in the solution increased. This effect is not unexpected since nitrate promotes passivation of Alloy 22.

Table I
Environments for Corrosion Rate Studies

$[Cl^-]$ (m)	$[NO_3^-]$ (m)	$[NO_3^-]/[Cl^-]$
6	0.9	0.15
6	0.3	0.05
3.5	0.525	0.15
3.5	0.175	0.05
1	0.15	0.15
1	0.05	0.05

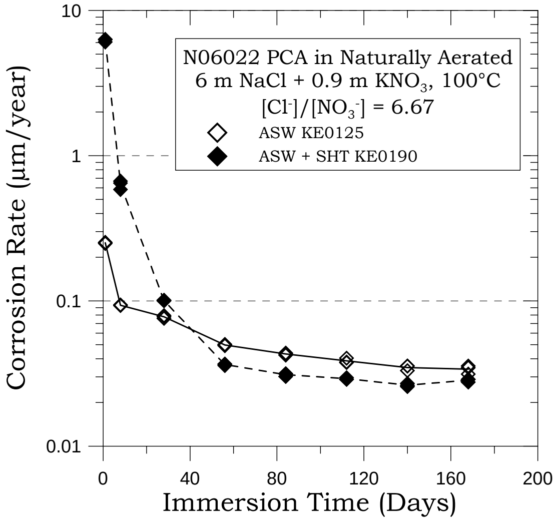

Figure 1 – Corrosion Rate vs. time for Alloy 22

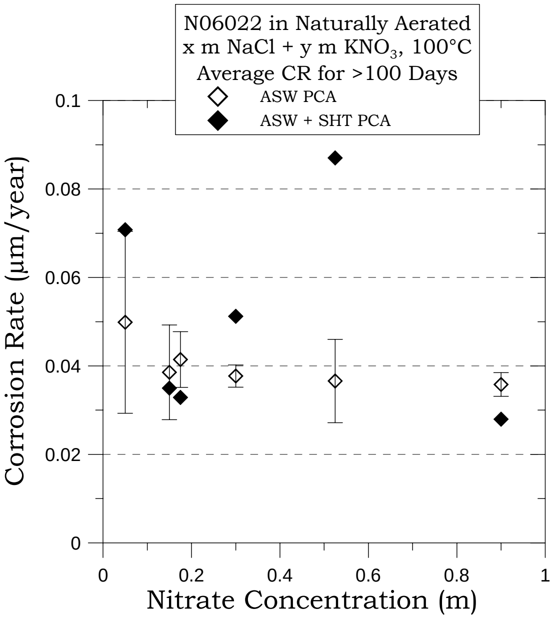

Figure 2 – Average Final Corrosion Rate

In general, the corrosion rate data calculated using the polarization resistance technique (ASTM G 59 and G 102) showed that the values were extremely small, in the order of 50 nm/year or less. The tested conditions in this work were highly aggressive, since they were aerated brines at 100°C with salt contents of up to 30%. This salt content is approximately ten times higher than the salt content in seawater. In spite of the harsh tested conditions, and considering that the specimens were tightly creviced, the overall corrosion rate of Alloy 22 was negligible. When crevice corrosion occurs E_{corr} would move to a more cathodic (active) potential and the output polarization resistance (R_p) will decrease. The fact that the general corrosion remained so low (or the R_p so high) suggests that all the tested specimens remained in the passive state.

Acknowledgments

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References

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