Electrochemical impedance spectroscopy of alloys in a simulated space shuttle launch environment

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Abstract

Type 304L stainless steel (304L SS) tubing is currently used in various supply lines that service the Orbiter at NASA's John F. Kennedy Space Center Launch Pads in Florida (USA). The atmosphere at the Space Shuttle launch site is very corrosive due to a combination of factors, such as the proximity of the Atlantic Ocean and the concentrated hydrochloric acid produced by the fuel combustion reaction in the solid rocket boosters. The acidic chloride environment is aggressive to most metals and causes severe pitting in many of the common stainless steel alloys such as 304L SS. Stainless steel tubing is susceptible to pitting corrosion that can cause cracking and rupture of both high-pressure gas and fluid systems. Outages in the systems where failures occur can impact the normal operation of the shuttle and launch schedules. The use of a more corrosion resistant tubing alloy for launch pad applications would greatly reduce the probability of failure, improve safety, lessen maintenance costs, and reduce downtime. A study which included ten alloys was undertaken to find a more corrosion resistant material to replace the existing 304L SS tubing. The study included atmospheric exposure at NASA's John F. Kennedy Space Center outdoor corrosion test site near the launch pads and electrochemical measurements in the laboratory which included DC techniques and electrochemical impedance spectroscopy (EIS). This paper presents the results from EIS measurements on three of the alloys: AL6XN (UNS N08367), 254SMO (UNS S32154), and 304L SS (UNS S30403). Type 304L SS was included in the study as a control. The alloys were tested in three electrolyte solutions which consisted of neutral 3.55% NaCl, 3.55% NaCl in 0.1N HCl, and 3.55% NaCl in 1.0N HCl. The solutions were chosen to simulate environments that were expected to be less, similar, and more aggressive, respectively, than those present at the Space Shuttle launch pads. The results from the EIS measurements were analyzed to evaluate the corrosion susceptibility of the alloys and to predict the long-term corrosion performance of the subject materials. The results from the EIS measurements for the three alloys indicated that the higher-alloyed 254SMO and AL6XN exhibited a significantly improved resistance to corrosion than the 304L SS as the concentration of hydrochloric acid in the 3.55% NaCl solution was increased. The polarization resistance values obtained from the EIS measurements were consistent with those from linear polarization measurements, and were indicative of the actual long-term corrosion performance of the alloys during a two-year atmospheric exposure study.

Keywords: EIS; 304L SS; 254SMO; AL6XN; Acidified chloride environment