

Corrosion and Protection in Aeronautical Alloys

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Corrosion in the aircraft industry continues to be a major problem that directly affects safety, costs, and aircraft availability. Metals and alloys, such as titanium, aluminum, superalloys, and stainless steel, are increasingly applied in aircraft and aeronautical components that require high mechanical strength and strong corrosion resistance.

The aeronautical industry demands improvements in structural and functional material components based on scientific research on new materials and corrosion protection methods. The intrinsic strength of alloys is insufficient to protect structural components exposed to aggressive environments. Such improvements can be achieved by optimizing the alloy design and metallurgical processes and by appropriating corrosion control strategies, such as novel pretreatments and coating designs for low- and high-temperature applications or chromate-free coatings, which help extend the service life of metallic components.

This Special Issue, “Corrosion and Protection of Aeronautical Alloys”, focuses on the current trends in corrosion science, engineering, and technology, and aims to cover recent research related to the performance of metals and alloys used in the aeronautical industry that addresses corrosion mechanisms, electrochemical techniques, protection methods, corrosion and failure analysis case studies, and simulation and modeling. We hope that this Special Issue will be useful for anyone working in this exciting field.

This volume collects contributions from academic and industrial researchers with stimulating new ideas and original results. The present volume comprises eight research articles.

Jáquez-Muñoz et al. [1] studied the frequency analysis of transients in the electrochemical noise of Waspaloy and Ultemet superalloys immersed in 3.5 wt.% H₂SO₄ and NaCl solutions at two different temperatures, 25 and 60 °C. The localized corrosion behavior of the superalloys was assessed using the electrochemical noise (EN) technique. The results indicate that when a polynomial is used to demonstrate localized corrosion kurtosis for the two superalloys, it enhances the behavior and clarity of the current and potential noise transients.

Alvan-Galvin et al. [2] report on the application of a cerium-based conversion coating (CeCC) as an alternative to toxic chromate coating. A two-step surface pretreatment using commercial products was applied to obtain cerium-based chemical conversion coatings (CeCC) on AA2024-T3 and AA7075-T6 alloys. Scanning electron microscopy (SEM) and energy-dispersive X-ray analysis (EDX) results showed that CeCC was initially observed as deposits, followed by crack formation on the surface when the coating began to thicken. Glow discharge optical emission spectroscopy (GDOES) confirmed an increase in the CeCC thickness as the deposition continued, and the formation of CeCC over 7075 was faster than that over 2024. Electrochemical impedance spectroscopy (EIS) and potentiodynamic linear polarization (PLP) indicated that CeCC in all samples provided cathodic protection and comparable degradation in chloride-containing media. Finally, a neutral salt spray (NSS) test corroborated the anti-corrosion properties of the CeCC obtained after commercial pretreatments.

Chavez et al. [3] conducted an investigation comparing the initial stages of corrosion process development on the AM60-AlN metal matrix nanocomposite surface and on AM60



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during a 30-day exposure to simulated acid rain solution (SAR). The AlN nanoparticles were observed as “attached” to Mn-rich AlMn intermetallic particles, forming clusters. The introduction of 1.0 wt.% AlN (≈ 80 nm) in the AM60 alloy led to slight grain refinement and the formation of a denser and more protective corrosion layer, as suggested by the electrochemical impedance spectroscopy (EIS) values of higher charge transfer resistance (R_2) and capacitance, which are characteristic of the double layer in the presence of corrosion products, and also as suggested by R_n (EN) values, compared to those of the AM60 alloy. Thus, the concentration of Mg ions released from the composite surface was lower. Due to the increase in SAR solution pH time, Al de-alloying and $\text{Al}(\text{OH})_3$ formation may occur, as confirmed by X-ray photoelectron spectroscopy (XPS) analysis. Due to the presence of Cl ions in the SAR solution, localized corrosion was observed, suggested as the fractional Gaussian noise of a stationary and persistent process over time, according to the PSD of the corrosion current fluctuations (EN).

Jaquez-Muñoz et al. [4] studied the susceptibility to pitting corrosion of titanium alloys Ti CP2, Ti-6Al-2Sn-4Zr-2Mo, and Ti-6Al-4V immersed in 3.5 wt.% H_2SO_4 and NaCl solutions at room temperature. The results revealed pseudo-passivation in cyclic potentiodynamic polarization (CPP) and power spectral density (PSD) for Ti-6Al-2Sn-4Zr-2Mo exposed to NaCl, indicating instability and a lower corrosion rate. However, Ti-6Al-4V exhibited the highest corrosion rate in both electrolytes. Ti-6Al-2Sn-4Zr-2Mo exhibited pseudo-passivation in CPP and PSD when exposed to NaCl, indicating an unstable passive layer. However, the corrosion rates were lower for both solutions.

Cabral-Miramontes et al. [5] report on the characterization of mechanical properties and corrosion resistance of hard-anodized aluminum 6061 in a citric acid solution as a replacement for sulfuric acid. Hard anodizing was conducted in a citric and sulfuric acid solution by applying current densities of 3 and 4.5 A/cm^2 and subsequently exposed to 3.5 wt.% NaCl solution. The results indicated that all the samples anodized in a citric acid solution showed negative hysteresis and lower corrosion current density ($1 \times 10^{-10} \text{ A}/\text{cm}^2$), indicating generalized corrosion on the material surface. Electrochemical impedance spectroscopy (EIS) results showed that anodizing in a citric acid solution provided stronger corrosion protection compared to anodizing in a sulfuric acid solution.

Samaniego-Gamez et al. [6] report on the corrosion behavior of CUSTOM 450 and AM 350 stainless steel passivated in (a) citric acid and (b) nitric acid solutions for 50 and 75 min at 49 and 70 °C, and subsequently exposed in 5 wt.% NaCl and 1 wt.% H_2SO_4 solutions, respectively. The results indicated that passivation in nitric acid made the surface prone to localized corrosion. Electrochemical noise (EN) statistical and PSD values showed a tendency toward pitting corrosion. Overall, passivated CUSTOM 450 stainless steel exhibited the best corrosion behavior in both the NaCl and H_2SO_4 test solutions.

Almeraya-Calderón et al. [7] studied the passive state of martensitic and semi-austenitic PHSS passivated in citric and nitric acid baths at 49 and 70 °C for 50 and 75 min, and subsequently immersed in 5 wt.% NaCl and 1 wt.% H_2SO_4 solutions, respectively. The potentiodynamic polarization results indicated that martensitic and semi-austenitic steels passivated in nitric acid exhibited lower corrosion resistance values. The X-ray photoelectron spectroscopy (XPS) characterization confirmed that the martensitic and semi-austenitic surface films contained a mixture of chemical compounds, such as Cr_2O_3 and $\text{Fe}(\text{OH})\text{O}$. Overall, the citric acid passivation process of PHSS could be a green alternative to the currently employed nitric acid passivation process.

Granados-Becerra et al. [8] report on the stress corrosion cracking (SCC) behavior of aged plates of Inconel 600 welded to Inconel 600 plates in the as-received condition using a slow strain rate test (SSRT) on two sodium-containing electrolytes at 25 and 80 °C. The aged plate was used to simulate the damage caused by the operation. Electrochemical noise (EN) was used to monitor the SCC. The results showed that some features of the microstructure in the weldments were differentiated by the chemical composition, cooling rate, and the formation of secondary phases. Regarding the SCC behavior, the results revealed that when sodium thiosulfate was used, the loss in plasticity was higher in the NiCrMo-3 joint

with around a 20 percent decrease. Conversely, in the 310 welds, the loss in plasticity was higher when sodium hydroxide was used, which decreased by 12 percent. A few secondary microcracks were observed in the transversal sections in both weld specimens. The EN results showed an increase in the potential and current when the sample reached tensile strength and then decreased when the neck was formed, indicating that some events occurred during the SSRT. The EN data showed two types of corrosion: general corrosion for NiCrMo-3 and mixed corrosion for the 310 welded joints in both environments.

Conflicts of Interest: The authors declare no conflict of interest.

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