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INFLUENCE OF PH AND SALINE EXPOSURE ON ZN-NI COATING DEGRADATION: INSIGHTS FROM NUMERICAL SIMULATIONS

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ABSTRACT

Corrosion-induced failures pose significant safety and economic challenges, particularly in automotive applications, where exposure to aggressive environments accelerates material degradation. Zinc-nickel (Zn-Ni) alloy coatings have gained prominence as an eco-friendly alternative to cadmium-based coatings due to their superior electrochemical performance, mechanical integrity, and enhanced corrosion resistance. Compared to pure Zn coatings, Zn-based alloys offer improved protection by forming a stable passive layer that mitigates localized corrosion, making them highly suitable for harsh conditions. This study investigates the mechanisms governing pit propagation in Zn-Ni electroplated 316L stainless steel surfaces through numerical modeling of single and double pits. Simulations were conducted using COMSOL Multiphysics 6.2 with the Tertiary Current Distribution, Nernst–Planck interface to analyze electrode kinetics, mass transport, and geometric deformation in a 0.35 mol/L NaCl solution at pH 3.0 and 7.0 over an eight-hour exposure period. The results indicate that single pits in an acidic environment exhibited an electrode potential of -0.897 V vs. RHE and a total electrode thickness change (pit depth) of 2.89 µm, which is significantly higher than the -0.777 V vs. RHE and 0.845 µm observed at neutral pH. Similarly, two-pit configurations in acidic conditions demonstrated more severe degradation, with an electrode potential of -0.946 V vs. RHE and a thickness change of 4.10 µm, compared to -0.814 V vs. RHE and 1.709 µm at pH 7.0. These findings highlight the critical role of substrate penetration in accelerating localized corrosion, emphasizing that acidic conditions significantly enhance the severity of pit growth. The study underscores the necessity of optimizing Zn-Ni alloy coatings to enhance pitting resistance, prolong service life, and improve the durability of components exposed to saline environment. These insights contribute to the advancement of protective strategies, ensuring long-term material performance and structural integrity in critical infrastructure applications.

Keywords: Corrosion; Pit propagation; Zn-Ni coatings; Electrochemical modeling; Electrodeposition.