Impact of biofilm formation on the electrochemical behaviour of marine grade steel

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Corrosion of metals and alloys in demanding environments such as seawater represents complex chemical, electrochemical, and biological interactions that require a comprehensive understanding. Since more than 70% of the corrosion in marine environments is associated with microorganisms, costing billions annually [1], this work focused on examining the impact of *Pseudomonas aeruginosa* biofilm formation on the electrochemical behaviour of 304 stainless steel (SS) in the simulated marine environment. Electrochemical behaviour was studied directly after incubation of 304 SS in the sterile artificial seawater (ASW) and ASW inoculated with PA (biotic ASW), using electrochemical impedance spectroscopy (EIS), and potentiodynamic polarization (PP) measurements. The characterization of the film formed on 304 SS surfaces after incubation in sterile and biotic ASW was performed by scanning electron microscopy (SEM), non-contact optical profilometry, Fourier transform infrared (FTIR) spectroscopy, and inductively coupled plasma-optical emission spectrometry (ICP-OES). During the incubation of coupons in sterile ASW, charge transfer resistance (R_1) and film resistance (R_2) increased with the increasing incubation time, indicating the properties of the surface layer against a corrosive marine environment enhanced over time. On the contrary, in the presence of bacteria, R_1 and R_2 decreased compared to sterile ASW for the same exposure time. The negative impact of PA on the film formation of 304 SS in ASW was also evident from PP curves obtained for coupons incubated in biotic ASW, where both anodic and cathodic current densities were shifted toward higher values compared to sterile ASW. As revealed by surface analysis, the latter was due to the formation of PA biofilms on the 304 SS surfaces that accelerated local dissolution of the material and increased pitting corrosion with the pit depth reaching up to 3.75 µm. The synergistic effect of biofilm and chlorides led to the formation of a porous α-FeOOH and γ-FeOOH surface layer. The limiting factor for the repair and growth of the surface film was also restricted concentration of available oxygen. A decrease in the concentration of O_2 and pH of biotic ASW due to metabolic activity of bacteria, resulted in the transition of the primary cathodic reaction from the reduction of oxygen to the reduction of protons, as suggested by an increase in alkalinity of biotic ASW after 30 days of incubation. The loss of Cr (3.72 ± 0.25 µg L^{-1} cm^{-2}) and Fe (10.21 ± 0.63 µg L^{-1} cm^{-2}), as confirmed by ICP-OES, made it more difficult to repair the surface film.

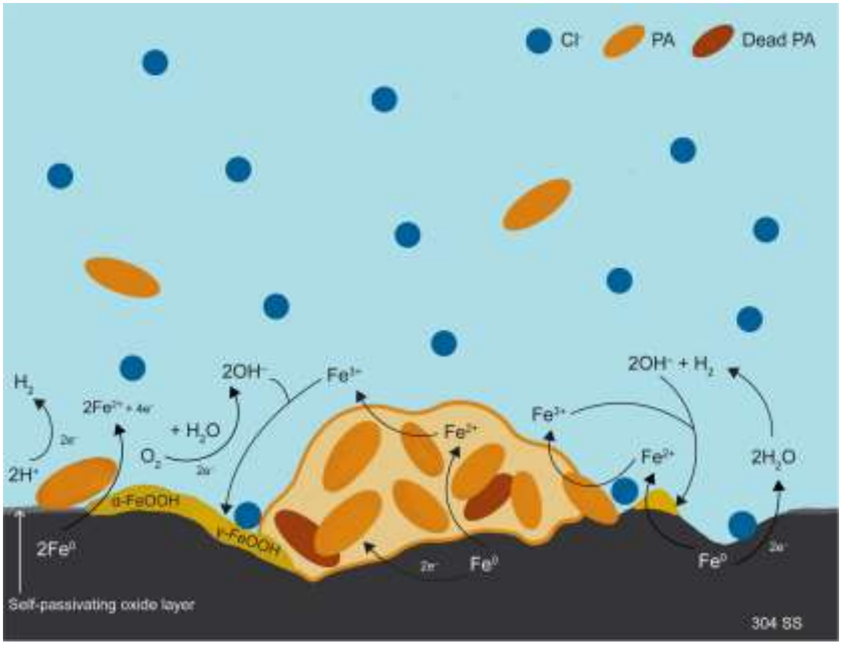

Figure 1. Illustration of corrosion mechanism of 304 SS in artificial seawater inoculated with Pseudomonas aeruginosa (PA)

Reference:

1. Y. Jin, Z. Li, E. Zhou, Y. Lekbach, D. Xu, S. Jiang, F. Wang, *Electrochim. Acta* **316** (2019) 93-104, https://doi.org/10.1016/j.electacta.2019.05.094