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Biocorrosion Study of Aluminum Aerospace Alloy in Marine and Urban Environments

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Introduction

Aluminum alloys are widely employed in the aeronautic industry due to their unique combination of mechanical properties. This metal and its alloys develop a thin and adherent oxide layer when exposed to oxygen, which acts as a barrier that prevents the continuous attack of the metal substrate exposed to mildly aggressive environments. Nevertheless, in severe environments, the oxide film does not provide long-term corrosion resistance. The problems associated with aircraft corrosion are also implied for the not only affect flight safety, but also the efficient operation of the aircrafts. This is further enhanced by the critical geographic areas in terms of corrosive environments, where pitting and crevice corrosion types are major problems. However, microbiologically influence corrosion (MIC) has also reported affect aircrafts.
The purpose of the present research is to investigate MIC of aluminum alloys used for manufacturing of A-36 and T-35 aircrafts components which were exposed often in marine and urban environments.

Experimental

The material used was a 2024-T3 aluminum alloy. Two types of working electrodes were used: (a) 150×80×0.3 mm plates and (b) rod of 0.8 cm^2 cross-sectional area machined from a rolled plate. The samples were ultrasonically degreased in acetone and subsequently in ethanol. After, the specimens were individually etched in 20 g L^{-1} NaOH solution at 313 K and subsequently desmutted in 4.7 M HNO_3 at room temperature.
The bacteria consortium was cultured for different immersion times. The morphologies of the metallic surfaces covered by biofilm were studied by scanning electron microscopy. The quantification of biofilm mass and optic density was determinate by UV-Vis spectroscopy. Gram stain and viability test were performed by confocal microscopy. The bacteria consortium was analyzed by denaturing gradient gel electrophoresis (DGGE) and DNA sequence analysis (16S rRNA). Later, by using Biological Activity Reaction Test (BART) the presence of iron related bacteria (IRB), sulfate-reducing Bacteria (SRB) and slym-producing bacteria (SLYM) were identified.
Susceptibility to corrosion was further investigated by electrochemical impedance spectroscopy (EIS) at $E = E_{corr}$ by using a large platinum grid as counter electrode and a saturated calomel electrode (SCE) as reference electrode and a Bipotentiostast 760D CH Instruments.

Results

The quantification of biofilm mass showed a decrease for shorter immersion times and then an increase for much greater immersion times.
The fluorescence microscopy images, including green fluorescent (viable cells) and red fluorescent (dead cells) showed a distribution of viable and dead bacteria on 2024-T3 alloy depending of immersion times in an inoculated medium. SEM images revealed for shorter immersion time that the surface remains almost unchanged and no corrosion signs were observed. However, numerous bacterial cells, either individually or in small clusters, and corrosion products were observed for longer days of exposure in the inoculated medium (see Fig. 1). DGGE and DNA sequence analysis of the main bands on the DGGE gel showed the presence of Bacilus subtilis and Microbacterium phyllosphaerae in the real samples from A-36 aircrafts.
Electrochemical results for 2024-T3 alloys were obtained in two inoculated medium for different exposition times. For the both inoculated medium E_{corr} undergoes a shift in the positive direction with exposure time. I_{corr} remain almost unchanged for shorter days as immersion time. However, for longer immersion times, I_{corr} showed a light protective effect by the biofilm.

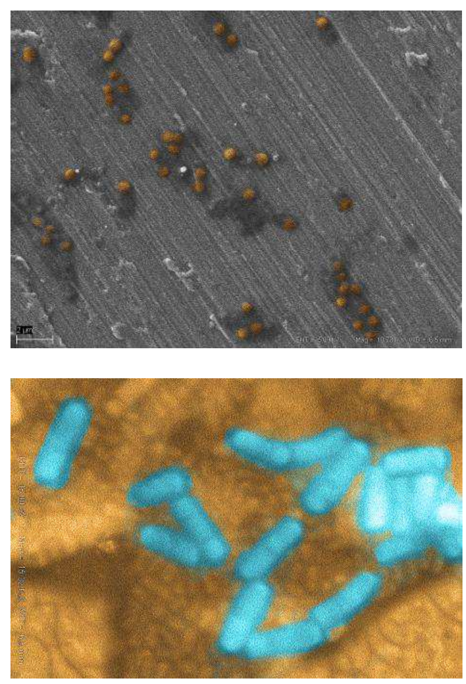

Figure 1: SEM image of (a) 2024 alloy exposed 21 days in an inoculated medium and (b) bacteria consortium representative of a sample from A-36 aircraft exposed in Marine Chilean Air Base.

Reference

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