

THE CORROSION BEHAVIOR OF ALUMINIUM-MAGNESIUM ALLOY IN NATURAL SEAWATER: EFFECTS OF THE BIOLOGICAL ACTIVITY

M.J.F. Marques^{a,b}, A. Benedetti^c, F. Castelli^{d,e}, M. Delucchi^d, M. Faimali^e, D. Delsante^{c,f}, F. Valenza^c, F. Garaventa^e, G. Pavanello^g, M. Losurdo^c, R. Basseguy^b

^a LMR – Laboratório de Materiais e Revestimentos, LNEG – Laboratório Nacional de Energia e Geologia, Lisbon, Portugal

^b LGC – Laboratoire de Genie Chimique, Université de Toulouse, CNRS, INPT, UPS, Toulouse, France

^c ICMATE, Istituto di Chimica della Materia Condensata e di Tecnologie per l'Energia, CNR - Consiglio Nazionale delle Ricerche, Genova - alessandro.benedetti@cnr.it

^d UNIGE-DICCA, Dipartimento di Ingegneria Civile, Chimica e Ambientale, Genoa, Italy

^e CNR-IAS, National Research Council, Institute for the study of Anthropic impact and Sustainability in the Marine Environment, Genoa, Italy

^f UNIGE-DCCI, Dipartimento di Chimica e Chimica Industriale, Genoa, Italy

^g ALVIM Srl, Genoa, Italy

Introduction

Concerning the corrosion in seawater environments, microorganisms can cause corrosion (Microbiologically Influenced Corrosion - MIC) [1], but also inhibit it or protect against it, a process known as MIC Inhibition (MICI) [2-3]. Corrosion studies of Al-Mg alloys of the 5XXX series, widely used in the shipbuilding industry, requires wider comprehension regarding the impact of the microbial activity [4-7]. Recent studies indicate that the biological activity tends to mitigate the Al alloy corrosion processes [8-11]. The objective of the present study is to assess the influence of natural seawater and the related biological activity on the resistance of the AA5083 Al-Mg alloy by the means of immersion experiments in natural (biotic) vs control (abiotic) seawater. Ennoblement of the open circuit potential (OCP) on Stainless steel (SS) probes was used to monitor the biofilm growth [12].

[1] L. Liu, X. Wu, Q. Wang, Z. Yan, X. Wen, J. Tang, X. Li, An overview of microbiologically influenced corrosion: mechanisms and its control by microbes, *Corrosion Reviews* 40 (2) (2022) 103–117, <https://doi.org/10.1515/corrrev-2021-0039L>.

[2] Y. Lou, W. Chang, T. Cui, J. Wang, H. Qian, L. Ma, X. Hao, D. Zhang, Microbiologically influenced corrosion inhibition mechanisms in corrosion protection: A review, *Bioelectrochemistry* 141 (oct. 2021), 107883, <https://doi.org/10.1016/j.bioelechem.2021.107883>.

[3] N. Kip, J.A. van Veen, The dual role of microbes in corrosion, *ISME J.* 9 (3) (mars 2015,) 542–551, <https://doi.org/10.1038/ismej.2014.169>.

[4] K.A. Yasakau, M.L. Zheludkevich, S.V. Lamaka, M.G.S. Ferreira, Role of intermetallic phases in localized corrosion of AA5083, *Electrochimica Acta* 52 (27) (oct. 2007,) 7651–7659, <https://doi.org/10.1016/j.electacta.2006.12.072>.

[5] E. Canepa, R. Stifanese, L. Merotto, P. Traverso, Corrosion behaviour of aluminium alloys in deep-sea environment: A review and the KM3NeT test results, *Mar. Struct.* 59 (mai 2018,) 271–284, <https://doi.org/10.1016/j.marstruc.2018.02.006>.

[6] Kemal Nisancıoğlu, "Corrosion and Protection of Aluminum Alloys in Seawater", EUROCORR 2004, Nice, France, 2004.

[7] M. Liang, R. Melchers, Two years pitting corrosion of AA5005-H34 aluminium alloy immersed in natural seawater: data interpretation, *Corros. Eng. Sci. Technol.* 56 (2) (févr. 2021,) 129–136, <https://doi.org/10.1080/1478422X.2020.1820157>.

[8] M.J.F. Marques, I.N. Alves, R.P. Gonçalves and T.C. Diamantino, "AA 5083 Al Alloy Corrosion in Estuarine Environment", Eurocorr 2013, Estoril, Portugal, 2013.

[9] M.J.F. Marques, T.C. Diamantino and R. Basseguy, "Assessment of Anticorrosion Properties of Biomineralized Induced Coating formed on Al Alloy in Marine Environment. A new Nature-Inspired Approach for Corrosion Protection.", in: Oral Presentation at Eurocorr 2020, online Eurocorr, 2020.

[10] M.J.F. Marques, J. Jaume, T.C. Diamantino and R. Basséguy, "Impact of Biomineralization in Marine Corrosion Protection of Aluminum Alloys", EUROCORR 2019, Seville, Spain, 2019.

[11] M.J.F. Marques, G. Pavanello, T.C. Diamantino, M. Faimali and R. Basséguy, "Influence of microbial activity on Al Alloys in marine medium: natural vs artificial seawater", Eurocorr 2017, Prague, Czech Republic, 2017.

[12] A. Benedetti, S. Gambaro, F. Valenza, M. Faimali, M. Colli, J. Hostasa, M. Delucchi, Ag and AgCu as brazing materials for Ti6Al4V-Y3Al5O12 joints: Does ennoblement affect the galvanic behaviour in seawater? *Electrochimica Acta* 283 (Sep. 2018) 155–166, <https://doi.org/10.1016/j.electacta.2018.06.084>.

Experimental procedure

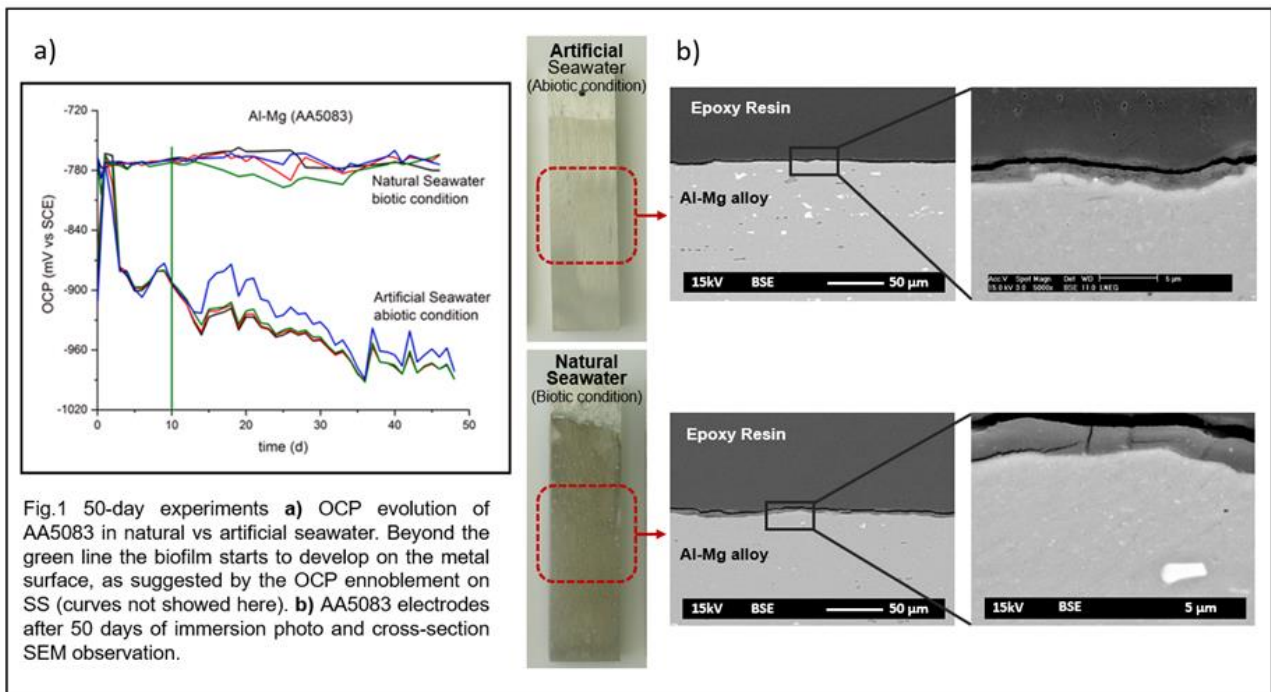
Immersion experiments on AA5083 and SS specimens were completed in two stages:

- 50-day immersion in natural (4 samples for each alloy) vs artificial seawater (4 samples for each alloy), realized in the LGC – Toulouse and CNR-IAS Genoa laboratories. OCP monitoring rate: 1 point d⁻¹,
- 8-day immersion in natural seawater (18 samples for each alloy) exposed to the natural photoperiod vs NaCl solution (9 samples for each material), realized in the MARECO-CNR marine laboratory in Bonassola (La Spezia). OCP monitoring rate: 1 point h⁻¹

After the immersions SEM-EDX analysis were performed.

Discussion and results

For both the 50 and 8-day experiments in the abiotic (control) conditions the OCP downward shifts revealed an active behavior of AA5083, conversely, in the biotic seawater environments OCP laid around -750/-800 mV/SCE (fig.1a and 2a). Under the photoperiod OCP exhibited oscillations averagely 120 mV wide (fig.2a). The OCP results were consistent with SEM-EDX analyses showing a lower degree of corrosion attacks since early stages of exposition (fig.1b and 2b). The emerging indication concerns the protective effects that are exerted throughout the biological chain, from the formation of the conditioning film (a few hours to a few days), followed by the growth of the bacterial biofilm (a few days to a few weeks), to the formation of organic-inorganic complexes with the involvement of the extracellular substance (EPS). OCP oscillations met in the natural photoperiod likely depended on adsorption cycles of organic mixtures responding to the light/dark phases.



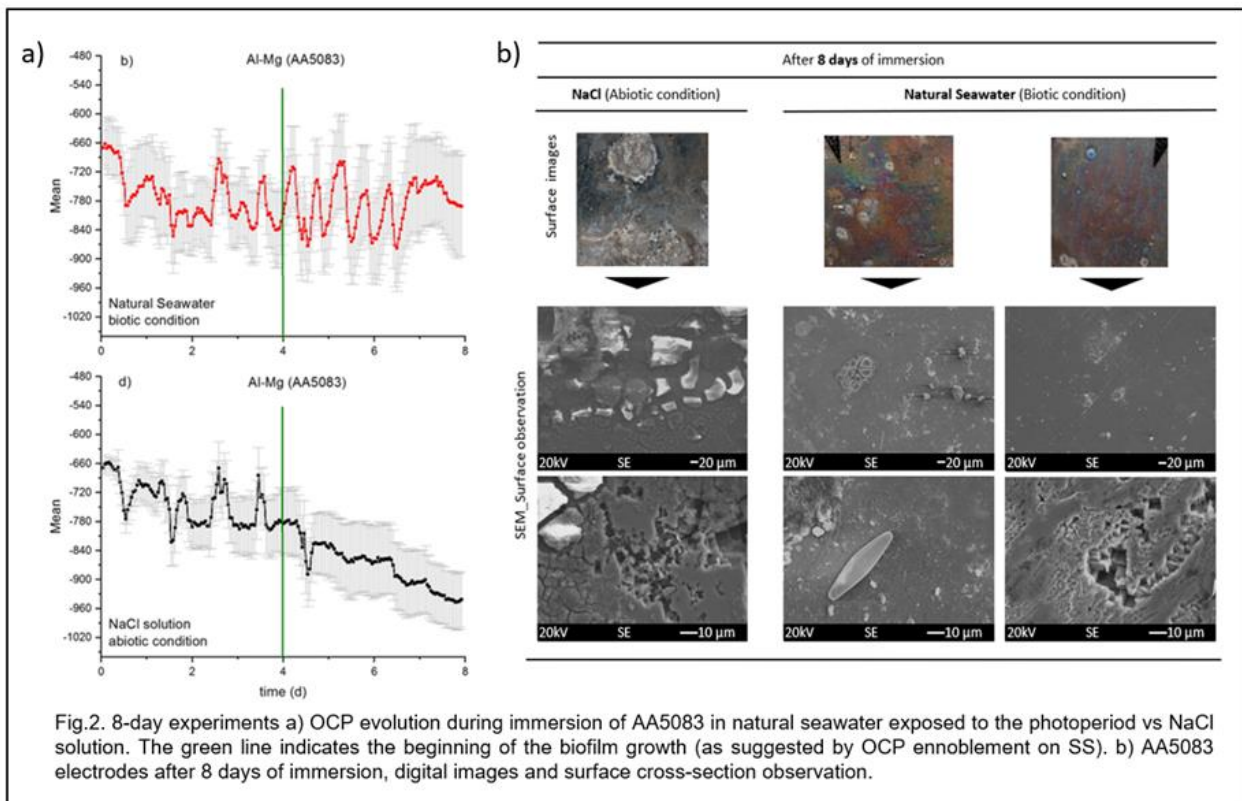


Fig.2. 8-day experiments a) OCP evolution during immersion of AA5083 in natural seawater exposed to the photoperiod vs NaCl solution. The green line indicates the beginning of the biofilm growth (as suggested by OCP ennoblement on SS). b) AA5083 electrodes after 8 days of immersion, digital images and surface cross-section observation.

Conclusions

The marine biological activity was shown to modify the Al-Mg alloy surface counteracting the corrosion aggressiveness of chloride solutions, as natural seawater is. Further investigations might regard how the Al-Mg passivity is affected by the biological activity, treating the natural seawater exposed to the photoperiod as a distinct environment maybe able providing specific protecting effects.