Towards Predictive Durability for Aerospace Aluminium Alloys: Multi-Physics FEM Modelling of Corrosion and Active Inhibitor Protection

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In the advanced materials industry, there is a growing shift toward sustainable solutions, and this trend is clearly reflected in the development of metals. Today, metals are typically engineered for lifespans ranging from 10 to 25 years, though their actual durability heavily depends on environmental exposure and the associated ageing processes. Currently, lifetime and ageing assessments rely on both accelerated laboratory tests and long-term field testing. Accelerated tests, however, often fail to replicate real-world environmental conditions, and their results do not always correlate reliably with actual field performance. Our long-term scientific goal is to establish a comprehensive knowledge and technology platform capable of predicting the durability and estimating the lifetime of smart organic-coated metals under long-term environmental ageing and corrosion. Achieving this is a complex challenge, as corrosion of organic-coated metals involves a dynamic interplay of multiple physical phenomena that must be characterized under real conditions and accurately modelled. Here we present a modelling tool capable of predicting corrosion protection provided by an active protection coating including inhibitors. Finite element modelling techniques are utilized to consider the processes of dissolution and leaching of the inhibitors through the coating, their diffusion through defects, and the changes reflected in the electrochemical reactions at Al2024. Changes in the environmental conditions in terms of electrolyte composition, and layer thickness, as well as, the changes of the coating status like geometrical parameters to concentration of its components, are included in the model's physics. This multi-Ion Transport and Reaction model accounts for the concentration and movement of the different ions and their chemical interactions through the different solution domains. Eventually, the model predicts corrosion protection conditions and supports coating system design.

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