Developing Corrosion Prediction Models from X-ray Measurements

Alison J. Davenport
University of Birmingham School of Metallurgy and Materials, Edgbaston, Birmingham, UK
a.davenport@bham.ac.uk

Corrosion pits in stainless steel show different morphologies depending upon whether they grow under conditions of full immersion in relatively dilute solutions, or under atmospheric corrosion conditions where the solutions are highly concentrated. Under full immersion conditions, they grow with "lacy" covers, where the metal is perforated by fine holes [1-5]. However, under atmospheric corrosion conditions, the pits are shallow and dish-shaped [6-8].

Laycock and co-workers [9] have developed a model that is able to predict the complex shape of lacy-covered pits. However, in order to validate and refine the model, it is necessary to make experimental measurements. In the present work, synchrotron radiography was used to monitor the growth of 2D pits in real time, extracting the local current density from the movement of the pit boundary with time [10] while making parallel electrochemical measurements. The interfacial potential and local solution concentration can be determined by finite element modeling, giving the relationship between current density, interfacial potential and solution composition that is a necessary input to corrosion prediction models.

For further development of models, it is important to know the chemical species that are present in corrosion pits. In situ synchrotron X-ray methods reveal both the solution species (determined from X-ray absorption spectroscopy) and solid species (from X-ray diffraction), highlighting how species present can influence pit stability.

It is highly desirable to develop a model to predict corrosion damage under atmospheric corrosion conditions. However, this requires knowledge of the interfacial electrochemistry in the highly concentrated solutions in which atmospheric corrosion takes place, and also the geometry of the electrolyte layer. Preliminary investigations of the evolution of pit growth under atmospheric conditions using X-ray microtomography have shown that pits can propagate under very thin solution layers, but their morphology can be strongly influenced by precipitation of salt crystals in these layers.

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