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Models for the anaerobic phases of marine immersion corrosion

Robert E. Melchers [*], Tony Wells

Centre for Infrastructure Performance and Reliability, School of Engineering,
The University of Newcastle, University Drive, Callaghan, NSW 2308, Australia

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Abstract

In the phenomenological model for the general marine corrosion of mild (and high strength low alloy) steel introduced previously, the corrosion process eventually enters a state governed predominantly by the activity of sulphate-reducing bacteria (SRB). This state has been modelled by two consecutive phases, the first describing a transient behaviour and the second the longer-term quasi-steady-state corrosion response. In earlier papers these have been described only by bounding parameters, calibrated to comprehensive field data. Herein a plausible idealized mathematical model is proposed for the corrosion losses within these phases. The model is based on an idealization of the distribution of nutrients within the corrosion product layer and its depletion by SRB as the anaerobic conditions necessary for their metabolism develop. With the gradual depletion of nutrients, the activity of the SRB reduces to a quasi-steady-state process governed by the rate of external nutrient supply and the loss of (protective) corrosion product. It follows that high levels of nutrients, such as in offshore oilfields and in nutrient-polluted waters can be associated with high rates of corrosion under anaerobic conditions. Also, in warmer (tropical) waters, the metabolism of SRB is enhanced. Both phenomena are consistent with field observations. A preliminary calibration of the models for phases 3 and 4 is attempted using the limited available field data.

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[*] Corresponding author. Tel.: +61 249216044; fax: +61 249216991.
E-mail address: rob.melchers@newcastle.edu.au (R.E. Melchers).

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1. Introduction

Fig. 1 shows the phenomenological model for the general marine corrosion of mild (and high strength low alloy) steel previously introduced and calibrated to an extensive range of field data for carbon steels [1], for copper-bearing steels [2] and for examining the effects of alloying [3]. The model predicts that after an early but quite short-term phase (0), the corrosion process is cathodically controlled and hence limited by oxygen diffusion, first through the water boundary layer immediately adjacent to the corroding surface (phase 1—'concentration control') and then through oxygen diffusion controlled by the increasing thickness of the corrosion products layer (phase 2). The model is aimed primarily at representing the average loss of steel through corrosion and is therefore based on the plausible assumption that corrosion depth variations over the surface area can be neglected.

The model of Fig. 1 departs from previous corrosion loss modelling efforts through introducing the concept that the increasing difficulty of oxygen diffusion through the thickening rust layer produces anaerobic conditions eventually at the corrosion interface [4]. As is well known, such conditions permit the activity of sulphate-reducing bacteria (SRB). This has been represented by phases 3 and 4, which are, respectively, a transient and a longer-term quasi-steady-state corrosion response. So far phase 4 has been assumed a linear function. As will be seen, phase 4 behaviour is more likely to be slightly non-linear.

Previous papers [4,5] have described the detailed mathematical modelling of phases 1 and 2, including allowance for variation of corrosion product with depth

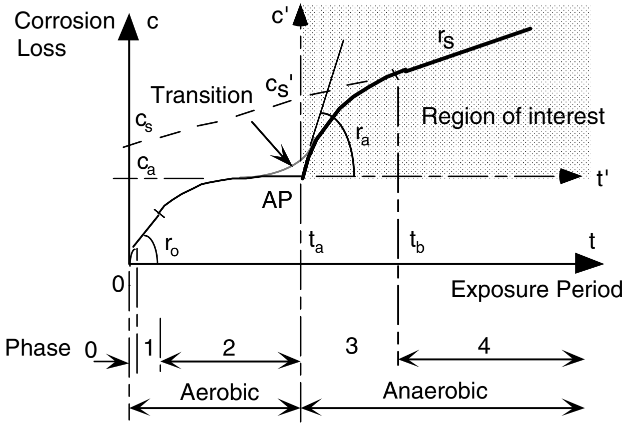

Fig. 1. Phenomenological model for the general marine corrosion of steel showing phases of interest and model parameterization.