

Prediction and Measurement of Pitting Damage Functions
For AISI Type 403 Blade Alloy

Yancheng Zhang¹, Digby Macdonald¹, Mirna Urquidí-Macdonald², George Engelhardt³, and Barry Dooley⁴

¹Department of Materials Science and Engineering

²Department of Engineering Science and Mechanics
The Pennsylvania State University, University Park,
PA 16802

³OLI Systems Inc., 108 American Road, Morris Plains,
NJ 07950

⁴Electric Power Research Institute, 3412 Hillview Ave.,
Palo Alto, CA 94303

The pitting damage function (the pit number vs the pit depth) is recognized as the most effective means of describing the accumulation of pitting damage to a metal surface. The prediction of the damage functions (DFs) and hence accumulated damage for long-term exposure, based on known or experimental short-term DFs, is one of the principal goals of this study. Damage Function Analysis (DFA) has been developed as a means of deterministically predicting pitting DFs. The DFA used in the present study combines the pit nucleation model from the Point Defect Model (PDM) with a deterministic, coupled environment model for pit growth and a first order model for delayed repassivation. In applying DFA, values for various model parameters need to be determined either through separate experiments or by calibration. The maximum depth in the DF at any given observation time is of particular interest, because of our recent reconciliation of the statistical method of describing damage, in the form of extreme value statistics (EVS) with the deterministic DFA. Thus, we are now able to predict failure times by knowing only the maximum depth of the pits at several (short) times that can be used for calibration purposes.

Pitting corrosion on the common steam turbine blade alloy, AISI Type 403 SS, readily occurs in the severe, corrosive environments that form on steel surfaces in low pressure (LP) steam turbines in the phase transition region, where concentrated, chloride containing, electrolyte films may form on the surface. DFA and EVS are used in this study for the first time to predict the accumulation of pitting damage to Type 403 SS blade alloy.

Pitting damage functions for Type 403 SS blade alloy were measured in borate buffer solution (pH=8.1) with 0.10 M NaCl at ambient temperature ($T = 22\text{ }^{\circ}\text{C}$, Figure 1). Potentiostatic polarization experiments were designed to yield damage functions at a constant potential in the neighborhood of V_c for a predetermined time to allow the accumulation of pitting damage to be assessed in the form of event density (pits/cm²) versus pit depth. The pit depth distribution was measured by using an optical microscopy to focus on the steel surface and then on the pit bottom. Too low a chloride concentration in the electrolyte leads to excessively long pitting induction time for Type 403 SS. However, a high chloride concentration accelerates pit nucleation and growth, and may result in excessive damage to the surface that prevented the accurate characterization of the damage. For these reasons, it was necessary to restrict the chloride concentration to the range 0.001M to 0.10M.

A calculated pitting DF for Type 403 SS in 0.10M NaCl borate buffer solution at an applied potential $0.090V_{SCE}$ (Figure 2) is in good agreement with the experimental normalized DF (Figure 1), considering the complexity of pitting process and the scattered nature of the experimental data. The normalized DF (N/N_0) is calculated via dividing the total pit number N_0 on the metal surface, instead of the usual distribution of pit number N . The prediction of the extreme value in pit depth for long-term exposure becomes possible based on experimental short-term extreme depth and some parameter values extracted from DFA, as seen in Figure 3. The reader will note that the maximum pit depth reaches a plateau after ca. 750 hours, for this particular case. This is a commonly observed phenomenon, which may be attributed to delayed repassivation of the active pits coupled with a high pit nucleation rate at short times.

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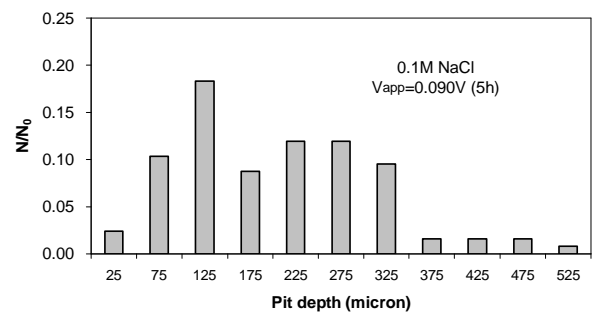


Figure 1. Normalized pitting DF for Type 403 SS in 0.10M NaCl-containing borate buffer solution at an applied potential $0.090V_{SCE}$ for 5 hours ($V_c = 0.080V_{SCE}$)

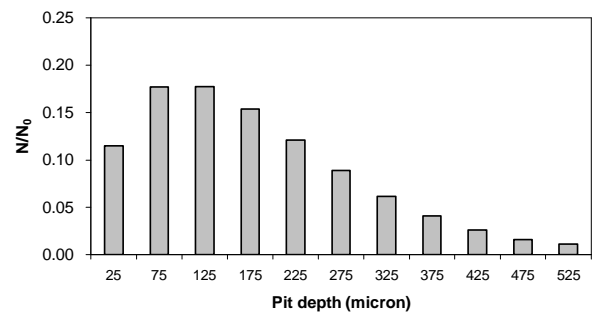


Figure 2. Calculated, normalized pitting DF for Type 403 SS in 0.10M NaCl-containing borate buffer solution at an applied potential of $0.090V_{SCE}$ for 5 hours.

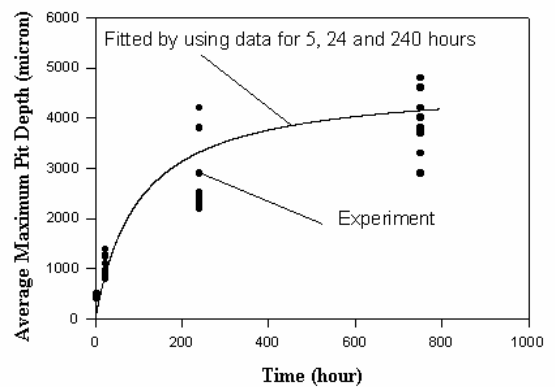


Figure 3. Variation of the extreme value (EV) in pit depth with exposure time for Type 403 SS in 0.10M NaCl-containing borate buffer solution at an applied potential of $0.090V_{SCE}$.