Formation and rupture of carbonate film: an electrochemical noise approach

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Abstract

Purpose – The purpose of this paper is to evaluate advanced mathematical electrochemical noise analysis (ENA) as a way of corrosion monitoring for carbon steel.

Design/methodology/approach – The electrochemical potential/current noise was recorded simultaneously with a working-reference-working electrode set up and the processing of data was performed through fast Fourier transformation (FFT) and wavelet transformation (WT) routes. The formation and rupture of carbonate films on St37 steel electrodes in a 0.5 M sodium bicarbonate electrolyte was studied for 20 h utilizing an electrochemical noise approach.

Findings – Although the slope of mid-range of noise impedance exhibited a mechanistic style, and increased with film formation and decreased with film rupture, FFT of potential noise was more sensitive to film formation and rupture. WT of potential noise depicted that $\nu = 1.41 \times 10^{-2}$ Hz was the boundary frequency in the film formation. At frequencies higher than the mentioned limit, the fraction of distributed potential decreased with time. However, the opposite behavior was observed during the rupture of the film.

Originality/value – The preliminary results show that the proposed novel electrochemical method, wavelet and FFT ENA, is very able to monitor the corrosion behavior of carbon steel corrosion in carbonate media.

Keywords Electrochemical devices, Steel, Corrosion, Fourier transforms

Paper type Research paper

1. Introduction

Electrochemical noise analysis (ENA) has been applied by researchers for the investigation of different systems that were further analyzed with different mathematical approaches, such as fast Fourier transformation (FFT) and wavelet transformations (WT). FFT is a principal and significant method in the analysis of frequencies of electrochemical noise (Bertocci *et al.*, 1997; Cottis, 2001; Mansfeld *et al.*, 2001a, b; Nagiub and Mansfeld, 2001, 2002; Gouveia-Caridade *et al.*, 2004) and is considered to be a suitable method for corrosion system identification. Although FFT is not a general approach relevant for extrapolating to different systems, it is applicable in some cases (Fukuda and Mizuno, 1996; Cheng *et al.*, 2000). WT is a novel mathematical approach in ENA calculations (Aballe *et al.*, 1999a, b; Zheng *et al.*, 1999; Darowicki and Zielinski, 2001; Wharton *et al.*, 2003; Cai *et al.*, 2005; Zhang *et al.*, 2005; Cao *et al.*, 2006; Liu *et al.*, 2006). The technique has some advantages over FFT, such as modifiable levels of decomposition and mother-waves (Aballe *et al.*, 1999a, b, 2001; Dong *et al.*, 2001; Guo *et al.*, 2005).

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1.1 Wavelet theory

Correlation between the original noise and a supposed wave is evaluated in wavelet calculations (Aballe *et al.*, 1999a, b, 2001; Dong *et al.*, 2001; Guo *et al.*, 2005; Cao *et al.*, 2006). Wavelet analysis breaks down the time record ($x(t)$ ($t = 1, 2, \ldots, N$)) to dyadic wavelet functions ($\psi_{j,k}(t)$) and scaling functions ($\Phi_{j,k}(t)$). Translating in time and dilating in scale, the mother wavelet ($\psi(t)$) and the father wavelet ($\Phi(t)$), form the dyadic function:

$$\Psi_{j,k}(t) = 2^{-j/2}\Psi(2^{-j}t - k) \quad (1)$$

$$\Phi_{j,k}(t) = 2^{-j/2}\Phi(2^{-j}t - k) \quad (2)$$

where $j, k \in Z$ and $k = 1, 2, \ldots, N/2$ that N is the number of data. Breaking down the wavelet produces a family of hierarchically organized decompositions. The j-level approximation ($A_j(t)$) and a deviation signal called the j-level detail ($D_j(t)$) can be calculated according to the following equations for each of the j-levels:

$$D_J(t) = \sum_{k \in Z} C(j,k)\Psi_{j,k}(t) \quad (3)$$