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APPLICATION OF THE WAVELET TRANSFORMATION TO ESTIMATION OF INTENSITY OF PITTING CORROSION

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Summary: The electrochemical noise data at presence of pitting corrosion were analysed. Correlation between intensity of the observed noise and a mass loss of the steel electrodes was recognized. The new parameter, that characterizes the pitting corrosion intensity has been proposed. The parameter is derived by noise decomposition using wavelet transform. It has been observed that the proposed parameter was most strictly correlated with a mass loss of electrodes in a group of the calculated noise parameters. The additional measurements for greater number of electrodes are necessary to confirm statistically the received preliminary results.
Keywords: electrochemical noise, wavelet transform, pitting corrosion

INTRODUCTION

Many attempts were performed to establish reliable method of pitting corrosion intensity determination. Electrochemical noise (EN) seems to be one of the most promising [1]. Increase of interest in this technique is observed after publications of Iverson [2]. In earlier investigations electrochemical noise was considered rather as the source of measurement errors than the valuable information. Simoes and Fereira [3] were first who presented quantitative results of testing of crevice corrosion of steel. However correlation between results of noise measurements and physicochemical processes was not established.

Electrochemical noise is defined as spontaneous fluctuations of potential and current occurring in the given electrochemical system. Depending on the regime of experiment (potentiostatic, galvanostatic or open-circuit) one or both of above mentioned quantities can be measured.
The RMS, mean value and variance are usually treated as parameters of electrochemical noise [4]. Other techniques utilize power spectral density plots, and their slope in the function of frequency, as the method for distinction between different forms of localized attack [5]. In the recent years new methods of analysis of electrochemical noise were introduced [6,7]. In this paper author proposes new approach to this problem. As the computational tool the wavelet analysis is introduced.

METHOD OF ANALYSIS

Continuous wavelet transform of signal $s(t)$ is defined as [8]:

$$W(a,t) = |a|^{-1/2} \int_{-\infty}^{\infty} s(t)\, w^*\left(\frac{t-t}{a}\right) dt \qquad (1)$$

where variable *t* denotes time shift, and *a* variable denotes degree of expansion or compression of so-called mother wavelet $w(t)$. Set of analyzing wavelets is obtained by translations and rescaling of mother wavelet defined for a=1 and t=0.

Continuous transform as presented above is redundant. In practice use of discrete version is sufficient. In order to discretize the parameters a and t are described as:

$$a = a_0^j, \quad t = t_0 k a^j, \; j,k \in Z \qquad (2)$$

what leads to new formula describing translations and dilations of mother wavelet:

$$w_{j,k}(t) = |a_0|^{-j/2}\, w\left(a_0^{-j} t - t_0 k\right) \qquad (3)$$

Assuming a_0=2 and t_0=1 orthonormal, dyadic base in L^2 is obtained. In that case analyzed signal can be described as the sum of the wavelet series.

$$s(t)=\sum_{j,k} b_{j,k} w_{j,k}(t) \quad (4)$$

where $b_{j,k}$ are coefficients of expansion of signal $s(t)$ in the wavelet basis $w_{j,k}(t)$.
The set of coefficients $b_{j,k}$ describes correlation degree between signal $s(t)$ and wavelet of time and frequency localization determined by k and j respectively.
Development of the tree algorithm, made by Mallat [9] led to application of the sets of digital filters (filter banks) to obtain coefficients of discrete wavelet transform. The vector of wavelet coefficients is computed by application of high-pass filtering by bank corresponding to the given wavelet.

$$\mathbf{b}=b(n)=\mathbf{h}*\mathbf{s}=\sum_{k} h(k)s(n-k) \quad (5)$$

where: $\mathbf{b}=b(n)$ – output vector of coefficients, $\mathbf{s}$ – input vector (analyzed signal), $\mathbf{h}$ – filter.
After this operation the decimation of resulting vector takes place.

The output of the low-pass filtering is then taken as input for the next level of filter bank. Such operation is repeated iteratively, leading to decomposition of signal into frequency bands (analysis levels).

EXPERIMENTAL

The corrosion processes in 0H18N9 steel were monitored by electrochemical noise measurements. The electrodes were immersed in solution of 0.5 M $FeCl_3$. The surface of the working electrodes has been mechanically polished with sandpaper to grade 1000 and degreased with acetone just before the measurements.

The described conditions assured the presence of pitting corrosion even after 10 minutes after time when electrodes were immersed in electrolyte. The current fluctuations at sampling frequency $f_s = 9$ Hz were recorded using National Instruments DAQ-PCI 16 XE 50 card. The time of data collecting did not exceed 4 hours. The characteristic transients for pitting corrosion were observed in current fluctuations. The loss of mass of working electrodes was measured just after finishing noise measurements and their drying. The eight identically prepared electrode sets were used. The surface of the working electrodes had visible pits.

All necessary calculations were obtained by functions present in *Wavelet Toolbox* in *Matlab* software [10].

RESULTS AND DISCUSSION

In figure 1 the example records of electrochemical current noise (ECN), accompanying the process of pitting corrosion, are presented.

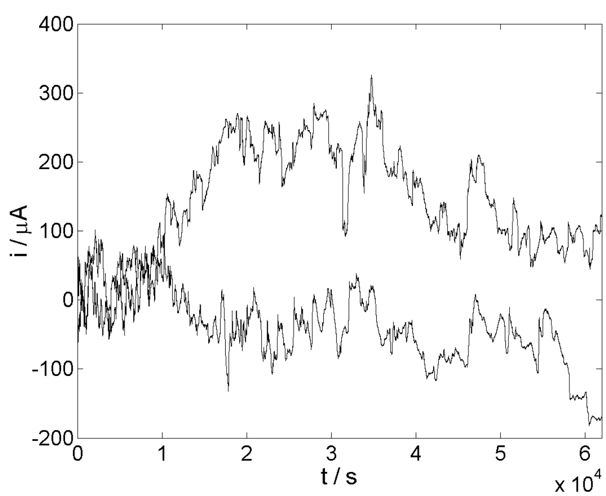

Fig. 1. Examples of records of electrochemical current noise (ECN). 0H18N9T steel immersed in 0.5 M solution of $FeCl_3$. Sampling frequency $f_s = 9$ Hz

Figure 2 shows the PSD plot corresponding to analyzed courses. The change of character of spectrum in the region of 2 Hz is visible. High-frequency portion of PSD is the white noise whereas the low-frequency part is related to the process of pitting corrosion.

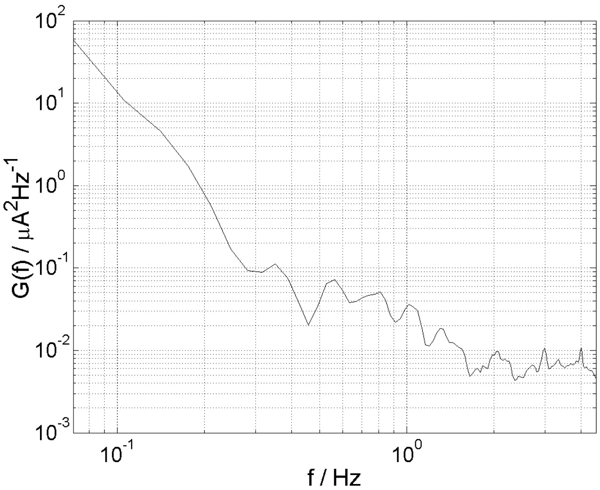

Fig. 2. Power spectral density (PSD) plot of one of the ECN records.

The correlation between recorded mass losses and some parameters of signals, derived by means of wavelet transform is postulated. The standard deviation of approximation on the third level of filter bank $\sigma(a_3)$ was assumed as above-mentioned parameter. Such assumption was made on the basis of taking 2 Hz frequency as the point of change of mechanism of corrosion process.

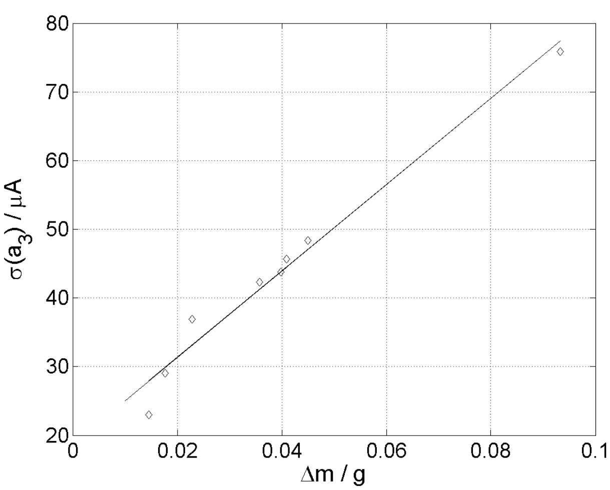

Fig. 3. Linear correlation of the loss of mass of investigated steel electrodes with the standard deviation of the third level approximation of ECN.

In figure 3 plot of $\sigma(a_3)$ versus the loss of mass Δm of set of 8 working electrodes is presented. Analysis was performed using *db5* wavelet and then compared to result of application of several other wavelets giving similar results.

CONCLUSIONS

Measurements of electrochemical noise were performed with set of stainless steel samples exposed in corrosive medium. The pitting corrosion was preferred mechanism of degradation of metal. The parameter binding the loss of mass with results of application of wavelet transform was proposed.

The main aim of presented work was presentation of possibility of implementation of new approach to the analysis of electrochemical noise. It should be stressed that work in this field is not finished and authors are still searching for the best description of physicochemical process taking place during pitting corrosion.

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