Study on Atmospheric Corrosion of metal based on Electrochemical Noise

Huanhuan HU
School of Big Data and Artificial Intelligence, Chizhou University
Chizhou247100, China
hhh18226970040@163.com

Wenchang Yu
School of Big Data and Artificial Intelligence, Chizhou University
Chizhou247100, China
547706301@qq.com

Jiezhen HU
School of Mechanical and Power Engineering, Guangdong Ocean University,
Zhanjiang524000,China
422123889@qq.com

***Abstract*—In this paper, the atmospheric metal corrosion based on electrochemical noise (EN) technology was studied. Polynomial fitting, windowing fast Fourier transform and Hilbert-Huang transform had been employed to interpret the EN. The morphology and XRD analysis results were compared to explore the atmospheric corrosion behavior of Q235 carbon steel. The results show that the atmospheric corrosion monitoring device can continuously monitor Q235 carbon steel in the atmosphere, and the monitoring results can accurately reflect the noise fluctuation caused by atmospheric corrosion. The time domain spectrogram characterizes five different characteristic spectra of metals. Q235 carbon steel exposure for 45 days, power spectral density (PSD) curve white noise level (W) of voltage noise value is the minimum, Linear slope (k) of PSD value is the maximum, at this time the sample surface corrosion resistance is the worst. According to different corrosion periods of metals, three different characteristics of the time spectrum appear.**

Keywords*：*atmospheric corrosion; polynomial fitting; windowing fast Fourier transform; Hilbert-Huang transform

I. INTRODUCTION

Metal corrosion affect people's daily life, such as: oil pipeline corrosion leads to oil leakage and pollution of the environment, bridge corrosion leads to bridge collapse and casualties, metal products corrosion leads to greatly reduced service life [1,2]. In this paper, the electrochemical noise sensor electrode of atmospheric corrosion was designed to realize online monitoring of metal corrosion in atmospheric environment. The signal processing system [3] of our research group was used to analyze electrochemical noise signals and study the corrosion rate and mechanism of metal.

II. EXPERIMENT

A. Meterials and Electrode Production

The experimental material is carbon steel Q235. which is provided and processed by Corporation of Luo Song Electromechanical Equipment. The electrochemical noise electrode of Q235 carbon steel is shown in Fig. 1.

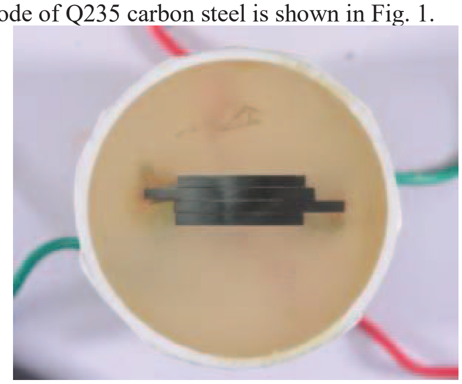

Figure 1. Physical picture of Q235 carbon steel electrode

III. RESULTS AND DISCUSSION

A. The time domain analysis

Fig. 2 is the time domain spectrum of Q235 carbon steel electrode exposed to the atmosphere at different time periods.

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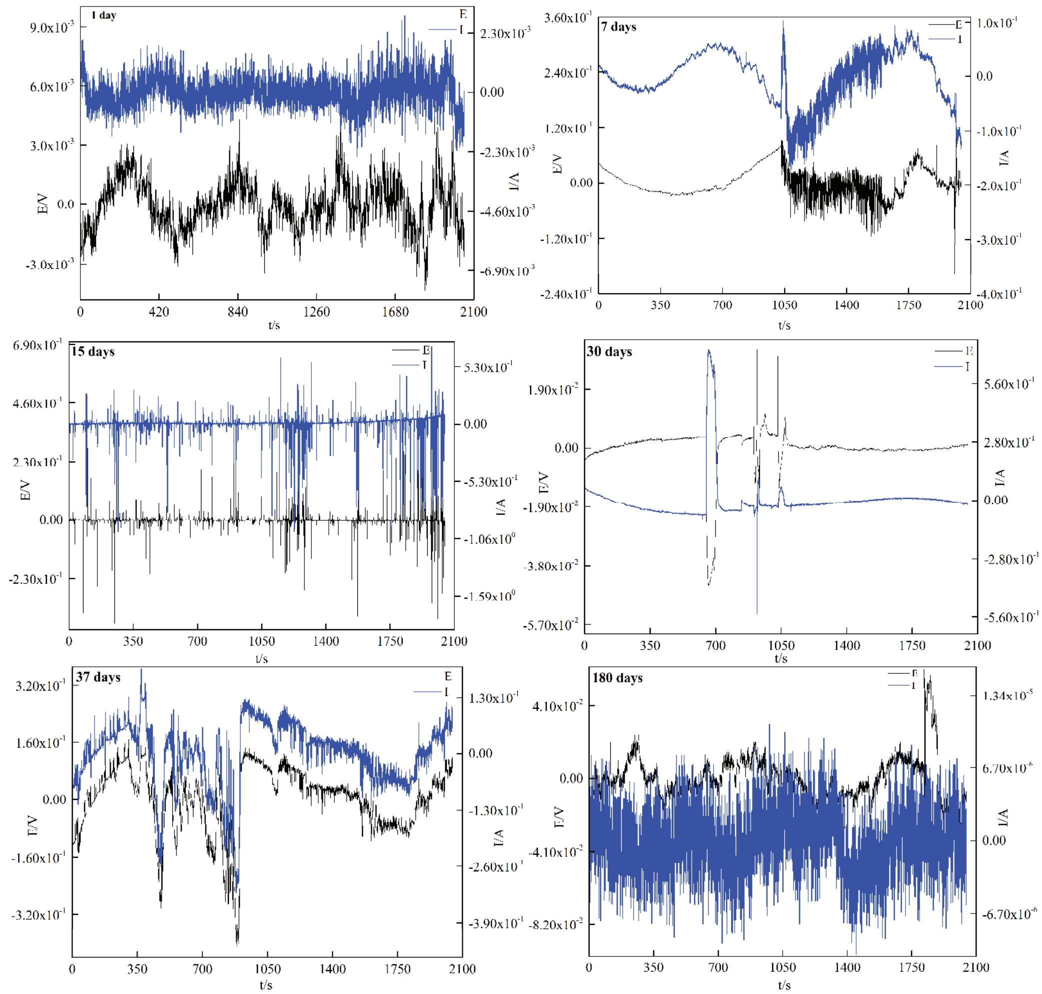


Figure 2. Time domain spectra of electrochemical noise of Q235 carbon steel at different exposure times

At the beginning of the experiment (1 day and 3 days), the noise fluctuated around 0 with large frequency and a small number of transient peaks. At this stage, the corrosion rate of Q235 carbon steel electrode was fast and uniform corrosion was the main corrosion. In the first 1050s of the time domain spectrogram on the 7th day, the noise fluctuated at low frequency, drifted greatly, and there was no transient peak.From 1050s to 2048s, the noise shows high-frequency fluctuation. When the sample is exposed to the sun for 15 days, a large number of transient peaks of noise appear. The appearance of cracks on the metal surface makes the erosive ions in the atmosphere contact with the matrix, and the corrosion rate in local areas is fast, resulting in the generation of a large number of transient peaks.According to the study of Li Ji [4], the rupture of passivation film on metal surface will cause the appearance of transient peak.In the high Cl^- Marine atmosphere environment, the corrosion rate of Q235 carbon steel is fast and the passivation period is short. In this paper, the cracking process of the passivation film is not monitored. After 30 days of exposure, there were a small number of noise peaks with higher peak value and the noise changed in a different direction. In the spectrogram, the noise in the area without noise peak showed a linear change. After exposure to 37 days, the noise signal has a transient peak, showing the same direction. After exposure to 45 days, the current noise and voltage noise appear different changes. In the case of 0~1500s, the voltage noise has no vibration around 0, and in the case of 1500s~2048s, the voltage noise vibrates at high frequency, and the current noise presents high-frequency vibration characteristics with large amplitude on the whole time axis. After exposure to 60 days, the voltage noise vibrated at high frequency with small amplitude, and the current noise change characteristics were similar to the current change characteristics of exposure to 45 days. During the exposure period of 2 to 3 months (time domain spectra from day 60 to day 90), the noise peak appeared synchronous changes again and lasted for a long time. At this stage, the corrosion pits on the surface of Q235 carbon steel gradually grew up, and multiple corrosion pits gradually fused to form larger corrosion pits. At the late stage of the experiment (time domain spectra from day 140 to day 180), the morphology of voltage noise peaks was similar, with high-frequency vibration and no obvious transient peak characteristics. At this stage, the electrode corrosion tended to be stable, with uniform corrosion as the main corrosion.

B. Frequency domain analysis

Fig. 3 shows the power spectral density map of Q235 carbon steel at different exposure times. The spectral characteristics of noise signal can be obtained by frequency domain analysis method [5,6]. The variation trend of W value of voltage noise and current noise is basically consistent with that of K value, while the variation trend of W value of noise is opposite to that of K value. When the experiment is carried out for 30 days, the W value of voltage noise is large, and the K value of voltage noise and current noise is reduced to the lowest. At this time, there are corrosion pits on the surface of Q235 carbon steel, and the local corrosion rate is fast. With the experiment, in 45 days, the voltage noise W value to the minimum, and K reached the maximum at this time, Q235 carbon steel surface rust layer damage, the matrix protection is poor, gradually generated inner rust layer, at this time the corrosion resistance of Q235 carbon steel surface is poor. With the experiment going on, the K value fluctuates greatly, which indicates that the corrosion process of Q235 carbon steel is controlled by different corrosion mechanisms.

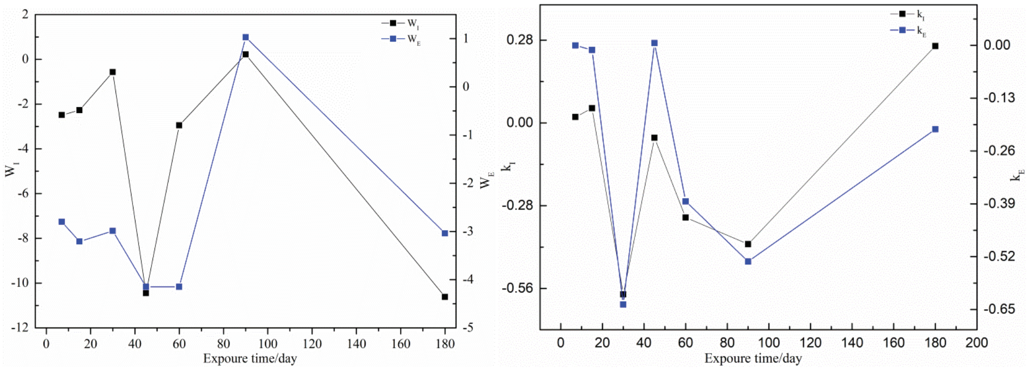
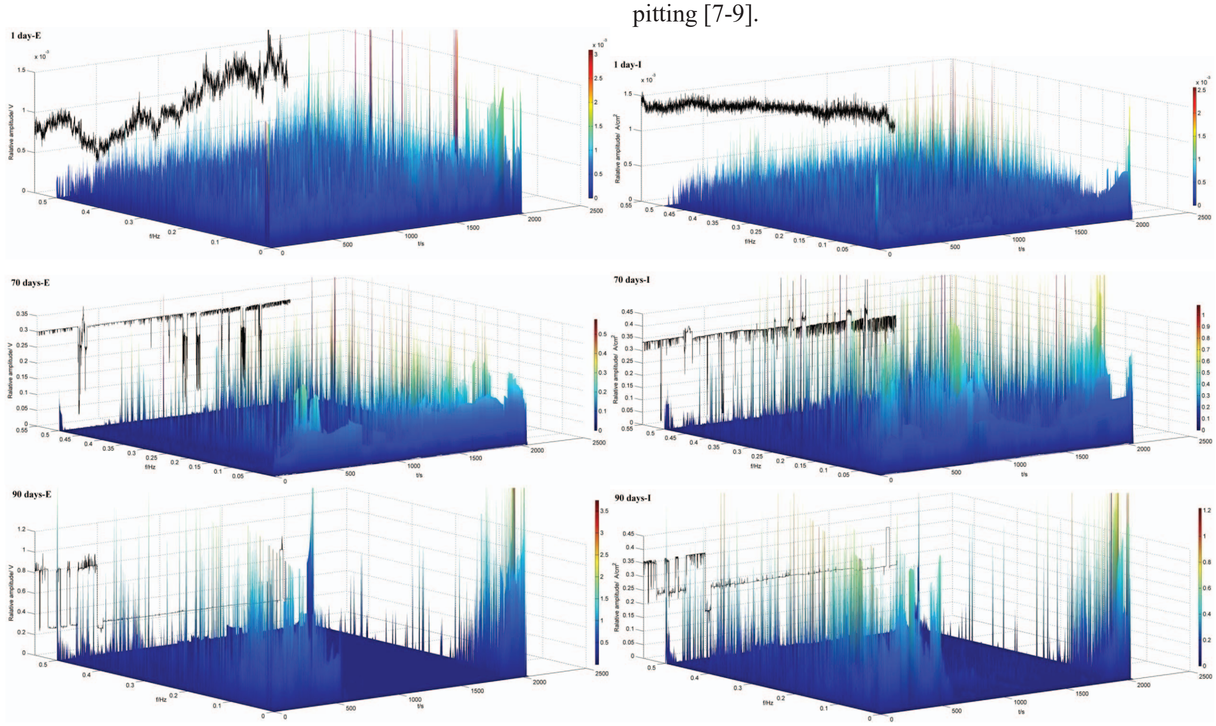


Figure 3. Changes of linear slopes W and K of PSD curve for Q235 carbon steel at different exposure times

C. The time-frequency analysis

Fig. 4 is the amplitude-time-frequency diagram of the unfiltered 2048S original noise signal of the electrode at different exposure times. The vertical axis is the relative amplitude of the unfiltered original signal. A large number of overlapping transient peak decomposition is caused by pitting. The time spectrum diagram obtained by Hilbert-Huang transformation can be used to analyze the corresponding relationship between time and frequency, and to analyze the details of overlapping transient peak signals generated during pitting [7-9].



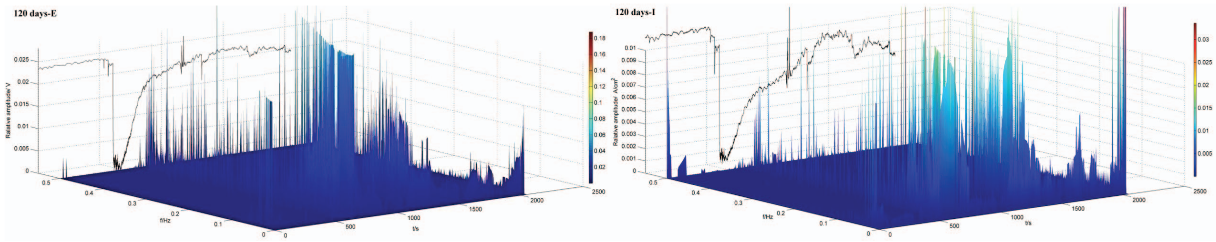


Figure 4. Hilbert spectra of voltage noise and current noise of Q235 carbon steel at different exposure times

The transient peaks of voltage and current noise in the early stage of the experiment (1 day and 3 days) were uniformly distributed along the time and frequency axes (as shown in FIG. 4), and the noise was dominated by white noise. Shi [10] showed that such distribution characteristics indicated that the metal was in a passivation state. In this experiment, the characteristic diagram of Q235 carbon steel in the early stage of exposure is that the surface corrosion of the initial carbon steel is mainly uniform corrosion, and there is no corrosion pit. Exposure to 70 days, 90 days, the noise signal in low frequency (< 10^{-2} Hz) the distribution is dense, high frequency area distribution is sparse, the signal component gradually shift to low frequency area, carbon steel surface loose outer rust layer can't stop the Cl^- the invasion of the corrosive ions, such as carbon steel substrate by erosion, longitudinal further corrosion occurs, carbon steel corrosion pit depth increases. With the progress of the experiment (120 days), the distribution of the noise signal at low frequency gradually decreased, and the distribution of the noise signal at the whole frequency gradually moved to high frequency. At this time, the inner rust layer was basically formed, and the corrosion of the electrode had both transverse and longitudinal diffusion, but the longitudinal diffusion rate decreased and the transverse diffusion rate increased.

IV. Conclusion

(1) There are 5 different characteristic time domain spectra of electrochemical noise, and different spectra correspond to different corrosion laws of Q235 carbon steel in the atmosphere.

(2) When Q235 carbon steel is exposed for 45 days, the W value of voltage noise is the smallest, and the K value is the largest. At this time, the corrosion resistance of the sample surface is the worst.

(3) When the noise signal of the spectrum pattern is uniformly distributed on the axis of the frequency domain, the Q235 carbon steel is mainly corroded uniformly, and there is no corrosion pit. When the noise signal is concentrated in the low-frequency region, the corrosion pit on the surface of Q235 carbon steel is deepened, and the corrosion is mainly by longitudinal diffusion. When the noise signal is transferred to the high frequency region, the inner rust layer of Q235 carbon steel is formed, and the longitudinal diffusion rate of corrosion decreases, while the transverse diffusion rate increases.

Acknowledgment

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