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Short communication

Assessing atmospheric corrosion of metals by a novel electrochemical sensor combining with a thin insulating net using electrochemical noise technique

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ABSTRACT

In this work, a novel electrochemical sensor combining with a thin insulating net is designed for monitoring atmospheric corrosion of metals by using electrochemical noise (EN) technique. Experimental results reveal that the sensor can successfully in-situ detect the atmospheric process and the corresponding corrosion form, which has promising applications in the field of atmospheric corrosion monitoring of metal structures in the future.

1. Introduction

Monitoring atmospheric corrosion of metals by using electrochemical methods has received much attention due to its in-situ properties, which offers evaluation of instant corrosion resistance or corrosion rate (instant corrosion resistance means the corrosion rate at certain specific time). Electrochemical noise (EN) is the generic term given to fluctuations of current and potential of metals during corrosion. It is widely used as corrosion monitoring method in aqueous solutions and has also been recognized as a promising electrochemical method which does not disturb the investigated system [1]. Though EN is frequently used in corrosion detection in aqueous solutions, it has not been widely applied in atmospheric environment, because atmospheric corrosion of metals proceeds under an extremely thin electrolyte film, and it is not very easy to establish electrode systems on metal surface that covered by such thin electrolyte film.

One way to establish electrode systems for EN measurement is to use atmospheric corrosion probe [2]. The investigated metal materials were cut into three nominally identical electrodes which were placed in an insulating material. Between two adjacent electrodes, a thin insulating film with a thickness of 100–200 μm was placed to avoid short-circuit. Using this probe, EN can be measured if the probe is covered by a thin electrolyte film. For example, Guo et al. [3] used an atmospheric corrosion probe to monitor the atmospheric corrosion of 2B06 aluminium alloy in outdoor atmosphere of Beijing by using EN technique. However, one flaw of using atmospheric corrosion probe for EN test is that the tested materials must be cut and fabricated to a probe, as a result, the atmospheric corrosion of metal structures under service condition cannot be detected.

The present paper presents a new idea to fabricate an electrochemical sensor to in-situ detect the atmospheric corrosion of metals. By using the sensor and some mathematical methods, the instant atmospheric corrosion resistance and corrosion form of metal can be evaluated.

2. Experimental

The current investigation involved electrochemical sensor design and applying the sensor to detect atmospheric corrosion

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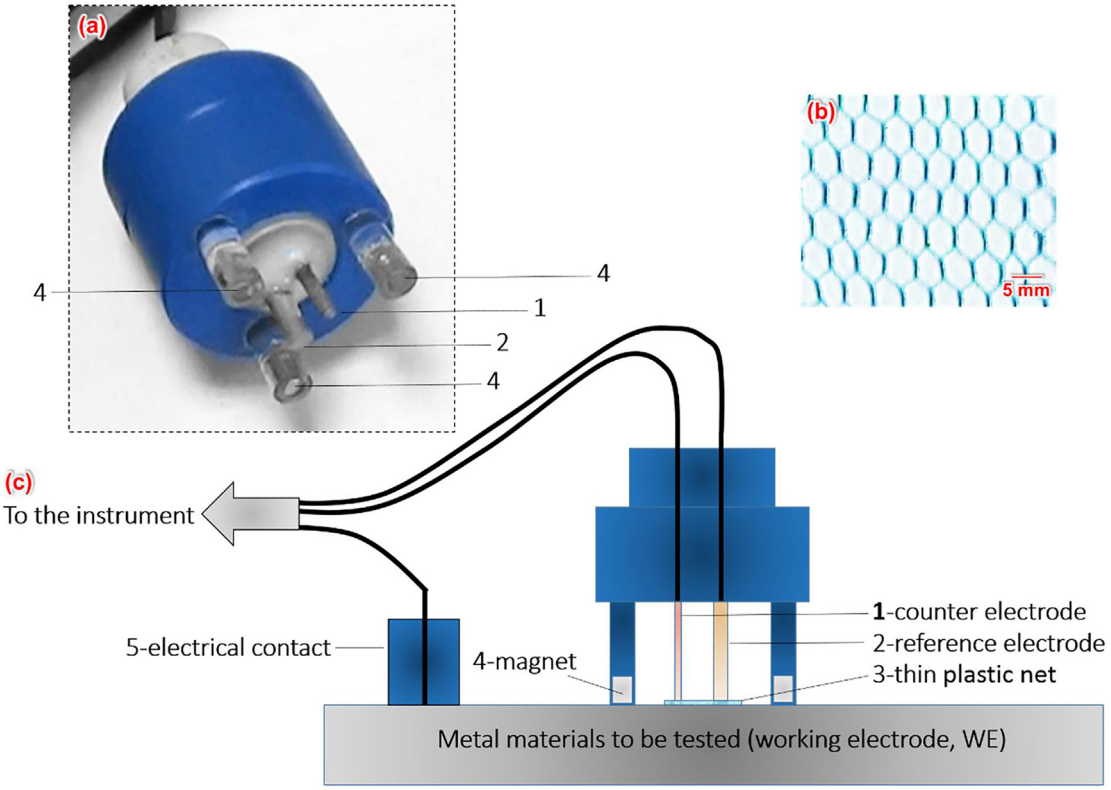

Fig. 1. A new electrochemical sensor for atmospheric corrosion monitoring (a) a photo of the sensor (b) the thin plastic net used as the electrical insulating material (c) a sketch map of the sensor during corrosion monitoring.

of Q235B and T91 steels that exposed to Zhoushan marine atmosphere. These two steels were selected because there is a significant difference in their corrosion forms and corrosion rates in the marine atmosphere.

Fig. 1(a) shows the sensor and Fig. 1(c) shows a schematic diagram of the designed electrochemical sensor adsorbing on the tested metal surface. Numbers 1–5 display the main components of the sensor. No. 1 is the platinum microcathode made by a platinum wire tip, which is used as counter electrode. During EN test, the microcathode is connected to a working electrode (WE) via a zero resistance ammeter (ZRA). In this situation, the galvanic current caused by the microcathode could be disregarded because the microcathode has a very small surface area [4]. As a result, the corrosion potential of WE cannot be affected. No. 2 is the reference electrode which is made by a pure zinc electrode. Because the corrosion potential of pure zinc is stable in humid marine atmosphere where chloride ions are rich in it [5]. No. 3 denotes thin insulating plastic net which is made by polyethylene glycol terephthalate with a thickness of 180 μm (Supplied by the Guangfu reagent, Tianjin). The photo of the insulating plastic net is shown in Fig. 1(b). This net plays a key role in the corrosion detection: On the one hand, it avoids the two electrodes in the sensor contacting with the WE; on the other hand, the porous film permits humid atmospheric filling with it, to form an electrochemical cell and to facilitate EN test. No. 4 denotes magnet, the magnet is small therefore the effect of magnetic field on corrosion detection is negligible. The sensor has three magnets, therefore it can adsorb on the tested metal surface. No. 5 denotes an electrical contact, which connect the WE to the EN instrument.

The EN measurement system was composed of a National Instruments Compact FieldPoint (CFP) industrial control unit, FieldPoint analog input module CFP-AI-118, and a ZF-3 potentiostat (Shanghai Zhengfang Electricity & Electronics Limited Company). The EN test was performed in a zero-resistance ammeter (ZRA) mode, and the data were stored in a USB flash drive. In this mode, electrochemical potential noise (EPN) and electrochemical current noise (ECN) were recorded synchronously. EPN was recorded between the reference electrode and the WE, and ECN was recorded between the counter electrode and the WE. The sampling rate of EN was set as 2 Hz, which is suitable to capture corrosion events [6,7]. The temperature and humidity is recorded by using a DL-WS20 hygrothermograph.

After EN test, the data were decomposed by using discrete wavelet transform. Before wavelet analysis, the mean or direct current (DC) component was removed from original signals prior the wavelet analysis using a five-order polynomial fitting method. For discrete wavelet transform, the EN data in time domain were decomposed into wavelet crystals ($D1$, $D2$, $D3$, $D4$, $D5$, $D6$, $D7$) with different timescales and wavelet approximation $S7$. The type of the used wavelet transformation was db4, which is a Daubechies wavelet. The energy contribution of each crystal to the overall signal is given by:

$$E_j^d = \frac{1}{E}\sum_{k=1}^{\frac{N}{2^j}} d_{j,k}^2 \, (j = 1, 2, \ldots, J) \tag{1}$$

$$E_J^s = \frac{1}{E}\sum_{k=1}^{\frac{N}{2^J}} s_{J,k}^2 \tag{2}$$

where $s_{J,k}$, $d_{j,k}$ are the wavelet coefficients, E_j^d is energy of wavelet detal of j level, E_J^S is energy of wavelet approximation $J(J = E + 1)$, E is wavelet level number, N is the sampling number. The orthogonality