PAPER • OPEN ACCESS

Monitoring corrosion of steel bar using acoustic emission

View the article online for updates and enhancements.

Monitoring corrosion of steel bar using acoustic emission

Luying Zhang[a], Lei Qin[*]

School of Civil Engineering and Architectural Engineering, University of Jinan, Jinan 250022, China

*Corresponding author e-mail: cea_qinl@ujn.edu.cn, [a]Icnet99@163.com

Abstract. In order to realize real-time dynamic monitoring, the reinforcement corrosion was monitored using acoustic emission technology. The three stages of reinforcement corrosion could be responded by the analysis of acoustic emission parameters and waveforms. And the results indicated that acoustic emission could monitor the corrosion process in reinforced concrete structure. Early warning of steel bar corrosion damage can be realized.
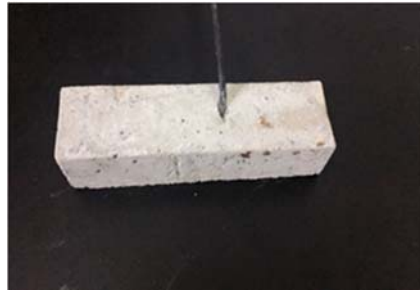
1. Introduction

Durability of reinforced concrete (RC) structures is an important factor affecting the service life of structures [1]. Monitoring corrosion has become one of the research hotspots in the field of civil engineering health monitoring in recent years [2-4]. Nowadays, researchers have developed many monitoring methods for steel corrosion, but these methods usually have defects [5-6]. Acoustic emission (AE) receives the signal of defects from the materials or components itself directly, which is basically not limited by the materials or components. And AE technology can reflect the internal defects of the materials or components directly [7]. In this paper, the real-time, on-line and continuous monitoring of steel corrosion by AE monitoring technology is used to judge the different stages of steel corrosion (development) and realize the real meaning of structural health monitoring [8-11].
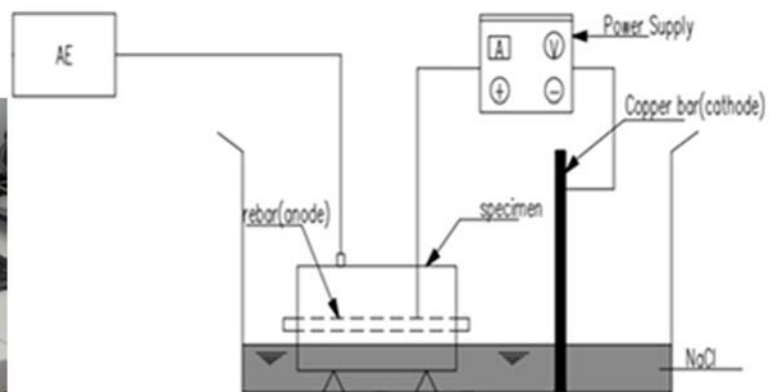
2. Experimental processes

The diameter of the steel is 10mm, and the length is 140mm. And the steel bars were connected with a wire (Fig. 1). The experiment used the mortar with proportions of cement, sand and water as 1:2:0.55, because concrete was not used in this study to avoid possible interaction with large aggregates. The dimensions of the specimens are 160mm × 160mm × 40mm (Fig. 2). In order to accelerate corrosion of rebar, the specimen was submerged in electrolyte solution (5% NaCl). The embedded reinforcement bar in the specimen was connected to the anode of the direct-current power and the cooper rod was connected to the cathode of the direct-current power.

Figure 1. Steel bar with wire   **Figure 2.** A specimen

The experimental setup of AE monitoring system was shown in Fig. 3. Before the experiment, sandpaper should be used to smooth the paste position of the sensor. To ensure good acoustic coupling between sensors and RC specimens, the sensor was coupled to the surface of the specimen by Vaseline, which could minimize the loss of AE signals. When the AE threshold was set to 45 dB, no signal is detected, indicating that there is no AE activity. Each time the signal is acquired, the threshold was reset to ensure that the value was reasonable. Monitoring system was shown in Fig. 4.

Figure 3. Acoustic emission instrument   **Figure 4.** Acoustic emission monitoring system

All manuscripts must be in English, also the table and figure texts, otherwise we cannot publish your paper. Please keep a second copy of your manuscript in your office. When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question. Should authors use tables or figures from other Publications, they must ask the corresponding publishers to grant them the right to publish this material in their paper.

3. Results and Discussion

3.1. Parameter Analysis
Cumulative impact curve and energy-time curve were shown in Fig. 5.

(a) Cumulative impact curve
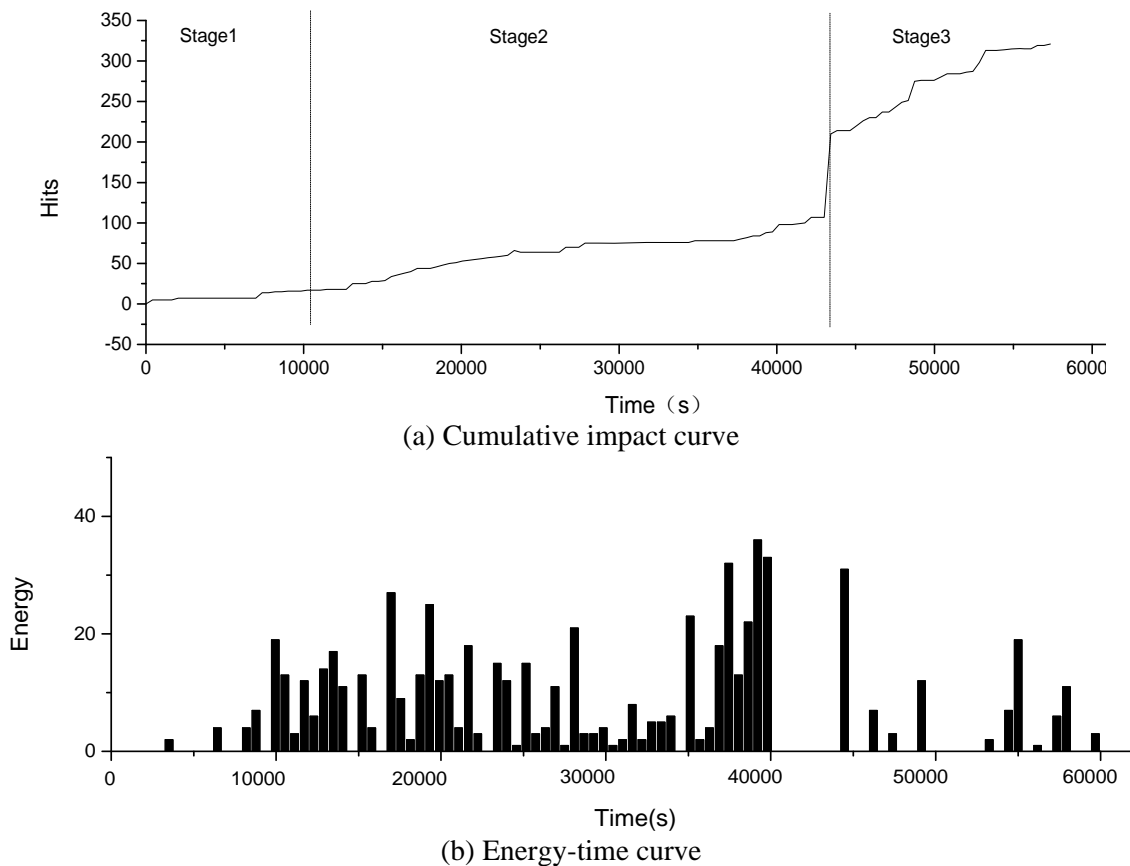

(b) Energy-time curve

Figure 5. The change curves of acoustic emission parameters

According to the change of the slope of cumulative impact curve and energy-time curve, the corrosion process of steel bar could be divided into three stages. Stage 1, the slope of the impact curve was not obvious, the time was short, and the energy density was small; Stage 2, the slope of the impact curve continues to increase which was the largest of the three stages. The energy density was high, and the maximum energy appeared at this stage; Stage3, impact curve continues to change, but it was not as large as stage2, and the energy was relatively sparse. From the curve of impact, it could be found that there was a point of change before the occurrence of macroscopic crack, and the activity of acoustic emission increased sharply. Therefore, the catastrophe point was regarded as the characteristic point of the appearance of crack, which provided a reference time for damage warning. Through the analysis of the changing curve of cumulative impact number, it could be seen that the number had a corresponding relationship with the corrosion time of steel bars, which could reflect the different stages of reinforcement corrosion in concrete by changing trend.

3.2. Waveform analysis

Waveform analysis was based on the whole process, using AE instrument to collect time-domain waveform to analyze the source of AE. Waveform signal is the most original signal collected, which contains the comprehensive information of AE source. Some characteristic waveforms are extracted to judge the information of AE.
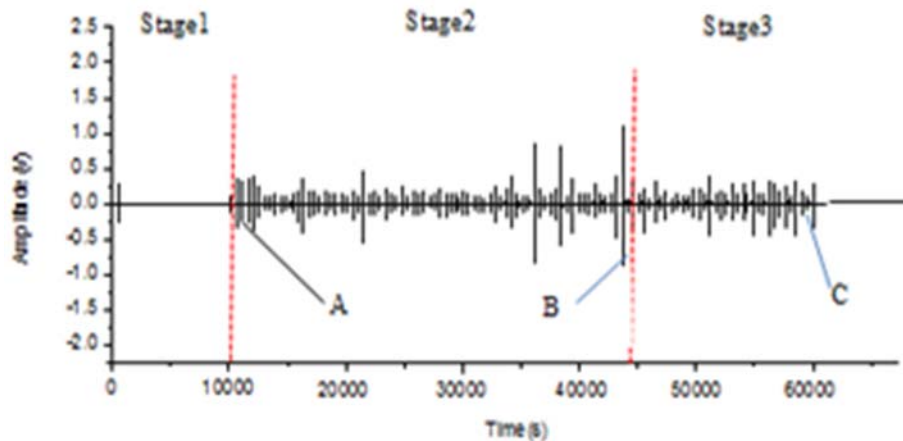
Figure 6. AE waveforms

Fig. 6 shows that there was no waveform in the early stage of steel bar corrosion. The density of waveform and the number of waveforms increased sharply in Stage 2 over time. The number of waveforms continued to increase, and the amplitude of the waveforms was slightly higher. Hence, the steel corrosion process could be divided into three stages by waveform analysis.

In this paper, the AE waveform signals of A, B and C points were analyzed. The time-domain waveform and frequency-domain waveform of the signals collected in different stages were as follows:

(a) time-domain waveform of point A

(b) frequency-domain waveform of point A

(c) time-domain waveform of point B

(d) frequency-domain waveform of point B

(e) time-domain waveform of point C

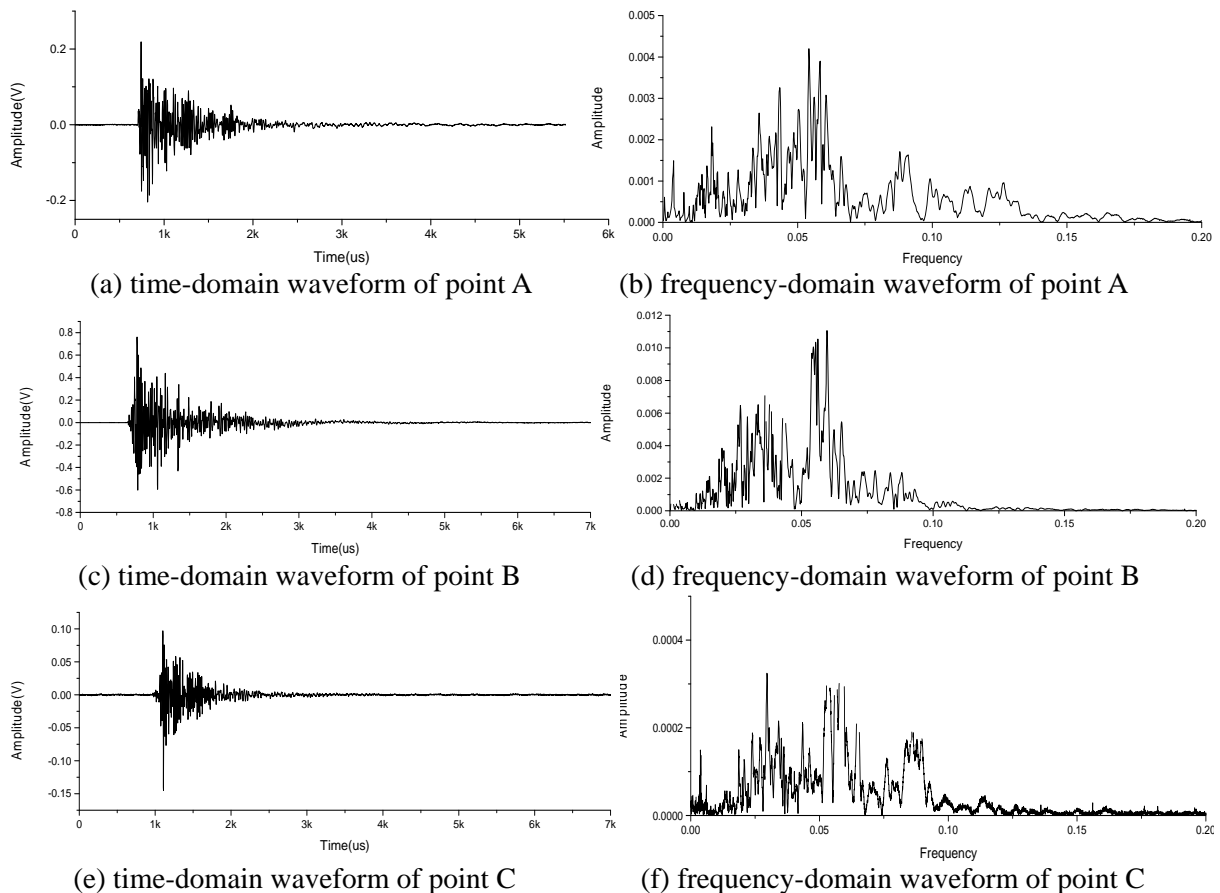(f) frequency-domain waveform of point C

Figure 7. Time domain and frequency-domain charts for three monitoring points of A, B and C

4

As shown in Fig.7, the amplitude of waveforms was the highest at point B, and the corresponding peak frequency reached 60 kHz. The beginning time of visible crack can be considered to point B. The amplitude and peak frequency of point A are slightly higher than that of point C. However, the AE activity was not as intense as that of point B. Thus, the point A could be regarded as the initial appearance of internal micro-cracks, which leaded to more significant changes in AE waveform.

4. The result

Through the analysis of acoustic emission parameters and waveforms, the corrosion of reinforcing steel could be divided into three stages. The first stage was initial corrosion of steel bar. No waveforms generated at this stage. The number of hits was almost zero, and the curve was gentle relatively. The damage of RC specimen was small. The main ingredient of concrete did not change significantly, so the acoustic emission signals were less. The development of concrete internal cracks was the second stage. With the increase of electrifying time, the steel bar gradually corroded and released acoustic emission energy higher. The second stage of steel corrosion corresponded to the generation and development of cracks in concrete. The number of acoustic emission impact increased continuously and the waveform signals increased sharply. The third stage was the period after concrete cracking. Although the value of the impact number continued to increase, the slope of the curve was not as large as that of the crack. Similarly, the waveform density was large at this stage, but the amplitude was not as high as the previous stage. In the process of crack development, the mechanical properties of concrete materials could prevent crack propagation. The expansion of concrete cracks led to the rapid reduction of acoustic emission energy.

5. Conclusion

In this paper, the analyses of monitoring steel bar corrosion by acoustic emission were described. The corrosion process of steel bar was divided into three stages by acoustic emission parameter analysis and waveform analysis. In the first stage, the micro cracks were produced. The AE parameters developed smoothly, and the AE activity was low. In the second stage, internal micro crack started to expand which leading to development of the external macroscopic cracks. The maximum variation of parameters was observed. The activity of AE was the highest when macro cracks were produced. In the third stage, new cracks were generated constantly, and the cumulative values of parameters increased. Compared with the second stage, parameter-rate was smaller. Acoustic emission signals were not active when macroscopic cracks occurred. Through the analysis of the waveform, the amplitude and peak frequency of the waveform were the highest when the concrete cracks were visible. It also explained the three stages of the development of steel corrosion.

Acknowledgments

References

[1]   Chaix J F, Garnier V, Corneloup G. Concrete damage evolution analysis by backscattered ultrasonic waves [J]. Ndt & E International, 2003, 36 (7): 461 - 469.

[2]   Leung C K Y, Wan K T, Chen L. A Novel Optical Fiber Sensor for Steel Corrosion in Concrete Structures [J]. Sensors, 2008, 8 (3): 1960-1976. [3] Vassie P R. The Half-cell Potential Method of Locating Corroding Reinforcement in Concrete Structures [J]. TRRL Application Guide, 1991.

[3]   G. Ping, J.J.Beaudoin.Obtaining Effective Half-Cell Potential Measurements in Reinforced Concrete Structure [J]. Corrosion Science, 2004, (97): 246 - 255.

[4]   Y. Liu, R. E. Weyers. Comparison of Guarded and Unguarded Linear Polarization Ccd Devices with Weight Loss Measurements. Cement and Concrete Research. 2003, 33(7): 1093 - 1101.

[5]   D. D. Macdonald, M. C. H. Mckubre and M. Urquidimacdonald. Theoretical Assessment of Ac

Impedance Spectroscopy for Detecting Corrosion of Rebar in Reinforced-Concrete. Corrosion. 1988, 44 (1): 2 - 7.

[6]   Mukhopadhyay C K, Jayakumar T, Haneef T K, et al. Use of acoustic emission and ultrasonic techniques for monitoring crack initiation/growth during ratcheting studies on 304LN stainless steel straight pipe [J]. International Journal of Pressure Vessels & Piping, 2014, 116 (4): 27 - 36.

[7]   Shigeishi M, Colombo S, Broughton K J, et al. Acoustic emission to assess and monitor the integrity of bridges [J]. Construction & Building Materials, 2001, 15 (1): 35 - 49.

[8]   Fricker S, Vogel T. Site installation and testing of a continuous acoustic monitoring[J]. Construction & Building Materials, 2007, 21 (3): 501 - 510.

[9]   Sagaidak A I, Elizarov S V. Acoustic emission parameters correlated with fracture and deformation processes of concrete members [J]. Construction & Building Materials, 2007, 21 (3): 477 - 482.

[10] Chen B, Liu J. Investigation of effects of aggregate size on the fracture behavior of high performance concrete by acoustic emission [J]. Construction & Building Materials, 2007, 21 (8): 1696 - 1701.