Structural Monitoring and Maintenance, *Vol. 6, No. 3 (2019) 173-190*
DOI: https:// doi.org/10.12989/smm.2019.6.3.173

Non-destructive evaluation and pattern recognition for SCRC columns using the AE technique

Fangzhu Du and Dongsheng Li*

School of Civil Engineering, Dalian University of Technology, China

(Received March 6, 2019, Revised April 29, 2019, Accepted August 27, 2019)

Abstract. Steel-confined reinforced concrete (SCRC) columns feature highly complex and invisible mechanisms that make damage evaluation and pattern recognition difficult. In the present article, the prevailing acoustic emission (AE) technique was applied to monitor and evaluate the damage process of steel-confined RC columns in a quasi-static test. AE energy-based indicators, such as index of damage and relax ratio, were proposed to trace the damage progress and quantitatively evaluate the damage state. The fuzzy C–means algorithm successfully discriminated the AE data of different patterns, validity analysis guaranteed cluster accuracy, and principal component analysis simplified the datasets. A detailed statistical investigation on typical AE features was conducted to relate the clustered AE signals to micro mechanisms and the observed damage patterns, and differences between steel-confined and unconfined RC columns were compared and illustrated.

Keywords: steel-confined RC structure; acoustic emission; damage evaluation; cluster analysis; pattern recognition

1. Introduction

Steel-confined reinforced concrete (RC) columns are widely used in civil engineering, especially in high-rise buildings, large-span bridges, and massive structures. The casing steel tube serves as a formwork and protective jacket that constrains the plastic deformation of core concrete and prevents premature shear failure (Han *et al*. 2009). Several scholars (Liu *et al.* 2009, Wang *et al.* 2017, Zhou *et al.* 2008) have investigated the mechanical behavior of steel-confined RC columns under different loading conditions and proved that the proposed column features good confinement effects, loading capacity, and anti-seismic capacity. The wide utilization of steel-confined RC column emphasizes the necessity of developing structural health monitoring (SHM) and evaluating approaches.

Acoustic emission (AE) is a non-destructive technique that can provide reliable and real-time information on various structures; it has been widely explored in civil engineering for SHM and damage recognition (Abouhussien and Hassan 2017). At present, most studies on AE utilization are focused on concrete structures (Behnia *et al.* 2014, Carpinteri *et al.* 2011) and steel materials (Droubi *et al*. 2017). Due to the highly complex and invisible damage patterns, few studies have

*Corresponding author, Professor, E-mail: lidongsheng@dlut.edu.cn

http://www.techno-press.org/?journal=smm&subpage=7 ISSN: 2288-6605 (Print), 2288-6613 (Online)

Kadkhodapour, J., Butz, A. and Rad, S.Z. (2011), "Mechanisms of void formation during tensile testing in a commercial, dual-phase steel", *Acta. Mater.*, **59**(7), 2575-2588.

Lai, Y.S., Xiong, Y. and Cheng, L.F. (2014), "Frequency band energy characteristics of acoustic emission signals In damage process of concrete under uniaxial compression", *J. Vib. Shock*, **32**(2), 12-19.

Li, D., Du, F. and Ou, J. (2017), "Damage evaluation of fiber reinforced plastic-confined circular concrete-filled steel tubular columns under cyclic loading using the acoustic emission technique", *Smart. Mater. Struct.*, **26**(3), 035014.

Liu, J., Zhang, S., Zhang, X. and Guo, L. (2009), "Behavior and strength of circular tube confined reinforced-concrete (CTRC) columns", *J. Constr. Steel Re*s., **65**(7), 1447-1458.

Ma, G. and Li, H. (2017), "Acoustic emission monitoring and damage assessment of FRP-strengthened reinforced concrete columns under cyclic loading", *Constr. Build. Mater*.,**144**, 86-98.

Manson, G., Worden, K., Holford, K. and Pullin, R. (2001), "Visualisation and dimension reduction of acoustic emission data for damage detection", *J. Intel. Mat. Syst. Str.*, **12**(8), 529-536.

Marec, A., Thomas, J.H. and El Guerjouma, R. (2008), "Damage characterization of polymer-based composite materials: Multivariable analysis and wavelet transform for clustering acoustic emission data", *Mech. Syst. Signal Pr. Special Issue: Mechatronics*, **22**(6), 1441-1464.

Pashmforoush, F., Fotouhi, M. and Ahmadi, M. (2012), "Damage characterization of glass/epoxy composite under three-point bending test using acoustic emission technique", *J. Mater. Eng. Perform.*, **21**(7), 1380-1390.

Prem, P.R. and Murthy, A.R. (2016), "Acoustic emission monitoring of reinforced concrete beams subjected to four-point-bending", *Appl. Acoust.*, **117**, 28-38

Saeidi, N., Ashrafizadeh, F., Niroumand, B., Forouzan, M.R. and Barlat, F. (2014), "Damage mechanism and modeling of void nucleation process in a ferrite-martensite dual phase steel", *Eng. Fract Mech.*, **127**, 97-103.

Sagar, R.V., Prasad, B.K.R. and Singh, R.K. (2015), "Kaiser effect observation in reinforced concrete structures and its use for damage assessment", *Arch. Civ. Mech. Eng.*, **15**(2), 548-557.

Sahu, H.B., Mahapatra, S.S. and Panigrahi, D.C. (2012), 'Fuzzy C-means clustering approach for classification of Indian coal seams with respect to their spontaneous combustion susceptibility", *Fuel Process Technol.*, **104**, 115-120.

Wang, Y., Wang, W., Zhou, X. and Liu, J. (2017), "Experimental study on seismic behavior of steel tube confined reinforced concrete columns subjected to combined compression-bending-torsion", *J. Build. Struct.*, **38**(1), 185-189.

Xie, X.L. and Beni, G. (1991), "A validity measure for fuzzy clustering", *IEEE T. Pattern Anal.*, **13**(13), 841-847.

Zhang, Y., Zhao, G., Zhou, J. and Zhu, R. (2013), "Acoustic emission analysis of frequency characteristic for 20 # steel during tensile process", *Chem. Machinery*, **40**(5), 569-573.

Zhou, X., Zhang, S. and Liu, J. (2008), "Seismic behavior of steel tube confined reinforced concrete (RC) beam-columns", *J. Build. Struct.*, **29**(5), 75-84.

Zitto, M.E., Piotrkowski, R., Gallego, A., Sagasta, F. and Benavent-Climent, A. (2015), "Damage assessed by wavelet scale bands and b-value in dynamical tests of a reinforced concrete slab monitored with acoustic emission", *Mech. Syst. Signal Pr.*, **60-61**, 75-89.

TY