Marine Structures 33 (2013) 100–119

Contents lists available at SciVerse ScienceDirect

Marine Structures

journal homepage: www.elsevier.com/locate/marstruc

Detection of nonlinearity effects in structural integrity monitoring methods for offshore jacket-type structures based on principal component analysis☆

A. Mojtahedi [a,*], M.A. Lotfollahi Yaghin [a], M.M. Ettefagh [b], Y. Hassanzadeh [a], M. Fujikubo [c]

[a] Department of Civil Engineering, University of Tabriz, Tabriz, Iran
[b] Department of Mechanical Engineering, University of Tabriz, Tabriz, Iran
[c] Department of Naval Architecture and Ocean Engineering, Graduate School of Engineering, Osaka University, Osaka, Japan

ARTICLE INFO

Article history:
Received 21 September 2011
Received in revised form 6 April 2013
Accepted 13 April 2013

Keywords:
Offshore structure
Damage identification
Parametric model
Experimental verification

ABSTRACT

The detection of changes in the dynamic behavior of structures is an important issue in structural safety assessment. The development of detection methods assumes greater significance in the case of offshore platforms because the inherent problems are compounded by the harsh environment. Here, we describe an instrumented physical model for the structural health monitoring of an offshore jacket-type structure and the results of tests in several different damage scenarios. In a comparative investigation of two different methods, we discuss the difficulties of implementing damage detection techniques for complex structures, such as offshore platforms. The combined algorithm of a fuzzy logic system and a model updating method are briefly discussed, and a method based on stochastic autoregressive moving average with exogenous input is adopted for the structure. The consideration of uncertainties and the effects of nonlinearity were major objectives. So, the methods were also investigated based on the test scenarios consisting of the physical model with a geometric nonlinearity. The principal component analysis method was utilized

* Corresponding author. Tel.: +98 411 3334884; fax: +98 411 3344287.
E-mail address: Mojtahedi@tabrizu.ac.ir (A. Mojtahedi).

http://dx.doi.org/10.1016/j.marstruc.2013.04.007

for the detection of nonlinearity in the recorded data. The results show that the developed methods are suitable for damage classification, but the quality of the acquired signals must be considered an important factor influencing successful classification. The development of these methods may be extremely useful, as such technologies could be applied for offshore platforms in service, enabling damage detection with fewer false alarms.

Nomenclature

M, K, C Mass matrix, damping matrix, stiffness matrix
$\mathbf{X}(t), \dot{\mathbf{X}}(t)$ Displacement vector, velocity vector, acceleration vector
ω_a, ω_e Analytical natural frequency, experimental natural frequency
$D_k^{(l)}$ Percentage damage parameter
E Young's modulus
l Crisp number for a structural member
k Crisp number for damage intensity
p The number of linguistic variables of damage intensity
$\boldsymbol{z}_k^{(l)}$ Matrix of measurement deltas
α Noise level parameter
$\mu_k^{(l)}$ Membership function for fuzzy logic system
m Midpoint of the fuzzy set
σ Standard deviation
S_R Success rate
$M_k^{(l)}$ Fuzzy system rules for frequency domain extracted features
$M^{(t)}$ Fuzzy system rules for time domain extracted features of tth test scenario
$A(q)$, $B_\alpha(q)$, $C(q)$ Autoregressive parameters, moving average parameters, innovations variance parameters
n_a, n_b, n_c ARMAX model order of autoregressive, moving average, and innovation variance
$e(t)$ Variance of the white noise
s Number of divided parts of the signal used to calculate the fuzzy system rules
$\mathbf{R}_{nm}$ Observation matrix for n number of sensor and m number of sampled data
$\boldsymbol{U}$ Orthogonal matrix of the principal components
$\boldsymbol{S}$ Diagonal matrix of the singular values
$\boldsymbol{V}$ Orthogonal matrix
$\boldsymbol{Q}$ Subspace matrix
SHM Structural health monitoring
FL Fuzzy logic
PCA Principal component analysis
FE Finite element
OMAX Operational modal analysis with exogenous forces
ARMAX Autoregressive moving average with exogenous input
MAC Modal assurance criterion
MD Measurement delta
SVD Singular value decomposition
PC Principal component
FRF Frequency response function
PSD Power spectral density