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Damage Detection in Offshore Fixed Platforms Using Concepts of Energy Entropy in Wavelet Packet Transform

H. Rahami[1], H. Amini Tehrani[2*], M. Akhavat[2], Gh. R. Ghodrati Amiri[3]

1- Associate Professor, School of Engineering Science, College of Engineering, University of Tehran
2- M.Sc. Graduate, School of Civil Engineering, Iran University of Science and Technology
3- Professor, Centre of Excellence for Fundamental Studies in Structural Engineering, Iran University of Science and Technology

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ABSTRACT

Structural health monitoring is of great importance in order to ensure safe and reliable performance of structures during the service life. Offshore platforms have been widely used in offshore oil and gas exploitation and are highly susceptible to damage since a major part of these structures is under water exposed to corrosive ocean environments. Utilizing signal processing tools is one of the effective methods in identifying the structural damages. In this paper, at first a jacket platform model is introduced and various damage patterns are applied to the model through members' stiffness reduction. Then, structural response is recorded under the Gaussian white noise excitation. At this stage, the recorded acceleration response is decomposed at different levels via wavelet packet transform and then by using the concepts of energy entropy and performing a sensitivity analysis, damage sensitive components are selected. Results show that the selected damage sensitive components have good efficiency even in low intensity damages and also the change rate of of these components is markedly related to the severity of the damage.

KEYWORDS:

Structural Health Monitoring, Offshore Platforms, Signal Processing, Wavelet Packet Transform, Energy Entropy, Sensitivity Analysis

[*] Corresponding Author, Email: hmdamini@yahoo.com

1- Introduction

For marine jacket platforms, damage creation in various parts of structure, such as connections due to cyclic stresses and fatigue, is unavoidable. Accordingly, identification and reparation of damages for platforms are necessary matters. Nowadays, with regard to expensive cost of visual test (VT) in deep sea, damage identification methods based on structural response signals, are more considerable.

In order to recognize damages in offshore structures, researchers utilize modal parameters and also signal based methods. Zhang and Chen [1] considered variation of frequency dependent response of platform as a damage sensitive feature. Applying free decay response, Alshafi et al. [2] used artificial neural networks to determine damage index. Mojtahedi et al. [3] considered upgraded finite element model to anticipate changes in dynamic characteristics of platform components followed by various damage patterns.

In the present paper, it is tried to recognize damage in the structure using recorded acceleration response signal by located sensor in the jacket platform deck. Hence, damage sensitive features, are investigated using energy entropy concept and performing sensitivity analysis on the components.

2- Wavelet packet transform and energy entropy

Wavelet packet transform (WPT) is widely applicable for signals analysis. Indeed, it is such transform that passes signal through more filters in comparison with discrete wavelet transform. Wavelet packet transform performs a comprehensive decomposition in different levels and consequently, presents acceptable clarity in higher frequencies. Signal decomposition is consecutively repeated for both high and low frequencies up to the initiation of upcoming decomposition hierarchies.

Entropy represents the stored data in signal. In other words, the more amplitude of entropy entails in the more amount of stored data and vice versa. In wavelet packet decomposition tree for a signal, energy entropy in node i is a special state of P-norm entropy which P=2. P-norm entropy is defined as Eq. (1):

$$e_i = \sum_k \left| c^i_{j,\mathrm{k}} \right|^p \; ; \; \left(P \geq 1 \right) \qquad (1)$$

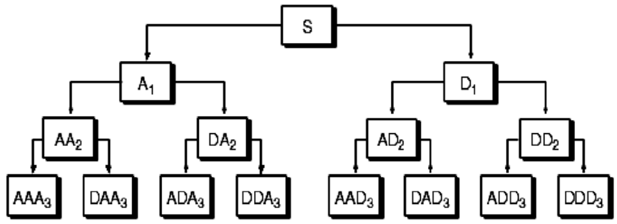

Fig.1. Signal decomposition via wavelet packet transform

where $c^i_{j,k}$ are wavelet coefficients belong to j-th level and i-th node of wavelet packet decomposition tree. In fact, when P=2, P-norm entropy depicts energy concept and therefore it is named as energy entropy.

Damage sensitive Index for entropy is defined as Eq. (2):

$$EDSI_n = \left| \frac{E^u_{j,n} - E^d_{j,n}}{E^u_{j,n}} \right| \times 100 \qquad (2)$$

where $EDSI_n$ is the damage sensitive Index belonging to n-th component at j-th level of decomposition tree, $E^u_{j,n}$ and $E^d_{j,n}$ are energy entropies of n-th component at level j for intact and damaged states, respectively. Apparently, this index is based on the fact that, damage occurrence in structure, causes significant variations in energy entropy for such wavelet packet tree components.

3- Case Study

3- 1- Modeling procedure

To perform a case study modeling, a two dimensional model of the platform which is located in Resalat oil field, is simulated. This two dimensional model is considered as a mass spring one with translational degree of freedom at each level along the horizon.

Fig. (2) demonstrates platform shear model and Table (1) shows stiffness and mass values at each level. To excite mentioned platform, white noise has been exerted to the top level of platform.

Random input signal, considered as excitation, is modeled in MATLAB programming based on white noise characteristics in 2000 nodes with time step of 0.01 second.

In the current study, damage patterns have considered in the way that: first of all conforms to reality and the second, represents an acceptable proposed procedure in terms of various damage severities. Investigated damage patterns are shown in Table (2). These patterns have applied at related level

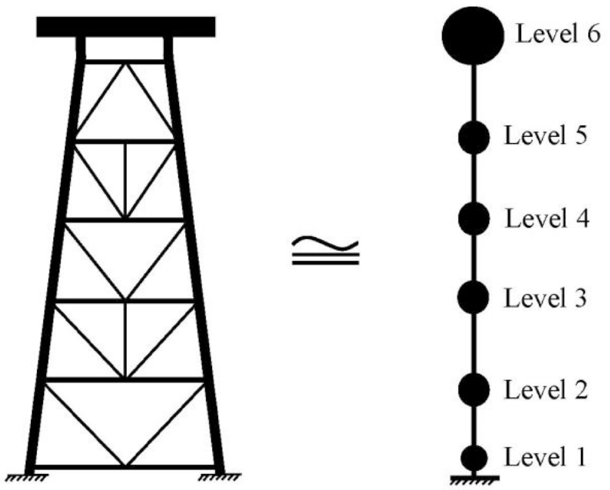

Fig. 2. Equivalent shear model of platform

Table 1. Stiffness and mass values in each level of structure

level	1st	2nd	3rd	4th	5th	6th
Mass (ton)	110	183	152	146	132	865
Stiffness (ton/cm)	4354	1269	1183	1076	9701	1006

Table 2. Investigated damage patterns

Damage patterns	Level (1)	Level (2)	Level (3)	Level (4)	Level (5)	Level (6)
Pattern (1)	0	0	0	10	0	0
Pattern (2)	0	10	0	0	0	0
Pattern (3)	0	0	0	0	0	15
Pattern (4)	0	15	0	0	10	0
Pattern (5)	0	20	15	0	0	0
Pattern (6)	0	10	0	30	10	0
Pattern (7)	0	20	0	30	0	10
Pattern (8)	0	0	10	25	0	15
Pattern (9)	0	10	0	0	15	30
Pattern (10)	0	15	0	25	15	10

in the form of stiffness reduction.

3- 2- Results and Discussion

In order to health monitoring of mentioned platform, at first, the structural excitation is performed via Gaussian white. In this stage, utilizing wavelet packet analysis, captured response of structure is decomposed and wavelet packet coefficients are calculated at each level. Since in level j of wavelet packet decomposition tree, 2^j components are available, time signal corresponding to each of 2^j components should be reconstructed. After signals reconstruction, energy entropy is calculated through mentioned equation and entropy damage sensitive index for each component is determined. Accomplishing sensitivity analysis in the current stage, effective level as well as sensitive components possessing the most amount of damage in case of deficiency are chosen.

Investigations by authors show that the 6th level is the most convenient one to achieve damage sensitive components. In Fig. (3), variation of entropy damage sensitive index for ten damage patterns is depicted. Obviously from this figure, components 46, 61, 12, 10 and 57 among all 64 ones at level 6th, show the most sensitivity to damage occurrence in platform and clearly represent damage entity in all defined patterns which are explanatory of different severities of damage in platform stories.

3- 3- Measuring sensitivity of EDSI to damage severity

In order to measure sensitivity of predefined index (*EDSI*) to damage severity, variation of damage sensitive index is investigated. In this investigation two assumptions considered:

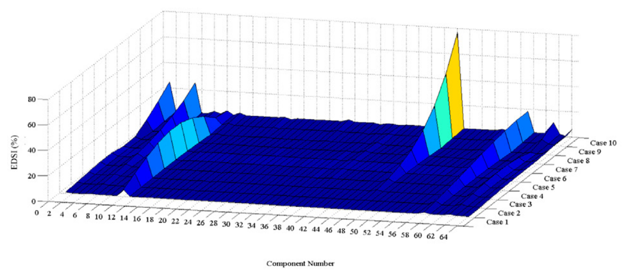

Fig. 3. Variation of entropy damage sensitive index for ten damage patterns at sixth level

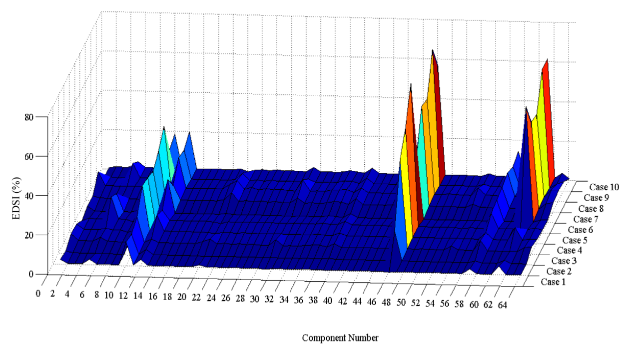

Fig. 4. Variation of entropy damage sensitive index for stepped damage pattern at third level

- Location of damage creation is invariable.
- Damages have stepped increasing pattern.

Apparently from Fig. (4) with growth in damage severity from 5% to 50% (10 patterns) at third level, entropy index value for components 46 and 57 increases. It can be inferred that proposed index can qualitatively evaluate damage severity as well.

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