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Damage localization of structures using adaptive neuro-fuzzy inference system

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Abstract

The identification of cracks or similar damages at their initial levels in the load carrying members of structures is an important problem in civil and earthquake engineering. In this paper, adaptive neuro-fuzzy inference system (ANFIS) method was employed as a new approach to make prediction on damage locations in beam like structures. Single and multiple damages in some parts of numerical samples are caused by concrete elasticity modulus reduction. Mode shapes and modal strains of damaged beams were analyzed through ANFIS approach and the results were compared. Analyses suggest that decision making based on a particular mode shape or modal strain would not be applicable and using some vibrational modes seems to be essential to damage detection. Results also show that modal strains are significantly more sensitive for damage localization than mode shapes and the locations of damage scenarios can be predicted precisely.

Keywords: Damage location, ANFIS method, Mode shapes, Modal strains.

1. INTRODUCTION

Many civil engineering structures, exposed to various external loads such as earthquakes, traffic and wind during their lifetime, have been suffering damage and deterioration in recent years which seriously affects their performance and may even lead to structural failure. Because of this, structural health monitoring and damage assessment of these structures is becoming increasingly important in order to determine their safety and reliability. During the past two decades, a variety of analytical and experimental investigations have been carried out on cracked structures with a view to developing robust crack detection methods [1]. Any crack or localized damage in a structure reduces the stiffness in the structure which is associated with decreases in the natural frequencies and modification of the mode shape of the structure. Several researchers have used mode shape measurements to detect damage. Ratcliffe [2] found that the mode shapes associated with higher natural frequencies can be used to verify the location of damage, but they are not as sensitive as the lower modes. Modal curvatures seem to be locally much more sensitive to damage than modal displacements and some researches have shown that higher derivatives give a more sensitive detection. Pandey et al.[3] showed that absolute changes in the curvature mode shapes are localized in the region of damage and hence can be used to detect damage in a structure. The change in the curvature mode shapes increases with increasing size of damage [4].

The traditional methods use the modal data change from intact and damaged structures as a basic feature for damage identification. The baseline data from intact structure can be obtained from either an experimental test or an accurate numerical model of the intact structure. In these methods, damage locations are usually obtained by using statistical approaches. As an example, Pandey et al. [3] compared the curvatures of the modes shapes between the undamaged and damaged structures. Sampaio et al. [5] directly subtracted the values of the mode shape curvature of the damaged structure from that of the undamaged structure.

In recent years, artificial neural networks (ANN) have been used to improve the diagnostic yield, but have yet to provide sufficient classification for damage detection [6]. Fuzzy set theory plays an imperative role in dealing with uncertainty when making decisions in different applications. First introduced by Zadeh [7], fuzzy logic and fuzzy set theory are employed to illustrate human thinking and reasoning in a mathematical framework. Fuzzy-rule based modeling is a qualitative modeling method where the system behavior is expressed using a natural language [8]. Fuzzy sets have attracted the growing interest in modern information technology, production technique, decision making, pattern recognition, diagnostics, data