Structural Damage detection using Modal Strain Energy

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ABSTRACT
Structural damage detection, damage localization and severity estimation, based on computation of modal strain energy is presented in this paper. Damage often causes a loss of stiffness in some elements of the structure, so modal parameters; mode shapes and natural frequencies, in damaged structure are different from the undamaged state. In this paper location of damage is detected by computing modal strain energy change ratio (MSECR) for each structural element, which elements with higher MSECR are suspected to be damaged. By computing cross-modal strain energy for each suspected damage element, severity of damage as the stiffness reduction factor is estimated. Numerical studies are demonstrated for a two dimensional, single bay; three stories of two one-sixth scale steel frames of existing jacket platform. It is observed that this method can be used for damage detection of these kinds of structure.
KEYWORDS: DAMAGE DETECTION, MODAL ANALYSIS, STRAIN ENERGY.

INTRODUCTION
All load-carrying structures such as buildings, bridges, aircrafts, spacecrafts and offshore platforms continuously accumulate damage during their service life due to many source of damage (Asgarian and Amiri, 2008). In the past, numerous damage inspection methods and monitoring systems such as x-ray; electron scanning; ultrasound; magnetic resonance imagery; coin tapping; dye penetration; and visual inspection have been developed. These methods tend to be time consuming and costly, often requiring the exposure of structural elements for local damage detection (Lam, 1994, Kosmatka and Ricles, 1999). The methods for damage identification are commonly classified into four levels: Level 1: Determination that damage is present in the structure, Level 2: determination of the geometric location of the damage, Level 3: quantification of the severity of the damage, and Level 4: prediction of the remaining service life of the structure (Doebling et al., 1998).
Damage would alter the physical properties of structure such as mode shapes and natural frequencies. These Modal parameters characterize the state of a structure, therefore based on changes in natural frequencies, mode shapes, or their combinations, several structural damage detection techniques have been proposed in recent years. Shi suggested a method to detect the location of damage using the elemental energy quotient difference and modal strain energy change and to quantification of damage based on sensitivity analysis (Shi et al., 1998, 2000), also proposed an algorithm to improve structural damage quantification based on modal strain energy change (Shi et al., 2002). Mangal used an experimental investigation on a laboratory model of a jacket platform, for exploring the feasibility of adapting vibration responses due to impulse and relaxation, for structural monitoring (Mangal et al., 1999). Hu developed a new method to estimate the damage severity termed as cross-modal strain energy method that is the exact and non-iterative method to damage quantification (Hu et al., 2006). Udwadia proposed a method from information about some of measured modal parameter for the identification of stiffness matrices of structural and mechanical systems (Udwadia, 2005).
Some researchers proposed an algorithm to locate and size damage in jacket-type offshore structures and a Nondestructive Damage Detection (NDD) in large/complex structures via vibration monitoring (Stubbs et al., 1995, 2002), or suggested a method for identification of local damage of multi story frame building in terms of changes in story stiffness (Koh et al., 1995), or proposed a method based on using damage index to detect the location and the severity of damage in structural or mechanical systems (Barroso et al., 2004) and introduce a new form of