ABSTRACT

Structural health monitoring (SHM) techniques can be divided broadly into global (for moderate to severe damage) and local (for incipient damage). The global techniques are further divided into categories based on measuring static displacement, strain, etc., or dynamic modal parameters like natural frequencies, mode shapes, modal damping, etc. Some of the most popular local conventional non-destructive evaluation (NDE) methods are ultrasonic, guided waves and acoustic emission using a single or array of mobile transducers and local SHM technique like the modern electro-mechanical impedance (EMI) technique using permanently installed smart piezoelectric lead zirconate titanate (PZT) material patches as sensors/actuators. All the currently prevalent techniques heavily rely on signals obtained from the structure's current condition compared to those from the pristine condition (baseline signals) and thus connect variation in signals characteristics to damage in terms of location and severity. While this strategy has proved effective in the laboratory, significant limitations depend on the baseline signal's availability in actual field operations. Most existing structures do not have attributes that correlate to their pristine condition. Even when accessible, operational and environmental changes tend to conceal the impact of damage on signal characteristics. Most crucially, when measuring the status of a structure following an extraordinary event such as an earthquake or a hurricane, baseline data may become useless. Such occurrences may damage the sensors themselves, necessitating replacing them in various positions around the structure. As a result, the main research field of this thesis, baseline-free structural damage detection, can expand the scope of SHM in the circumstances outlined.

The primary objective of this research is to develop integrated global and local baseline-free technique using low-cost smart PZT patches acting as sensors and actuators. Firstly,

the global baseline free gapped smoothing method (GSM) using non-linear functions is employed to detect damages in beam type structures by measuring curvature mode shapes. Secondly, the EMI technique is rendered baseline free using polarization properties of PZT patch's employed in EMI technique's framework. This renders the proposed approach sensitive to local damage and easily applicable to complex structures. Both global and local techniques integrated and experimentally verified with the help of experiments conducted on an aluminium beam. The results highlight the better damage detecting ability of the proposed integrated approach as compared to existing techniques. Detailed numerical simulation is also carried out using a finite element method employing simulation software, and results establish the feasibility of the proposed approach.

The main contribution of this research is that for the first time, such extensive studies have been carried out on the application of the baseline free health assessment of structures. A new baseline-free assessment approach is proposed for further developing the existing global (modal analysis) and local (EMI) techniques and eliminating their dependency on baseline data by using the same PZT patches acting as actuators and sensors. With the help of this approach, the SHM field can be covered both globally and locally. In addition, an integrated system that operates the very same PZTs by altering the detecting mode may be less complicated in specific ways. Also, global modal analysis experiments which require dynamic forces such as impact hammers (no fixed excitation device) and shakers (fixed or not) to excite the structure in the desired frequency range to develop frequency response functions (FRF), are useless in case of inaccessible or confined structures. The proposed approach involving PZT-patches acting as exciters is a good solution for such cases. In overall, it is hoped that the outcome of this research will be of significant help SHM based on baseline-free domain.