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Studies on Damage Detection Using Frequency Change Correlation Approach for Health Assessment

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Abstract

Damage Location Assurance Criteria (DLAC) which is a correlation based approach between vectors of experimental natural frequency change ratios with vectors of analytical natural frequency change ratios, is adopted in this study for damage assessment. Here, the focus is on damage detection and correlation-based localization. For this study, numerical models of cantilever beam with three different damage locations have been modelled using finite element tool. Decreased mass is considered in this study to incorporate as damage. Natural frequencies for the first four modes are arrived for both undamaged and the damaged state of the structures. The damage incorporated is in the range of 10 percent of mass. From the correlation analysis carried out, the locations of the damage are matching with that of the damage considered. Further, to automate the correlation based algorithm, coding is developed using MATLab.

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1.0 Introduction to Health Monitoring

Structural health monitoring or condition monitoring by way of a structure's global dynamic behaviour is not a new concept. It has been suggested that some of the first clay potters would strike their clayware and listen to its tone as a way to determine the condition to the vessel [1]. The potters understood that any deviation from the expected norm in the tone indicated the presence of a defect in the work carried out. The oldest know collection of pottery has been dated to as early as 10500 BC [2], which is a quite an impressive discovery.The above mentioned concept is the basis of global vibration based structural health monitoring. There are really only two fundamental differences between the monitoring done by potters and such system today. Instead of human ear, innovative sensing devices are used to record data and the other is that the mathematics behind the monitoring process is better

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understood.The structural integrity world over is monitored by simple techniques such as visual inspection, concrete sounding and ultrasonic [3]. If the tests are performed on potential damaged areas, the above mentioned techniques can provide strong indication on the presence of damage. And, the prior knowledge of damage in the structure is a must, or this calls for scrupulously examination of the entire structure. The experience of the inspector comes in handy in diagnosing test results which may only reveal potential symptoms of damage.

Large amount of limitations concerning the use of the above procedures is highly prevalent. These methods are labour intensive and time consuming, perhaps requiring both a trained field technician to perform tests and a structural engineer to interpret results. Inspections are costly and this large expense is likely to affect the rate at which they are conducted. Fully constructed buildings may not be inspected until after a natural disaster occurs and damage is explicitly evident. Many methods mentioned above require visual inspection to locate potential damage sites in the testing [3]. Thus, these methods are most successful when all critical structural elements are exposed. The labour intensive manual inspection process coupled with hazardous working conditions can fatigue workers. This fatigue in turn could introduce judgment errors which may undermine safety of the structure despite the preventative measures being taken.

Due to the limitations associated with manual inspection methods and the need to keep structures functioning, more robust monitoring alternatives are being sought. Currently, analytical health monitoring methodologies based on the mathematics describing simple harmonic motion are being developed. These health monitoring schemes are generally classified by the extent of damage information they can extract from structural response behaviour. The last few decades saw the usage of these mathematical techniques. This technique is borrowed from the aerospace industry and applied to civil infrastructure with some success. The transition of this technique from one industry to another has been proven to be quite challenging. Rytter [1] is credited with the first to carry out such classification as given in Table 1.

Table 1: Rytter's classification of Damage Detection Methods

CATEGORY	CLASSIFICATION
Level 1	Detection- a qualitative indication that damage is present
Level 2	Localization-the probable location of damage
Level 3	Assessment-the size of damage
Level 4	Consequence-the safety of the structure given a certain damage state

2.0 Damage Detection Methodology

Despite new advancements in wireless radio transmitters, better radios themselves do not appear to be able to address the demands of a dense wireless sensor network as envisioned for health monitoring. That is to say that transmission power consumption, radio bandwidth, and latency attributed to data compression schemes will continue to stand in the way of the development and implementation of a full-scale Wireless Sensor Network (WSN) for centralized Structural Health Monitoring (SHM).

Clearly, the idea of using a dense WSN that can exchange reduced sets of data to increase the global sensitivity of an SHM method would be advantageous. As such, distributed SHM algorithms which extract meaningful features from response data without multiple channels of data need to be embedded on wireless system. The potential of vibration- based SHM coupled with smart wireless sensors has not yet been fully appreciated. To date, WSNs have been configured in civil engineering applications to operate in a fashion consistent to that of a centralized data acquisition system. While complex routing and compression algorithms have been to send all data to one centralized collection center for post processing.In response to this limitation placed on data transmission a decentralized smart wireless sensor paradigm for vibration-based SHM is proposed here. Comprehensive literature reviews of vibration-based SHM implementing smart wireless sensors are available in Lynch et al. and Spencer et al. [4, 5]. Feature correlation-based monitoring techniques essentially function by comparing the characteristics of a numerical model to those of the actual structure. In general, these methods are implemented according to the