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Beam Using Cross-Correlation Analysis of Vibration Response: A Review

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Abstract

The main goal of SHM is to be able to replace current inspection cycles with a continuously monitoring system. The function required in the SHM system during the in-service operation is to identify the load applied to the structure or damage in it. Reducing maintenance costs, increasing civil structures like dam's bridges, and other type of truss structures, Aircraft Availability, Reducing Weight, increasing the strength and Quality control are the primary goals of Structural Health Monitoring. Civil structures have one of the highest payoffs. For SHM applications since damage can lead to catastrophic and expensive failures, and the vehicles involved undergo regular costly inspections. Currently 27% of an average Materials life cycle cost, both for naturals and composite structures, is spent on inspection and repair which excludes opportunity cost. By the use of SHM it is observed that there is reduction in maintenance and savings up to 75%. New reliable approaches for damage detection such as SHM need to be developed to ensure that the total cost of ownership of critical structures does not become limiting factor for their use. In this thesis cross correlation technique is used to detect and locate the damage in the structure using vibration analysis.

Keywords: Structural Health Monitoring; Damage Detection; Cross-correlation Functions; Transient Analysis; Vibrational Analysis;

1. Introduction

A detection technique to localize and quantify the multiple damages in structures is proposed in this thesis. At first, acceleration response histories at multiple sensor locations are collected numerically from damaged and undamaged structures using ANSYS. Here cantilever beam with single as well as multiple damages has been considered. The cross correlation between the acceleration histories at each sensor location is computed and for this MATLAB code is also validated. The damage indicators are used to calculated from the outputs of maximum amplitudes of normalized cross-correlation. However, the accuracy of the damage-detection techniques has been shown for different-different damage cases in the result section.

The three fundamental steps involved in Structural Health Monitoring are Diagnosis, Localization and Prognosis. Diagnosis is a process of detection, identification &assessment of faults and flaws that may affect the performance of the structure in the future. However, Localization involves the identification of the location of damages. Prognosis involves the prediction of remaining life of the structural beam or any structures. Now a days the people are more focusing on the detection of the damages which is the most important technique in structural health monitoring. As you know that there are several methods in damage detection techniques but the vibration analysis using cross-correlation technique provides the more perfections, easier, simple as well as cheaper way in damage detections for localizing and quantifying the damage.

Cross-correlation function describes the dependence between two sets of amplitude responses. In this analysis the response signals are accelerations. First the beam of composite material is modeled in UGNX and meshed in the ANSYS APDL interface, then the boundary conditions are applied for the case of cantilever and an impulse load is applied, finally the model is simulated for transient set upto obtain the displacement values. The accelerations are obtained from the displacements which are found by using central difference method. In order to determine the damages in the structural beam a proper excitation is given to the beam and the responses are recorded at different degree of freedoms (DOF's). Here the responses may be displacements, velocities or accelerations based on the approach using in the cross-correlation technique. But in this approach, the acceleration values are giving the best and appropriate results.

1.1 Procedure Development

This includes the collection and analysis of information such as material properties, structural design, history of operation, repairs, results of previous history, applied load, operational and environmental conditions.

1.2 Sensing

It is a data measurement process. The measured data includes strain, displacement, acceleration, pressure, temperature and any other response depending upon the developed SHM method.

1.3 Diagnosis

Diagnosis is a process of detection, identification and assessment of flaws and faults that may affect the performance of the structure in the future. This process requires the modeling and research on the model.

1.4 Monitoring

Monitoring is the process of inspection of flaws developed in the structure, evaluation of flaw development rate and conditions of the structure.

1.5 Prediction

The primary goals of prediction are to identify the remaining life of structure and detecting the next inspection cycle required based on the previously obtained data.

1.6 Analogy between SHM and Human Body

Structural Health Monitoring is quite analogous to the function of human body. Basic SHM consists of two parts:

1- Interrogator

2- Sensor network.

Brain is known as the central part of body without which human intelligence will fail to take a decision in the similar way interrogator acts as a human brain.

And the Sensor network which includes Sensors and Data processing & Communication is compared to the nervous system in the human body which takes a effective role in transferring signals from brain to other parts of the b rain and vice-versa.

2. Literature Review

C. M. Diwakar, N. Patil, and Mohammed Rabius Sunny[13] In this thesis the traditional threshold-based method of detecting damages from these damage indicators has been observed to be inadequate for the detection of multiple damages. Here, the drawback of threshold-based damage-detection method is overcome by using an artificial netural network.

Le Wang, Tim P. Watersand Zhichun Yang[14] Structural damage detection methods based on vibration responses are appealing for a variety of reasons such as their potential to observe damage from sensor placed remote from an unknown damage site.

Chiu et al.[11]prescribed that structural monitoring in damage detection can be achieved by placing a sensor system on a structure/machine to measure a physical quantity for e.g. vibration signature, impedance, power flow, strain, acoustic emissions, etc.

Habib, Fady [6] described various Structural Health Monitoring Techniques in detecting the damage, they mainly focused on the Acoustic-Ultrasonic (AU), Capacitance Disbond Detection Technique (CDDT) and Surface Mountable Crack Detection System (SMCDS).

Hou, Yan Fang, and Wei Bing Hu[3]introduced the Cross Correlation Function Amplitude Vector(CorV) to detect the damage of a historic timber structure based on the random vibration.

Zhu, Yi, Wang and Sabra [1] had described the application of cross-correlation function for structural damage detection by collecting data by using vibration analysis.

They conducted the laboratory experiment by introducing various Damage Scenarios to validate the damage detection approach. In their experiment they collected the response signals using mobile sensor prototype from the undamaged structure and the structures with three different Damage Scenarios which includes loosened bolts, including extra mass and loss of section area. The mobile sensors which are located at different positions on the structure record the acceleration data at corresponding locations, these acceleration data is used to find the damage indicators. With reference to their experimental work in this thesis damage in the form of triangular cut which indicates the scenario of loss of section is introduced and numerical study is performed to validate the damage detection approach.

The monitoring and maintenance of structures in the modern society has long been considered to be crucial work. Applying effective approaches to the regular repair of bridges, roads, and other structures is essential for safety of human life. In addition, to keep the buildings and other infrastructures running smoothly and maintaining safety as well as public health is also of great importance.

Now a days, the new technological developments & methods are being utilized as Structural Health Monitoring (SHM) process. Supporter of this emerging capability and understanding the importance of successfully maintaining the civil infrastructures. Today, the government rules and regulations for building and construction, and new mandates as well as required maintenance have also contributed to the development of SHM. This supervenes trend has a number of benefits, from improving the safety standards, reducing risks up to the cost-effective opportunity.

Increased Safety

However, the greater efforts made to improve SHM, will ultimately work to improve the overall public safety include everything from new policies and guidelines that help to ensure the building and construction safety, due to the development of new technologies.

Advanced SHM methods have greatly improved the ability of engineers to contribute to public safety with the use of sensors, data collection and analysis. This is mainly important with aging structures. The SHM process could involve testing the faltering strength of old buildings, structures, beams, etc.,as well as it is also more effective in analyzing the corrosion levels of older pipes that transport water, fuels or gas. Advanced SHM technologies are also having more benefits in new structures. Continuous monitoring and analysis helps to pinpoint design of the new structures

Detecting Early Safety Risks

In addition, it will help the engineers in recognizing the poor conditions of the structures and other safety issues, Due to advanced technical development in SHM also help professionals to determine the potential future risks for safety. The modern monitoring technologies can also be used to track the geotechnical details for buildings, roads, and other structures. This also provides the ability to detect the ground movement such as risks involved with earthquakes, landslides, and other disasters.

Cost Efficiency

SHM has greatly reduced the long & short-term costs related to structural maintenance by improving safety as well as ensuring the longer life for structures. However, there are little challenges with SHM in terms of standardizing the policies and diversity of new and old structures as well as the ranges of methods of construction.

3. Further Studies

In this study, damage detection and localizing is validated by using cross-correlation function through vibration analysis. Comparison of maximum absolute values of normalized cross correlation functions between the undamaged and damaged beam indicates the effect of damage between the pairs of location. And the damage is located between the pairs of measurement nodes where the maximum values of Damage Indicators obtained. Later the damage depths are increased from 10mm to 13mm and 16mm and observe that increase in the values of Damage Indicators due to the effect of increase in damage.

Further multiple damages are introduced and observed that the peak values of Damage Indicators show all the locations of the damage. By this it has seen that this numerical study of Vibration Response Using Cross-correlation Analysis working well in detection of single and multiple damages.

Also, this study can be extended for multiple excitations, hoping so the method followed in this thesis may give an appropriate result for multiple unknown excitations.

Reference

[1] Zhu, Dapeng, et al. "Structural damage detection through cross correlation analysis ofmobile sensing data." Proc. of the 5th World Conference on Structural Control and Monitoring, USB. (2010).

[2] Lei, Jia Yan, QianFeng Yao, and Ying Lei. "Structural Damage Detection with Cross Correlation Function of Vibration Observations." Advanced Materials Research. Vol.163. (2011).

[3] Hou, Yan Fang, and Wei Bing Hu. "Damage Detection of Historic Timber Structure Based on Cross Correlation Function Amplitude Vectors. "Advanced Materials Research. Vol. 368. (2012).

[4] Yan,Y. J.,etal."Development in vibration-based structural damage detection technique. "Mechanical Systems and Signal Processing 21.5: pp. 2198-2211. (2007).

[5] Bjorkmon, Mikael. "Evaluation of finite element tools for transient structural dynamic simulations of firing systems." (2010).

[6] Schallhorn, Charles Joseph. "Localization of vibration-based damage detection method in structural applications." (2012).

[7] Habib, Fady. Structural Health Monitoring of Adhesively Bonded Composite Joints.(2012).

[8] Wang, Le, Zhichun Yang, and T. P. Waters. "Structural damage detection using cross-correlation functions of vibration response." Journal of Sound and Vibration 329.24: pp.5070-5086. (2010).

[9] Guemes, Alfredo. “SHM Technologies and Applications in Aircraft Structures.” Proceedings of the 5th International Symposium on NDT in Aerospace, Singapore. (2013).

[10] W. Staszewski, C. Boiler, and G. Tomlinson, Health monitoring of aerospace structures: smart sensor technologies and signal processing. Hoboken, NJ, USA: J. Wiley. (2004).

[11] Sohn, Hoon, and Charles R. Farrar. "Damage diagnosis using time series analysis of vibration signals." Smart materials and structures 10.3: pp. S446. (2001).

[12] Chiu, W.K.; Koh, Y.L.; Galea, S.C.; Rajic, N. “Smart structure application in bonded repairs” Composite Structure. Vol. 50, pp. 433-444. (2000).

[13] C. M. Diwakar, N. Patil, and Mohammed Rabius Sunny“Structural Damage Detection Using Vibration Response Through Cross-Correlation Analysis: Experimental Study”.2018

[14] Le Wang, Tim P. Waters and Zhichun Yang “structural Damage detection using cross correlation functions of vibration response”.2010

[15] Sohn et al., “ A review of Structural Health Monitoring literature : 1916-2001,rep.LA13976-MS, Los Alamos National Laboratory, Los Alamos NM, USA,2004.