Structure Damage Localization by a Reliable Guided Waves Damage Detection Technique

Justin Wernette, Alex Myers, Nate Schrauben, Tiancheng Yang and Ahmed Abdelgawad
Central Michigan University
Mt Pleasant, MI

Abstract

Structural Health Monitoring (SHM) is the process of using nondestructive evaluation techniques to detect both damage location and the extent of the damage of large solid structures. In this process, sensors that generate Lamb waves through solid structures can receive information that tell the extent of damage to the solid structure, if there is any at all. These guided waves can travel at relatively large distances with very little loss in amplitude, and offer the advantage of covering a large area with a minimum of installed sensors. SHM is extremely important in monitoring the health of structures such as bridges, buildings, and airframes. In recent years, ultrasonic guided waves have been gaining momentum as an effective approach for detecting structural damage and health monitoring. These Lamb waves are not only reliable due to their sensitivity to changes in structures, but can be much more cost effective as well. Lamb waves can be transmitted and received in solids via piezoelectric transducers (PZT). If there is damage in the structure, the guided waves would be reflected or scattered by the damage. To distinguish the damage, the difference signal is acquired and compared to that of a damage free signal. For the structural damage localization, no matter the geometrical or imaging method, the key to this process is the acquired time of flight and amplitude of response of the signal. These factors directly determine the precision of the localization of the damage. The time of flight of these guided waves is linear, and is directly dependent on the properties of the material, such as its modulus of elasticity and modulus of rigidity. Finite Element analysis (FEA) simulation software, such as Abaqus, can be used to simulate guided longitudinal waves. Based on the input of the materials properties in the program, such as the materials density and modulus of elasticity, this software can simulate feedback from the sensors used to detect damage in solid structures. This software is extremely accurate, and can help to simulate damage detection results of countless real life scenarios in a quick and easy experimental manner. There are two basic active sensing techniques used to detect damage in structures; Pitch-catch and pulse-echo. In pitch-catch technique, two PZT sensors are used; one as transmitter before the damage, and the other as receiver after the damage, the received signal is then used to determine the location and/or the extent of the damage. On the other hand, pulse-echo technique relies on the reflected wave from the damage. The primary objective of this research project is to use these Structural Health Monitoring techniques and FEA software to create a low cost, high accuracy system that detects damage in solid structures. The accuracy of this system is crucial, for again failure to detect damage could result in a structural collapse. The cost of the system is important as well, for the system would be useless if it is too expensive to implement and maintain, especially if the cost outweighs the alternative damage detection technique of sending people out to manually inspect the structure for damage. From the initial familiarization of FEA software and piezoelectric transducers to real life experimentation, we have proposed a hybrid technique to detect the damage in any structure. The proposed technique is used both pitch-catch technique and pulse-echo technique. Through the simulation studies, the proposed technique produced accurate and consistent results which can be used in many SHM applications.