STEVENS INSTITUTE OF TECHNOLOGY 1870

Ph.D. DISSERTATION DEFENSE

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Degree:	Doctor of Philosophy
School/Department:	Department of Civil, Environmental and Ocean Engineering
Date:	Monday, May 1st, 2023
Time/Location:	12:00 p.m. Davidson Lab conference room (#235)
Title:	Modification of Vibroacoustic Modulation for Robustness
Chairperson:	Dr. Dimitri Donskoy, Department of Civil, Environmental and Ocean Engineering
Committee Members:	Dr. Cheng Chen, Department of Civil, Environmental and Ocean Engineering Dr. Yi Bao, Department of Civil, Environmental and Ocean Engineering Dr. Frank Fisher, Schaefer School of Engineering & Science

ABSTRACT

The Vibro-Acoustic Modulation (VAM) method is a nonlinear acoustic Nondestructive Testing (NDT) and Structural Health Monitoring (SHM) technique that employs low-frequency vibration (pump wave) and ultrasound (probe wave) to detect defects in structures. In the presence of a defect, these input waves interact at the defect area and generate a modulated output signal. The severity of the defect can be revealed by the intensity of the modulation, which is quantified by the value of the modulation index (MI). Although the VAM method has several advantages over other NDT/SHM techniques, two main problems limit its widespread implementation in the industrial field.

The first problem is the acoustic nonlinearity inherent in the intact structure. The MI value cannot distinguish between the cause of the modulation, making it difficult to identify whether the modulation is due to the defect or other factors such as material nonlinearity or contact-type structural components. Previous research attempted to address this issue by separating the Amplitude Modulation (AM) and Frequency Modulation (FM) components and assessing the structural integrity by the FM characteristics. However, a physical explanation for the FM mechanism is lacking. This study proposes theoretical models for both AM and FM phenomena, leading to the development of a baseline-free VAM-based NDT method that addresses material nonlinearity.

The second problem is the response variability, as the MI value is highly affected by the frequency of the probe wave. The use of a linear frequency sweeping signal, a chirp signal, has been employed to increase the robustness of VAM. However, previous signal processing methods did not consider the effect of the phase difference between the probe and pump waves. This study incorporates the cross-correlation algorithm to account for the phase difference. Additionally, machine learning algorithms are used to increase the robustness without the need for extra equipment or procedures compared to conventional VAM testing.
Overall, this study aims to improve the robustness of the VAM method, allowing it to be applied for solving practical NDT problems.