Defense Announcement

INTELLIGENT DETECTION OF BOLT LOOSENESS USING STRUCTURAL HEALTH MONITORING METHODS AND PERCUSSION APPROACH

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Abstract: The bolted joint has been widely used to connect different components across multiple engineering structures, while its looseness detection is an urgent issue to be solved. Recently, several piezo-enabled structural health monitoring (SHM) methods have been utilized to detect bolt looseness, including the active sensing method, electromechanical impedance (EMI) method, and the vibro-acoustic modulation (VAM) method. However, current approaches mostly focus on single-bolt looseness detection, and we still lack theoretical investigation to explore the principle of these methods.

In this dissertation, I carry out several in-depth studies to enhance the development of research in the bolt looseness detection. First, a numerical model, a semi-analytical model, and an analytical model of the active sensing method for single-bolt looseness detection is proposed, respectively. Then, several new entropy-based indices are developed to replace the current index, i.e., signal energy. Via these entropy-based indices and machine learning (ML) technique, I achieve the detection of multi-bolt looseness for the first time. Second, I theoretically develop a model to describe the relationship between bolt preload and EMI signal, thus providing a better understanding of the EMI method. Third, in terms of the VAM method, I employ swept sine waves as inputs to improve practicability, and a new entropy-based index is developed to enable the VAM method to detect multi-bolt looseness.

Moreover, considering that the above methods depend on permanent contact between transducers and structures, I propose a new percussion-based approach. By tapping the bolted joint and analyzing the percussion-induced sound signals, the bolt looseness can be detected without contact-type sensors. First, I develop an analytical model to research the mechanism of the percussion-based approach for bolt looseness detection. Then, by using deep learning (DL) based techniques to process and classify the percussion-induced sound signals under different bolt preloads, I propose two practical percussion-based approaches to detect bolt looseness detection.

Overall, several in-depth investigations of SHM methods and a new percussion-based approach for bolt looseness detection have been conducted in this dissertation. We can expect that these methods have great potential for future industrial applications.