Assessing Structural Integrity using Mechatronic Impedance Transducers with Applications in Extreme Environments

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ABSTRACT

This research reviews and extends the impedance-based structural health monitoring technique in order to detect and identify structural damage on various complex structures. The basic principle behind this technique is to apply high frequency structural excitations (typically higher than 30 kHz) through the surface-bonded piezoelectric transducers, and measure the impedance of structures by monitoring the current and voltage applied to the transducers. Changes in impedance indicate changes in the structure, which in turn can indicate that damage has occurred.

Several case studies, including a pipeline structure, a composite reinforced aluminum plate, a precision part (gear), a quarter-scale bridge section, and a steel pipe header, demonstrate how this technique can be used to detect damage in real-time. A method to process impedance measurements to prevent significant temperature and boundary condition changes registering as damage has been developed and implemented. Furthermore, the feasibility of using the technique for high temperature structures and for condition monitoring of critical facilities subjected to a severe natural disaster has been investigated.

While the impedance-based structural health monitoring technique indicates qualitatively that damage has occurred, more information on the nature of damage is necessary for remote structures. In this research, two different damage identification schemes have been combined with the impedance method in order to quantitatively assess the state of structures. One is based on a wave propagation modeling, and the other is the use of artificial neural networks. A newly developed wave propagation model has been developed and combined with the impedance method in order to estimate the severity of damage. Numerical and experimental investigations on 1-dimensional structures were presented to illustrate the effectiveness of the combined approach. Furthermore, to avoid the complexity introduced by conventional computational methods in high frequency ranges, multiple sets of artificial neural networks were integrated with the impedance-based health monitoring technique. By incorporating neural network features, the technique is able to detect damage in its early stage and to determine the severity of damage without prior knowledge of the model of structures. The dissertation concludes with experimental examples, investigations on a quarter-scale steel bridge section and a space truss structure, in order to verify the performance of the proposed methodology.

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