New Jersey Department of Transportation Bureau of Research

Research at a Glance

Technical Brief

BUREAU OF RESEARCH

Detection of Damage Precursors in Steel Components for Life-Cycle Assessment

Up to 90 percent of failures of in-service metallic structures happen due to fatigue cracks. A fatigue crack starts as a damage precursor at un-perceivable levels (such as molecular dislocation or micro cracking) when the material is subjected to repeated loading. The crack can often continue to grow to a critical size without sufficient warning, causing total failure of a structural component. Structural Health Monitoring (SHM) and Non-Destructive Evaluation (NDE) techniques are frequently used to identify, monitor and assess the evolution of damage. Today's methods are applicable to small areas of the component and are not sensitive to the earliest evolution of damage.

Research Problem Statement

A new breakthrough technology based on Nonlinear Vibro-Acoustic Modulation (VAM) is been developed. The method offers a highly sensitive testing process that will greatly enhance the current capabilities of SHM and NDE.

Research Objectives

The objective is to develop a monitoring method that:

- Works for various materials and complicated geometries;
- Is very fast (near real-time sensing);
- Interfaces with simple data output, thus does not require trained-expert evaluation and data interpretation;
- Is a **global technique** well suited for inspection and monitoring of large sections of a structure **without sensor scanning**;
- Evaluates damage severity.

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Methodology

Nonlinear VAM is one of the prevailing nonlinear methods for material characterization and structural-damage evaluation. This approach, however, does not differentiate between the amplitude and frequency modulations. The present study developed algorithms that separate the two modulations. By separating the amplitude and frequency modulations, the new algorithms address shortcomings of the Hilbert Transform and contribute to an improved non-linear acoustic method for damage detection. The algorithms have been tested both numerically and experimentally for their ability to detect the evolution of fatigue damage in the presence of additional nonlinearities provided by bolts, welding, or other structural contact interfaces.

The new algorithms have been incorporated into an N-Scan testing system that will be employable for field-testing in order to enhance its capabilities to detect damage in large-scale and full-scale structures.

Results

A new VAM system, trade name FN-Scan©, capable of data collection in the field utilizing bridge ambient vibrations, has been developed and fabricated. The system consists of 3D accelerometer for acquiring bridge vibrations for triggering, extracting resonance frequencies and amplitude normalizing, at least two ultrasonic broadband transducers for transmitting and receiving high frequency signals, signal pre-amplifier with variable gain and band-pass filter, ultrasonic power amplifier, multi-channel high speed digital acquisition system (DAQ), and a laptop computer with in-house developed software which generate signals, controls DAQ, processes received signals and stores the data.
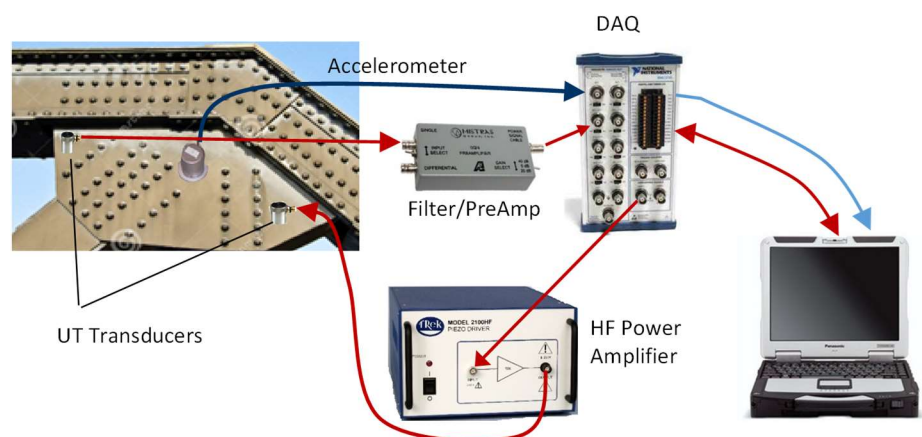
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