LA-UR-06:xxxx, 15th US National Congress on Theoretical and Applied Mechanics, Mini-Symposium on Mechanics in Structural Health Monitoring, Univ. of Colorado, Boulder, June 25 -30, 2006

Identifying Damage-Sensitive Features based on Nonlinear System Response Characteristics

Charles Farrar, The Engineering Institute, Los Alamos National Laboratory
Keith Worden, The University of Sheffield, Sheffield, UK
Mike Todd, University of California, San Diego
Gyuhae Park, The Engineering Institute, Los Alamos National Laboratory

In many cases damage causes a structure, which exhibits predominantly stationary and linear dynamic response properties in its undamaged state, to exhibit non-stationary and nonlinear properties. Common examples of such damage include cracks or delaminations that open and close when the structure is subjected to normal operating environments and loose parts rattling or sliding against one another. Another type of nonlinearity encountered in engineering systems is the bilinear stiffness characteristics exhibited by a metallic structure that yields during severe loading. An example of such damage is the yielding of steel frame civil engineering structures during an earthquake. This type of damage and its associated nonlinearity is particularly challenging to detect because of the strain-hardening characteristics exhibited by these materials.

The authors' approach is to address the structural health monitoring (SHM) problem in the context of a statistical pattern recognition paradigm. In this paradigm, the process can be broken down into four parts: (1) Operational Evaluation, (2) Data Acquisition, (3) Feature Extraction, and (4) Statistical Model Development for Feature Discrimination. This paper will focus on the feature extraction portion of the SHM process. In particular, the application of nonlinear system identification methods to the feature extraction process is discussed. This discussion begins by briefly summarizing commonly used damage-sensitive features, many of which are based on fitting linear models to measured system response data before and after damage, and their limitations. Next, two substantial illustrations of nonlinear structural dynamics applied to SHM are presented and a number of indicators for nonlinearities associated with damage are discussed. Various chaotic attractor based quantities are also used to diagnose nonlinearity in simulated piecewise linear systems that represent structures with breathing cracks. Finally, an approach based on the ideas of nonlinear system identification is used to estimate the equations of motion for SDOF and MDOF nonlinear systems. This parametric modeling not only allows the immediate characterization of the nonlinearity, but also yields information on its location. In the interest of brevity, the other portions of the statistical pattern recognition paradigm associated with each of these applications are only briefly described and the reader is referred to the appropriate references for more detailed summaries of these respective studies. The paper concludes with some discussion and conclusions regarding the application of nonlinear dynamics concepts to the SHM feature extraction problem.