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Parameters Sensitivities to Damage Initiation in a Beam-Mass System

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Variations in parameters representing natural frequency, damping and effective nonlinearities before and after damage initiation in a beam carrying a lumped mass are assessed. The identification of these parameters is performed by exploiting and modeling nonlinear behavior of the beam-mass system and matching an approximate solution of the representative model with quantities obtained from spectral analysis of measured vibrations. The representative model and identified coefficients are validated through comparison of measured and predicted responses. Percentage variations of the identified parameters before and after damage initiation are determined to establish their sensitivities to the state of damage of the beam. The results show that damping and effective nonlinearity parameters are more sensitive to damage initiation than the natural frequency. Moreover, the sensitivity of nonlinear parameters to damage is better established using a physically-derived parameter rather than spectral amplitudes of harmonic components.

I. Introduction

The understanding of how structural components endure loads, in particular variable loads, is that these components gradually, over some period of time depending on the nature of the loading and the material, develop a microcrack. After some additional time and loading, the microcrack grows to a size that might be detected. To date, structural health monitoring approaches that seek to detect cracks offer no insight into the extent of deterioration occurring in the initial stages of damage. An approach that would facilitate monitoring the extent of the deterioration in these stages promises to improve life prediction capabilities of structural components. The challenge, thus, is to develop quantitative assessment of damage accumulation from the earliest stages of the fatigue process and to provide a structure's signature that is dependent on its damage stage. One such signature is the structure's response to forced excitation; a concept that is very intuitive, yet quite challenging because of several difficulties. These difficulties include practical implementation, information loss in data reduction, and parameter sensitivities (Doebling et al.[1]).

Most of the reported damage analysis procedures of structures and their components that make use of vibration signatures relate their state of damage to a reduction in their stiffness. Consequently, the decrease in a structure's natural frequency has been proposed as a measure of its damage condition. Yet, such a reduction in the initial fatigue stages may not be large enough to be measurable. This raises the issue of whether other parameters, such as damping or geometric and inertial nonlinearities, would have a higher sensitivity to damage initiation and progression in these stages. The objective of this work is to assess sensitivities of different parameters including natural frequency, damping, and nonlinear effects to damage initiation with the goal of using representative parameters of these properties for damage identification. This objective is demonstrated through nonlinear excitations of a beam carrying a lumped mass before and after damage initiation in the beam. Vibration measurements under both conditions are then used to quantify damage-induced variations in stiffness, damping and nonlinear parameters. The identification procedure

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