A new Damage measure for Structural Health Monitoring using Reduced-Order FE models and Free Vibration Data

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Abstract

Most of the conventional damage assessment techniques (Non-Destructive Evaluation) are off-line methods and requires the structure to be put off-line. Many of the current damage detection methodologies require the availability of baseline information either by direct or indirect methods. Solving a full size Finite Element model will take enormous amount of resources in terms of computational time and memory requirements. These are very significant in addressing the problems under dynamic loading rather than in static loading. To alleviate these problems, reduced order models are used. In this paper, Finite Element based Reduced Order Model (ROM) methods like system equivalent reduction expansion process (SEREP) is used to obtain the reduced stiffness and mass matrices of healthy and damaged structures. These are used in the numerical simulation along with the free vibration data to obtain damage measures. Two new damage measures are introduced in this paper, 1) the Damage Index which is defined as the ratio of total energy of healthy structure to the damaged structure and 2) based on residue which is obtained using the equation of motion.

Free vibration response depends on the initial displacement and velocity, these parameters are studied along with the new damage measures around the damaged region (at selected master nodes) over all natural frequencies of the system. The effect of the range (band) of modes used in SEREP lying in frequency span on the response at these master nodes is discussed. 2D structures like beams and plates with and with out cracks are analyzed using the proposed methods. Damage measures are presented for different crack sizes and orientations. It is shown that the developed method can suitably be used to detect size, location and to some extent the orientation of the crack. The magnitude of the damage measure is slightly higher around crack tip.

Key words: SHM, Damage Index, FEM, reduced-order model, SEREP, Free vibration.

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