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Damage Detection of Beam-like Structures Using an Improved Genetic Algorithm

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This paper addresses a proficient strategy for detection of beams damages using the variation of eigenvalues and eigenvectors. We deal with damage detection as an optimization problem in which the difference between of the measured responses and analytical model as the objective function should be minimized. Practically, in damage detection problems the number of equations (measured parameters) is usually less than the unknown variables (damage variables). Hence, this is an undetermined problem in mathematics and has infinite solutions. So, there are many local minimums which the solution may trap on them. In addition, the severity of damage could vary within the damaged elements, and also it is possible the damaged extent doesn't exactly fit to the pre-generated finite elemental meshing. These facts were the main motivations of this work for non-uniformly modeling of elemental damage distributions by employing the proper shape functions, and also considering nodal positions as design variables. Hence, an improved genetic algorithm is introduced in which three new operators are embedded. In the first and second operators the sensitivity matrices of eigenpairs with respect to damage ratios and nodal positions are established to improve the individuals, respectively. In the last one some elements during optimization process are eliminated from damage candidates to reduce the search space. This strategy is applied to a beam structure, and the numerical results demonstrate high capacity and efficiency of the proposed method for in details structural damage detection.

Keywords: damage detection, genetic algorithm, shape function, sensitivity analysis, eigenvalue, eigenvector.

1. INTRODUCTION

The need of industry to health monitoring and curing makes damage detection techniques one of the most active fields of research in the current years. Although damage is a nonlinear phenomenon; however, it is widely accepted that the damage can be simulated by changing in some parameters such as Young's modulus, cross-sectional area, moment of inertia and/or boundary conditions, etc. In this work the damage is modelled by reduction in the Young modulus.

We deal with the damage detection as a system of nonlinear equations, in which the damage parameters like location and severity should be determined. So the analytical responses of the structure match the measured ones in an optimal way. If the number of unknown variables is more than the number of equations, so the corresponding system of equations will be undetermined and has infinite solutions. To find the damage solution uniquely, it should be noted that the true damage solution has low Euclidean norm. Also, because most of the structural elements are still intact in the damaged structure, consequently the solution has high sparsity [1, 2]. However, for time dependent responses (e.g. time history or FRF responses) the number of unknown variables, i.e. damage parameters, is usually less than the number of equations, i.e. structural responses, so the system of equations is over-determined. Generally, the nonlinear system of equations can be solved using heuristic optimization methods, sensitivity-based methods [3], or a combination of both. Gomes and silva [4] compared modal sensitivity method and genetic algorithm for structural damage detection problems. Meruane and Heylen [5] implemented a hybrid real-coded Genetic Algorithm with damage penalization to detect location and severity of structural damage. Na, et al. [6] proposed an improved structural damage detection method based on a genetic algorithm using a flexibility matrix. They introduced a new method to identify damage in a shear building with dynamic analyses. Au, et al. [7] reduced the potentially damaged elements by differences between elemental modal strain energies of intact and damaged