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Damage Identification of Truss Structures Based on Force Method

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Abstract. An computationally efficient damage identification technique for the planar and space truss structures is presented based on the force method and the micro genetic algorithm. For this purpose, the general equilibrium equations and the kinematic relations in which the reaction forces and the displacements at nodes are take into account, respectively, are formulated. The compatibility equations in terms of forces are explicitly presented using the singular value decomposition (SVD) technique. Then governing equations with unknown reaction forces and initial elongations are derived. Next, the micro genetic algorithm (MGA) is used to properly identify the site and extent of multiple damage cases in truss structures. In order to verify the accuracy and the superiority of the proposed damage detection technique, the numerical solutions are presented for the planar and space truss models. The numerical results indicate that the combination of the force method and the MGA can provide a reliable tool to accurately and efficiently identify the multiple damages of the truss structures.

AMS subject classifications: 65F99

Key words: Damage identification, truss, force method, micro genetic algorithm.

1 Introduction

The matrix structural analysis is usually carried out through two counterpart approaches known as displacement method and force method. Due to its generality and simplicity in the computer implementation, the displacement method can be considered as dominated structural analysis method and a lot of commercial software have been developed based on this method. Although, this method is an efficient approach for the stress-displacement type analysis, but it presents some disadvantages in the optimization problems when the number of stress constraints are larger than the displacement constraints [1]. In comparison with the displacement method, the force method of the

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structural analysis is appealing to engineers since the properties of members of the structure most often depend on the member forces rather than joint displacements and the formulation for optimization problems including stress constraints is relatively simple [2–5].

In general, for the force method, equilibrium equations are not adequate enough in solving the structural analysis problems and need to be augmented by the compatibility conditions. This force method can be classified into four different approaches [6]: (i) topological force method; (ii) algebraic force method; (iii) mixed algebraic-combination force method; (iv) integrated force method. Topological method was developed by several researchers [7–10] and algebraic force method was performed by many investigators [11–13]. Also the mixed algebraic-combinational force method has been used by Coleman and Pothen [14, 15], Pothen [16], Gilbert and Heath [17]. Patnaik [18, 19] developed the integrated force method, in which member forces were used as variables, the equilibrium equations and the compatibility conditions were satisfied simultaneously in terms of these variables.

Turning now to the problems of the detecting the site and extent of damage in the structural systems, considerable research efforts have been made. Among the variety of damage detection methods, the genetic algorithms (GAs) are one of the most successful search methods, and they have been applied to the problems of the multiple structural damage identification. Villalba and Laier [20] proposed the use of a self-adaptive multi-chromosome GA to locate and quantify damage in structures. A combined GA and eigensensitivity algorithm has been used by Friswell et al. [21] to identify the location and magnitude of damage from measured vibration data. He and Hwang [22] combined a real-parameter GA with simulated annealing algorithm and adaptive mechanism for finding the actual damage. Koh and Dyke [23] investigated the use of correlation-based damage detection methods for long-span cable-stayed bridges. The locations of damage were determined by iteratively searching for the combination of structural responses that maximizes the correlation coefficient through the application of GA. Gomes and Silva [24] used a genetic real coded algorithm as an optimization tool to match the damaged natural frequencies with those obtained by a parametric finite element code through a modified multiple damage location assurance criterion index. Moslem and Nafaspour [25] used a technique based on a residual force vector to define the probably damaged elements and Ananda Rao et al. [26] proposed a simple GA with binary representation, and the optimization function was formulated in terms of diagonal terms in residual force matrix. Mares and Surace [27] presented the concept of residual force vectors to specify the objective function for the optimization procedure which was then implemented by using GA.

Even though a significant amount of research has been conducted on development of the damage detection methods in structural systems, to the authors' knowledge, there was no study reported on the damage detection techniques using the force method in the literature.

In this study, the efficient numerical method to determine the site and extent of the multiple structural damages in planar and space trusses is proposed through the force