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Detecting structural damage in beams by solving the inverse problem via a CSS optimization algorithm

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Abstract

Although several publications have been presented on health monitoring of existing structures, the issue still needs further investigation. In this respect, a model updating approach is suggested in this paper that detects structural damages in beams via a meta-heuristic optimization algorithm (Charged System Search (CSS)). The model detects damages in beams by means of an objective function based on natural frequencies and mode shapes, and the effects of measurement noise are taken into consideration to make the results more realistic. The method is validated on several numerical examples the results of which indicate the efficacy of the suggested strategy.

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Keywords: Damage Detection, Optimization Algorithm, Model Updating

1. INTRODUCTION

Unexpected failures of structures of great significance such as bridges and dams throughout history, which had been designed and constructed under considerable budgets and were supposed to serve large populations, led structural engineers towards structural health monitoring. This field has successfully prevented several important structures from unpredicted collapses resulted from minor structural defects. Accordingly, damage detection in civil structures has been holding so much appeal among researchers and engineers over the past decades. Apart from identifying the existence of these defects, determining their severity and location is also of great importance as it allows engineers to take action to repair and restore the affected parts long before the entire structure fails. As a result, several publications have been devoted to this area, each of which has dealt with a certain aspect of the problem. Of all different approaches suggested by scholars to tackle the problem of damage detection, vibration-based techniques have been among the most successful methods, reviews on different approaches of which have been presented in a wide range of papers [1-5]. Finite element model updating of structures, which is among the most commonly used damage detection techniques so far developed by researchers, is known as one of the most practical methods to identify defects in a diversity of structures. This finite element-based approach, which still is under further development despite a large number of papers published, has been reviewed in many review papers such as the paper presented by Alkayem et al. in 2018 [6].

In the field of structural damage diagnosis, Kang et al. presented a damage detection scheme using an immunity enhanced particle swarm optimization (IEPSO) algorithm, in which natural frequencies and modal shapes are used to define an objective function. Their method has been tested on several numerical examples to show the efficiency of their method [7]. Zordan et al. developed a finite element model updating technique to detect structural damage in a reinforced concrete bridge using Douglas-Reid method mixed with Rosenbrock optimization algorithm [8]. In a research presented by Ding et al., a technique has been suggested to solve the problem of damage detection of a truss and a plate using the Artificial Bee Colony (ABC) with hybrid search based on modal data, where the method has been compared with other optimization algorithms [9]. Cuckoo search algorithm has been used as the optimization technique to solve the problem of damage detection via frequency residual error and the modal assurance criteria (MAC) in a study conducted by Xu et al. [10]. Moreover, structural damage has been evaluated by Safari and Gholizad