Optimal Sensor Network for Health Monitoring of Strap-braced Cold Formed Steel Frame

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Abstract
The problem of sensor placement is a fundamental part of dynamic testing, modal identification, damage detection and structural health monitoring (SHM) of structures. This paper is considered with the problem of optimal placement of sensors on a strap-braced cold formed steel frame in order to identify modal parameters of the frame for the purpose of structural health monitoring. Several optimal sensor placement methods are applied to the verified numerical model of the strap braced cold formed steel frame and different criteria are employed to evaluate the performance of the methods. The results show that among the methods, effective independence and effective independence-driving point residue methods provide commendable methodologies for optimal sensor placement of the frame. They have the ability to guarantee the criteria, as well as the deployment of sensors in a uniform fashion for the frame.
Keywords: Optimal sensor placement, cold formed steel, Strap brace, Modal analysis.

1. INTRODUCTION

The problem of sensor placement is a fundamental part of structural health monitoring (SHM) of structures. Because of the limited number of sensors installed in a structure, deciding on an optimal configuration of sensors can be an important issue in implementation of an effective structural health monitoring of structure. The design of an optimal sensor configuration causes to minimize the number of sensors required and to optimize the places sensors installed in to increase accuracy and robustness of the system. In optimal sensor placement (OSP) problems, the parameters of a structure, described in terms of continuous functions from the set of infinite degrees of freedom (DOFs), need to be identified using discrete sensor information. Therefore, OSP deals with how many and which DOFs the sensors should be installed in from the set of infinite DOFs of a structure. Correspondingly the OSP objective can be defined as selecting the appropriate DOFs for the sensor placement in order to robustly identify the structural behavior. Numerous techniques have been developed for solving the OSP problem and are widely reported in the literature. The main aim of this paper is to find the best solution for the problem of placing m sensors on a strap-braced cold formed steel (CFS) frame at locations which will provide the best fit to a set of n target mode shapes. The layout of the paper is as follows: At the first step, the researches deal with OSP techniques are reviewed; Then a brief description of the strap-braced CFS frame as the structural system for OSP is given; Thirdly the modeling process for the frame is presented in detail; Then, several algorithms are employed to conduct the OSP for modal identification of the frame; different evaluation criteria are applied to assess the results obtained by the OSP techniques; finally, based on the criteria, the most appropriate method for OSP of the strap-braced CFS frame is proposed.

In the past two decades, OSP approaches with various placement techniques and criteria have become the subject of several studies in SHM area especially in the case of modal identification. In most cases, an optimal configuration is one which provides the best observability and distinguishability of the identified target modes [1]; e.g., methodologies based on maximization of the determinant of the Fisher information matrix (FIM) [2, 3], minimization of the off-diagonal elements of the modal assurance criterion (MAC) matrix [4], the QR decomposition of the modal matrix [5], degree of observability [6], information entropy [7], and adequate robustness with respect to a given level of model uncertainty [8]. Numerous techniques have been advanced for OSP problem with aforementioned objectives. These have been developed using a number of approaches, some based on intuitive or heuristic approaches, others employing systematic optimization methods. Among them, one of the most common OSP methodologies called the effective independence method (EFI) used for the SHM was proposed by Kammer in 1991 [2]. Cheng accelerated the optimization process by developing a backward deletion algorithm which was based on an improved modal