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Damage identification by response surface based model updating using D-optimal design

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ABSTRACT

Statistical tools, as well as mathematical ones, have been widely adopted and their performance has been shown in different engineering problems where randomicity usually exists. In the realm of engineering, merging statistical analysis into structural evaluation and assessment will be a tendency in the future. As a combination of mathematical and statistical techniques, response surface methodology has been successfully applied to design optimization, response prediction and model validation. This methodology provides explicit functions to represent the relationships between the inputs and outputs of a physical system, which is also a desirable advantage in damage identification. However, so far little research has been carried out in applying the response surface methodology to structural damage identification. This paper presents a damage identification method achieved by response surface based model updating using D-optimal designs. Compared with some common designs constructing response surfaces, D-optimal designs generally require a minimum number of numerical samples and this merit is quite desirable when analysts cannot obtain enough samples. In this study, firstly D-optimal designs are used to establish response surface models for screening out non-significant updating parameters and then first-order response surface models are constructed to substitute for finite element models in predicting the dynamic responses of an intact or damaged physical system. Three case studies of a numerical beam, a tested reinforced concrete frame and a tested full-scale bridge have been used to verify the proposed method. Physical properties such as Young's modulus and section inertias were chosen as the input features and modal frequency was the only response feature. It has been observed that the proposed method gives enough accuracy in damage prediction of not only the numerical but also the real-world structures with single and multiple damage scenarios, and the first-order response surface models based on the D-optimal criterion are adequate for such damage identification purposes.

1. Introduction

There has been a large volume of research devoted to vibration-based methods for damage identification of engineering structures during recent years [1,2]. Besides some approaches by establishing precise finite element (FE) dynamic models for direct damage detection [3,4], damage evaluation techniques using measured modal data are often based on the model

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