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Crack identification in a freely vibrating plate using Bayesian parameter estimation

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ABSTRACT

In this paper a new approach is proposed for identifying the presence and location of a crack in a simply supported plate undergoing free vibration. Specifically, the approach uses a Markov-chain Monte-Carlo implementation of Bayes' Rule to estimate the crack parameters (i.e., its location, orientation, and size) and their probability distributions. Special attention is paid to developing a fast and accurate forward model for the response of the cracked plate. To generate the required time series, a semi-analytical free response is calculated using an FEM based eigen-solution. To speed up the simulations, modified elements are used at the crack tips; this permits a more course mesh without sacrificing accuracy. The approach is demonstrated to be effective at identifying all of the crack parameters. Furthermore, a natural by-product of this method is that it also provides a confidence (credible) interval for each of these parameters. The results show the utility and accuracy of this method in identifying cracks of various sizes, orientations, and locations.

1. Introduction

Plates appear in a broad range of engineering applications, from small-scale MEMS components to large-scale naval and aerospace systems. Damage in general, and cracks in particular, undermine the viability of these structure and may lead to reduced performance and shorter lifetimes, while opening the door to catastrophic failure. As such, it would be desirable to develop a reliable, automated method for accurately identifying the presence, location, and size of a crack. The key features of an ideal non-destructive crack detection method would include (i) the ability to find small cracks using a minimum number of sensors and limited data, (ii) the system would work in real-time and be reliable (repeatable results that are independent of the operator), (iii) the method would be impervious to environmental changes (i.e., temperature, humidity, etc.) in the field, and (iv) the approach would not require response information from a pristine, undamaged structure.

While there have been many damage *detection* methods proposed, there are relatively few references related to crack *identification* in plates. Ultrasonic devices are commonly used in industry, but their search radius is very small; so some information about the location of the damage is needed *a priori*. Additionally, ultrasonic methods rely in large extent on an expert operator to reliably identify crack-related signatures. X-ray devices are also used in industry to detect damage, but they too yield a spatially local approach that tends to perform poorly in identifying closed cracks. The use of X-rays to detect cracks was developed before World War II, and was used to inspect tanks used in the Manhattan Project [1]. In response, a number of researchers have attempted to use a global, vibration-based approach to damage detection. The

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