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The Fourier Virtual Fields Method for the identification of material property distributions

by

TRUONG THO NGUYEN

A Doctoral Thesis

submitted in partial fulfilment of the requirements

for the award of

Doctor of Philosophy of Loughborough University

Loughborough University, United Kingdom

Abstract

THE FOURIER VIRTUAL FIELDS METHOD FOR THE IDENTIFICATION OF MATERIAL PROPERTY DISTRIBUTIONS

– TRUONG THO NGUYEN –

April, 2013

The requirement of a fast and accurate modulus identification technique has arisen in many fields of research, such as solid mechanics, structural health monitoring, medical diagnosis, etc. An inverse technique based on an appropriate interpretation of the principle of virtual work, namely the virtual fields method, has been proposed in the literature, which is able to return elastic modulus values after a single matrix inversion. An extension of the virtual fields method to the spatial frequency domain in order to determine modulus distributions of materials based on a sine/cosine parameterisation of the unknown modulus is developed in this thesis, and will be called the Fourier-series-based Virtual Fields Method (F-VFM). The technique accepts in-plane (two-dimensional) or volumetric (three-dimensional) deformation measurement data as its input. An efficient numerical algorithm of the F-VFM based on the fast Fourier transform is presented, which can return thousands of unknown Fourier coefficients within a minute thus reducing the computation time by several orders of magnitude compared to a direct implementation of the F-VFM for typical dataset sizes. The F-VFM technique is also adapted to cope with a common situation in experimental mechanics where the knowledge of the boundary conditions is limited. The three versions of the F-VFM in this situation are respectively the 'experimental traction', 'windowed traction' and 'Fourier-series traction' approaches. The technique is then validated with numerical data from different stiffness patterns. The performance is compared to that of an iterative updating technique based on a genetic algorithm for one of these patterns, and computational effort is demonstrated to be at least five orders of magnitude less for the new F-VFM than for this updating method. The sensitivity of the performance of the F-VFM to noise is also investigated. Finally, the technique is applied to experimental data in both 2-D and 3-D cases with promising results.

KEYWORDS: Inverse problems, stiffness distribution identification, virtual fields method, Fourier series, fast algorithm, Fourier transform, genetic algorithm.

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