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Enhanced meta-modelling technique for analysis of mode crossing, mode veering and mode coalescence in structural dynamics

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ABSTRACT

In this paper, an enhanced meta-modelling procedure for the approximation of structural eigenfrequencies and eigenvectors is introduced. The procedure allows for correct prediction of the modal parameters in case of mode crossing, veering, and coalescence phenomena that can be observed when variations of the structural parameters occur. The procedure overcomes the erroneous approximation of these phenomena which results from a direct approximation of the modal parameters. The methodology is based on the response surface approximation of the structural matrices and on the concept of modal reduction. A comparison with a direct response surface approximation of the eigenfrequencies shows a considerable improvement in the accuracy as it is presented for a finite element frame structure.

1. Introduction

Meta-models [1] are particularly beneficial within the design phase, where the designer is analysing various features of the product for differing values of the structural parameters, aiming to provide a prototype of the final product. Various types of numerical analysis and experimental testing are performed in order to improve the quality of the component and to achieve industrial standards. The sensitivity [2,3] of structural properties of the component with respect to specific parameters and parameter combinations is especially of interest. The influence of inherent variability of structural parameters needs to be investigated for designing a robust product. In context of uncertainty quantification in structural dynamics [4], meta-models provide a versatile tool for fast approximation of structural response quantities such as displacements and velocities or structural properties such as eigenfrequencies and mode shapes as a function of structural parameters varying with respect to a reference configuration. The utilisation of response surfaces provides an approximate solution based on finite element results obtained from a planned design of experiments (DOE) and avoids a repeated solution of the full finite element model which may be computationally demanding.

A large number of different meta-modelling procedures are known, such as, for instance, linear regression [1], polynomial interpolation [5], kriging [6], radial basis functions [7], etc. Each of these procedures has some areas of application for which it is especially suitable to be utilised. A descriptive and comparative assessment of meta-modelling techniques can be found in many references (see e.g. [8,9]). All methods have in common that their range of application is limited by the number of design variables; i.e., these meta-modelling techniques are of restricted applicability due to the curse of dimensionality. However, for many problems it can be shown that there is only a dependence on few (i.e. less than 20–25) parameters. These parameters can

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