Accepted Manuscript

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PII: S0997-7538(17)30539-9

DOI: 10.1016/j.euromechsol.2017.10.007

Reference: EJMSOL 3506

To appear in: *European Journal of Mechanics / A Solids*

Received Date: 10 July 2017

Revised Date: 5 October 2017

Accepted Date: 30 October 2017

Please cite this article as: Belgaid, H., Bouazzouni, A., Vibration analysis of mechanical structures with a new formulation of the isogeometric collocation method, *European Journal of Mechanics / A Solids* (2017), doi: 10.1016/j.euromechsol.2017.10.007.

Vibration analysis of mechanical structures with a new formulation of the isogeometric collocation method.

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Abstract We propose and validate a new formulation of the isogeometric collocation method, IGA-C in short, for the dynamical analysis of mechanical structures with ideal and special boundary conditions. Precisely, a new method of imposing the boundary conditions is developed. We apply this new formulation to selected models of thick beams, helical springs and composite beams. The detailed results are discussed and compared to recently published works in the aim of appreciating the presented models and determining the parameters of their optimal use. In particular, our results are compared with those obtained by different methods as isogeometric Galerkin, Tchebyshev pseudo-spectral, transfer matrix and finite element methods.

In this paper, our method is developed based on IGA-C. However, it can be based on other numerical methods as well. In addition, it may be of great help for developing automatic algorithms in simulation software.

Highlights

- Isogeometric collocation method for vibration analysis of mechanical structures.
- Ideal and non-ideal boundary condition imposing method.
- Effects of damaged boundaries on the dynamical behaviour of mechanical structures.
- Accuracy, robustness and computational efficiency verified in convergence studies.
- Application to Timoshenko beams, helical springs and composite beams.
- Simplify the implementation of the isogeometric method in mechanical structures analysis.

Introduction

The prediction of the dynamic behaviour of structures is important in many applications relevant to mechanical, aeronautical or civil engineering. Thickness of beams and plates may be great enough so that transverse shearing effects and rotation inertia may not be neglected contrarily to what is supposed in classical theories like Bernoulli's model. Furthermore, structures may contain damage, discontinuities or special boundary conditions. In the last few years, more interest has been devoted for modelling such structures. These models are formulated as partial derivative equations (PDE) coupled with initial or/and boundary conditions.

Various methods were successively proposed for the resolution of such PDE problems, each one trying to remedy to the failures of the preceding ones. In the chronological order, we may cite the finite differences method, the finite element method (FEM), the collocation methods (pseudo-spectral methods) [1], the isogeometric method (IGA) [2] and finally the isogeometric collocation method (IGA-C) [3]. In what follows, we summarize the advantages and the disadvantages of those methods that brought us to investigate and develop further the isogeometric collocation method.

Nowadays, most of the software developed for the structures analysis uses the FEM. This method had a very broad diffusion and proved to be reliable in many applications. However, it remains limited and not very effective for approximating a certain number of fields of solutions. For example, the polynomial functions like Lagrange or Hermit ones that traditional FEM uses as shape functions do not accurately represent the fields of solutions of circular or elliptical form [2], i.e. there is no polynomial parametric description capable of accurately representing circular and elliptical solutions shapes. In addition, the polynomials basis, quickly become unstable with the increasing degree of approximation (p-refinement). As a consequence, these proprieties limit the precision.