



HAL
open science

Reduced order modeling of rotating structures featuring geometric nonlinearity with the direct parametrisation of invariant manifolds method

Adrien Martin, Andrea Opreni, Alessandra Vizzaccaro, Loic Salles, Olivier Thomas, Attilio Frangi, Cyril Touzé

► To cite this version:

Adrien Martin, Andrea Opreni, Alessandra Vizzaccaro, Loic Salles, Olivier Thomas, et al.. Reduced order modeling of rotating structures featuring geometric nonlinearity with the direct parametrisation of invariant manifolds method. NODYCON 2023, Third International Nonlinear Dynamics Conference, 18 - 22 june 2023, Rome, Italy, Sapienza, Universita di Roma, Jun 2023, Roma, Italy. hal-04126358

HAL Id: hal-04126358

<https://hal.science/hal-04126358>

Submitted on 13 Jun 2023


HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.


L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.


Reduced order modeling of rotating structures featuring geometric nonlinearity with the direct parametrisation of invariant manifolds method


Adrien MARTIN¹, Andrea OPRENI², Alessandra VIZZACCARO³,

Loïc SALLES⁴, Olivier THOMAS⁵, Attilio FRANGI² and Cyril TOUZÉ¹

¹IMSIA, ENSTA Paris, CNRS, EDF, CEA, Institut Polytechnique de Paris, Palaiseau, France 

²Department of Civil and Environmental Engineering, Politecnico di Milano, Milano, Italy 

³Department of Engineering Mathematics, University of Bristol, Bristol, England 

⁴Departement of Aerospace & Mechanical Engineering, University of Liège, Liège, Belgium 

⁵Arts et Métiers Institute of Technology, LISPEN, HESAM Université, Lille, France 

Abstract. The direct parametrisation method for invariant manifolds (DPIM) is applied to rotating structures. Reduced-order models of arbitrary order expansion can be derived for non-autonomous systems of nonlinear differential equations stemming from finite element models of continuous structures. The method is applied to a rotating simplified fan blade with comparisons to full order model simulations.

Introduction

Aircraft engine manufacturers are developing larger systems with longer blades where the geometric nonlinearity is enhanced. As a result, the derivation of efficient reduction method to tackle such problems at the design stage is important.

This work addresses the application of the direct parametrisation method for invariant manifolds (DPIM), following the implementation proposed for non-autonomous problems in [2], to rotating structures subjected to large displacements. This method relies on the assumption that the unknowns of the problem, displacement and velocity, as well as the reduced dynamics equation, can be expressed under the form of arbitrary orders polynomials of the new coordinates of the problem, the *normal coordinates*. Examples of such developments are given for the displacement, eq. (1), and the reduced dynamics, eq. (2). More details are given in a dedicated paper [1].

$$\mathbf{u}(t) = \Phi \mathbf{z} + \sum_{p=2}^{o_a} [\psi(\mathbf{z})]_p + \sum_{p=0}^{o_{na}} [\hat{\psi}(\mathbf{z})]_p \quad (1) \quad \dot{\mathbf{z}} = \Lambda \mathbf{z} + \sum_{p=2}^{o_a} [\mathbf{f}(\mathbf{z})]_p + \sum_{p=0}^{o_{na}} [\hat{\mathbf{f}}(\mathbf{z})]_p \quad (2)$$

Results and discussion

The method is applied to a simplified fan blade, shown in fig. 1a, which is 1 m long. The Campbell diagram is given in fig. 1b and shows the classic stiffening of the structure with increasing rotation speed. Finally, comparison between full order simulation and ROM computations using a single master mode, are shown in fig. 1c (blue : 0 rpm; red : 2000 rpm). One can observe the perfect match between the reduced model (dashed line) and the full model (solid line) highlighting the efficiency of the method, coupled to a significant time saving in terms of computation (1 day versus 1 minute).

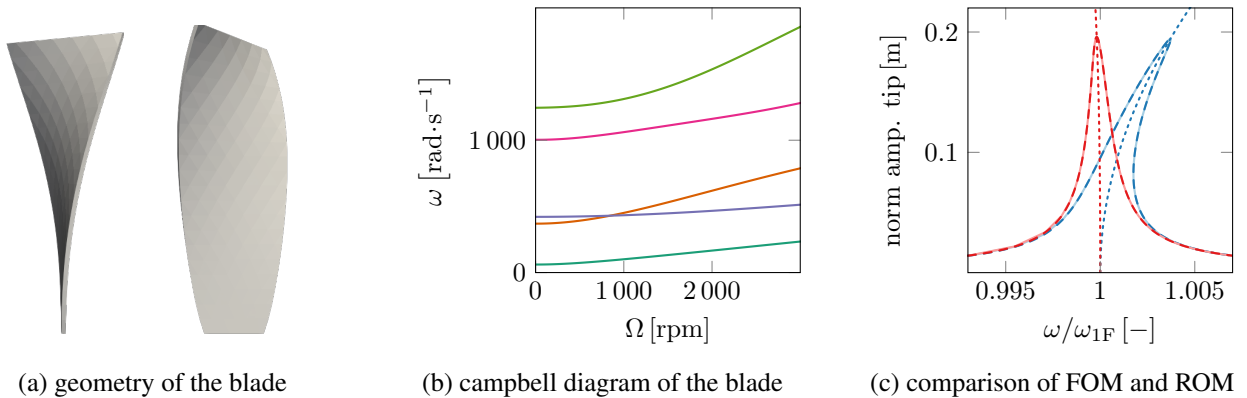


Figure 1: Reduced order model of a simple rotating blade;

(b) : — : 1F; — : 2F; — : 1T; — : 1E; — : 3F; (c) : — : FOM; - - - : DPIM $\mathcal{O}(5, 4)$; ···· : DPIM $\mathcal{O}(5)$

References

- [1] A. Martin, A. Opreni, A. Vizzaccaro, L. Salles, A. Frangi, O. Thomas, and C. Touzé. Reduced order modeling of slender structures subjected to centrifugal effects using the direct parametrisation of invariant manifolds. *in preparation*.
- [2] A. Opreni, A. Vizzaccaro, C. Touzé, and A. Frangi. High order direct parametrisation of invariant manifolds for model order reduction of finite element structures: application to generic forcing terms and parametrically excited systems. *Nonlinear Dynamics*, accepted, 2022. doi:10.21203/rs.3.rs-1359763/v1.