DYNC: a Cast3M module for the bifurcation analysis of nonlinear mechanical vibrations

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Abstract. This work presents a recently developed implementation of numerical methods for vibration problems involving nonlinear mechanical systems in the finite element software Cast3M. Branches of periodic solutions (as well as their bifurcations) are found through a combination of harmonic balance and pseudo arc-length continuation. Current tests show promising results in terms of performance and accuracy, namely regarding strong nonlinearities such as impacts.

Introduction

The need for numerical methods capable of tackling nonlinear differential equations has motivated a great deal of research over the course of the past few decades, leading to the creation of efficient and robust programs dealing with such problems as the computation and continuation of (quasi-)periodic solutions, stability analyses, and bifurcation tracking for generic dynamical systems. The most widely-known example is probably the software AUTO [1], which employs orthogonal collocation techniques coupled with arc-length continuation to compute branches of solutions with respect to the system's parameters. With MANLAB [2], the same types of problems are solved through the use of a frequency-domain (harmonic balance, *HMB*) approach and asymptotic continuation. While the generic nature of these and other freely-available codes offers great flexibility, they are seldom used for the analysis of large-scale finite element models, as this functionality is not an intrinsic part of their current versions. This fact suggests that a numerical toolbox which similar capabilities, but streamlined for the analysis of structures and integrated in a finite-element software, would be very convenient for engineering applications. The objective of this paper is to present such a toolbox, which has been implemented in the open-source multi-physics code Cast3M [3].

Principle and workflow

The starting point of a DYNC calculation is a modal-basis representation of a given system, which is obtained easily thanks to the built-in functions of Cast3M. An arbitrary number of nonlinearities are then defined by the user directly in modal form, in terms of physical coordinates, or a combination of both. An initial periodic solution to the equations of motion is found by the HBM/AFT procedure (see, for example, [4]). This allows quite strong nonlinearities to be treated, such as stiff, intermittent contacts with friction, which are ubiquitous in practical engineering studies. Afterwards, pseudo arc-length continuation is used to find solution branches, along which stability is evaluated and codimension-1 bifurcations are computed. Three types of computations are currently supported: forced response, autonomous (self-excited) response, and nonlinear modal analysis.

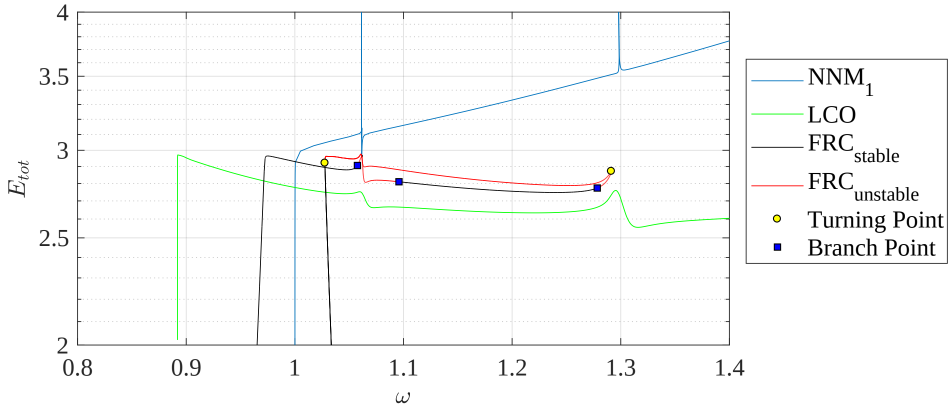

Figure 1: Example: Forced response (FRC), first Nonlinear Mode (NNM) and flow-induced Limit Cycles (LCO) for a cantilever beam with stiff two-sided stops.

References

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[4] Alcorta R., Baguet S. et al. (2019) Period doubling bifurcation analysis and isolated sub-harmonic resonances in an oscillator with asymmetric clearances. *Nonlinear Dyn*, **98**(4):2939-2960.