Identification of primary and secondary resonances: experimental continuation and broadband data-based modeling

Dario Anastasio[*], Ghislain Raze[**], Stefano Marchesiello[*] and Gaëtan Kerschen[**]
[*] *Politecnico di Torino, Dipartimento di Ingegneria Meccanica e Aerospaziale*
[**] *University of Liège, Aerospace and Mechanical Engineering Department*

Abstract. This paper presents a comparative study of two sets of techniques for identifying primary and secondary resonances in nonlinear dynamic systems: experimental continuation and broadband data-based modeling. The former refers to methods integrating control and continuation processes to empirically derive the bifurcation diagram of a nonlinear system. These approaches do not require a model, but the need for a controller introduces complexity in the experiments. Conversely, broadband data-based modeling uses wide-spectrum excitation data to develop a nonlinear model of the system. Proper model validation is crucial in this process to ensure accurate results. In this work, the comparison is carried out using an electronic Duffing system. Results show that both approaches can accurately identify primary and secondary resonances and highlight advantages and disadvantages of each.

Introduction

Over recent decades, significant efforts have been dedicated to developing effective techniques for identifying nonlinear systems - that is, constructing a mathematical model from experimental data. However, this process remains challenging and requires care in the validation and use of the estimated model. Among the available methods, nonlinear subspace identification has been used recently to estimate the nonlinear frequency response curves (NFRCs) and study the stability of several nonlinear systems starting from broadband input-output data (HB-NSI method) [1]. In this case, frequency responses are predicted by the model rather than obtained directly from experiments. Their experimental derivation is challenging in nonlinear systems, and several powerful methods have been developed recently to this end, taking advantage of feedback control loops and experimental continuation. In particular, phase-locked loop (PLL) and arc-length control-based continuation (ACBC) methods proved to be effective in different scenarios [2], provided that a non-invasive controller with proper tuning is adopted. This step is the most critical and is generally done by trial-and-error.

Results and Discussion

An electronic Duffing system is driven through high-level random excitation in an open-loop setting to identify its NFRCs across different frequency regions with the HB-NSI method. These frequency response curves are also obtained empirically by experimental continuation in a closed-loop setting. The comparison is first carried out on the primary resonance, and then on 2:1 and 3:1 secondary resonances, which are particularly challenging. The results show that the two approaches yield nearly identical NFRCs around the primary resonance, while minor discrepancies are observed on secondary ones (Figure 1). This proves the reliability of the two approaches in capturing the nonlinear behavior in different resonance regions.

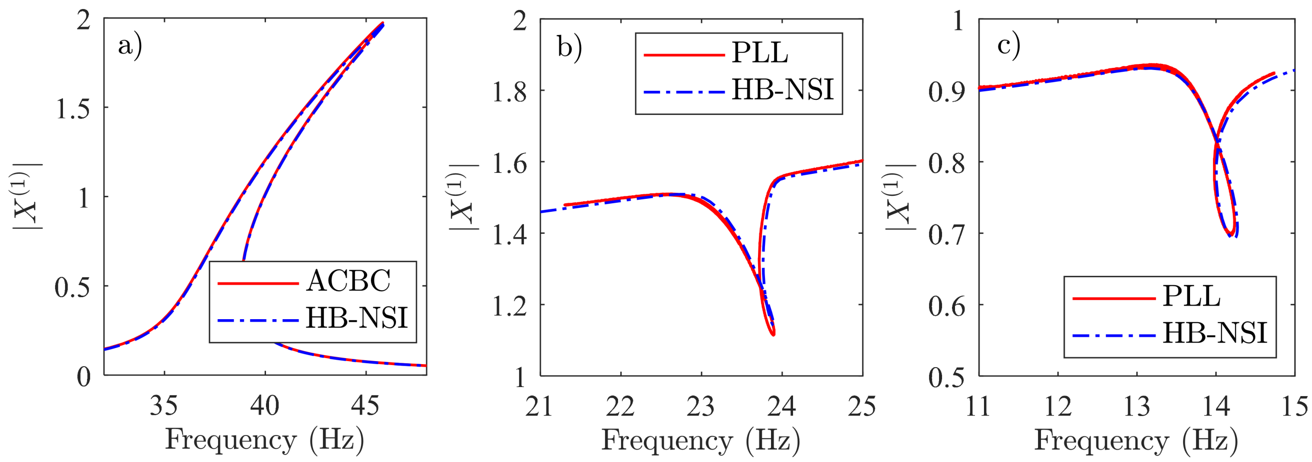

Figure 1: NFRCs of the electronic Duffing system. a) Primary resonance; b) 2:1 resonance; c) 3:1 resonance.

References

[1] Anastasio D., Marchesiello S. (2023) Nonlinear frequency response curves estimation and stability analysis of randomly excited systems in the subspace framework. Nonlinear Dyn, **111**:8115-8133.

[2] Abeloos, G. (2022) Control-based methods for the identification ofnonlinear structures. Doctoral Thesis, University of Liege, Liege, Belgium.