Experimental Analysis of a Nonlinear Piecewise Multi-Degrees of Freedom System

Cristiano Martinelli*, Andrea Coraddu** and Andrea Cammarano †

* *Department of Naval Architecture, Ocean & Marine Engineering, University of Strathclyde, U.K.*

** *Department of Maritime and Transport Technology, Delft University of Technology, The Netherlands*

† *James Watt School of Engineering, University of Glasgow, U.K.*

Abstract. The growing industrial demand for lightweight and low-carbon emission systems is eroding the safety factors adopted in the linear design of vehicles and structures. This exposes the ultimately nonlinear nature of mechanical systems, creating the need for a better understanding of their nonlinear behaviour. In this context, we have experimentally investigated the dynamic behaviour of a nonlinear two-degree-of-freedom mechanical system with piecewise stiffness characteristics. The system is clamped at both ends and one constraint is directly excited by a shaker. The system allows the adjustment of non-contact gaps and stiffness of the piecewise characteristic and provides a valuable resource for the validation and verification of numerical studies in this field. The experimental results show the very rich dynamics of the system, revealing the presence of quasi-periodic, chaos, and multi-periodic responses as well as branches of bifurcating stable solutions.

Introduction

The need for high-performance and lightweight mechanical structures is revealing the intrinsic nonlinear nature of mechanical systems [1, 2, 3]. Between them, piecewise-smooth dynamical systems represent a particular class of systems which find practical applications in the study of mechanical oscillators and aeroelastic systems with free-play gaps, linear-capsule and impact drilling systems, the description of aerodynamics forces, foldable wings for low carbon emission aircraft, mechanical gear systems, non-linear energy harvesters, and non-linear vibration suppression systems. Nevertheless, in the literature, only a few experimental studies account for nonlinear Multi-Degrees of Freedom (MDOF) mechanical systems with piecewise characteristics, and most of them are dedicated to structures with free ends, like nonlinear energy sinks [4]. Moreover, the large majority of these studies provide only a limited amount of data, generally referring only to a single feature, e.g. a single orbit, and neglecting the rich dynamics content of these systems. Thus, in this paper, we propose a detailed experimental analysis of the dynamics of a nonlinear MDOF piecewise system, focusing attention on the nonlinear transfer functions and system attractors.

Results and discussion

The experimental test rig is constituted of masses, supports, and stoppers with adjustable positions, and the analysis is carried out at different excitation amplitudes and frequencies to highlight the details of its dynamics. The experimental results show the presence of quasi-periodic, chaotic, and multi-period responses which can co-exist at the same excitation frequency, as shown in Figure 1.

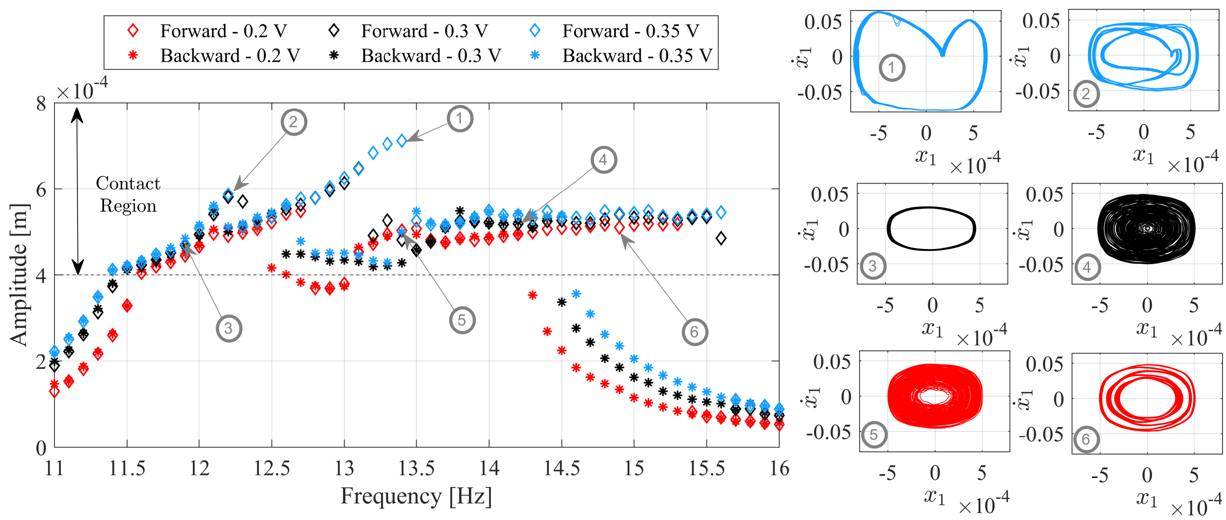

Figure 1: Experimental nonlinear transfer functions between the input sinusoidal voltage applied on the shaker and the impacting mass displacement for forward/backward frequency sweeps (left) and some associated orbits (right).

References

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