Influence of stopper hardness on the nonlinear dynamics of a beam-based system: an experimental study

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Abstract. The nonlinear dynamics of beam-based systems with impacting stoppers is investigated. Stopper cases are introduced involving variation of following stopper gap distance from the beam. Vibration experimental analysis using methods, such as harmonic and free vibration tests are performed to extract the linear and nonlinear dynamic characteristics. These results will be verified using an analytical and numerical solution. Natural frequencies, bifurcation diagrams, phase portraits, Poincaré maps, and frequency response curves will be investigated to characterize the nonlinear response and fundamentally understand the physics of beam-based systems subject to contact/impact. Results from this work can contribute to prevention of premature wear by avoiding the ranges of frequencies that exhibit chaotic responses increasing the overall lifetime of systems.

Introduction

Understanding the unpredictability of contact/impact nonlinearities is a highly motivated subject [1]. Complex systems have become embedded into the modern world, so it is important to understand the unique challenges associated with these systems. Experimental testing has been extensively used to investigate the modal behavior of systems, such as a cantilever beam. In this work, the contact/impact problem in a mechanical system with different kinds of stoppers, from very flexible to rigid (route to impact) is experimentally investigated [2]. These solutions are verified using analytical solutions provided by Euler-Bernoulli beam theory and the characteristic equation associated with the beam's boundary conditions. Complex systems, especially those exhibiting nonlinear behaviors, are unpredictable and difficult to analyze. For this reason, a system without contact/impact is first investigated. The impact of varying stoppers on the nonlinear characteristics of the system displayed in Figure 1 will be highlighted through frequency responses, phase portraits, Poincaré maps, and bifurcation analyses.

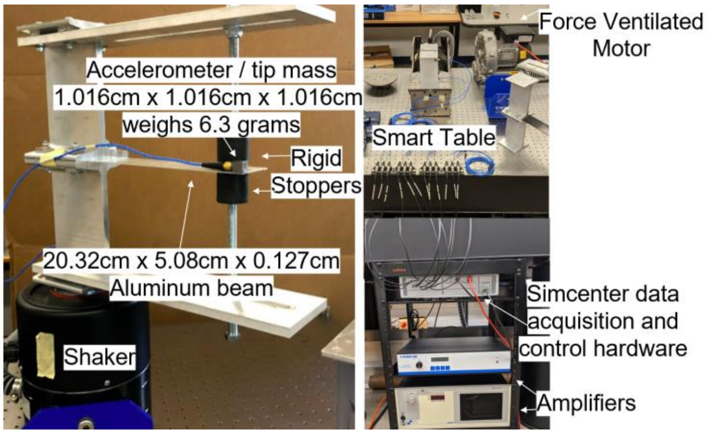

Figure 1: Experimental setup consisting of a cantilever beam with tip mass and stoppers excited by a shaker.

Results and discussion

Understanding the effects of contact/impact events will help foreshadow behaviors that would not be predicted in a linear model. First, a cantilever beam system is analyzed analytically to obtain transverse bending mode frequencies. The beam is then examined using multiple simulations in SolidWorks® to produce a reliable numerical solution. The bending modes are compared between the finite element solutions, analytical solutions, and experimental results. After this validation is complete, experimental nonlinear characterization for these systems' outputs when subjected to contact will be conducted. In order to address a wide range of contact/impact problems, the model is designed with the ability to be reconstructed into infinite configurations.

References

[1] de Langre, Emmanuel & Lebreton, G.. (1996). An experimental and numerical analysis of chaotic motion in vibration with impact. 328. 317-321.

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