Nonlinear dynamic substructuring with localized nonlinearities

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Abstract. The present work deals with the analysis of nonlinear systems in which the main source of nonlinearities can be localized at the interface between the connected subsystems. The nonlinear dynamics of the assembly is found using a substructuring technique set in the modal domain: the connected subsystems are assumed to behave linearly and thus described through their Linear Normal Modes while the nonlinear connections are regarded as auxiliary nonlinear substructures using their Nonlinear Normal Modes. The substructuring procedure is applied on a discretized continuous system to evaluate the effects of modal truncation either on the resonance frequencies and on the mode shapes of the complete system.

Introduction

The approximation of considering mechanical systems as linear might not be valid in many engineering structures where the nonlinearities significantly affect their dynamics, as in the automotive or aerospace sectors. In particular, it is very common that the main source of the nonlinear effects is localized at the connecting interface between coupled subsystems. Inspired by the work of Kuether and Allen [1], a Nonlinear Coupling Procedure (NLCP) in the modal domain is developed [2] to analyze the dynamics of these assemblies. Since it is assumed that the connections are significantly more nonlinear than the connected subsystems, the former are considered as auxiliary nonlinear substructures, while the latter are assumed to behave linearly. The nonlinear effects due to the connections is accounted by computing their Nonlinear Normal Modes (NNMs). This technique allows to obtain the main backbone of the NNMs of coupled assemblies and it can be used to analyze the behavior of real systems [3]. In this work, this technique is validated on a discretized continuous system composed of two beams of equal length and material but different thicknesses and connected together through two cubic springs.

Results and discussion

The results of the NLCP are compared to those obtained performing the Harmonic Balance method with one harmonic on the system. The comparison between the first five NNMs is shown in Figure 1. It is possible to see that the NLCP manages to retrace the main backbone of the NNMs in a wide energy range, even in the areas in which there is a significant variation of the resonance frequency, as for the third and fifth mode. It is important noticing that the method can only retrace the main backbone of each NNM since it is based on a quasi-linear approximation. However, it still provides very meaningful results, since in most of the cases the main behavior of the system is needed and super-harmonics effects can be neglected.

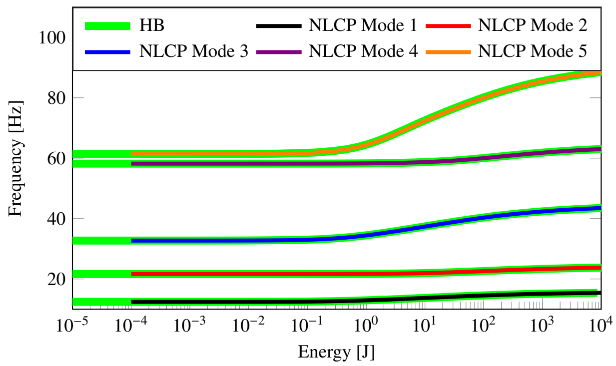

Figure 1: Comparison between the NNMs obtained using the Nonlinear Coupling Procedure and the Harmonic Balance method.

References

[1] R. J. Kuether and M. S. Allen, "Nonlinear modal substructuring of systems with geometric nonlinearities," in *54th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference*, p. 1521, 2013.

[2] F. Latini, J. Brunetti, W. D'Ambrogio, and A. Fregolent, "Substructures' coupling with nonlinear connecting elements," *Nonlinear Dynamics*, vol. 99, no. 2, pp. 1643–1658, 2020.

[3] F. Latini, J. Brunetti, M. Kwarta, M. S. Allen, W. D'Ambrogio, and A. Fregolent, "Experimental results of nonlinear structure coupled through nonlinear connecting elements," in *Proceedings of ISMA 2020 - International Conference on Noise and Vibration Engineering and USD 2020 - International Conference on Uncertainty in Structural Dynamics*, 2020.