Nonlinear dynamics of piecewise smooth systems and damage identification

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Abstract

In the field of damage identification through vibration testing, there are mainly two approaches: methods based on linear models and methods that consider nonlinear behaviour of the damaged structures. The first ones consider only open crack and exploit changes in modal parameters; the nonlinear methods consider breathing crack models and focus on the characteristics of the nonlinear response. The first group of methods can identify the crack only at an advanced stage, once changes in modal parameters become significant; for this reason, several studies focus on the nonlinear response characteristics that can be investigated to identify the presence of the crack in an early stage. In fact, the structures with breathing cracks behave similarly to bilinear systems and hence exhibit nonlinear phenomena in the dynamic response even for low damage. The idea is supported by the study of a simple piecewise smooth 2dofs model where a wide variety of nonlinear phenomena has been evidenced, which include among others the bifurcations of super-abundant modes, a number of resonances greater than the system degrees of freedom. All these phenomena are strongly dependent on the stiffness discontinuity, that is the damage parameter.

A novel method able to detect crack severity and position through measurements of the system nonlinear response has been developed and a cantilever beam with a breathing crack is considered as a test case. A direct formulation of this problem is first presented with the twofold aim of highlighting the sensitivity of the response to the nonlinear effects introduced by the damage and to build a database of behaviour necessary to the identification procedure.

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In particular, a finite element model of the cracked cantilever beam is developed using one dimensional beam elements; the cracked zone is modelled by an element with bilinear stiffness. The beam is excited at its tip with a slowly varying sweep force whose frequency range is centered to multiple and sub-multiple of its resonances. It is possible to detect the presence of significant sub- and super-harmonics of the exciting frequency in the response. Moreover, the amplitude of such harmonics can be related to the location and depth of the crack, thus providing sufficient data for an identification procedure.

Finally, the inverse procedure is tested by identifying the position and depth of a crack using pseudo-experimental data; the results show a strong robustness of the method even in the case when the data are affected by measuring errors.