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Exploiting Global Dynamics to Unveil the Nonlinear Response and Actual Safety of Systems and Structures

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In the last decade, global nonlinear dynamics has been evolving in a revolutionary way, with the development of sophisticated techniques employing concepts/tools of dynamical systems, bifurcation, and chaos theory, and applications to a wide variety of mechanical/structural systems. The relevant achievements entail a substantial change of perspective in dealing with vibration problems, and are ready to meaningfully affect the analysis, control, and design of systems at different scales, also in multiphysics contexts [1]. The lecture aims at highlighting the role played by global dynamics in unveiling the nonlinear response and actual safety of engineering structures in different environments.

First, thermomechanical laminated plates with von Kármán nonlinearities, possible shear deformability and consistently assumed temperature distributions along the thickness are considered. Kinematic condensation of in-plane dynamics and Galerkin modal reduction allow to obtain minimal reduced models with one mechanical and two thermal unknown variables, which still exhibit the full thermomechanical coupling embedded in the underlying, yet more complicated, continuum models. Besides mechanical (in-plane and transverse) excitations, a variety of body and boundary thermal sources can be considered [2]. Complementing local bifurcation analyses with global investigations made through cross-sections of multidimensional basins of attraction allows to detect conditions under which the lengthy (membrane/bending) thermal transients of the coupled system meaningfully affects its unbuckled/buckled steady responses, with strong modifications with respect to the dynamics occurring for the uncoupled mechanical system directly subjected to steady thermal excitations [3].

Then, a minimal order model of atomic force microcantilever for noncontact detection of sample surface properties is considered. Analysis of global effects of a feedback control aimed at keeping the cantilever vibration to a suitable periodic one, with no unstable/chaotic response, allows to highlight a severe worsening of the system practical stability around its main resonance frequencies. This corresponds to a highly detrimental effect of the locally-tailored control not only in terms of system final escape (i.e., the unwanted jump-to-contact) but also as regards the features of the erosion process which leads to a substantial reduction of robustness of the safe response with respect to the uncontrolled system. The relevant topological motivations are made apparent just by the global analysis [4]. The active role played by the latter in conceiving/implementing an effective numerical control procedure to enhance the overall engineering safety is also addressed [5].

The lecture will end by dwelling on the great potential of dynamical integrity evaluations based on global analysis [1] as regards conceiving a less conservative, yet aware and safe, design of systems and structures.

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