Preface to the Special Issue on Nonlinear Dynamics and Chaotic Phenomena in Nonlinear Vibrations

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The developments of Nonlinear Dynamics and Chaos Theory in the past years have had a big impact in the way scientists and engineers understand many phenomena of Nature and the way they apply analytical and computational techniques, with the benefits of more precise analysis for the synthesis and design of new products. Ideas, techniques and methods derived from subjects such as bifurcation theory, dynamical systems theory and chaotic dynamics, control and synchronization are common tools for the engineer as the scientist today.

There are numerous vibration phenomena that oftentimes have been well modeled using linear vibration theory, including small amplitude vibrations of many physical systems. However, many fundamental interactions between physical systems and the systems themselves are nonlinear, in such a way that nonlinear models need to be introduced. These nonlinear systems display very many different behaviors that linear systems cannot. Among them, we can consider multiple steady state solutions with different stability properties, some stable and some unstable, in response to the same inputs; self sustained oscillations in the absence of external periodic forcing; response at frequencies other than the forcing frequency; internal resonances, involving different parts of the system vibrating at different frequencies; jump phenomena in the response of the system as some forcing parameter is slowly varied and chaotic behavior, that is, complex, irregular motions that are extremely sensitive to initial conditions. Of course, these are rather general properties of nonlinear systems going beyond mechanical systems.

Another key ingredient of the analysis of nonlinear vibrations is the analytical intractability, what makes that very often computational techniques need to be used and even sometimes these are not sufficient for a systematic study especially of more complicated systems. That is why a qualitative understanding of the phenomena observed for systems of few degrees of freedom can be very useful in order to apply some of the learnt insights into more complicated systems, when similar phenomena are found. As a matter of fact, an intelligent combination of numerical simulations with analytical and theoretical analysis is fundamental in order to understand nonlinear vibration phenomena. Furthermore, the role of nonlinear oscillators for this aim is really important, and simple models such as the nonlinear pendulum or the Duffing oscillator have contributed to a development of ideas with further applications to more complicated physical systems.

This Special Issue on Nonlinear Dynamics and Chaotic Phenomena in Nonlinear Vibrations aims to contribute to provide a general picture of the importance of these ideas, techniques and methods in the field of nonlinear vibrations at large. It includes among other topics, an analysis of the nonlinear dynamics of oscillators where numerical and analytical techniques are used; an investigation of the phenomena arisen during the cutting process by using nonlinear embedding methods and other techniques derived from nonlinear time series analysis; a study of the sensitivity analysis on dynamic responses of geometrically imperfect base excited cantilevered beams and the stability, bifurcation of motions in a Fermi oscillator under dual excitations by the use of discontinuous dynamical systems as well as noise effects. A very interesting application to double swing power systems is also included, since nonlinear vibrations certainly go beyond mechanical systems.

As the Editor of this Special Issue I have tried to present a collection of articles showing some of the applications of nonlinear and chaotic dynamics in nonlinear vibrations, with the hope that it would contribute to the further development of these applications to nonlinear vibration problems of different nature, as well as to stimulate research along these lines. Hopefully these objectives can be fulfilled.