

Editorial

Uncertainties in Nonlinear Structural Dynamics

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Nonlinear dynamical systems usually display high complexity. The last decades have seen a remarkable and fruitful development of nonlinear dynamics, and a large number of papers have been published in all branches of science. In modeling natural and man-made systems, it is assumed in general that the system is perfect and that all parameters of the system are known. However, real systems are usually imperfect, and uncertainties are present both in system parameters and in the modeling stage. This is associated with the lack of precise knowledge of the system parameters, random or noisy external loading, operating conditions, and variabilities in manufacturing processes, among other things. In many situations, these uncertainties are not important and may be overlooked in the mathematical modeling of the problem. However in several situations, the uncertainties can have significant influence on the dynamic response and the stability of the system. Uncertainties may also be found in system response, even in cases where all parameters are well established, such as systems exhibiting high sensitivity to initial conditions. This is particularly important in strongly nonlinear chaotic systems and those with fractal-basin boundaries. However, the influence of uncertainties in local and global bifurcations and basins of attractions and on important engineering concepts such as reliability, safety, and robustness is not well studied in literature. Even the definition of a random bifurcation is still an open problem in nonlinear dynamics. This is a rather broad topic in nonlinear dynamics.

So, the present special issue is dedicated to the influence of uncertainties in structural dynamics. In engineering structures, the main sources of uncertainties are: imperfections, uncertainties in system parameters (mass, damping, and stiffness), uncertainties in the external load, such as random loads (wind and earthquake), sensitivity to initial conditions,

and interaction between load and structure. These types of uncertainties coupled to system nonlinearities may have a marked influence on the structure's response, particularly in a dynamic environment. So, it is useful to study their influence on bifurcations, stability boundaries, and basins of attraction. It is also interesting to discuss their influence on safety factors, integrity measures, and confiability. These topics are essential for a safe design of structures and the development of mathematically based safe (but not too conservative) design codes and methodologies.

This issue comprises 16 contributions from 8 different countries, which give a picture of the current research on uncertainties in engineering problems. Several aspects are addressed, including the following: influence of uncertainties on buckling and vibration of structural elements: trusses, cables, piles, beams, plates, and shells, the consideration of uncertainties in vibration control, stochastic systems, and numerical algorithms for the analysis of systems with different types of uncertainties.

The effect of geometric imperfections, unavoidable in real systems, and viscous damping on the type of nonlinearity (i.e., the hardening or softening behavior) of circular plates and shallow spherical shells is investigated in the paper written by C. Touzé et al. The von Kármán large-deflection theory is used to derive the continuous models. Then, nonlinear normal modes (NNMs) are used for predicting the structures' nonlinear behavior.

D. S. Sophianopoulos et al. study the local instability of a 2 degree of freedom (DOF) weakly damped systems using the Liénard-Chipart stability criterion. The individual and coupling effects of mass and stiffness distribution on the dynamic asymptotic stability due to mainly infinitesimal damping are examined. The validity of the theoretical findings presented herein is verified via a nonlinear dynamic analysis.

The nonlinear modeling of cables with flexural stiffness is discussed by W. Lacarbonara and A. Pacitti. A geometrically exact formulation of cables suffering axis stretching and flexural curvature is presented. The dynamical formulation is based on nonlinearly viscoelastic constitutive laws for the tension and bending moment with the additional constitutive nonlinearity accounting for the no-compression condition.

The paper by D. M. K. N. Kunitaki et al. uses probabilistic and fuzzy arithmetic approaches for the treatment of uncertainties in the installation of torpedo piles used in the foundations of mooring lines and risers of floating production systems for offshore oil exploitation. Methodologies involving, respectively, the Monte Carlo method and concepts of fuzzy arithmetic are used to assess the sensitivity of the response to the variation of the uncertain parameters.

The effects of uncertainties in nonlinear damping coefficients on the parametric vibration of a cantilever beam with a lumped mass are investigated by D. G. Silva and P. S. Varoto. The effects of a turbulent frictional damping force on the dynamic behavior of the flexible structure are studied numerically and experimentally. The results indicate that variations on the damping coefficient significantly alter the dynamics of the structure under investigation.

The influence of uncertainties on the dynamic buckling loads of structures liable to asymmetric postbuckling behavior is studied by P. B. Gonçalves and D. M. Santee. A parametric analysis illustrates the influence of uncertainties in system parameters and random perturbations of the forcing on the dynamic buckling load. A lower bound for the buckling loads, obtained by the application of the Melnikov criterion, is proposed, which compare well with the scatter of buckling loads obtained numerically.

The paper by J. Lew presents an approach to model validation for structures with significant parameter variations. Model uncertainty of the structural dynamics is quantified

with the use of a singular value decomposition technique to extract the principal components of parameter change, and an interval model is generated to represent the system with parameter uncertainty. A beam structure with an attached subsystem, which has significant parameter uncertainty, is used to demonstrate the proposed approach.

J. Zhu et al. investigate a robust Kalman filtering design for continuous-time Markovian jump nonlinear systems with uncertain noise. The statistical characteristics of system noise and observation noise are time-varying or unmeasurable instead of stationary. By view of robust estimation, maximum admissible upper bound of the uncertainty to noise covariance matrix is given based on system state estimation performance. The robustness of the Kalman filter against noise uncertainty and stability of dynamic systems is studied by Game theory.

The “Ga-based fuzzy sliding mode controller for nonlinear systems” is studied by P. C. Chen et al. First, they approximate and describe an uncertain and nonlinear plant for the tracking of a reference trajectory via a fuzzy model incorporating fuzzy logic control rules. Next, the initial values of the consequent parameter vector are decided via a genetic algorithm. After this, an adaptive fuzzy sliding model controller, designed to simultaneously stabilize and control the system, is derived. The stability of the nonlinear system is ensured by the derivation of the stability criterion based upon Lyapunov’s direct method.

The robust active vibration control of flexible structures considering uncertainties in system parameters is addressed by D. D. Bueno et al. The paper proposes an experimental methodology for vibration control in a 3D truss structure using PZT wafer stacks and a robust control algorithm solved by linear matrix inequalities.

The paper written by D. Chen and W. Zhang is concerned with the sliding mode control for uncertain stochastic neutral systems with multiple delays. A switching surface is adopted first. Then, by means of linear matrix inequalities, a sufficient condition is derived to ensure the global stochastic stability of the stochastic system in the sliding mode for all admissible uncertainties. The synthesized sliding mode controller guarantees the existence of the sliding mode.

W. T. M. Lima and L. M. Bezerra’s paper presents an implicit time integration scheme for transient response solution of structures under large deformations and long-time durations. The influence of different substep sizes on the numerical dissipation of the method is studied throughout three practical examples. The method shows good performance and may be considered good for nonlinear transient response of structures.

C. Soize and A. Batou study the identification of stochastic loads applied to a nonlinear dynamical system for which a few experimental responses are available using an uncertain computational model. A nonparametric probabilistic approach of both parameter uncertainties and model uncertainties is implemented to take into account uncertainties, and the level of uncertainties is identified using the maximum likelihood method. The identified stochastic simplified computational model which is obtained is then used to perform the identification of the stochastic loads applied to the real nonlinear dynamical system.

A homotopy perturbation method for solving reaction-diffusion equations is proposed by L. Mo et al. In this method, the trial function (initial solution) is chosen with some unknown parameters, which are identified using the method of weighted residuals. Some examples are given, and the obtained results are compared with the exact solutions.

Z. H. Wang presents, on the basis of Lambert W function, an iterative algorithm for the calculation of the rightmost roots of the neutral delay differential equations so that the stability of the delay equations can be determined directly. The application of the method is illustrated with two examples.

Finally, dynamical models for computer viruses propagation are proposed by J. R. C. Piqueira and F. B. Cesar. Data from three different viruses are collected in the Internet, and two different identification techniques, autoregressive and Fourier analyses, are applied showing that it is possible to forecast the dynamics of a new virus propagation by using the data collected from other viruses that formerly infected the network.

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