Preface

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This special issue on “Advances in Dynamics, Stability and Control of Mechanical Systems” presents a survey of recent studies carried out by researchers who are members of the AIMETA GADeS group. AIMETA is the Italian Association of Theoretical and Applied Mechanics, and GADeS is the acronym of the AIMETA Group of Dynamics and Stability.

The aim of GADeS is to promote scientific interaction between researchers operating in the fields of applied mathematics, solid dynamics, structural dynamics, machine dynamics, dynamical system theory, stability, bifurcation and control. GADeS is aimed at sharing knowledge from different sectors, specifically mathematics and civil and mechanical engineering, through the organization of workshops, mini-symposia, special sessions at AIMETA’s conferences and coordinated participation in European research projects.

The material contained in this issue covers a broad spectrum of topics in solid mechanics, structural dynamics and control, in both linear and nonlinear fields. Analytical, numerical and experimental methods are presented, using deterministic as well as stochastic approaches.

The issue is organized into the following sections, each grouping a few papers:

- (A) Solids
- (B) Friction
- (C) Structures
- (D) Control
- (E) Wind
- (F) Damage

Section A contains three papers, dealing with micropolar mixtures, material with memory and damping modelling.

In Ref. [1], the balance equations for anisotropic fluids, modelled as mixtures of reacting micropolar constituents, are derived. Thermodynamic restrictions are obtained for constitutive equations involving the temperatures, the mass densities, their gradients and the stretching tensors of the constituents. The relation to the main models appearing in the literature is provided, and the reason for the different form of the evolution equations is outlined.

In Ref. [2], materials with memory are considered, governed by integro-differential equations with non-local kernel. Here, differently from the classical case, a singular kernel is considered. This category includes: (a) viscoelastic models with a relaxation modulus unbounded at the origin, and (b) rigid heat conductors with a heat flux relaxation function singular at the origin. One-dimensional problems are examined.

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Reference [3] deals with a linear model for multi-degree-of-freedom systems with rate-independent damping. A viscoelastic model with memory, equivalent to the ideal hysteretic model, is developed, in which the loss modulus is substantially independent of frequency in a range of interest. A finite-element formulation, which encompasses a number of internal variables, is then provided for the sake of system identification.

Section B collects two papers, in which friction effects on dynamics are analysed.

In Ref. [4], a lumped system in frictional contact with a slider is studied, and unstable dynamics investigated. In a first approach, complex eigenvalue analysis (CEA) is applied. In a second approach, unstable motions are detected via numerical integrations accounting for stick–slip detachment at the interface. It is found that frictional contact can give rise to mode-coupling instabilities, producing harmonic vibrations of large amplitude, causing noise emission and possible failure.

In Ref. [5], frictional phenomena, including macroscopic stick–slip and mode-coupling instabilities, are analysed. Comparisons between experimental observations reproduced in a laboratory set-up and numerical results, obtained by transient finite-element simulations, are performed. Macroscopic stick–slip, modal instabilities and transitions to continuous sliding are observed. Maps of the instability scenarios are drawn as a function of boundary conditions or system parameters.

Section C is made up of seven papers, dealing with vibrations, dynamic instabilities, buckling as well as formulation and numerical methods for structural systems.

Reference [6] discusses the well-posedness and the asymptotic behaviour of a Kelvin–Voigt nonlinear string-beam system, modelling a suspension bridge. The existence and uniqueness of solutions and the exponential stability of the homogeneous system are proved, under the hypothesis that the constant axial force is smaller than a critical value. For a general value of this force, a regular global attractor exists when the external loads are independent of time.

In Ref. [7], the nonlinear free vibrations of a two-layer elastic composite beam are investigated for different boundary conditions. The analysis is carried out by means of the multiple time scale method. Linear and nonlinear frequencies are found to be dependent

on two dimensionless parameters only and, for boundary conditions different on each layer, also on the ratio between the axial stiffness of each layer.

Reference [8] treats free nonlinear flexural vibrations of circular elastic rings, accounting for exact kinematics and nonlinear material behaviour. A direct asymptotic approach based on the method of multiple scales is used for investigation. It is shown that the flexural motions are softening for linearly elastic rings, while there are nonlinearly elastic rings for which the motions are hardening. There are thresholds in the constitutive laws separating softening from hardening behaviours.

In Ref. [9], compressive and tensile buckling occurring in slender beams with multiple concentrated shear deformations are studied. Singularities due to internal sliders endowed with translational springs inducing deflection discontinuities along the beam axis are considered. Exact closed-form solutions are derived, irrespective of the number of concentrated singularities. Sudden switches from symmetric to antisymmetric buckling shapes are identified. A comparison with a uniform column with distributed shear deformations is presented.

Reference [10] concerns the dynamics of chains of linearly coupled mechanical oscillators with on-site cubic nonlinearity. Spatially periodic and stationary localized solutions are investigated, aiming to explore the relationship with the underlying nonlinear wave propagation regions. Occurrences of discrete breathers and multibreathers, associated with homoclinic or heteroclinic connections, are identified.

Reference [11] analyses the aeroelastic stability of a multi-body system, which describes the section of a suspended bridge. A multi-parameter perturbation approach is employed to investigate the region of the triple internal resonance among a torsional mode of the deck and two modes of hanger cables. The bifurcation scenario is described, in which the occurrence of strong interactions is highlighted. A parametric analysis, in which passive viscous dampers are accounted for, supplies information useful to prevent aeroelastic instability.

Reference [12] is devoted to numerical simulation of the dynamic response of frame structures undergoing large displacements and three-dimensional (3D) rotations. Geometrically exact and corotational approaches are combined in the formulation of a 3D beam element. A new procedure is proposed, formally

independent from the definition of the corotated frame, which avoids some cumbersome calculations of the classical approach. Literature benchmarks involving 3D slender frame structures undergoing large displacements and 3D rotations are discussed.

Reference [13] proposes a new class of shape polynomials, able to solve the well-known shear-locking phenomena and the high-order time derivative effect problems. These polynomials eliminate the inconsistency of the higher-order spectra. The new class of interdependent shape polynomials is obtained by introducing a new kinematic variable: the fictitious deflection. The interdependence of the polynomials ensures that the corresponding FE model is free of locking.

Section D contains four papers, dealing with passive control pursued by different added devices.

Reference [14] considers a nonlinear elastic string with an attached nonlinear energy sink (NES), excited by distributed forces harmonically varying in time. The string is rendered internally nonresonant via a point mass and an elastic spring connected at a free tip. The multiple scale/harmonic balance method, already introduced by the authors for finite degree of freedom systems, is extended here to partial differential equations. Amplitude modulation equations are obtained, whose numerical integration proves the beneficial effect of the NES.

Reference [15] deals with tuned liquid column dampers (TLCDs), used as passive devices. An approximated simplified formulation, based on a statistical linearization technique previously developed by the same authors, is here employed for computing optimal TLCD parameters. A smooth function, defining the main system variance, is formulated and minimized, resulting in a significant reduction of computational time and a valuable tool for design purposes. Optimal design charts are supplied.

In Ref. [16], the design of tuned mass dampers (TMDs) for mitigation of pedestrian-induced vibrations is addressed. A numerical optimization criterion is proposed, based on maximization of an efficiency factor, defined as the ratio between the uncontrolled acceleration variance and the controlled one. Monte Carlo simulations are carried out to confirm the validity of the standard deviation-based optimization for the reduction of the maximum dynamic response of the bridge. An application to a real footbridge is presented.

In Ref. [17], discrete models of piezoelectric-controlled mechanical systems, subjected to follower forces, are derived. A targeted strategy of control is first discussed, leading to the detection of three novel linear controllers. Based on an eigenvalue sensitivity analysis, the effectiveness of the three controllers is investigated. As an application, the two-degree-of-freedom Ziegler column, undergoing Hopf bifurcation triggered by a follower force, equipped with piezoelectric controllers, is studied, and the different strategies proposed are compared.

Section E collects two papers, devoted to the analysis of instabilities caused by wind flow.

In Ref. [18], the interaction between galloping and vortex-induced vibration is experimentally investigated for an infinitely long rectangular cylinder with side ratio of 3:2. Instabilities are detected in a range of flow speeds where no excitation is expected according to the classical theory. Measurements highlight nonlinear features such as superharmonic resonances and hysteresis. In particular, due to secondary resonance, a non-negligible excitation is observed at low reduced wind speed.

Reference [19] gives experimental evidence, in two different wind tunnels, of a new type of bistable flow, induced around a circular cylinder of finite length, even at moderately high Re . Stiffening rings, applied along the height of a circular cylinder at a distance smaller than the diameter, are found to be responsible for the phenomenon. A finite volume model, based on the iterative solution of the unsteady Reynolds-averaged Navier–Stokes equations, is formulated, able to confirm the experimental results.

Section E contains two papers, concerning damage detection via vibration tests.

Reference [20] presents a combined method to detect very small defects on roller bearings. Wavelet packet decomposition, ensemble empirical mode decomposition and support vector machine algorithm are used in sequence. The data are generated by means of a test rig assembled in a laboratory. Various operating conditions are considered to obtain reliable results. The combined method is found to effectively identify the states of the bearings.

Reference [21] proposes an approach based on artificial neural networks and genetic algorithms for structural damage identification. A reduced scale three-storey steel spatial frame is instrumented and progressively damaged. The modal properties of the

steel frame are evaluated through a neural network approach. Two error functions measuring the differences between the experimental and finite-element results are defined, and a genetic algorithm is employed for damage detection. The algorithm is proved to be able to match the actual damage.

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