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Dynamic Stability and Bifurcation in Nonconservative Mechanics

Springer

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Preface

Nonconservative mechanical systems have been known about since the end of the nineteenth century when Greenhill posed a problem on the buckling of a screw shaft of a steamer subject to both an end thrust and an axial torque. In the 1920s, Nicolai introduced a follower torque into the Greenhill problem and demonstrated a dynamic instability (flutter) of the shaft. In the 1930s, Theodorsen presented a model of flutter of flexible structures in a flow and derived circulatory lift and drag forces. In the 1950s, Ziegler proposed a classification of conservative and nonconservative loads, distinguishing nonpotential positional forces that produce nonzero work on a closed contour, and, inspired by aerodynamics, called them circulatory. Nearly at the same time as Greenhill published his work, Kelvin and Tait, studying models of formation of binary stars, discovered the destruction by viscosity of gyroscopic stabilization of rotating ellipsoidal masses of fluid. This was the first example of dissipation-induced instabilities. Nowadays dissipative and circulatory forces are recognized as the two fundamental nonconservative forces in a growing number of scientific and engineering disciplines including physics, fluid and solid mechanics, fluid–structure interactions, and modern multidisciplinary research areas such as biomechanics, micro- and nanomechanics, optomechanics (for instance, optical tweezers generate a circulatory force field), robotics, energy harvesting, and material science.

Nonconservative systems display unusual and counter-intuitive dynamics and stability properties. The occurrence of flutter and divergence instabilities is usually analyzed to be avoided in mechanical structures, although sometimes these become desirable, for instance, to harvest energy. However, the determination of these instabilities is a challenging mechanical problem. This is due to the nonself-adjoint (non-Hermitian) character of the governing equations that, as a rule, depend on multiple parameters. Traditional university curricula do not offer a coherent collection of modern mathematical tools for the analysis of multiparameter families of nonself-adjoint differential equations combined with a firsthand demonstration of how they actually work in practical applications.

This monograph is the collection of the Lecture Notes for the CISM-AIMETA Advanced School *Dynamic Stability and Bifurcation in Nonconservative Mechanics* held at the International Centre for Mechanical Sciences (CISM) in Udine, Italy, April 10–14, 2017. The course was given by six lecturers (D. Bigoni from the University of Trento, O. Kirillov from the University of Northumbria, O. Doaré from ENSTA Paris Tech, E. Hemingway from the University of California at Berkeley, A. Metrikine from Delft University, and A. Ruina from Cornell University) and attended by participants from European and extra European countries. The chapters are devoted to flutter and divergence instability in structures and solids (D. Bigoni), to dissipation-induced instabilities in fluid–structure interactions (O. Doaré), to perturbation theory of the Ziegler destabilization paradox and general stability theorems for nonconservative systems (O. Kirillov) and to new results on conservative and nonconservative moments in the dynamics of rods and rigid bodies (E. Hemingway and O. O'Reilly).

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