Preface

This is the third and final volume of a triad of books devoted to classical mechanics; it uses the theoretical background presented in *Classical Mechanics: Kinematics and Statics* and *Classical Mechanics: Dynamics*. It is focused on presenting a unique approach, rooted in classical mechanics, to studying mechanical and electromagnetic processes occurring in applied mechanics and mechatronics. In contrast to the majority of books devoted to applied mechanics, this volume places particular emphasis on theory, modeling, and analysis and control of gyroscopic devices, including military applications. This book provides practicing mechanical/mechatronic engineers and designers, researchers, and graduate and postgraduate students with a knowledge of mechanics focused directly on advanced applications.

Chapter 1 deals with dynamics in mechatronic systems. A unified approach based on mechanics and variational calculus is applied first to the study of dynamical processes in electromechanical systems, henceforth referred to as mechatronic systems. In Sect. 1.1, the constitutive relations of elements of electric circuits such as resistors, coils, capacitors, and inductors are introduced, and two of Kirchhoff's laws are presented in the form of two theorems. Then, the application of Hamilton's principle and the Lagrange equations to electrical (electromagnetic) systems is described. An illustrative example is also presented. In Sect. 1.2, dynamical processes in mechatronic systems are studied. The Lagrange equations for mechatronic systems are derived. Then various mechatronic transducers are described, including resistive-displacement transducers, resistance-based sensors, inductive transducers, capacitive and angular velocity transducers, temperature transducers, thermocouples, pressure transducers, magnetoelectric sensors and piezoelectric transducers. A single mechatronic system is also studied, and the magnetic force magnitude is derived. In Sect. 1.3, magnetic levitation is analyzed. A levitating cylindrically shaped rigid body is studied experimentally, and the governing equations of the body levitating in magnetic and gravitational fields are derived. Two cases of the numerical control are studied, and the numerical examples are presented. In Sect. 1.4, dynamics of the string-type generator is studied. Governing equations consist of a PDE and ODE with time delay, and they are analyzed using the averaging approach and numerical simulation. Lastly, Sect. 1.5 studies the dynamics of a rotor supported by a magnetohydrodynamic bearing. Both resonance and non-resonance cases, as well as rotor chaotic dynamics are analyzed

In Chap. 2, the dynamics of a rigid spherical body is studied with emphasis put on applications. In Sect. 2.1, the kinematics of a rigid body is revisited including the Euler and Cardan angles. In Sect. 2.2, the kinematic energy of a rigid body is defined and equations of the spherical motion of a rigid body are given. Here the Euler and Lagrange cases are studied more extensively in comparison to the book *Classical Mechanics: Dynamics*. The same applies to the Kovalevskaya case, and the essence of the gyroscopic effect is outlined.

Chapter 3 is devoted to the theory of gyroscopes. In Sect. 3.1, an historical outline of the theory of gyroscopes is given. In Sect. 3.2, elements of gyroscope classification are introduced, and then the evolution of the gyroscope concept is presented. Milestones in gyroscope development are highlighted in Sect. 3.4. In Sects. 3.5–3.9, the following gyroscope-type devices are considered: the directional gyroscope, the gyroscopic vertical, the stabilized gyroscopic platform, the laser gyroscope, the fiber-optic gyroscope, the piezoelectric gyroscope, the fork gyroscope, and the microgyroscope with a spinning disk and with a vibrating ring. Section 3.10 contains examples of devices for gyroscopic navigation. An example of an observation device with a built-in gyroscope is provided in Sect. 3.10. In Sect. 3.11, new challenges for the gyroscope are briefly summarized.

Chapter 4 is devoted to the dynamics and control of gyroscopes. In Sect. 4.1, the dynamics of the gyroscope on a movable platform is described. Then the equations of motion of the gyroscope axis and the gyroscope rotor are derived. The particular case of a static gyroscope placed on a fixed platform with the axis fixed to the rotor is studied. Finally, a technical equation of gyroscope motion and some remarks regarding the modeling of gyroscope dynamics are outlined. Gyroscope control is presented in Sect. 4.2. First, an inverse problem of gyroscope dynamics, i.e., motion control of the gyroscope axis in an open-loop system is studied and a numerical example is provided. Then, control with constant programmable moments is discussed and clarified through an illustrative numerical example. Section 4.3 deals with motion control of the gyroscope axis in a closed-loop system. First, a gyroscopic system with a PID controller is considered, and its stability is analyzed. Then, a regulator whose role is to minimize errors between the prescribed and actual motions is introduced into the gyroscope control system. In Sect. 4.4, selection of optimal parameters of a gyroscopic system in an elastic suspension is carried out and its optimal control is studied. Section 4.5 focuses on the selection of the optimal parameters of a gyroscope system with an axis fixed to the rotor; this section also includes the optimization of a classically controlled gyroscope.

In Chap. 5, gyroscopic control in self-guidance systems of flying objects is presented. In Sect. 5.1, a gyroscope control in an unmanned aerial vehicle is studied. First, the navigation kinematics of an unmanned aerial vehicle is analyzed, and then the control of a gyroscope fixed on its board as well as its full control are discussed. A gyroscope in a guided aerial bomb is studied in Sect. 5.2, which includes an analysis of the kinematics of a bomb self-guided motion to a ground target, the equations of motion of a guided bomb, and a description of a gyroscopic system devoted to bomb control including automatic pilot control.

The authors wish to express their thanks to Mr. P. Dąbek and Mr. M. Kaźmierczak for their help in the book's preparation. J. Awrejcewicz acknowledges also the hospitality of the Fraunhofer Institute of the Technical University of Darmstadt during his research, made possible by the Alexander von Humboldt Award.

Kielce, Poland Zbigniew Koruba
Łódź, Poland Jan Awrejcewicz

http://www.springer.com/978-1-4614-3977-6

Classical Mechanics
Applied Mechanics and Mechatronics
Awrejcewicz, J.; Koruba, Z.
2012, XXI, 250 p., Hardcover
ISBN: 978-1-4614-3977-6