Book Reviews

Dynamics of Multibody Systems

Robert E. Roberson and Richard Schwertassek, Springer-Verlag, New York 1988, 460 pp., $79.50.

Dynamics, the branch of mechanics that deals with forces and their relation to motions of material objects, has changed greatly during the past three decades; problems that could not have been solved by the most skilled dynamicists of earlier times are being solved routinely today. One reason for this is that in many situations solving a dynamics problem is tantamount to integrating a set of coupled, nonlinear differential equations, a task that, while formerly frequently impossible, now can be accomplished relatively easily with the aid of a high speed digital computer. A second, perhaps less obvious, reason is that computers can enable one not only to solve but also to generate equations of motion, which becomes important when attempting to deal with systems of more than a few bodies, for the generating of such equations "by hand" is generally a very laborious, highly error-prone undertaking. The book under review is concerned primarily with this aspect of dynamics.

The book is divided into four parts, entitled Introduction, Kinematics of Rigid Body, Dynamics of a Rigid Body, and Multibody Systmes, respectively containing 56, 69, 44, and 226 pages. In addition, there are three appendices and a comprehensive alphabetical index.

Part I, divided into two chapters, begins with historical material that provides an instructive background for the sequel. After focusing attention on issues arising in connection with rotational, as distinct from translational, motions, the authors show how power technology, the designing of mechanisms, the development of gyroscopic instruments, land-, water-, air-, and space vehicles, and even the field of biomechanics have furnished the impetus for the development of methodologies capable of dealing with multibody systems. By reference to technologically important examples, they set the stage for a careful exposition of mathematical preliminaries, which they undertake in the second chapter. This material, although probably familiar to most readers of the book, serves to establish a solid point of departure for what follows.

Kinematics of a rigid body is the topic treated in the three chapters of Part II. Location and orientation, translational and rotational time-rates of change, and kinematical differential equations are discussed in turn. Once again, the material itself can be regarded as well known, but it is presented with notable clarity, and historical material is interjected in a stimulating manner, as when it is pointed out that Euler's work on the parametrization of finite rotations was linked closely to his efforts to generate magic squares whose rows and columns satisfy the same relationships as do those of direction cosine matrices.

In the first of the two chapters that form Part III, the treatment of fundamental topics continues under the headings of Mass Geometry, Momentum, and Force and Torque. Only 13 pages are devoted to all of this material, which suggests that it is included primarily for the sake of completeness and to establish the meanings of terms used later. As throughout the book, the authors pay meticulous attention to terminology, with one exception, this involving their use of the words "couple" and "torque." On page 137, there appears the statement that "the simplest system of forces is the *couple* of forces, represented by two parallel vectors . . .," and later on "The torque produced by a couple, calculated with respect to *any* point, is

$$\mathbf{L} = \mathbf{a} \times \mathbf{F}^1$$

where $\mathbf{a}$ is a vector . . ., so that couple refers to a *system* of vectors, that is, more than one vector, whereas torque is a *single* vector; but, on pages 139 and 140, they invite the reader to "reduce the pairs F^i and $-{}_0F^i$ to the couple

$${}_0\mathbf{L}^i = {}_0\mathbf{R}^i \times \mathbf{F}^i$$

and combine . . .", so that couple here is being used as a synonym for torque. The fact that this practice is rather widespread throughout the American mechanics literature does not preclude the possibility of its encumbering one in the study of the second chapter of Part III, where the important concepts of generalized applied forces and generalized constraint forces are introduced.

In Part IV, which is divided into seven chapters entitled Foundations, Formalisms, Kinematics, Dynamics, Special Topics, Linearized Equations, and Computer Simulation, the material set forth in the preceding parts is drawn upon extensively to generate the equations proposed by the authors as the basis for computer programs to be used for the numerical simulation of motions of multibody systems. Systems possessing tree-topology as well as those containing closed loops are considered in detail, and several technologically important special cases are discussed in detail.

At the end of each chapter of the book there appears a list of the references cited in the chapter. Some of these are among the 257 items that form the general bibliography in Appendix C.

This book is more of a treatise than a textbook; there are no problems to be solved by the reader. Written in a lucid and stimulating style, it can serve as a model for all who would write on the very complex subject with which it deals.

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