BOOK REVIEWS

Theory and Practice of Force Measurement

Reviewed by Professor E. O. Doebelin, Department of Mechanical Engineering, The Ohio State University, Columbus, OH 43210.

REFERENCE: Bray, A., Barbato, G., and Levi, R., *Theory and Practice of Force Measurement*, Academic Press, San Diego, Calif., 1990, 380 pp.

The senior author, A. Bray, has been with the Institute of Metrology "G. Colonetti" in Turin, Italy, for many years, having established the first nucleus of the institute, which is today the Force Measurement Section. His colleagues G. Barbato and R. Levi are associated also with Politecnico di Torino. Reflective of the authors' experience, the major focus of the book is on high accuracy force measurement and calibration in standards laboratories. This relatively narrow focus limits the range of readership to which the book is addressed, but allows a high technical level in the treatment of those topics which are covered. Of the eight chapters, only the fifth, "Force-Measuring Devices," would be of prime interest to the more general force-measurement community. The entire book, however, is of uniformly high quality and fills an important gap in the measurement literature.

While the authors' foreword indicates a translation from Italian, I could really detect no evidence of this in the text's usage. I found the material very well organized and presented and a pleasure to read. Illustrations are quite numerous and well executed, equations are clearly numbered, references are profuse and significant, and the index is extensive and useful. As mentioned earlier, however, the book does not attempt to cover, except by brief mention, all the common methods used to measure force in laboratory and industrial applications and the difficult practical problems attendant to such uses. Measurement of unsteady (dynamic) forces, for example, is not covered.

Each chapter is briefly reviewed below:

Chapter One: The Concept of Force (18 pages)—This chapter contains mainly historical and philosophical material of general interest in the definition and measurement of force.

Chapter Two: Metrological Regulations for Weighing and Force Measurement (32 pages)—Here are addressed the standard legal and technical documents associated with force metrology. Terminology and definitions used in force calibration are reviewed, and spurious influences such as temperature and eccentricity of loading are discussed. Already here we begin to see the careful attention to important technical details; roughness and elasticity of contact surfaces is discussed with the aid of photoelastic model results. Standard methods of evaluating test results are reviewed.

Chapter Three: The Measurement of the Acceleration Due to Gravity (32 pages)—This topic is not of great interest to the general force-measurement community but plays an important role in standards and calibration work, and so it is discussed in considerable (and interesting) detail.

Chapter Four: Force-Standard Machines (56 pages)—A partial listing of topics will indicate the impressive depth of technical detail presented in this chapter that is typical of the book's general tone: deadweight machines, weights and weight-suspension systems, mechanical amplification, hydraulic amplification, stress analysis of machine structure using finite-element methods, selection of materials used for weights, machines used with force-reference transducers (pyramid method), electrical measuring circuits, load-frame flexibility.

Chapter Five: Force-Measuring Devices (42 pages)—This chapter will be of the most interest to the general (rather than standards laboratory) force-measuring community. After a very brief review (hardly more than a mention) of the basic methods of force measurement, the chapter concentrates almost entirely on resistance strain-gage load cells. An appendix gives an in-depth analysis of spoked-wheel elastic elements.

Chapter Six: Ring-Type Dynamometers (74 pages)—Proving-ring type elastic elements using both mechanical and electrical readout are covered in great detail. Use of factorial-design of experiments and response-surface methods to model behavior of this type of device are interesting features of the treatment.

Chapter Seven: Multicomponent Dynamometers for the Control of Force-Measuring Machines (83 pages)—One of the major thrusts of the text is methods for the resolution of disturbing discrepancies often observed when interlaboratory comparisons of force calibrations are carried out. It is suggested that many of these could be explained if multicomponent force transducers were to be used. This problem and its possible solution are explored in this chapter.

Chapter Eight: The Dissemination of the Standard of the Unit of Force (23 pages)—This chapter discusses how force standards can be transferred from one place to another and how a world network can be established within which the existing standards may be harmonized.

An Introduction to the Design and Behavior of Bolted Joints

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REFERENCE: Bickford, J. H., *An Introduction to the Design and Behavior of Bolted Joints*, 2nd ed., Marcel Dekker, New York, 1990, 709 pages, tables, illustrations and index.

Although the title of this book includes the word "introduction", the treatment of the subject is extensive and complete. The material goes well beyond the coverage of bolted joint design received in a typical undergraduate machine design course. The easy-to-read text begins with the fundamentals of bolt strength, deformation, and material selection and proceeds to cover the topics of preload, torque, and stretch control. The emphasis is on practical considerations for the efficient design of joints, including cost, ease of assembly, inspection, and disassembly. This second, revised edition has expanded the coverage of corrosion, fatigue, gaskets, and ultrasonic measurement of bolt strain. Also

