Mechanical Engineering Series

Frederick F. Ling
Editor-in-Chief

Mechanical Engineering Series

W. Cheng and I. Finnie, **Residual Stress Measurement and the Slitting Method**

J. Angeles, **Fundamentals of Robotic Mechanical Systems: Theory Methods and Algorithms, 3rd ed.**

J. Angeles, **Fundamentals of Robotic Mechanical Systems: Theory, Methods, and Algorithms, 2nd ed.**

P. Basu, C. Kefa, and L. Jestin, **Boilers and Burners: Design and Theory**

J.M. Berthelot, **Composite Materials: Mechanical Behavior and Structural Analysis**

I.J. Busch-Vishniac, **Electromechanical Sensors and Actuators**

J. Chakrabarty, **Applied Plasticity**

K.K. Choi and N.H. Kim, **Structural Sensitivity Analysis and Optimization 1: Linear Systems**

K.K. Choi and N.H. Kim, **Structural Sensitivity Analysis and Optimization 2: Nonlinear Systems and Applications**

G. Chryssolouris, **Laser Machining: Theory and Practice**

V.N. Constantinescu, **Laminar Viscous Flow**

G.A. Costello, **Theory of Wire Rope, 2nd Ed.**

K. Czolczynski, **Rotordynamics of Gas-Lubricated Journal Bearing Systems**

M.S. Darlow, **Balancing of High-Speed Machinery**

W. R. DeVries, **Analysis of Material Removal Processes**

J.F. Doyle, **Nonlinear Analysis of Thin-Walled Structures: Statics, Dynamics, and Stability**

J.F. Doyle, **Wave Propagation in Structures: Spectral Analysis Using Fast Discrete Fourier Transforms, 2nd ed.**

P.A. Engel, **Structural Analysis of Printed Circuit Board Systems**

A.C. Fischer-Cripps, **Introduction to Contact Mechanics**

A.C. Fischer-Cripps, **Nanoindentations, 2nd ed.**

J. García de Jalón and E. Bayo, **Kinematic and Dynamic Simulation of Multibody Systems: The Real-Time Challenge**

(continued after index)

Weili Cheng and Iain Finnie

Residual Stress Measurement and the Slitting Method

Springer

Weili Cheng
Berkeley Engineering and Research, Inc.
Berkeley, CA
USA

Iain Finnie
Department of Mechanical Engineering
University of California, Berkeley
Berkeley, CA
USA

Residual Stress Measurement and the Slitting Method

Library of Congress Control Number: 2006931571

ISBN 0-387-37065-X e-ISBN 0-387-39030-8
ISBN 978-0-387-37065-1 e-ISBN 978-0-387-39030-7

Printed on acid-free paper.

Printed in the United States of America.

9 8 7 6 5 4 3 2 1

springer.com

Mechanical Engineering Series

Frederick F. Ling
Editor-in-Chief

The Mechanical Engineering Series features graduate texts and research monographs to address the need for information in contemporary mechanical engineering, including areas of concentration of applied mechanics, biomechanics, computational mechanics, dynamical systems and control, energetics, mechanics of materials, processing, production systems, thermal science, and tribology.

Series Preface

Mechanical engineering, and engineering discipline born of the needs of the industrial revolution, is once again asked to do its substantial share in the call for industrial renewal. The general call is urgent as we face profound issues of productivity and competitiveness that require engineering solutions, among others. The Mechanical Engineering Series is a series featuring graduate texts and research monographs intended to address the need for information in contemporary areas of mechanical engineering.

The series is conceived as a comprehensive one that covers a broad range of concentrations important to mechanical engineering graduate education and research. We are fortunate to have a distinguished roster of consulting editors, each an expert in one of the areas of concentration. The names of the consulting editors are listed on page vi of this volume. The areas of concentration are applied mechanics, biomechanics, computational mechanics, dynamic systems and control, energetics, mechanics of materials, processing, thermal science, and tribology.

To
Weihsun and Joan

Preface

The early development of the slitting method is closely related to the work in Fracture Mechanics. G. Irwin's strain energy release rate is the foundation for computation of the crack compliance functions. H. F. Bueckner's principle for crack growth leads to the superposition principle for the release of the residual stresses. R. J. Hartrenft and G. G. Sih's, and G. Chell's expressions of K_I for shallow and deep cracks lead to an expression of K_I that works for both cases. The body force method introduced by H. Nisitani and his colleagues is a very useful tool for computing the compliance functions for a cut of finite width for near-surface measurements. The inherent-strain method developed by Y. Ueda and his colleagues has inspired the use of initial strains to approximate the residual stresses in the slitting method and the single-slice method.

The method of measuring residual stresses by a cut of progressively increasing depth was first tried in 1971 by S. Vaidyanathan and I. Finnie, who estimated the residual stress from a variation of K_I obtained by a photoelastic technique. It was not until fourteen years later that the method was extended by W. Cheng and I. Finnie in 1985 to measure residual stresses from a strain variation. In the years that followed a number of researchers around the world carried out similar measurements: D. Ritchie and R. H. Leggatt in 1987, T. Frett in 1987, C. N. Reid in 1988, and K. J. Kang, J. H. Song and Y. Y. Earmme in 1989.

Part of our early work was supported by Joe Gilman and Raj Pathania of EPRI and Wayne Kroenke of Bettis Laboratory. We appreciate the significant contribution of Mike Prime, who chairs the ASTM E.28.13.02 Task Group, and all Task Group members, Mike Hill, Gary Schajer, Yung Fan, Hans Schindler, and Can Aydiner, who have devoted their time to working towards a standard for the slitting method.

Our thanks also go to Öktam Vardar, Marco Gremaud, Glen Stevick, Ron Streit and Robert Ritchie for their contributions, friendship, and help over the years.

Fremont, California — *Weili Cheng*
Berkeley, California — *Iain Finnie*
June 2006

Contents