# Patigues and Deformation Testing Techniques

STP 1280

Sreeramesh Kalluri and Peter J. Bonacuse, editors

### **STP 1280**

# Multiaxial Fatigue and Deformation Testing Techniques

Sreeramesh Kalluri and Peter J. Bonacuse, editors

ASTM Publication Code Number (PCN): 04-012800-30



ASTM 100 Barr Harbor Drive West Conshohocken, PA 19428-2959 Printed in the U.S.A.

### Library of Congress Cataloging-in-Publication Data

Multiaxial fatigue and deformation testing techniques / Sreeramesh Kalluri and Peter J. Bonacuse, editors.

(STP; 1280)

"ASTM STP publication code number (PCN): 04-012800-30." Includes bibliographical references and index.

ISBN 0-8031-2045-1

- 1. Materials—Dynamic testing. 2. Materials—Fatigue.
- 3. Deformations (Mechanics) I. Kalluri, Sreeramesh. II. Bonacuse, Peter J., 1960— . III. Series : ASTM special technical publication ; 1280.

TA418.32.M85 1996 620.1/126—DC21

96-37368

CIP

Copyright © 1997 AMERICAN SOCIETY FOR TESTING AND MATERIALS, West Conshohocken, PA. All rights reserved. This material may not be reproduced or copied, in whole or in part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of the publisher.

### **Photocopy Rights**

Authorization to photocopy items for internal, personal, or educational classroom use, or the internal, personal, or educational classroom use of specific clients, is granted by the American Society for Testing and Materials (ASTM) provided that the appropriate fee is paid to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923; Tel: 508-750-8400; online: http://www.copyright.com/.

### **Peer Review Policy**

Each paper published in this volume was evaluated by three peer reviewers. The authors addressed all of the reviewers' comments to the satisfaction of both the technical editor(s) and the ASTM Committee on Publications.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of these peer reviewers. The ASTM Committee on Publications acknowledges with appreciation their dedication and contribution to time and effort on behalf of ASTM.

## **Foreword**

This publication, *Multiaxial Fatigue and Deformation Testing Techniques*, contains papers presented at the Symposium on Multiaxial Fatigue and Deformation Testing Techniques, which was held in Denver, Colorado, on 15 May 1995. The Symposium was sponsored by the ASTM Committee E8 on Fatigue and Fracture. Sreeramesh Kalluri, NYMA, Inc., NASA Lewis Research Center, and Peter J. Bonacuse, U.S. Army Research Laboratory, NASA Lewis Research Center, presided as symposium chairman and cochairman, respectively, and both were editors of this publication.

# Contents

Overview	1
Multiaxial Testing Facilities	
Testing Facilities for Multiaxial Loading of Tubular Specimens—F. ELLYIN AND J. WOLODKO	7
A Structural Test Facility for In-Plane Biaxial Testing of Advanced Materials— P. A. BARTOLOTTA, J. R. ELLIS, AND A. ABDUL-AZIZ	25
Adjustable Work Coil Fixture Facilitating the Use of Induction Heating in Mechanical Testing—J. R. ELLIS AND P. A. BARTOLOTTA	43
MULTIAXIAL DEFORMATION	
Biaxial Deformation Experiments Over Multiple Strain Regimes—M. P. MILLER AND D. L. McDOWELL	65
Experimental Determination of Yield and Flow Surfaces Under Axial-Torsional Loading—C. J. LISSENDEN, B. A. LERCH, J. R. ELLIS, AND D. N. ROBINSON	92
Additional Hardening Due to Tension-Torsion Nonproportional Loadings: Influence of the Loading Path Shape—S. CALLOCH AND D. MARQUIS	113
Notch-Tip Stresses and Strains Under Nonproportional Loading—M. N. K. SINGH, G. GLINKA, AND R. N. DUBEY	131
Multiaxial Fatigue	
Crack Initiation Life Behavior Under Biaxial Loading Conditions: Experimental Behavior and Prediction—H. NOWACK, D. HANSCHMANN, W. OTT, KH. TRAUTMANN, AND E. MALDFELD	159
An Axial-Torsional, Thermomechanical Fatigue Testing Technique—S. KALLURI AND P. J. BONACUSE	184
Fretting Fatigue Strength of Specimens Subjected to Combined Axial and Transversal Loading—w. switek	208

Characterization of Ceramic Matrix Composite Tubes Under Uniaxial/Biaxial  Monotonic and Cyclic Loading—K. LIAO, E. R. GEORGE, AND K. L. REIFSNIDER	224
STRUCTURAL FAILURE AND CRACK PROPAGATION UNDER MULTIAXIAL LOADING	
Plane Stress Crack Resistance Curves of an Inclined Crack Under Biaxial Loading— C. DALLE DONNE AND H. DÖKER	243
Instability and Failure of Corrugated Core Sandwich Cylinders Under Combined Stress—P. PATEL, T. NORDSTRAND, AND L. A. CARLSSON	264
Crack Propagation in Cruciform IMI 834 Specimens Under Variable Biaxial Loading—KH. TRAUTMANN, E. MALDFELD, AND H. NOWACK	290