

fracture mechanics

Sixteenth Symposium

kanninen/hopper, editors



STP 868

FRACTURE MECHANICS: SIXTEENTH SYMPOSIUM

Sixteenth National Symposium
on Fracture Mechanics
sponsored by
ASTM Committee E-24
on Fracture Testing
Columbus, Ohio, 15-17 August 1983

ASTM SPECIAL TECHNICAL PUBLICATION 868
M. F. Kanninen, Southwest Research Institute,
and A. T. Hopper, Battelle's Columbus
Laboratories, editors

ASTM Publication Code Number (PCN)
04-868000-30



1916 Race Street, Philadelphia, PA 19103

Library of Congress Cataloging in Publication Data

National Symposium on Fracture Mechanics (16th: 1983: Columbus, Ohio)
Fracture mechanics.

(ASTM special technical publication; 868)

Includes bibliographies and index.

“ASTM publication code number (PCN) 04-868000-30.”

I. Fracture mechanics—Congresses. I. Kanninen, Melvin F. II. Hopper, A. T.
III. ASTM Committee E-24 on Fracture Testing. IV. Title. V. Series.
TA409.N38 1983 620.1'126 85-8382
ISBN 0-8031-0225-9

Copyright © by AMERICAN SOCIETY FOR TESTING AND MATERIALS 1985
Library of Congress Catalog Card Number: 85-8382

NOTE

The Society is not responsible, as a body,
for the statements and opinions
advanced in this publication.



George E. Pellissier
1915–1982

Dedication

George E. Pellissier contributed significantly to the success of ASTM Committee E-24 on Fracture Testing. He was a member of the committee from 1966 until his death on 25 June 1982, and was the first chairman of Subcommittee 1 on Fracture Testing (now E24.01 on Fracture Mechanics Test Methods).

George received bachelor's (1936) and master's (1938) degrees in chemistry from Cornell and a bachelor's degree (1941) in metallurgical engineering from Carnegie-Mellon. The completion of his thesis for a doctor's degree was precluded by World War II. Early in his career he worked for Inco, Columbia University, Union Carbide, and Carnegie Illinois Steel Corporation in such diverse areas as powder metallurgy, nondestructive testing, corrosion, and mechanical metallurgy. He was considered a pioneer in the fields of electron microscopy and spectrographic analysis of molten steel.

George then went to the U.S. Steel Research Laboratory, where he held the posts of Research Associate, Di-

vision Chief, Manager of Advanced Applied Research, and Senior Research Consultant. He was involved in the areas of chemical, crystal, and microstructural analyses; defect detection; oxidation and chemisorption; and toughness and failure mechanisms of high-strength steels. He originated the concept of dual-mechanism strengthening of alloy steels; developed a noncontact thickness gage for thin sheet and coatings; and helped develop a new class of low-carbon, weldable, high-strength/high-toughness alloy plate steels.

From 1968 to 1982 George worked for E. F. Fullam, RRC International, and Mechanical Technology, where he used his extensive experience to provide internal and external consulting services on a broad range of metallurgical problems. George was a charter member of the Electron Microscopy Society of America, a Fellow of the American Society for Metals and the American Institute of Chemists, a member of various ASTM committees (including E-2 on Emission Spectroscopy, E-4 on Metallography, and E-24 on Fracture Testing), a member of The Electrochemical Society and Sigma Xi, and a licensed professional engineer in Pennsylvania. He published 26 technical papers.

Foreword

The Sixteenth National Symposium on Fracture Mechanics was held at Battelle's Columbus Laboratories, Columbus, Ohio, on 15–17 August 1983. ASTM Committee E-24 on Fracture Testing was the sponsor. M. F. Kanninen, Southwest Research Institute, and A. T. Hopper, Battelle's Columbus Laboratories, served as symposium chairmen and have edited this publication.

Related ASTM Publications

Methods for Assessing the Structural Reliability of Brittle Materials, STP 844 (1984), 04-844000-30

Damage Tolerance of Metallic Structures: Analysis Methods and Applications, STP 842 (1984), 04-842000-30

Fracture Mechanics: Fifteenth Symposium, STP 833 (1984), 04-833000-30

Fractography of Ceramic and Metal Failures, STP 827 (1984), 04-827000-30

Environment-Sensitive Fracture: Evaluation and Comparison of Test Methods, STP 821 (1984), 04-821000-30

Fracture Mechanics: Fourteenth Symposium—Volume I: Theory and Analysis, STP 791 (1983), 04-791001-30

Fracture Mechanics: Fourteenth Symposium—Volume II: Testing and Applications, STP 791 (1983), 04-791002-30

Elastic-Plastic Fracture: Second Symposium—Volume I: Inelastic Crack Analysis, STP 803 (1983), 04-803001-30

Elastic-Plastic Fracture: Second Symposium—Volume II: Fracture Resistance Curves and Engineering Applications, STP 803 (1983), 04-803002-30

Fracture Mechanics (Thirteenth Conference), STP 743 (1981), 04-743000-30

A Note of Appreciation to Reviewers

The quality of the papers that appear in this publication reflects not only the obvious efforts of the authors but also the unheralded, though essential, work of the reviewers. On behalf of ASTM we acknowledge with appreciation their dedication to high professional standards and their sacrifice of time and effort.

ASTM Committee on Publications

ASTM Editorial Staff

Allan S. Kleinberg
Janet R. Schroeder
Kathleen A. Greene
Bill Benzing

Contents

Introduction	1
---------------------	---

LINEAR ELASTIC ANALYSES

Stress Intensity Factors for a System of Cracks in an Infinite Strip— M. B. CIVELEK	7
Wide-Range Displacement Expressions for Standard Fracture Mechanics Specimens—J. A. KAPP, G. S. LEGER, AND B. GROSS	27
Evaluation of Analytical Solutions for Corner Cracks at Holes— J. B. HECKEL AND J. L. RUDD	45
Stress Distribution at the Tip of Cracks Originating from a Circular Hole under Biaxial Loads—M. K. OLADIMEJI	65
Wide-Range Weight Functions for the Strip with a Single Edge Crack—T.W. ORANGE	95
Analysis of an Externally Radially Cracked Ring Segment Subject to Three-Point Radial Loading—B. GROSS, J. E. SRAWLEY, AND J. L. SHANNON, JR.	106
The Dugdale Model for Compact Specimen—S. MALL AND J. C. NEWMAN, JR.	113

TEMPERATURE AND ENVIRONMENTAL EFFECTS

Internal Hydrogen Degradation of Fatigue Thresholds in HSLA Steel—K. A. ESAKLUL AND W. W. GERBERICH	131
Effect of Hydrogen on Crack Initiation and Growth in 18Mn-4Cr Steel—Y.-J. KIM, B. MUKHERJEE, AND D. W. CARPENTER	149
A Model for Creep/Fatigue Interactions in Alloy 718— T. NICHOLAS, T. WEERASOORIYA, AND N. E. ASHBAUGH	167

ELASTOPLASTIC ANALYSES

- Critical Load Assessment Method for Stable Crack Growth Analysis—**
H. C. RHEE 183
- Analysis of Fracture Parameters for Bending-Type Specimens—**
T. AIZAWA AND G. YAGAWA 197
- Three-Dimensional Elastic-Plastic Finite Element Analysis of Three-
Point Bend Specimens—**G. W. WELLMAN, S. T. ROLFE,
AND R. H. DODDS 214
- Fracture Toughness Improvement in a Carbon Steel Due to
Normalization—**B. D. MACDONALD 238
- Studies on Size Effects and Crack Growth of Side-Grooved CT
Specimens—**M. KIKUCHI, S. N. ATLURI, AND H. MIYAMOTO 251

ELASTOPLASTIC EXPERIMENTS

- J-R* Curve Determination Using Precracked Charpy Specimens and
the Load-Drop Method for Crack Growth Measurements—**
J. A. KAPP 281
- Strain-Hardening Effects on Fracture Toughness and Ductile Crack
Growth in Austenitic Stainless Steels—**P. BALLADON,
J. HERITIER, AND C. JARBOUI 293
- Axial Fracture Toughness Testing of Zr-2.5Nb Pressure Tube
Material—**P. H. DAVIES AND C. P. STEARNS 308
- Fracture Toughness Testing of Ductile Cast Irons—**R. J. SALZBRENNER,
J. A. VAN DEN AVYLE, T. J. LUTZ, AND W. L. BRADLEY 328

FATIGUE CRACK GROWTH

- A Similitude Criterion for Fatigue Crack Growth Modeling—**
D. BROEK 347
- Characterization of Crack Closure—**H. SEHITOGLU 361
- Effects of Load Gradient on Applicability of a Fatigue Crack Growth
Rate-Cyclic *J* Relation—**M. JOLLES 381

Observations on a Fracture Mechanics Approach to Fatigue Crack Initiation in Ti-6Al-4V—G. R. YODER, L. A. COOLEY, AND T. W. CROOKER	392
Discussion	403

DYNAMIC FRACTURE MECHANICS

Strain-Rate Dependence of the Deformation at the Tip of a Stationary Crack—R. HOFF, C. A. RUBIN, AND G. T. HAHN	409
Crack Tip Plasticity of a Tearing Crack—O. S. LEE AND A. S. KOBAYASHI	431
Dynamic Crack Propagation Through Welded HY-80 Plates under Blast Loading—C. R. BARNES, J. AHMAD, AND M. F. KANNINEN	451
Crack Arrest Behavior of a High-Strength Aluminum Alloy—C. LIN AND R. G. HOAGLAND	467

BASIC CONSIDERATIONS AND APPLICATIONS

<i>In Situ</i> SEM Observation of Fracture Processes in Short Glass Fiber Reinforced Thermoplastic Composite—N. SATO, T. KURAUCHI, S. SATO, AND O. KAMIGAITO	493
Some Three-Dimensional Aspects of Subcritical Flaw Growth as Measured in a Transparent Polymeric Material—C. W. SMITH AND J. S. EPSTEIN	504
Stress Intensity Factors for Surface Cracks with Arbitrary Shapes in Plates and Shells—T. MIYOSHI, M. SHIRATORI, AND O. TANABE	521
On the Three-Dimensional Implications of LEFM: Finite Element Analysis of Straight and Curved Through-Cracks in a Plate—J. S. SOLECKI AND J. L. SWEDLOW	535
Fracture Behavior of a Uranium or Tungsten Alloy Notched Component with Inertia Loading—J. H. UNDERWOOD AND M. A. SCAVULLO	554
Strain-Rate Effects on the Ductile/Brittle Transition in Steels—G. A. KNOROVSKY	569

Elastic-Plastic Failure Analysis of Pressure Vessel Tests— C. A. SCIAMMARELLA	597
Fracture Mechanics Analysis of a Pressure Vessel with a Semi- Elliptical Surface Crack Using Elastic-Plastic Finite Element Calculations— D. AURICH, W. BROCKS, H.-D. NOACK, AND H. VEITH	617
Application of Maximum Load Toughness to Defect Assessment in a Ductile Pipeline Steel— A. A. WILLOUGHBY AND S. J. GARWOOD	632
SUMMARY	
Summary	659
Author Index	665
Subject Index	667

ISBN: 0-8031-0225-9