Fracture Resistance Testing of MONOLITHIC and COMPOSITE BRITTLE MATERIALS

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ASTM INTERNATIONAL

STP 1409

STP 1409

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J. A. Salem, G. D. Quinn, and M. G. Jenkins, editors

ASTM Stock Number: STP1409

ASTM International
100 Barr Harbor Drive
PO Box C700
West Conshohocken, PA 19428-2959

Printed in the U. S. A.

Library of Congress Cataloging-in-Publication Data

Fracture resistance testing of monolithic and composite brittle materials / J.A. Salem, G.D. Quinn, and M.G. Jenkins, editors.
p. cm.
"ASTM stock number: STP1409."
Includes bibliographical references and index.
ISBN 0-8031-2880-0
1. Brittleness—Congresses. 2. Fracture mechanics—Congresses. I. Salem, J. A. (Jonathan A.), 1960- II. Quinn, G. D. (George D.) III. Jenkins, Michael G., 1958-

TA418.16.F73 2002
620.1'126—dc21

2001053953

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Printed in Bridgeport, NJ
January 2002

Foreword

This publication, Fracture Resistance Testing of Monolithic and Composite Brittle Materials, contains papers presented at the symposium of the same name held in Orlando, Florida, on 14 November 2000. The symposium was sponsored by ASTM Committee C28 on Advanced Ceramics. The symposium chairman was Jonathan A. Salem, NASA Glenn Research Center at Lewis Field, and the symposium co-chairmen were George D. Quinn, National Institute for Standard and Technology, and Michael G. Jenkins, University of Washington.

Overview

During the past decade, ASTM Committee C28 on Advanced Ceramics, along with its European and Japanese counterparts, has made great progress in the development of new standards for the measurement of fracture toughness, slow crack growth, and biaxial strength. These standards are designed to result in quality measurements for engineering, research, and general characterization purposes. They strive to strike a balance between accuracy and reasonable convenience. Although work continues on improvement of existing standards and the development of new standards, members of Committee C28 felt that the time had come to review and summarize the recent efforts by sponsoring a symposium on fracture resistance testing of brittle materials. The symposium was held in Orlando, Florida during November of 2000. Participants came from Europe, Asia, and the Americas.

Four themes were encompassed in the presentations: *Implications for Design and Testing; Fracture Toughness Standardization; Crack Growth Resistance; and Unique Materials and Environmental Effects.* Although three of the themes are relatively broad and papers representing a variety of subtopics were presented, the session on *Fracture Toughness Standardization* was relatively focused. The emphasis on this topic merits some explanation. Fracture toughness is a fundamental measure of a ceramic's ability to tolerate flaws, or conversely, its brittleness; however, there are conflicting views on the importance of that property for design. Some design methodologies currently in use for ceramics (i.e., those based on strength statistics) do not employ fracture toughness, despite its overwhelming importance in classical deterministic design techniques. However, it is the fracture toughness and the flaws inherent in a ceramic material that control the strength measurements used as the basis for such reliability methodologies. Furthermore, deterministic design methods that employ fracture toughness are being used for ceramic component design.

Thus, quality fracture toughness measurements using a reasonable degree of similitude are needed. Furthermore, since research on toughening of ceramics exists and continues, the techniques need to be efficient in terms of the material used and the time required. Committee C28 chose three techniques for development and standardization in the new fracture toughness standard C 1421-99. These techniques are detailed in this special technical publication and, importantly, the three techniques show convergence when good metrology is employed. In addition to standardized techniques, the section *Fracture Toughness Standardization* discusses the single edged V-notched beam method that is on a fast track for standardization in Europe.

The section on *Implications for Design and Testing* contains papers on the analysis of plates for biaxial strength testing and the transition in measured fracture toughness from a value associated with the properties of a single grain to the polycrystalline value. A number of papers presented in the other sessions also had implications for design and testing. These included papers on the effect of stress rate on slow crack growth parameters for design usage, and the application of quantitative fractography to the characterization of the *R*-curve behavior of a silicon nitride for bearing applications.

The section on *Unique Materials and Environmental Effects* includes papers on elevated temperature fracture toughness testing of particulate reinforced ceramic composites, thermal and environmental effects on the fracture toughness of titanium carbonitrides for machining, and environmental interactions that lead to rate effects in "dynamic fatigue" (i.e., stress corrosion) testing.

The section on *Crack Growth Resistance* includes papers on testing of functionally graded materials, elevated temperature *R*-curve testing, and the study of a toughening mechanism. Although most researchers applied classical mechanical techniques for the measurement of fracture toughness or crack growth resistance, both theoretical and fractographic methods were also presented.

The papers are relevant in that they supply the background that determined many of the guidelines used in current Committee C28 standards. This volume not only summarizes the latest standard methods for the measurement of fracture toughness, slow crack growth, and biaxial strength, but also indicates new areas for fracture toughness test method development and standardization: testing of complex materials, elevated temperature measurement, and *R*-curve measurement. Indications were also given that test method development is needed in the areas of elevated temperature biaxial strength measurement and slow crack growth by static loading. It is hoped that in coming years these areas will be pursued fruitfully by Committee C28 on Advanced Ceramics.

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