STP 1429

PREDICTIVE MATERIAL modeling:

combining fundamental physics understanding, computational methods, and empirically observed behavior

Technical Editor(s):
Mark T. Kirk and M. Erickson Natishan

ASTM INTERNATIONAL
Standards Worldwide

STP 1429

Predictive Material Modeling: Combining Fundamental Physics Understanding, Computational Methods and Empirically Observed Behavior

M. T. Kirk and M. Erickson Natishan, editors

ASTM Stock Number: STP1429

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

Predictive material modeling; combining fundamental physics understanding, computational methods and empirically observed behavior / M.T. Kirk and M. Erickson Natishan, editors.
p. cm. – (STP ; 1429)
Includes bibliographical references.
"ASTM Stock Number: STP1429."
ISBN 0-8031-3472-X
1. Steel--Metallurgy--Congresses. I, Kirk, Mark, 1961-II. Natishan, M. Erickson. III, ASTM special technical publication ; 1429.

2003062889

TN701.5.P74 2003
669'.142--dc22

Peer Review Policy

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

To make technical information available as quickly as possible, the peer-reviewed papers in this publication were prepared "camera-ready" as submitted by the authors.

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 the peer reviewers. In keeping with long-standing publication practices, ASTM International maintains the anonymity of the peer reviewers. The ASTM International Committee on Publications acknowledges with appreciation their dedication and contribution of time and effort on behalf of ASTM International.

Printed in Mayfield, PA
January 2004

Foreword

The Symposium on Predictive Material Modeling: Combining Fundamental Physics Understanding, Computational Methods and Empirically Observed Behavior was held in Dallas, Texas on 7–8 November 2001. ASTM International Committee E8 on Fatigue and Fracture sponsored the symposium. Symposium chairpersons and co-editors of this publication were Mark T. Kirk, U. S. Nuclear Regulatory Commission, Rockville, Maryland and MarjoricAnn Erickson Natishan, Phoenix Engineering Associates, Incorporated, Sykesville, Maryland.

Contents

Overview

An ASTM International Symposium conceming *Predictive Material Modeling: Combining Fundamental Physics Understanding, Computational Methods, and Empirically Observed Behavior* was held on 7–8 November 2001 in Dallas, Texas in conjunction with the semi-annual meetings of ASTM Intemational Committee E8 on Fracture and Fatigue. The symposium was motivated by the focus of many industries on extending the design life of structures. Safe life extension depends on the availability of robust methodologies that accurately predict both the fundamental material behavior and the structural response under a wide range of load conditions. Heretofore, predictive models of material behavior have been based on empirical derivations, or on fundamental physics-based models that describe material behavior at the nano- or micro-scale. Both approaches to modeling suffer from issues that limit their practical application. Empirically-derived models, while based on readily determined properties, cannot be reliably used beyond the limits of the database from which they were derived. Fundamental, physically-derived models provide a sound basis for extrapolation to other materials and conditions, but rely on parameters that are measured on the microscale and thus may be difficult and costly to obtain. It was the hope that this conference would provide an opportunity for communication between researchers pursuing these different modeling approaches.

The papers presented at this Symposium included six conceming ferritic steel; these address fracture in the transition regime, on the upper shelf, and in the creep range. Three of these papers used a combination of the Gurson and Weibull models to predict fracture performance and account for constraint loss. While successful at predicting conditions similar to those represented by the calibration datasets, all investigators found the parameters of the (predominantly) empirical Weibull model to depend significantly on factors such as temperature, strain rate, initial yield strength, strain hardening exponent, and so on. These strong dependencies make models of this type difficult to apply beyond their calibrated range. Natishan proposed the use of physically derived models for the transition fracture toughness of ferritic steels. While this approach shows better similarity of parameters across a wide range material, loading, and temperature conditions than does the Weibull approach, it has not yet been used to assess constraint loss effects as the Weibull models have.

Three papers at the Symposium addressed topics un-related to steels. One paper applied the Weibull models used extensively for steel fracture to assess the interfacial fracture of electronic components. As is the case for steel fracture, the Weibull models predict well conditions similar to the calibration dataset. In the remaining two papers researchers affiliated with the Naval Research Laboratory used advanced computational and experimental techniques to develop constitutive models for composite and shape memory materials.

We would like to close this overview by extending our thanks not only to the authors of the papers you find in this volume, but also to the many peer reviewers, and to the members of the ASTM International staff who made publication of this volume possible.

Mark T Kirk
Nuclear Regulatory Commission
Rockville, Maryland
Symposium chairperson and editor

MarjorieAnn Erickson Natishan
Phoenix Engineering Associates, Inc.
Sykesville, Maryland
Symposium chairperson and editor

ISBN # 0-8031-3472-X
Stock #: STP1429

www.astm.org