Dynamic fracture

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1985 **MARTINUS NIJHOFF PUBLISHERS**
a member of the KLUWER ACADEMIC PUBLISHERS GROUP
DORDRECHT / BOSTON / LANCASTER

Distributors

for the United States and Canada: Kluwer Academic Publishers, 190 Old Derby Street, Hingham, MA 02043, USA

for the UK and Ireland: Kluwer Academic Publishers, MTP Press Limited, Falcon House, Queen Square, Lancaster LA1 1RN, UK

for all other countries: Kluwer Academic Publishers Group, Distribution Center, P.O. Box 322, 3300 AH Dordrecht, The Netherlands

Library of Congress Cataloging in Publication Data

Main entry under title:

Dynamic fracture.

1. Fracture mechanics--Addresses, essays, lectures.

2. Structural dynamics--Addresses, essays, lectures.

I. Williams, M. L. (Max L.) II. Knauss, Wolfgang

Gustav.

TA409.D96 1985 620.1'126 85-10582

ISBN-13: 978-94-010-8765-0

e-ISBN-13: 978-94-009-5123-5

DOI: 10.1007/978-94-009-5123-5

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Softcover reprint of the hardcover 1st edition 1985

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Martinus Nijhoff Publishers, P.O. Box 163, 3300 AD Dordrecht,
The Netherlands.

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Foreword

From time to time the *International Journal of Fracture* has presented matters thought to be of special interest to its readers. In previous special issues (December 1980 and April 1981), Dr H.W. Liu as Guest Editor presented a series of review papers dealing with fatigue processes and characteristics in metals and non-metals. Continuing this policy, which is consistent with our stated objectives, a second review dealing with time dependence in the fracture process, including the effect of material inertia but essentially excluding very strong shock effects in solids, has been assembled under the generic term "dynamic fracture". We hope that the ensuing state-of-the-art review will yield an instructive and timely product which readers will find useful.

To assist us in presenting this subject, we have prevailed upon a well-known worker in dynamic fracture, Dr W.G. Knauss, Professor of Aeronautics and Applied Mechanics, California Institute of Technology to act as Guest Editor for this special double issue. On behalf of the editors and publisher, I wish to express our indebtedness to Professor Knauss and his invited authors for undertaking this special effort.

M.L. Williams
Editor-in-Chief

Pittsburgh, Pennsylvania
March 1985

Preface

W.G. KNAUSS

During the past three decades significant studies have been made in understanding fracture mechanics. These advances have encompassed both the fracture process itself and improved design criteria for engineering structures. Failure prevention in pressure vessels or in aerospace structures would be unthinkable today without fracture mechanics principles. Similarly, the development, improvement, and evaluation of materials depends upon many of the same advances.

The majority of past work on fracture has been devoted to the events which lead up to the onset of crack propagation. However, it is equally important to be concerned with those processes that govern the time dependent motion or growth of cracks. Time dependence in the fracture process develops for various reasons, such as viscoelastic or viscoplastic material behavior, cyclic loading histories leading to the phenomenon of fatigue, or through the involvement of material inertia in the form of stress waves. While these problems span a spectrum of time scales, it has been the practice to distinguish between situations in which the action of stress or shock waves dominates the fracture process and those in which material inertia plays a less significant role. Viscoelastic or creep fracture and fatigue fall in the latter category, although dynamically induced vibrations are often the cause of fatigue failure.

In this book the authors will review certain aspects of dynamic fracture in which stress waves dominate the crack propagation processes. This distinction is, however, not always clear cut and can include a spectrum of situations with inertia related vibrations, up to and including the effect of shock and impact physics. Such latter situations usually involve extensive fracturing. For this book, however, we chose to emphasize those problems in which individual cracks play a dominant role.

Systematic investigation of dynamic fracture and crack propagation commenced with Schardin's exploratory but extensive experiments in the 1930s and continued with Rinehart and Pearson's spall and impact studies about a decade and a half later. Since then interest and sophistication in dynamic fracture has grown at an accelerating pace, motivated by several important engineering problems. They include: The safety of nuclear pressure vessels under rapid cool down which can spawn dynamically growing cracks; The rapid propagation of cracks in gas and off-shore oil pipelines can generate economical problems of large proportions; Dynamic comminution arises in the pharmaceutical industry as well as with explosively generated porosity in geological formations for augmented gas and oil recovery; Nucleation and growth of micro-cracks in the earliest stages of fatigue failure.

The diversity of these problems is an indication of the breadth of topics considered under the heading of Dynamic Fracture. A full exposition is not possible, and indeed is not intended, for the immediate review purpose. Nevertheless, it was deemed desirable to collect a number of papers, each with a large component of review material, to summarize at least a significant portion of this field. It is hoped that such a "snapshot" of the current state of affairs will illuminate common underlying principles and behavior in such varied situations.

Much of the work of the last decade was concerned with the experimental definition of the state of stress in laboratory specimens for which analytical solutions could not be obtained. That work is not represented here in proportion to the effort expended on it. The applications of results to dynamic fracture in reactor vessels and pipelines is also not represented extensively. Fracture in geological formations, as occurs in earthquake related problems, is only presented in one paper to present a frame of reference to exhibit similarities and differences commended to the reader's attention. Finally, and despite the lack of emphasis on gross spallation, there are presented some problems of crack initiation for single and multiple cracks which might be applied to an elemental understanding of the general spall problem. In this characterization, the stress field around the moving crack tip in model and actual structural materials are considered from both the experimental and analytical point of view. Finally the question of dynamic crack branching which governs the technical problem of comminution receives considerable attention as does the process of how cracks come to rest under dynamic loading.

The reader will find that many questions on these topics remain unanswered. We do hope however that someone who has a basic appreciation of fracture problems can readily evaluate the current state of knowledge in this field.

W.G. Knauss
Guest Editor

Pasadena, California
March 1985