

# FATIGUE FRACTURE DYNAMICS OF HIGH STRENGTH STEEL STUDIED BY ACOUSTIC EMISSION TECHNIQUE

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## Abstract

This paper discusses the feasibility of AE technique for monitoring of fatigue damage of high strength bearing steel. We studied AE source mechanism in fatigue process using the waveform and source simulation analyses. The steel specimens, subjected to four-point cyclic bending, produced a few but strong AE signals just before the final fracture. Fractographic study showed a change of fracture type from transgranular (TG) to intergranular (IG). Crack volume was estimated by source simulation of AE as approximately  $10^{-16} \text{ m}^3$ . Another fatigue fracture test of a compact tension (CT) specimen also showed a change of fracture type from TG- to IG-fracture at around  $K_{\max}$  of 8 MPa $\sqrt{\text{m}}$ , above which both the fast crack propagation and high AE generation rates were detected. The source simulation analysis indicated simultaneous IG fracture of neighboring few grains as the source of AE for fatigue test of the CT specimen.

**Keywords:** High strength steel, fatigue fracture, source wave analysis, microcrack dynamics

## Introduction

A consideration of ultra-high-cycle fatigue of more than  $10^7$  cycles is becoming important for maintenance of infrastructure [1]. This type of fatigue is called as giga-cycle fatigue, producing fatigue failure at stress lower than the fatigue limit determined by the conventional fatigue test up to  $10^7$  cycles. High-strength steels have been reported to exhibit a distinct knee point within a cycle range of  $N = 10^5$ - $10^6$  and the curve has another knee point in the long-life region of  $N > 10^7$  [2, 3]. This “duplex  $S$ - $N$  curve”, consisting of two different curves, is observed for long-term cyclic loading, and suggests that the endurance limit by the conventional fatigue concept cannot provide the safety design data for mechanical structures. Many researchers [4] have studied the fracture mechanisms in high-cycle range. Although the monitoring technique of fatigue crack is urgent in infrastructure, it has not been performed well so far. Development of the monitoring method is also an important issue.

We studied feasibility of acoustic emission (AE) as a method of fatigue damage monitoring of a bearing steel (SUI2). Both the smooth rectangular bend specimens and compact tension (1/2 CT) specimens were used for studying fatigue crack initiation and propagation. The mechanism of fatigue damage was also investigated by waveform and source simulation analyses of AE signals.

## Test Specimen and Experimental Procedures

The specimen used is a high-carbon chromium bearing steel (JIS G4805), which is commonly used for bearing components. The steel grade is designated as SUI2. Chemical composition and mechanical properties of the specimen were shown in Tables 1 and 2, respectively.

# Dynamics Of Fracture Dynamics Of Fracture

**Dominique P. Miannay**



## **Dynamics Of Fracture Dynamics Of Fracture:**

*Dynamics of Fracture* N. Morozov, Y. Petrov, 2013-06-05 In this book a new phenomenological approach to brittle medium fracture initiation under shock pulses is developed. It provides an opportunity to estimate fracture of media with and without macrodefects. A qualitative explanation is thus obtained for a number of principally important effects of high speed dynamic fracture that cannot be clarified within the framework of previous approaches. It is possible to apply this new strategy to resolve applied problems of disintegration, erosion and dynamic strength determination of structural materials. Specialists can use the methods described to determine critical characteristics of dynamic strength and optimal effective fracture conditions for rigid bodies. This book can also be used as a special educational course on deformation of materials and constructions and fracture mechanics.

Dynamic Fracture Mechanics Arun Shukla, 2006 Covering a wide variety of topics in dynamic fracture mechanics, this volume presents state of the art experimental techniques and theoretical analysis on dynamic fracture in standard and exotic materials. Written by world renowned researchers, this valuable compendium contains eleven chapters on crack initiation, crack propagation, crack arrest, crack stress wave interactions and experimental, analytical and numerical methods in dynamic fracture mechanics. Contents: Modeling Dynamic Fracture Using Large Scale Atomistic Simulations. H. J. Gao. Dynamic Crack Initiation Toughness. D. Rittel. The Dynamics of Rapidly Moving Tensile Cracks in Brittle Amorphous Material. J. Fineberg. Optical Methods for Dynamic Fracture Mechanics. H. V. Tippur. On the Use of Strain Gages in Dynamic Fracture. V. Parameswaran. Dynamic and Crack Arrest Fracture Toughness. R. E. Link. Dynamic Fracture in Graded Materials. A. Shukla. Dynamic Fracture Initiation Toughness at Elevated Temperatures with Application to the New Generation of Titanium Aluminides Alloys. M. Shazly et al. Dynamic Fracture of Nanocomposite Materials. A. Shukla et al. Readership: Researchers, practitioners and graduate students in fracture mechanics and materials science.

**Dynamic Fracture K.** Ravi-Chandar, 2004-10-16 Dynamic fracture in solids has attracted much attention for over a century from engineers as well as physicists due both to its technological interest and to inherent scientific curiosity. Rapidly applied loads are encountered in a number of technical applications. In some cases such loads might be applied deliberately as for example in problems of blasting, mining and comminution or fragmentation. In other cases such dynamic loads might arise from accidental conditions. Regardless of the origin of the rapid loading it is necessary to understand the mechanisms and mechanics of fracture under dynamic loading conditions in order to design suitable procedures for assessing the susceptibility to fracture. Quite apart from its repercussions in the area of structural integrity, fundamental scientific curiosity has continued to play a large role in engendering interest in dynamic fracture problems. In depth coverage of the mechanics, experimental methods, practical applications, Summary of material response of different materials, Discussion of unresolved issues in dynamic fracture.

Dynamic Fracture Mechanics L. B. Freund, 1998-03-28 This volume focuses on the development and analysis of mathematical models of fracture phenomena.

Time-Dependent Fracture Mechanics Dominique P. Miannay, 2012-12-06

Intended for engineers researchers and graduate students dealing with materials science structural design and nondestructive testing and evaluation this book represents a continuation of the author's Fracture Mechanics 1997 It will appeal to a variety of audiences The discussion of design codes and procedures will be of use to practicing engineers particularly in the nuclear aerospace and pipeline industries the extensive bibliography and discussion of recent results will make it a useful reference for academic researchers and graduate students will find the clear explanations and worked examples useful for learning the field The book begins with a general treatment of fracture mechanics in terms of material properties and loading and provides up to date reviews of the ductile brittle transition in steels and of methods for analyzing the risk of fracture It then discusses the dynamics of fracture and creep in homogeneous and isotropic media including discussions of high loading rate characteristics the behavior of stationary cracks in elastic media under stress and the propagation of cracks in elastic media This is followed by an analysis of creep and crack initiation and propagation describing for example the morphology and incubation times of crack initiation and growth and the effects of high temperatures The book concludes with treatments of cycling deformation and fatigue creep fatigue fractures and crack initiation and propagation Problems at the end of each chapter serve to reinforce and test the student's knowledge and to extend some of the discussions in the text Solutions to half of the problems are provided      Dynamic fracture M.L. Williams, W.G.

Knauss, 2012-12-06 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      Fracture Mechanics of Rock Barry Kean

Atkinson, 2015-05-11 The analysis of crack problems through fracture mechanics has been applied to the study of materials such as glass metals and ceramics because relatively simple fracture criteria describe the failure of these materials The increased attention paid to experimental rock fracture mechanics has led to major contributions to the solving of geophysical problems The text presents a concise treatment of the physics and mathematics of a representative selection of problems from areas such as earthquake mechanics and prediction hydraulic fracturing hot dry rock geothermal energy fault mechanics and dynamic fragmentation      Physical Aspects of Fracture Elisabeth Bouchaud, Dominique Jeulin, Claude

Prioul, Stéphane Roux, 2012-12-06 The main scope of this Cargese NATO Advanced Study Institute June 5 17 2000 was to bring together a number of international experts covering a large spectrum of the various Physical Aspects of Fracture As a matter of fact lecturers as well as participants were coming from various scientific communities mechanics physics materials science with the common objective of progressing towards a multi scale description of fracture This volume includes papers on most materials of practical interest from concrete to ceramics through metallic alloys glasses polymers and composite materials The classical fields of damage and fracture mechanisms are addressed critical and sub critical quasi static crack propagation stress corrosion fatigue fatigue corrosion as well as dynamic fracture Brittle and ductile fractures are considered and a balance has been carefully kept between experiments simulations and theoretical models and between the contributions of the various communities New topics in damage and fracture mechanics the effect of disorder and statistical aspects dynamic fracture friction and fracture of interfaces were also explored This large overview on the Physical Aspects of Fracture shows that the old barriers built between the different scales will soon fracture It is no more unrealistic to imagine that a crack initiated through a molecular dynamics description could be propagated at the grain level thanks to dislocation dynamics included in a crystal plasticity model itself implemented in a finite element code Linking what happens at the atomic scale to fracture of structures as large as a dam is the new emerging challenge

**Crack Dynamics in Metallic Materials** J.R. Klepaczko, 2014-05-04 This book provides an up to date knowledge on theory and experimental results of rate dependent fracture processes in metallic materials The objective is to expose the current status of a growing branch of fracture mechanics called generally Dynamic Fracture Crack dynamics takes into account not only the effects of inertia but also rate sensitivity of a material under consideration This volume has been prepared by four leading authorities in fracture dynamics D R Curran J F Kalthoff J R Klepaczko and F Nilsson A broad range of problem is covered dynamic fracture theory application of dynamic fracture mechanics dynamic crack initiation and microstatistical fracture mechanics in dynamic fracture The book in its present format may serve as a text supplement in lecturing on fracture mechanics On the other hand it may serve as an instructional aid in engineering of fracture prevention

**Fracture Mechanics** John D. Landes, Donald E. McCabe, 1994 *Fracture Mechanics* Alan T. Zehnder, 2012-01-03 Fracture mechanics is a vast and growing field This book develops the basic elements needed for both fracture research and engineering practice The emphasis is on continuum mechanics models for energy flows and crack tip stress and deformation fields in elastic and elastic plastic materials In addition to a brief discussion of computational fracture methods the text includes practical sections on fracture criteria fracture toughness testing and methods for measuring stress intensity factors and energy release rates Class tested at Cornell this book is designed for students researchers and practitioners interested in understanding and contributing to a diverse and vital field of knowledge

**Fracture Mechanics** Vladimir Zalmanovich Parton, 1992 An introduction to the mechanics and mathematics of fracture for undergraduates in a wide range of fields practical engineers and other inquisitive

readers with a background in at least the fundamentals of mechanics and mathematics Describes the historical development of the fracture mechanical concepts used today and how these are applied in industry Translated from the Russian about half of the brief bibliography are works in Russian Annotation copyrighted by Book News Inc Portland OR **Fracture Mechanics** Nicholas Perrone,1978 **Springer Handbook of Experimental Solid Mechanics** William N. Sharpe, Jr.,William N. Sharpe,2008-12-04 The Springer Handbook of Experimental Solid Mechanics documents both the traditional techniques as well as the new methods for experimental studies of materials components and structures The emergence of new materials and new disciplines together with the escalating use of on and off line computers for rapid data processing and the combined use of experimental and numerical techniques have greatly expanded the capabilities of experimental mechanics New exciting topics are included on biological materials MEMS and NEMS nanoindentation digital photomechanics photoacoustic characterization and atomic force microscopy in experimental solid mechanics Presenting complete instructions to various areas of experimental solid mechanics guidance to detailed expositions in important references and a description of state of the art applications in important technical areas this thoroughly revised and updated edition is an excellent reference to a widespread academic industrial and professional engineering audience **Fracture Mechanics** Ted L. Anderson,T. L. Anderson,1994-12-16 This bestselling text reference provides a comprehensive treatment of the fundamentals of fracture mechanics It presents theoretical background as well as practical applications and it integrates materials science with solid mechanics In the Second Edition about 30% of the material has been updated and expanded new technology is discussed and feedback from users of the first edition has been incorporated *Fracture Mechanics for Modern Engineering Design* K. R. Y. Simha,K.R.V. Simha,2001-11 Fracture is a natural reaction of solids to relieve stress and shed excess energy The fragility of solids is a constant threat to our survival as we drive over a bridge go through a tunnel or even inside a building This book weaves together the essential concepts underlying fracture mechanics **Cracks and Fracture** K. Bertram Broberg,1999-02-24 Cracks and Fracture consists of nine chapters in logical sequence In two introductory chapters physical processes in the vicinity of the crack edge are discussed and the fracture process is described Chapter 3 develops general basic concepts and relations in crack mechanics such as path independent integrals stress intensity factors and energy flux into the crack edge region Chapters 4 7 deal with elastostatic cracks stationary or slowly moving elastic plastic cracks elastodynamic crack mechanics and elastoplastic aspects of fracture including dynamic fracture mechanics Appendices include general formulae the basic theory of analytic functions introduction to Laplace and Hankel transforms and description of certain basic relations for instance for stress waves in solids There is an extensive bibliography containing references to both classical and recent work and a comprehensive index Presents an extensive bibliography containing references to both classical and recent works and a comprehensive index Appendices include general formulas the basic theory of analytic functions introduction to Laplace and Hankel transforms and descriptions of certain basic relations for

instance for stress waves in solids      Dynamic Fracture Mechanics L. B. Freund,1990      *Fracture Mechanics* J. P. Gudas,1990 Papers from the 21st National Symposium on Fracture Mechanics held in Annapolis Md June 1988 present new work in elastic plastic fracture dynamic fracture transition fracture in steels micromechanical aspects of the fracture process computational mechanics fracture mechanics testing and a      **Fracture Mechanics: Applications and Challenges** M. Fuentes,M. Elices,A. Martín-Meizoso,J.-M. Martínez-Esnaola,2000-09-13 This book contains 15 fully peer reviewed Invited Papers which were presented at the 13th Biennial European Conference on Fracture and is a companion to the CD ROM <http://www.elsevier.com/locate/008043701x>Proceedings The organisers of the ECF 13 opted from the very beginning for an application orientated conference and consequently this book contributes to the understanding of fracture phenomena and disseminates fracture concepts and their application to the solution of engineering problems to practitioners in a wide range of fields The fields covered in this book can be broadly classified into elastic plastic fracture mechanics fracture dynamics fatigue and interactive processes failure structural integrity coatings and materials with applications to the following industrial sectors transport aerospace engineering civil engineering pipelines and automotive engineering

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