

Preface

Prevention and assessment of fracture and damage processes play an essential role in the development and dimensioning of engineering constructions, components, and facilities in order to ensure their technical safety, durability, and reliability. In the case of failure, mistakes made by engineers in this respect can have catastrophic consequences for the lives of people, the environment, and even for the economy. In many engineering components and materials, defects may exist resulting from manufacturing or operation, which cannot always be avoided. Therefore, the fracture mechanical assessment of crack-like defects is of great importance. In the context of technical surveillance and studies of causes of failure cases, besides materials characterization the analysis of the mechanical loading situation at cracks, notches, and similar defects under in-service conditions is of particular interest.

In the past 50 years, *fracture mechanics* has been developed into an independent interdisciplinary scientific field, which resides between engineering mechanics, materials science, and solid-state physics. Fracture mechanics defines load parameters and criteria in order to quantitatively assess crack behavior in materials and components under static, dynamic, or cyclic loading.

Additionally, numerical methods of applied mechanics are used nowadays for fracture-mechanical stress analysis. The finite element method (FEM) has been established in many areas of engineering as a universal and efficient tool of modern engineering design and stress analysis. Numerous software packages are available, which offer not only standard methods of structural mechanics but also fracture-mechanical options of more recent invention. However, the treatment of crack issues requires particular theoretical precognition and numerical algorithms, much of which has not yet been integrated into the engineer's education and practice to the necessary extent, but has been available mostly to »fracture-mechanical experts« only.

The intention of the present monograph consists in closing this gap. In the introduction, we present the essential theoretical basics of fracture mechanics, whose parameters are to be determined using the FEM. The main part of the book is focused on specific numerical techniques to analyze plane and spatial crack

problems in elastic and plastic materials under all technically relevant loads. Finally, worked samples for the solutions of practical problems will be provided for each area.

This textbook is addressed to graduate students of engineering study courses, especially those in mechanical engineering, civil engineering, vehicle design, materials science, aerospace industry, or computational engineering. It shall provide an introduction into this area of expertise to graduates and postgraduates of these fields and support in their own research activities. Moreover, I consider as a target audience engineers in design and computation departments of many industrial branches and officials in technical controlling institutions, who are confronted with issues of dimensioning, assessment, and supervision of strength and durability of engineering constructions. Furthermore, this textbook should build a bridge for materials scientists and materials engineers to theoretical fracture mechanics in order to use numerical techniques for materials modeling or to analyze materials and components tests using computations. This textbook requires a basic knowledge of continuum mechanics, strength of materials, material theory, and the finite-element method. The essential basics of mechanics of materials are reviewed for convenience in the Appendix.

I was gratified at the positive response by which the scientific community in Germany has appreciated the first edition of this book entitled “Numerische Beanspruchungsanalyse von Rissen—Finite-Elemente in der Bruchmechanik”, edited by Vieweg-Teubner publisher in 2008. Many readers confirmed to me personally that the book was a useful help to understand fracture mechanics concepts and a real assistance in performing their own numerical computations. Meanwhile, the second improved edition appeared in 2010. Therefore, I feel encouraged to offer this book to a wider audience in the English language.

Many persons contributed to the preparation of the book. First of all, my very sincere thanks go to Ms. M. Beer for making all the excellent drawings. Numerous numerical examples were elaborated during the pleasant joint work with my former and current Ph.D.-students or co-workers at the institute. In particular, I would like to express my thanks to Dr. M. Abendroth, Dr. M. Enderlein, Dr. E. Kullig, Th. Leibelt, C. Ludwig, Dr. U. Mühlich, Dr. F. Rabold, Dr. B. N. Rao, Prof. Dr. A. Ricoeur, Dr. A. Rusakov, L. Sommer, and L. Zybell.

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