

Preface

The effectiveness of computational techniques such as finite elements in modeling material failure has lagged far behind their capabilities in traditional stress analysis. This difficulty arises because the mathematical foundation on which all such methods are based assumes that the body remains continuous as it deforms. Existing computational methods for the modeling of fracture in a continuous body are based on the partial differential equations (PDEs) of classical continuum mechanics. These methods suffer from the inherent limitation that the spatial derivatives required by the PDEs do not, by definition, exist at crack tips or along crack surfaces. Therefore, the basic mathematical structure of the formulation breaks down whenever a crack appears in a body. Various special techniques have been developed in fracture mechanics to deal with this limitation. Generally, these techniques involve redefining a body in such a way as to exclude the crack and then applying conditions at the crack surfaces as boundary conditions. In addition, existing methods for fracture modeling suffer from the need of external crack growth criteria and, possibly, remeshing. This is a mathematical statement that prescribes how a crack evolves a priori based on local conditions. The requirement of tracking individual crack fronts, particularly in three dimensions, as well as the possibility of fractures moving between constituent materials, interfaces, and layers, makes it difficult to provide accurate crack growth criteria.

The difficulties encountered in the methods utilizing classical continuum mechanics can be overcome by performing molecular dynamics simulations or by using atomistic lattice models. Atomistic methods, although providing insight into the nature of fracture in certain materials, cannot be expected to provide a practical tool for the modeling of engineering structures. It is clear that the atomistic simulations are insufficient to model fracture processes in real-life structures.

The peridynamic theory provides the capability for improved modeling of progressive failure in materials and structures. Further, it paves the way for addressing multi-physics and multi-scale problems. Even though numerous journal articles and conference papers exist in the literature on the evolution and application of the peridynamic theory, it is still new to the technical community. Because it is based on concepts not commonly used in the past, the purpose of this book is to

explain the peridynamic theory in a single framework. It presents not only the theoretical basis but also its numerical implementation. It starts with an overview of the peridynamic theory and the derivation of its governing equations. The relationship between peridynamics and classical continuum mechanics is established, and this leads to the ordinary state-based peridynamics formulations for both isotropic and composite materials. Numerical treatments of the peridynamic equations are presented in detail along with solutions to many benchmark and demonstration problems. In order to take advantage of salient features of peridynamics and the finite element method, a coupling technique is also described. Finally, an extension of the peridynamic theory for thermal diffusion and fully coupled thermomechanics is presented with applications.

Sample algorithms for the solutions of benchmark problems are available at the website <http://extras.springer.com> so that researchers and graduate students can modify these algorithms and develop their own solution algorithms for specific problems. The goal of this book is to provide students and researchers with a theoretical and practical knowledge of the peridynamic theory and the skills required to analyze engineering problems by developing their own algorithms.

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