Finite And Boundary Element Methods In Engineering

Starting from a clear, concise introduction, the powerful finite element and boundary element methods of engineering are developed for application to quantum mechanics. The reader is led through illustrative examples displaying the strengths of these methods using application to fundamental quantum mechanical problems and to the design/simulation of quantum nanoscale devices.

The analysis of plates and shells under static and dynamic loads is of greatinterest to scientists and engineers both from the theoretical and the practical viewpoint. The Boun- dary Element Method (BEM) has some distinct advantages over domain techniques such as the Finite Difference Method (FDM) and the Finite Element Method (FEM) for a wide class of structuralanalysis problems. This is the first book to deal specifically with the analysis of plates and shells by the BEM and to cover all aspects of their behaviour, and combi- nes tutorial and state-of-the-art articles on the BEM as ap- plied to plates and shells. It aims to inform scientists and engineers about the use and the advantages of this techni- que, the most recent developments in the field and the per- tinent literature for further study.

A novel computational procedure called the scaled boundary finite-element method is described which combines the advantages of the finite-element and boundary-element methods : Of the finite-element method that no fundamental solution is required and thus expanding the scope of application, for instance to anisotropic material without an increase in complexity and that singular integrals are avoided and that symmetry of the results is automatically satisfied. Of the boundary-element method that the spatial dimension is reduced by one as only the boundary is discretized with surface finite elements, reducing the data preparation and computational efforts, that the boundary conditions at infinity are satisfied exactly and that no approximation other than that of the surface finite elements on the boundary is introduced. In addition, the scaled boundary finite-element method presents appealing features of its own : an analytical solution inside the domain is achieved, permitting for instance accurate stress intensity factors to be determined directly and no spatial discretization of certain free and fixed boundaries and interfaces between different materials is required. In addition, the scaled boundary finite-element method combines the advantages of the analytical and numerical approaches. In the directions parallel to the boundary, where the behaviour is, in general, smooth, the weighted-residual approximation of finite elements applies, leading to convergence in the finite-element sense. In the third (radial) direction, the procedure is analytical, permitting e.g. stress-intensity factors to be determined directly based on their definition or the boundary conditions at infinity to be satisfied exactly. In a nutshell, the scaled boundary finite-element method is a semi-analytical fundamental-solution-less boundary-element method based on finite elements. The best of both worlds is achieved in two ways: with respect to the analytical and numerical methods and with respect to the finite-element and boundary-element methods within the numerical procedures. The book serves two goals: Part I is an elementary text, without any prerequisites, a primer, but which using a simple model problem still covers all aspects of the method and Part II presents a detailed derivation of the general case of statics, elastodynamics and diffusion.

The book provides a survey of numerical methods for acoustics, namely the finite element method (FEM) and the boundary element method (BEM). It is the first book summarizing FEM and BEM (and optimization) for acoustics. The book shows that both methods can be effectively used for many other cases, FEM even for open domains and BEM for closed ones. Emphasis of the book is put on numerical aspects and on treatment of the exterior problem in acoustics, i.e. noise radiation.

The boundary element method (BEM) is now a well-established numerical technique which provides an efficient alternative to the prevailing finite difference and finite element methods for the solution of a wide range of engineering problems. The main advantage of the BEM is its unique ability to provide a complete problem solution in terms of boundary values only, with substantial savings in computer time and data preparation effort. An initial restriction of the BEM was that the fundamental solution to the original partial differential equation was required in order to obtain an equivalent boundary in tegral equation. Another was that non-homogeneous terms accounting for effects such as distributed loads were included in the formulation by means of domain integrals, thus making the technique lose the attraction of its "boundary-only" character. Many different approaches have been developed to overcome these problems. It is our opinion that the most successful so far is the dual reciprocity method (DRM), which is the subject matter of this book. The basic idea behind this approach is to employ a fundamental solution corresponding to a simpler equation and to treat the remaining terms, as well as other non-homogeneous terms in the original equation, through a procedure which involves a series expansion using global approximating functions and the application of reciprocity principles.

Traditional FEM and the more recent BEM underlie many engineering computational methods and corresponding software. Both methods have their merits and also their limitations. The combination of both methods will provide an improved numerical tool in the future. The aim of this book is to present significant basic formulations of FEM and BEM and to show their common practical and mathematical foundations, their differences and possibilities for their combination. These include variational foundations, FEM and BEM for linear and non-linear elasticity and potential problems, the combination of FEM-BEM asymptotic error analysis, modifications due to corner and crack singularities and corresponding improvement of convergence, plastic analysis, numerical algorithms and engineering applications.

At the date of this writing, there is no question that the boundary element method has emerged as one of the major revolutions on the engineering science of computational mechanics. The emergence of the technique from relative obscurity to a cutting edge engineering analysis tool in the short space of basically a ten to fifteen year time span is unparalleled since the advent of the finite element method. At the recent international conference BEM XI, well over one hundred papers were presented and many were pub lished in three hard-bound volumes. The exponential increase in interest in the subject is comparable to that shown in the early days of finite elements. The diversity of appli cations of BEM, the broad base of interested parties, and the ever-increasing presence of the computer as an engineering tool are probably the reasons for the upsurge in pop ularity of BEM among researchers and industrial practitioners. Only in the past few years has the BEM audience become large enough that we have seen the development of specialty books on specific applications of the boundary element method. The present text is one such book. In this work, we have attempted to present a self-contained treatment of the analysis of physical phenomena governed by equations containing biharmonic operators. The biharmonic operator defines a very important class of fourth-order PDE problems which includes deflections of beams and thin plates, and creeping flow of viscous fluids.

This text considers the problem of the dynamic fluid-structure interaction between a finite elastic structure and the acoustic field in an unbounded fluid-filled exterior domain. The exterior acoustic field is modelled through a boundary integral equation over the structure surface. However, the classical boundary integral equation formulations of this problem either have no solutions or do not have unique solutions at certain characteristic frequencies (which depend on the surface geometry) and it is necessary to employ modified boundary integral equation formulations which are valid for all frequencies. The particular approach adopted here involves an arbitrary coupling parameter and the effect that this parameter has on the stability and accuracy of the numerical method used to solve the integral equation is examined. The boundary integral analysis of the exterior acoustic problem is coupled with a finite element analysis of the elastic structure in order to investigate the interaction between the dynamic behaviour of the structure and the associated acoustic field. Recently there has been some controversy over whether or not the coupled problem also suffers from the non-uniqueness problems associated with the classical integral equation formulations of the exterior acoustic problem. This question is resolved by demonstrating that .the solution to the coupled problem is not unique at the characteristic frequencies and that it is necessary to employ an integral equation formulation valid for all frequencies.

This book constitutes the edited proceedings of the Advanced Studies Institute on Boundary Element Techniques in Computer Aided Engineering held at The Institute of Computational Mechanics, Ashurst Lodge, Southampton, England, from September 19 to 30, 1984. The Institute was held under the auspices of the newly launched "Double Jump Programme" which aims to bring together academics and industrial scientists. Consequently the programme was more industr ially based than other NATO ASI meetings, achieving an excellent combination of theoretical and practical aspects of the newly developed Boundary Element Method. In recent years engineers have become increasingly interested in the application of boundary element techniques for'the solution of continuum mechanics problems. The importance of boundary elements is that it combines the advantages of boundary integral equations (i.e. reduction of dimensionality of the problems, possibility of modelling domains extending to infinity, numerical accura'cy) with the versatility of finite elements (i.e. modelling of arbitrary curved surfaces). Because of this the technique has been well received by the engineering and scientific communities. Another important advantage of boundary elements stems from its reduction of dimensionality, that is that the technique requires much less data input than classical finite elements. This makes the method very well suited for Computer Aided Design and in great part explains the interest of the engineering profession in the new technique.

This thorough yet understandable introduction to the boundary element method presents an attractive alternative to the finite element method. It not only explains the theory but also presents the implementation of the theory into computer code, the code in FORTRAN 95 can be freely downloaded. The book also addresses the issue of efficiently using parallel processing hardware in order to considerably speed up the computations for large systems. The applications range from problems of heat and fluid flow to static and dynamic elasto-plastic problems in continuum mechanics.

The Boundary Element Methods (BEM) has become one of the most efficient tools for solving various kinds of problems in engineering science. The International Association for Boundary Element Methods (IABEM) was established in order to promote and facilitate the exchange of scientific ideas related to the theory and applications of boundary element methods. The aim of this symposium is to provide a forum for researchers in boundary element methods and boundary-integral formulations in general to present contemporary concepts and techniques leading to the advancement of capabilities and understanding of this com putational methodology. The topics covered in this symposium include mathematical and computational aspects, applications to solid mechanics, fluid mechanics, acoustics, electromagnetics, heat transfer, optimization, control, inverse problems and other interdisciplinary problems. Papers deal ing with the coupling of the boundary element method with other computational methods are also included. The editors hope that this volume presents some innovative techniques and useful knowl edge for the development of the boundary element methods. February, 1992 S. Kobayashi N. Nishimura Contents Abe, K.

One of the most interesting developments in engineering analysis during the last few years has been the rapid growth of boundary element methods. The first and second international conferences on this topic held in 1978 and 1980 attracted approximately 30 papers each, most of them from a few well known groups around the world. The third meeting in 1981, produced instead approximately 40 papers, many of them from young investigators working in newly created research groups. They have been attracted to boundary elements by the many advantages of the technique and were able to assimilate rapidly, the new ideas unencumbered by previous con ceptions. That third conference held in 1981 constituted in many ways a turning point for boundary elements and it indicated for the first time a general awareness of the industry to the research being carried out in the new technique. Engineering firms started to appreciate the advantages of the method mainly from the computa tional aided engineering point of view. The advantages of simple data input and output was rapidly understood by those professional engineers who were forced up to them to use cumbersome finite element codes. Boundary element practitioners in close contacts with the industry started to perceive that the method was gather ing a critical momentum of its own. This is now more evident by the diversity and quality of the papers in this volume, which are the edited Proceedings of the 4th International Conference, held at the University of Southampton in September 1982.

The finite element and the boundary element methods are the two most important developments in numerical mathematics to occur in this century. Many engineering and mathematics graduate curricula now include a course in boundary element methods. Such a course must cover numerical methods, basic methodology to real problems, and interactive computer usage. Both theory and applications, necessary for applied courses, are available in this new textbook. An Introduction to Boundary Element Methods is logically organized and easy to read. The topics are carefully selected and meticulously presented. Applications are described for use in identifying potential problems and for heat transfer, diffusion equations, linear elasticity, water waves, ocean acoustics, acoustic scattering, aerodynamics, porous media, and simple laminar flows. More than 20 computer subroutines help develop and explain the computational aspect of the subject. Hundreds of figures, exercises, and solved examples supplement text and help clarify important information. The computer programs have been tested on some benchmark problems. Even in single precision the results are more accurate and better than those obtained from available Fortran programs.

?20?,???????????????,????????????????

Effectively Construct Integral Formulations Suitable for Numerical Implementation Finite Element and Boundary Methods in Structural Acoustics and Vibration provides a unique and in-depth presentation of the finite element method (FEM) and the boundary element method (BEM) in structural acoustics and vibrations. It illustrates the principles using a logical and progressive methodology which leads to a thorough understanding of their physical and mathematical principles and their implementation to solve a wide range of problems in structural acoustics and vibration. Addresses Typical Acoustics, Electrodynamics, and Poroelasticity Problems It is written for final-year undergraduate and graduate students, and also for engineers and scientists in research and practice who want to understand the principles and use of the FEM and the BEM in structural acoustics and vibrations. It is also useful for researchers and software engineers developing FEM/BEM tools in structural acoustics and vibration. This text: Reviews current computational methods in acoustics and vibrations with an emphasis on their frequency domains of applications, limitations, and advantages Presents the basic equations governing linear acoustics, vibrations, and poroelasticity Introduces the fundamental concepts of the FEM and the BEM in acoustics Covers direct, indirect, and variational formulations in depth and their implementation and use are illustrated using various acoustic radiation and scattering problems Addresses the exterior coupled structural–acoustics problem and presents several practical examples to demonstrate the use of coupled FEM/BEM tools, and more Finite Element and Boundary Methods in Structural Acoustics and Vibration utilizes authors with extensive experience in developing FEM- and BEM-based formulations and codes and can assist you in effectively solving structural acoustics and vibration problems. The content and methodology have been thoroughly class tested with graduate students at University of Sherbrooke for over ten years.

The boundary element method (BEM), also known as the boundary integral equation method (BIEM), is a modern numerical technique. It is an established alternative to traditional computational methods of engineering analysis. This book provides a comprehensive account of the method and its application to problems in engineering and science.

This book presents a unified theory of the Finite Element Method and the Boundary Element Method for a numerical solution of second order elliptic boundary value problems. This includes the solvability, stability, and error analysis as well as efficient methods to solve the resulting linear systems. Applications are the potential equation, the system of linear elastostatics and the Stokes system. While there are textbooks on the finite element method, this is one of the first books on Theory of Boundary Element Methods. It is suitable for self study and exercises are included.

Uses simple engineering terms to describe which types of problems can best be solved with each method, combining the two and the applications for which this might be suitable. Features a chapter devoted to the construction of finite and boundary element meshes, error analysis and confidence criteria. Contains a slew of practical applications.

Over the past decades, the Boundary Element Method has emerged as a ver satile and powerful tool for the solution of engineering problems, presenting in many cases an alternative to the more widely used Finite Element Method. As with any numerical method, the engineer or scientist who applies it to a practical problem needs to be acquainted with, and understand, its basic principles to be able to apply it correctly and be aware of its limitations. It is with this intention that we have endeavoured to write this book: to give the student or practitioner an easy-to-understand introductory course to the method so as to enable him or her to apply it judiciously. As the title suggests, this book not only serves as an introductory course, but also cov ers some advanced topics that we consider important for the researcher who needs to be up-to-date with new developments. This book is the result of our teaching experiences with the Boundary Element Method, along with research and consulting activities carried out in the field. Its roots lie in a graduate course on the Boundary Element Method given by the authors at the university of Stuttgart. The experiences gained from teaching and the remarks and questions of the students have contributed to shaping the 'Introductory course' (Chapters 1-8) to the needs of the stu dents without assuming a background in numerical methods in general or the Boundary Element Method in particular.

"Divided into two parts, this book deals with the theory of elasticity and computational solution of its problems. Part A named Theoretical Elasticity describes the mathematical theory and the analytical techniques of problem solving. Part B entitled Computational Elasticity, is devoted to the description of two of the most popular computational methods - the finite element and the boundary element methods."--BOOK JACKET.

The interest in finite element method as a solution technique of the computer age is reflected in the availability of many general and special purpose software based on this technique. This work aims to provide a complete and detailed explanation of the basics of the application areas.

The Boundary Element Method (BEM) has become established as an effective tool for the solutions of problems in engineering science. The salient features of the BEM have been well documented in the open literature and therefore will not be elaborated here. The BEM research has progressed rapidly, especially in the past decade and continues to evolve worldwide. This Symposium was organized to provide an international forum for presentation of current research in BEM for linear and nonlinear problems in solid and fluid mechanics and related areas. To this end, papers on the following topics were included: rotary wing aerodynamics, unsteady aerodynamics, design and optimization, elasticity, elasto dynamics and elastoplasticity, fracture mechanics, acoustics, diffusion and wave motion, thermal analysis, mathematical aspects and boundary/finite element coupled methods. A special session was devoted to parallel/vector supercomputing with emphasis on mas sive parallelism. This Symposium was sponsored by United Technologies Research Center (UTRC) , NASA Langley Research Center, and the International Association of Boundary Ele ment Methods (lAB EM) . We thank the UTRC management for their permission to host this Symposium. In particular, we thank Dr. Arthur S. Kesten and Mr. Robert E. Olson for their encouragement and support. We gratefully acknowledge the support of Dr. E. Carson Yates, Jr. of NASA Langley, Prof. Luigi Morino, Dr. Thomas A.

This text provides an accessible and up-to-date introduction to the Trefftz finite element method. The author's main emphasis is on fundamental concepts and the development of different Trefftz element formulations for stress analysis of various elastic problems. The book is a reference for postgraduate students, researchers, scientists and professional engineers in computational mechanics, structural design, and applied mathematics.

Introduction to Finite and Boundary Element Methods for EngineersJohn Wiley & Son Limited

These are the lecture notes of the seminar "Mathematische Theorie der finiten Element und Randelementmethoden" organized by the "Deutsche Mathematiker-Vereinigung" and held in Dusseldorf from 07. - 14. of June 1987. Finite element methods and the closely related boundary element methods nowadays belong to the standard routines for the computation of solutions to boundary and initial boundary value problems of partial differential equations with many applications as e.g. in elasticity and thermoelasticity, fluid mechanics, acoustics, electromagnetics, scatter ing and diffusion. These methods also stimulated the development of corresponding mathematical numerical analysis. I was very happy that A. Schatz and V. Thomee generously joined the adventure of the seminar and not only gave stimulating lectures but also spent so much time for personal discussion with all the participants. The seminar as well as these notes consist of three parts: 1. An Analysis of the Finite Element Method for Second Order Elliptic Boundary Value

Problems by A. H. Schatz. II. On Finite Elements for Parabolic Problems by V. Thomee. III. I30undary Element Methods for Elliptic Problems by \V. L. Wendland. The prerequisites for reading this book are basic knowledge in partial differential equations (including pseudo-differential operators) and in numerical analysis. It was not our intention to present a comprehensive account of the research in this field, but rather to give an introduction and overview to the three different topics which shed some light on recent research.

This study investigates the coupling of the finite and boundary element methods in elastostatics where each method is used to model a different portion of the domain. The principal interest is in applying a boundary element method (BEM) to model the infinite domain (assumed to be isotropic linear elastic) while using the finite element method (FEM) to model regions with more complex constitutive relations. The approach taken in this study, referred to as a FEM-hosted coupling, treats each BEM subdomain as a single finite element. Two derivations for an IBEM stiffness matrix are given; the first is a physically intuitive direct derivation while the second is the corresponding variational derivation. Though the emphasis is on the IBEM, the DBEM is also addressed. The inherent incompatibility between the BEM and FEM methods is discussed and explained in terms of the shape function fallacy.

The boundary element method is an extremely versatile and powerful tool of computational mechanics which has already become a popular alternative to the well established finite element method. This book presents a comprehensive and up-to-date treatise on the boundary element method (BEM) in its applications to various fields of continuum mechanics such as: elastostatics, elastodynamics, thermoelasticity, micropolar elasticity, elastoplasticity, viscoelasticity, theory of plates and stress analysis by hybrid methods. The fundamental solution of governing differential equations, integral representations of the displacement and temperature fields, regularized integral representations of the stress field and heat flux, boundary integral equations and boundary integro-differential equations are derived. Besides the mathematical foundations of the boundary integral method, the book deals with practical applications of this method. Most of the applications concentrate mainly on the computational problems of fracture mechanics. The method has been found to be very efficient in stress-intensity factor computations. Also included are developments made by the authors in the boundary integral formulation of thermoelasticity, micropolar elasticity, viscoelasticity, plate theory, hybrid method in elasticity and solution of crack problems. The solution of boundary-value problems of thermoelasticity and micropolar thermoelasticity is formulated for the first time as the solution of pure boundary problems. A new unified formulation of general crack problems is presented by integro-differential equations.

Presents Boundary Element Method (BEM) in a simple fashion in order to help the beginner to understand the very basic principles of the method. This book initially derives BEM for the simplest potential problems, and subsequently builds on these to formulate BEM for a wide range of applications in electromagnetics.