

Basic Solutions of Three Dimensional Elasticity

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Abstract. Elastic calculation method is an important research content of computational mechanics. The problems of elasticity include basic equations and boundary conditions. Therefore, the final solution consists of the general solutions of the basic equations and the special solutions satisfying the boundary conditions. Numerical method is often used in practical calculation, but the analytical solution is also an important subject for researchers. In this paper, the basic solution of three-dimensional elastic materials is given by theoretical derivation.

1 Introduction

Elasticity mainly studies the deformation and internal force of elastic objects under the action of external forces and other external factors [1-3]. Saint Venant's principle is the most commonly used method of elasticity, and its correctness has been fully verified. According to Saint Venant's principle, the boundary conditions can be replaced by equivalent loads, which makes the problem greatly simplified. However, the Saint Venant solution can only satisfy the average boundary conditions, ignoring the local effect, so it is an approximate solution. In many practical problems, researchers often ignore the local effect solution and only care about the overall effect of load on materials and structures. However, for some special cases, such as stress concentration caused by temperature or displacement constraints, the stress is not uniformly distributed, and the local solution plays a key role [4-6].

In this paper, on the basis of fully studying the traditional theory of elasticity, the dual form equations of three dimensional elastic body are constructed by using the methods of separation of variables and variational principle. Thus, the basic problem of elasticity is transformed into the solution of eigenvalues and general eigenvectors. Through strict theoretical derivation, we get the all eigenvectors in analytical form, and establish the closed form basic solution space composed of each order solution vectors, which provides a reliable basis for the numerical calculation of further engineering problems.

2 Solution method

A common calculation model of cylinder in elasticity. The displacement and stress components of elastic cylindrical solution can be described as follows

$$\begin{aligned}\bar{u} &= M_{1j} (C_j J_{n+1} + C_{j+3} Y_{n+1}) + N_{1j} (C_j J_n + C_{j+3} Y_n) \\ \bar{v} &= N_{2j} (C_j J_n + C_{j+3} Y_n) + K_{2j} (C_j J_{n+1} + C_{j+3} Y_{n+1}) \\ \bar{w} &= N_{3j} (C_j J_n + C_{j+3} Y_n) + K_{3j} (C_j J_{n+1} + C_{j+3} Y_{n+1})\end{aligned}\quad (1)$$

and

$$\begin{aligned}\bar{p}_1 &= N_{4j} (C_j J_n + C_{j+3} Y_n) + K_{4j} (C_j J_{n+1} + C_{j+3} Y_{n+1}) \\ \bar{p}_2 &= N_{5j} (C_j J_n + C_{j+3} Y_n) + K_{5j} (C_j J_{n+1} + C_{j+3} Y_{n+1}) \\ \bar{p}_3 &= M_{6j} (C_j J_{n+1} + C_{j+3} Y_{n+1}) + N_{6j} (C_j J_n + C_{j+3} Y_n)\end{aligned}\quad (2)$$

Respectively. Using the generalized variable method, we get

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Philippe G. Ciarlet



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Mathematical Elasticity Philippe G. Ciarlet, 2022-01-22 The first book of a three volume set *Three Dimensional Elasticity* covers the modeling and mathematical analysis of nonlinear three dimensional elasticity It includes the known existence theorems either via the implicit function theorem or via the minimization of the energy John Ball s theory An extended preface and extensive bibliography have been added to highlight the progress that has been made since the volume s original publication While each one of the three volumes is self contained together the *Mathematical Elasticity* set provides the only modern treatise on elasticity introduces contemporary research on three dimensional elasticity the theory of plates and the theory of shells and contains proofs detailed surveys of all mathematical prerequisites and many problems for teaching and self study These classic textbooks are for advanced undergraduates first year graduate students and researchers in pure or applied mathematics or continuum mechanics They are appropriate for courses in mathematical elasticity theory of plates and shells continuum mechanics computational mechanics and applied mathematics in general

Three-dimensional Elasticity Philippe G. Ciarlet, 1993 *Mathematical Elasticity, Volume II* Philippe G. Ciarlet, 2021 The *Mathematical Elasticity* set contains three self contained volumes that together provide the only modern treatise on elasticity They introduce contemporary research on three dimensional elasticity the theory of plates and the theory of shells Each volume contains proofs detailed surveys of all mathematical prerequisites and many problems for teaching and self study An extended preface and extensive bibliography have been added to each volume to highlight the progress that has been made since the original publication The first book *Three Dimensional Elasticity* covers the modeling and mathematical analysis of nonlinear three dimensional elasticity In volume two *Theory of Plates* asymptotic methods provide a rigorous mathematical justification of the classical two dimensional linear plate and shallow shell theories The objective of *Theory of Shells* the final volume is to show how asymptotic methods provide a rigorous mathematical justification of the classical two dimensional linear shell theories membrane generalized membrane and flexural These classic textbooks are for advanced undergraduates first year graduate students and researchers in pure or applied mathematics or continuum mechanics They are appropriate for courses in mathematical elasticity theory of plates and shells continuum mechanics computational mechanics and applied mathematics in general

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Three-Dimensional Elastic Bodies in Rolling Contact J.J. Kalker, 1990-10-31 This book is intended for mechanicians engineering mathematicians and generally for theoretically inclined mechanical engineers It has its origin in my Master s Thesis J 957 which I wrote under the supervision of Professor

Dr R Timman of the Delft TH and Dr Ir A D de Pater of Netherlands Railways I did not think that the surface of the problem had even been scratched so I joined de Pater who had by then become Professor in the Engineering Mechanics Lab of the Delft TH to write my Ph D Thesis on it This thesis 1967 was well received in railway circles which is due more to de Pater's untiring promotion than to its merits Still not satisfied I felt that I needed more mathematics and I joined Professor Timman's group as an Associate Professor This led to the present work Many thanks are due to G M L Gladwell who thoroughly polished style and contents of the manuscript Thanks are also due to my wife herself an engineering mathematician who read the manuscript through critically and made many helpful comments to G F M Braat who also read and criticised and in addition drew the figures together with J Schonewille to Ms A V M de Wit Ms M den Boef and Ms P c Wilting who typed the manuscript and to the Publishers who waited patiently Delft Rotterdam 17 July 1990 J J

Lectures on Three-dimensional Elasticity Philippe G. Ciarlet, 1983

Mathematical Elasticity, Three Volume Set Philippe G. Ciarlet, 2022-03-30 The Mathematical Elasticity set contains three self contained volumes that together provide the only modern treatise on elasticity They introduce contemporary research on three dimensional elasticity the theory of plates and the theory of shells Each volume contains proofs detailed surveys of all mathematical prerequisites and many problems for teaching and self study An extended preface and extensive bibliography have been added to each volume to highlight the progress that has been made since the original publication The first book Three Dimensional Elasticity covers the modeling and mathematical analysis of nonlinear three dimensional elasticity In volume two Theory of Plates asymptotic methods provide a rigorous mathematical justification of the classical two dimensional linear plate and shallow shell theories The objective of Theory of Shells the final volume is to show how asymptotic methods provide a rigorous mathematical justification of the classical two dimensional linear shell theories membrane generalized membrane and flexural These classic textbooks are for advanced undergraduates first year graduate students and researchers in pure or applied mathematics or continuum mechanics They are appropriate for courses in mathematical elasticity theory of plates and shells continuum mechanics computational mechanics and applied mathematics in general

A Problem in Three-dimensional Elasticity Andrawus Khuri, American University of Beirut. Faculty of Arts and Sciences. Department of Mathematics, 1966

Elasticity in Engineering Mechanics Arthur P. Boresi, Ken Pin Chong, 2000 Arthur Boresi and Ken Chong's Elasticity in Engineering Mechanics has been prized by many aspiring and practicing engineers as an easy to navigate guide to an area of engineering science that is fundamental to aeronautical civil and mechanical engineering and to other branches of engineering With its focus not only on elasticity theory but also on concrete applications in real engineering situations this work is a core text in a spectrum of courses at both the undergraduate and graduate levels and a superior reference for engineering professionals

BOOK JACKET

Theory of Shells Philippe G. Ciarlet, 2000-05-11 The objective of Volume III is to lay down the proper mathematical foundations of the two dimensional theory of shells To this end it provides without any recourse to any a priori assumptions

of a geometrical or mechanical nature a mathematical justification of two dimensional nonlinear and linear shell theories by means of asymptotic methods with the thickness as the small parameter

Three-Dimensional Problems of Elasticity and Thermoelasticity V.D. Kupradze, 2012-12-02 North Holland Series in Applied Mathematics and Mechanics Volume 25

Three Dimensional Problems of the Mathematical Theory of Elasticity and Thermoelasticity focuses on the theory of three dimensional problems including oscillation theory boundary value problems and integral equations The publication first tackles basic concepts and axiomatization and basic singular solutions Discussions focus on fundamental solutions of thermoelasticity fundamental solutions of the couple stress theory strain energy and Hooke s law in the couple stress theory and basic equations in terms of stress components The manuscript then examines uniqueness theorems and singular integrals and integral equations The book ponders on the potential theory and boundary value problems of elastic equilibrium and steady elastic oscillations Topics include basic theorems of the oscillation theory existence of solutions of boundary value problems integral equations of the boundary value problems and boundary properties of potential type integrals The publication also reviews mixed dynamic problems couple stress elasticity and boundary value problems for media bounded by several surfaces The text is a dependable source of data for mathematicians and readers interested in three dimensional problems of the mathematical theory of elasticity and thermoelasticity

Mathematical Elasticity Philippe G. Ciarlet, 2022-01-22 The objective of Theory of Shells the third book of a three volume set is to show how asymptotic methods provide a rigorous mathematical justification of the classical two dimensional linear shell theories membrane generalized membrane and flexural The book also shows how asymptotic methods justify nonlinear elastic shell theories and gives a detailed presentation of the Koiter equations for a nonlinearly elastic shell An extended preface and extensive bibliography have been added to highlight the progress that has been made since the volume s original publication While each one of the three volumes is self contained together the Mathematical Elasticity set provides the only modern treatise on elasticity introduces contemporary research on three dimensional elasticity the theory of plates and the theory of shells and contains proofs detailed surveys of all mathematical prerequisites and many problems for teaching and self study These classic textbooks are for advanced undergraduates first year graduate students and researchers in pure or applied mathematics or continuum mechanics They are appropriate for courses in mathematical elasticity theory of plates and shells continuum mechanics computational mechanics and applied mathematics in general

Mathematical Elasticity, 1997-07-22 The objective of Volume II is to show how asymptotic methods with the thickness as the small parameter indeed provide a powerful means of justifying two dimensional plate theories More specifically without any recourse to any a priori assumptions of a geometrical or mechanical nature it is shown that in the linear case the three dimensional displacements once properly scaled converge in H^1 towards a limit that satisfies the well known two dimensional equations of the linear Kirchhoff Love theory the convergence of stress is also established In the nonlinear case again after ad hoc scalings have

been performed it is shown that the leading term of a formal asymptotic expansion of the three dimensional solution satisfies well known two dimensional equations such as those of the nonlinear Kirchhoff Love theory or the von Kármán equations. Special attention is also given to the first convergence result obtained in this case which leads to two dimensional large deformation frame indifferent nonlinear membrane theories. It is also demonstrated that asymptotic methods can likewise be used for justifying other lower dimensional equations of elastic shallow shells and the coupled pluridimensional equations of elastic multi structures i.e. structures with junctions. In each case the existence uniqueness or multiplicity and regularity of solutions to the limit equations obtained in this fashion are also studied.

Differential Geometry Ta-tien Li, 2008 This book gives the basic notions of differential geometry such as the metric tensor the Riemann curvature tensor the fundamental forms of a surface covariant derivatives and the fundamental theorem of surface theory in a self contained and accessible manner. Although the field is often considered a 19th century classical one it has recently been rejuvenated thanks to the manifold applications where it plays an essential role. The book presents some important applications to shells such as the theory of linearly and nonlinearly elastic shells the implementation of numerical methods for shells and mesh generation in finite element methods. This volume will be very useful to graduate students and researchers in pure and applied mathematics.

Topics in Mathematical Elasticity Philippe G. Ciarlet, 1984

Microstructural Randomness and Scaling in Mechanics of Materials Martin Ostoja-Starzewski, 2007-08-13 An area at the intersection of solid mechanics materials science and stochastic mathematics mechanics of materials often necessitates a stochastic approach to grasp the effects of spatial randomness. Using this approach *Microstructural Randomness and Scaling in Mechanics of Materials* explores numerous stochastic models and methods used in the field.

Stability Theory of Elastic Rods Teodor M. Atanackovic, 1997 This book treats stability problems of equilibrium states of elastic rods. Euler energy and dynamical methods of stability analysis are introduced and stability criteria for each method is developed. Stability analysis is accompanied by a number of classical conservative and non conservative two and three dimensional problems. Some problems are treated by all three methods. Many generalized versions of known problems are presented: heavy vertical rod rotating rod Greenhill's problem Beck's column Pflüger's rod strongest column etc. The generalizations consist in using either a generalized form of constitutive equations or a more general form of loading or both. Special attention is paid to the influence of shear stresses and axis compressibility on the value of the critical load. Variational methods are applied to obtain estimates of the critical load and maximal deflection in the post critical state in a selected number of examples.

Fundamentals of Finite Element Analysis Ioannis Koutromanos, 2017-11-15 An introductory textbook covering the fundamentals of linear finite element analysis (FEA). This book constitutes the first volume in a two volume set that introduces readers to the theoretical foundations and the implementation of the finite element method (FEM). The first volume focuses on the use of the method for linear problems. A general procedure is presented for the finite element analysis (FEA) of a physical problem where the goal is to specify the

values of a field function First the strong form of the problem governing differential equations and boundary conditions is formulated Subsequently a weak form of the governing equations is established Finally a finite element approximation is introduced transforming the weak form into a system of equations where the only unknowns are nodal values of the field function The procedure is applied to one dimensional elasticity and heat conduction multi dimensional steady state scalar field problems heat conduction chemical diffusion flow in porous media multi dimensional elasticity and structural mechanics beams shells as well as time dependent dynamic scalar field problems elastodynamics and structural dynamics Important concepts for finite element computations such as isoparametric elements for multi dimensional analysis and Gaussian quadrature for numerical evaluation of integrals are presented and explained Practical aspects of FEA and advanced topics such as reduced integration procedures mixed finite elements and verification and validation of the FEM are also discussed Provides detailed derivations of finite element equations for a variety of problems Incorporates quantitative examples on one dimensional and multi dimensional FEA Provides an overview of multi dimensional linear elasticity definition of stress and strain tensors coordinate transformation rules stress strain relation and material symmetry before presenting the pertinent FEA procedures Discusses practical and advanced aspects of FEA such as treatment of constraints locking reduced integration hourglass control and multi field mixed formulations Includes chapters on transient step by step solution schemes for time dependent scalar field problems and elastodynamics structural dynamics Contains a chapter dedicated to verification and validation for the FEM and another chapter dedicated to solution of linear systems of equations and to introductory notions of parallel computing Includes appendices with a review of matrix algebra and overview of matrix analysis of discrete systems Accompanied by a website hosting an open source finite element program for linear elasticity and heat conduction together with a user tutorial Fundamentals of Finite Element Analysis Linear Finite Element Analysis is an ideal text for undergraduate and graduate students in civil aerospace and mechanical engineering finite element software vendors as well as practicing engineers and anybody with an interest in linear finite element analysis *Nonlinear Elasticity* Y. B. Fu, R. W. Ogden, 2001-05-07 Nonlinear elasticity is concerned with nonlinear effects associated with deformations of elastic bodies subjected to external forces or temperature variations It has important applications in many areas including the aerospace and rubber industries and biomechanics This book written by a group of leading researchers invited especially for the purpose provides an up to date and concise account of the fundamentals of the theory of nonlinear elasticity and a comprehensive review of several major current research directions in this important field It combines the characteristics of coherence and detail found in standard treatises with the strength and freshness of research articles The emphasis is placed firmly on coverage of modern topics and recent developments rather than on the very theoretical approach often found The book will be an excellent reference source for both beginners and specialists in engineering applied mathematics and physics It is also ideally suited for graduate courses DDC Retrieval and Indexing Terminology Defense Documentation Center

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