

Article

Contraction Integral Equation for Three-Dimensional Electromagnetic Inverse Scattering Problems

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Abstract: Inverse scattering problems (ISPs) stand at the center of many important imaging applications, such as geophysical explorations, industrial non-destructive testing, bio-medical imaging, etc. Recently, a new type of contraction integral equation for inversion (CIE-I) has been proposed to tackle the two-dimensional electromagnetic ISPs, in which the usually employed Lippmann–Schwinger integral equation (LSIE) is transformed into a new form with a modified medium contrast via a contraction mapping. With the CIE-I, the multiple scattering effects, i.e., the physical reason for the nonlinearity in the ISPs, is substantially suppressed in estimating the modified contrast, without compromising physical modeling. In this paper, we firstly propose to implement this new CIE-I for the three-dimensional ISPs. With the help of the FFT type twofold subspace-based optimization method (TSOM), when handling the highly nonlinear problems with strong scatterers, those with higher contrast and/or larger dimensions (in terms of wavelengths), the performance of the inversions with CIE-I is much better than the ones with the LSIE, wherein inversions usually converge to local minima that may be far away from the solution. In addition, when handling the moderate scatterers (those the LSIE modeling can still handle), the convergence speed of the proposed method with CIE-I is much faster than the one with the LSIE. Secondly, we propose to relax the contraction mapping condition, i.e., different contraction mappings are used in updating contrast sources and contrast, and we find that the convergence can be further accelerated. Several numerical tests illustrate the aforementioned interests.

Keywords: inverse scattering; nonlinear problem; contraction integral equation for inversion (CIE-I); imaging

1. Introduction

Inverse scattering problems (ISPs) in electromagnetics and acoustics are of great interest in industries due to important imaging applications in various areas, such as geophysical survey, non-destructive testing, ground-penetrating radar, bio-medical imaging, etc., as solving the ISPs provides rich information about the unknown targets, such as locations, shapes, and material distributions within some structures [1–4]. For instance, microwave imaging has been used to inspect the abnormalities in human bodies like bleeding in the head and tumours in breasts. On the other hand, they are also quite important due to the representative difficulties in solving a large group of inverse problems concerning waves and fields, and thus researchers in mathematics, physics, and engineering societies have devoted great efforts to improving efficiencies and accuracies of the numerical solvers [5]. As shown in Figure 1, solving ISPs is to determine the unknown scatterers within a domain, when the domain is illuminated by several different incidences and we can measure

Threedimensional Contact Problems

Valentin L. Popov, Markus Heß



Threedimensional Contact Problems:

Three-Dimensional Contact Problems A M Alexandrov, D a Pozharskii, 2001-11-30 [A Solution Method for Two- and Three-dimensional Contact Problems](#) Anil Bhaskar Chaudhary, 1985 **Stress Analysis of Three-dimensional Contact**

Problems Without Friction Using the Boundary Element Method Dominique Segond, University of Manchester. School of Engineering, 1996 *Three-Dimensional Contact Problems* A.M. Alexandrov, D.A. Pozharskii, 2001-08-31 A systematic treatment based on Green's functions and integral equations is given to the analytical and numerical methods and results for a great number of 3 D contact problems for elastic bodies Semi bounded elastic bodies layer cylinder space with cylindrical or spherical cavity 3 D wedge special cases of which are half and quarter spaces cone and finite elastic bodies circular plate finite cylinder spherical layer spherical lens sphere are considered Methods introduced in the book can also be applied in fracture mechanics hydrodynamics electrostatics thermodynamics and diffusion theory continuum mechanics and mathematical physics as well as by engineers and students in mathematics mechanics and physics **Boundary Element**

Analysis of Three-dimensional Contact Problems in Cracked Structures Christopher Mark Bainbridge, 1998

Three-dimensional Problems of the Theory of Elasticity Anatoliĭ Isakovich Lur'e, 1964 **A Lagrange Multiplier/segment Procedure for Solution of Three-dimensional Contact Problems** A. B. Chaudhary, 1985 **The Analysis of a Three-dimensional Contact Stress Problem as Applied to Grinding** Charles Bernard Matson, 1972

[Contact Mechanics](#) J.R. Barber, 2018-02-09 This book describes the solution of contact problems with an emphasis on idealized mainly linear elastic problems that can be treated with elementary analytical methods General physical and mathematical features of these solutions are highlighted Topics covered include the contact of rough surfaces and problems involving adhesive e g van der Waals forces The author is a well known researcher in the subject with hands on experience of the topics covered and a reputation for lucid explanations The target readership for the book includes researchers who encounter contact problems but whose primary focus is not contact mechanics Coverage is also suitable for a graduate course in contact mechanics and end of chapter problems are included **Multibody Dynamics** Krzysztof

Arczewski, Wojciech Blajer, Janusz Fraczek, Marek Wojtyra, 2010-11-08 The ECCOMAS Thematic Conference Multibody Dynamics 2009 was held in Warsaw representing the fourth edition of a series which began in Lisbon 2003 and was then continued in Madrid 2005 and Milan 2007 held under the auspices of the European Community on Computational Methods in Applied Sciences ECCOMAS The conference provided a forum for exchanging ideas and results of several topics related to computational methods and applications in multibody dynamics through the participation of 219 scientists from 27 countries mostly from Europe but also from America and Asia This book contains the revised and extended versions of invited conference papers reporting on the state of the art in the advances of computational multibody models from the theoretical developments to practical engineering applications By providing a helpful overview of the most active areas and the recent

efforts of many prominent research groups in the field of multibody dynamics this book can be highly valuable for both experienced researchers who want to keep updated with the latest developments in this field and researchers approaching the field for the first time **Finite Element Analysis of Beam-to-Beam Contact** Przemyslaw Litewka,2010-04-24

Phenomena occurring during a contact of two bodies are encountered in everyday life In reality almost every type of motion is related to frictional contact between a moving body and a ground Moreover modeling of simple and more complex processes as nailing cutting vacuum pressing movement of machines and their elements rolling or finally a numerical simulation of car crash tests requires taking contact into account Therefore its analysis has been a subject of many research efforts for a long time now However it is author s opinion that there are relatively few efforts related to contact between structural elements like beams plates or shells The purpose of this work is to fill this gap It concerns the beam to beam contact as a specific case of the 3D solids contact A numerical formulation of frictional contact for beams with two shapes of cross section is derived Further a couple of effective methods for modeling of smooth curves representing beam axes are presented A part of the book is also devoted to analyze some aspects of thermo electro mechanical coupling in contact of thermal and electric conductors Analyses in every chapter are illustrated with numerical examples showing the performance of derived contact finite elements Introduction to Nonlinear Finite Element Analysis Nam-Ho Kim,2026-02-16 This new

edition introduces the essential concepts of nonlinear finite element analysis FEA procedures The textbook guides students in implementing nonlinear FEA programs and utilizes commercial software to address practical engineering problems It thoroughly explains the fundamental theories and provides instructions on applying these concepts to tackle various engineering challenges Rather than covering numerous nonlinear problems the book focuses on four representative topics nonlinear elasticity elastoplasticity contact problems and dynamic problems with an added chapter on nonlinear dynamics The material is presented independently of any specific software and the tutorials and examples utilize four commercial programs included in the appendices ANSYS NASTRAN ABAQUS and MATLAB The MATLAB section includes all source codes allowing students to develop material models or different algorithms This edition introduces 2D plane strain elements in addition to 3D solid element with all the aforementioned functionalities It includes fully integrated frictional contact analysis and explicit and implicit nonlinear dynamic analysis in the MATLAB programs Introduction to Nonlinear Finite Element Analysis Second Edition is designed for graduate students studying mechanical civil aerospace biomedical and industrial engineering Researchers and practicing engineers in these disciplines will find it to be an invaluable professional reference Boundary Elements XIII C.A. Brebbia,G.S. Gipson,2012-12-06 Since its origin in 1978 the International Conference on Boundary Element Methods has provided the recognized and established forum for innovations in boundary element research Practically all new ideas on boundary elements have been presented at these conferences and the resulting papers can be found in the published books The conference brings together the most renowned scientists and

engineers working on boundary element research throughout the world A unique feature of these meetings is that the participation of younger researchers is actively encouraged by the organizers in an effort to bring forward to the attention of the international community an ever expanding range of new ideas This book contains the edited version of the papers presented at the XIIIth BEM Conference held in Tulsa Oklahoma in August of 1991 The meeting attracted a large number of participants and many excellent contributions which have been divided into nineteen different sections i e Potential Problems Diffusion and Convection Problems Fluid Mechanics Fluid Flow Wave Propagation Groundwater Flow Heat Transfer Electrical Problems Geomechanics Plates and Shells Inelastic Problems Damage Tolerance Contact Mechanics Industrial Applications Design Sensitivity and Optimization Inverse Problems Special Techniques Numerical Aspects and Computational Aspects

A Hybrid Elasticity and Finite Element Method for Three-dimensional Contact Problems with Friction, 2003 This dissertation presents a new hybrid elasticity and finite element method for general non conforming contact problems It is an iterative numerical procedure which has distinct advantage over classical theory of contact since general geometrical and loading profiles with friction can be treated And over the traditional contact solution approach in finite element method it eliminates the use of gap elements and therefore the non linearity in the solution enhancing accuracy and efficiency of the solution For the two dimensional problems the equations were derived for a triangular pressure element While for three dimensional problems the analytical solution was derived from Boussinesq and Cerruti equations for conical pressure elements from which a semi analytical approach to three dimensional contact problems with friction was evolved to find the extent of the contact area and the loading distribution over this area together with the extent of the stick and slip zones The linear static finite element method was then used to find the displacements and stresses throughout the two bodies in contact which were analyzed separately with the knowledge of the area of contact and the traction over such an area The method was used for non conforming bodies but it can be extended to include different kinds of contact problems The basic theory was presented for both two and three dimensional non conforming contact problem together with algorithm and numerical examples that showed the accuracy efficiency and robustness of the method

Method of Dimensionality Reduction in Contact Mechanics and Friction Valentin L. Popov, Markus Heß, 2014-08-19 This book describes for the first time a simulation method for the fast calculation of contact properties and friction between rough surfaces in a complete form In contrast to existing simulation methods the method of dimensionality reduction MDR is based on the exact mapping of various types of three dimensional contact problems onto contacts of one dimensional foundations Within the confines of MDR not only are three dimensional systems reduced to one dimensional but also the resulting degrees of freedom are independent from another Therefore MDR results in an enormous reduction of the development time for the numerical implementation of contact problems as well as the direct computation time and can ultimately assume a similar role in tribology as FEM has in structure mechanics or CFD methods in hydrodynamics

Furthermore it substantially simplifies analytical calculation and presents a sort of pocket book edition of the entirety contact mechanics Measurements of the rheology of bodies in contact as well as their surface topography and adhesive properties are the inputs of the calculations In particular it is possible to capture the entire dynamics of a system beginning with the macroscopic dynamic contact calculation all the way down to the influence of roughness in a single numerical simulation model Accordingly MDR allows for the unification of the methods of solving contact problems on different scales The goals of this book are on the one hand to prove the applicability and reliability of the method and on the other hand to explain its extremely simple application to those interested

Advances in Engineering Design Anamika Prasad, Shakti S. Gupta, R. K. Tyagi, 2019-04-27 This book presents select proceedings of the International Conference on Future Learning Aspects of Mechanical Engineering FLAME 2018 The book covers mechanical design areas such as computational mechanics finite element modeling computer aided designing tribology fracture mechanics and vibration The book brings together different aspects of engineering design and will be useful for researchers and professionals working in this field

Multibody Dynamics Zdravko Terze, 2014-06-26 By having its origin in analytical and continuum mechanics as well as in computer science and applied mathematics multibody dynamics provides a basis for analysis and virtual prototyping of innovative applications in many fields of contemporary engineering With the utilization of computational models and algorithms that classically belonged to different fields of applied science multibody dynamics delivers reliable simulation platforms for diverse highly developed industrial products such as vehicle and railway systems aeronautical and space vehicles robotic manipulators smart structures biomechanical applications and nano technologies The chapters of this volume are based on the revised and extended versions of the selected scientific papers from amongst 255 original contributions that have been accepted to be presented within the program of the distinguished international ECCOMAS conference It reflects state of the art in the advances of multibody dynamics providing excellent insight in the recent scientific developments in this prominent field of computational mechanics and contemporary engineering

Applications of Higher Special Functions to Some Three-dimensional Contact Problems in the Classical Theory of Elasticity Abdollah Darai, 2014

Advanced Tire Mechanics Yukio Nakajima, 2019-04-03 This book highlights the mechanics of tire performance offering detailed explanations of deriving basic equations for the fundamental properties of tires and discussing ways to improve tire performance using these equations It also compares the theory with practical measurements The book commences with composite mechanics which is the fundamental theory for belt and carcass tires and covers classical modified and discrete lamination theory It then addresses the theory of tire shape and spring properties and the mechanics of tread pattern contact properties as well as the performance of various tires This comprehensive book is a valuable resource for engineers involved in tire design and offers unique insights and examples of improvement of tire performances

Three-dimensional Contact Fracture Problems Using Enriched Finite Elements Umit Ozkan, 2007 Finally application of multi point constraint methodology in

fracture problems is demonstrated It is shown that mesh distortion and fine meshes due to the crack insertion into a model can be eliminated by global local analyses using multi point constraint methodology

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