Numerical methods for viscous flows with moving boundaries

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A review of numerical algorithms for the analysis of viscous flows with moving interfaces is presented. The review is supplemented with a discussion of methods that have been introduced in the context of other classes of free boundary problems, but which can be generalized to viscous flows with moving interfaces. The available algorithms can be classified as Eulerian, Lagrangian, and mixed, ie, Eulerian–Lagrangian. Eulerian algorithms consist of fixed grid methods, adaptive grid methods, mapping methods, and special methods. Lagrangian algorithms consist of strictly Lagrangian methods, Lagrangian methods with remeshing, free Lagrangian methods and particle methods. Mixed methods rely on both Lagrangian and Eulerian concepts. The review consists of a description of the present state-of-the-art of each group of algorithms and their applications to a variety of problems. The existing methods are effective in dealing with small to medium interface deformations. For problems with medium to large deformations the methods produce results that are reasonable from a physical viewpoint; however, their accuracy is difficult to ascertain.

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1. INTRODUCTION

A moving boundary problem is a problem where the domain of interest has an unknown boundary which has to be determined as part of the solution procedure. This is also sometimes referred to as a free boundary problem and/or a moving interface problem. Problems of this class are important in many technological applications in which moving fluid interfaces play a dominant role. Such applications include capillarity, melting and solidification, crystal growth, flame propagation, nuclear fusion, wetting, seepage, metal and glass forming processes, and many other areas in engineering and science. The quantitative description of such problems depends on the understanding of the physical processes taking place on the interfaces and on the successful solution of the corresponding moving boundary problems. The present state of knowledge in both these areas is far from complete.

The physical conditions occurring at a boundary between two immiscible fluids are described in Batchelor (1967) and Davies and Rideal (1963). When the interface has only the equilibrium property of a uniform surface tension, the appropriate interfacial boundary conditions are

$$\mathbf{V}_A \cdot \mathbf{n} = \mathbf{V}_B \cdot \mathbf{n} = V \cdot \mathbf{n}, \tag{1}$$

$$\mathbf{V}_A \cdot \mathbf{t} = \mathbf{V}_B \cdot \mathbf{t}, \tag{2}$$

$$\mathbf{n} \cdot (\mathbf{T}_A - \mathbf{T}_B) = 2\kappa\sigma\mathbf{n}. \tag{3}$$

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Numerical Methods For Steady Viscous Freesurface Flows

R. L. Taylor,P. Nithiarasu

Numerical Methods For Steady Viscous Freesurface Flows:

Numerical Methods for Steady Viscous Free-surface Flows E. H. van Brummelen,2003 **Numerical Methods for Steady Viscous Free-surface Flows** Einar Harald van Brummelen,2002 *The Finite Element Method for Fluid Dynamics* R. L. Taylor,P. Nithiarasu,2024-11-20 The Finite Element Method for Fluid Dynamics provides a comprehensive introduction to the application of the finite element method in fluid dynamics The book begins with a useful summary of all relevant partial differential equations progressing to the discussion of convection stabilization procedures steady and transient state equations and numerical solution of fluid dynamic equations In this expanded eighth edition the book starts by explaining the character based split CBS scheme followed by an exploration of various other methods including SUPG PSPG space time and VMS methods Emphasising the fundamental knowledge mathematical and analytical tools necessary for successful implementation of computational fluid dynamics CFD The Finite Element Method for Fluid Dynamics stands as the authoritative introduction of choice for graduate level students researchers and professional engineers A proven keystone reference in the library for engineers seeking to grasp and implement the finite element method in fluid dynamics Founded by a prominent pioneer in the field this eighth edition has been updated by distinguished academics who worked closely with Olgierd C Zienkiewicz Includes new chapters on data driven computational fluid dynamics and independent adaptive mesh and buoyancy driven flow chapters *Computational Fluid Dynamics 2000* Nobuyuki Satofuka,2012-12-06 This volume constitutes the Proceedings of the First International Conference on Computational Fluid Dynamics held at the Kyoto Research Park Kyoto Japan on 10 14 July 2000 The conference is the first one at which the Inter national Conference on Numerical Methods in Fluid Dynamics ICNMFD and the International Symposium on Computational Fluid Dynamics ISCFD were merged The purpose of the conference was to bring together scientists mathe maticians and engineers to review and share recent advances in mathematical and computational techniques for modeling fluid dynamics The conference had the following format Each day of the conference except Wednesday July 12 started with a plenary session at which an invited lecture was delivered During the rest of the day there were three sessions in parallel in which oral presentations were made Poster presentations were also made on Monday Tuesday and Thursday afternoons A total of 205 abstracts were submitted from all over the world and were evaluated by five paper selection committees chaired by J J Chattot USA KW Morton UK M Napolitano Italy K Srinivas Austraria and myself Out of 136 papers accepted for oral presentations 17 were withdrawn and out of 46 papers accepted for poster presentation 14 were cancelled **The Finite Element Method for Fluid Dynamics** O. C. Zienkiewicz,R. L. Taylor,P. Nithiarasu,2013-11-21 The Finite Element Method for Fluid Dynamics offers a complete introduction the application of the finite element method to fluid mechanics The book begins with a useful summary of all relevant partial differential equations before moving on to discuss convection stabilization procedures steady and transient state equations and numerical solution of fluid dynamic equations The character based split CBS scheme is introduced and

discussed in detail followed by thorough coverage of incompressible and compressible fluid dynamics flow through porous media shallow water flow and the numerical treatment of long and short waves Updated throughout this new edition includes new chapters on Fluid structure interaction including discussion of one dimensional and multidimensional problems Biofluid dynamics covering flow throughout the human arterial system Focusing on the core knowledge mathematical and analytical tools needed for successful computational fluid dynamics CFD The Finite Element Method for Fluid Dynamics is the authoritative introduction of choice for graduate level students researchers and professional engineers A proven keystone reference in the library of any engineer needing to understand and apply the finite element method to fluid mechanics Founded by an influential pioneer in the field and updated in this seventh edition by leading academics who worked closely with Olgierd C Zienkiewicz Features new chapters on fluid structure interaction and biofluid dynamics including coverage of one dimensional flow in flexible pipes and challenges in modeling systemic arterial circulation Numerical Methods for Free Boundary Problems VEITTAANMÄKI,2013-11-22 About 80 participants from 16 countries attended the Conference on Numerical Methods for Free Boundary Problems held at the University of Jyviiskylii Finland July 23 27 1990 The main purpose of this conference was to provide up to date information on important directions of research in the field of free boundary problems and their numerical solutions The contributions contained in this volume cover the lectures given in the conference The invited lectures were given by H W Alt V Barbu K H Hoffmann H Mittelmann and V Rivkind In his lecture H W Alt considered a mathematical model and existence theory for non isothermal phase separations in binary systems The lecture of V Barbu was on the approximate solvability of the inverse one phase Stefan problem K H Hoff mann gave an up to date survey of several directions in free boundary problems and listed several applications but the material of his lecture is not included in this proceedings H D Mittelmann handled the stability of thermo capillary convection in float zone crystal growth V Rivkind considered numerical methods for solving coupled Navier Stokes and Stefan equations Besides of those invited lectures mentioned above there were 37 contributed papers presented We shall briefly outline the topics of the contributed papers Stefan like problems Modelling existence and uniqueness The Finite Element Method Set O. C. Zienkiewicz,R. L. Taylor,2005-11-25 The sixth editions of these seminal books deliver the most up to date and comprehensive reference yet on the finite element method for all engineers and mathematicians Renowned for their scope range and authority the new editions have been significantly developed in terms of both contents and scope Each book is now complete in its own right and provides self contained reference used together they provide a formidable resource covering the theory and the application of the universally used FEM Written by the leading professors in their fields the three books cover the basis of the method its application to solid mechanics and to fluid dynamics This is THE classic finite element method set by two the subject s leading authors FEM is a constantly developing subject and any professional or student of engineering involved in understanding the computational modelling of physical systems will inevitably use the techniques in these books

Fully up to date ideal for teaching and reference *Computational Fluid Dynamics 2004* Clinton Groth,David W. Zingg,2006-09-27 Those interested in state of the art in computational fluid dynamics will find this publication a valuable source of reference The contributions are drawn from The International Conference on Computational Fluid Dynamics ICCFD held in 2004 The conference is staged every two years and brings together physicists mathematicians and engineers who review and share recent advances in mathematical and computational techniques for modeling fluid dynamics **IUTAM Symposium on Free Surface Flows** A.C. King,Y.D. Shikhmurzaev,2012-12-06 Free surface flows arise in the natural world physical and biological sciences and in some areas of modern technology and engineering Exam ples include the breaking of sea waves on a harbour wall the transport of sloshing fluids in partly filled containers and the design of micronozzles for high speed ink jet printing Apart from the intrinsic mathematical challenge in describing and solving the governing equations there are usually important environmental safety and engineering features which need to be analysed and controlled A rich variety of techniques has been developed over the past two decades to facilitate this analysis singular perturbations dynamical systems and the development of sophisticated numerical codes The extreme and sometimes violent nature of some free surface flows taxes these methods to the limit The work presented at the symposium addressed these limits and can be loosely classified into four areas i Axisymmetric free surface flows There are a variety of problems in the printing glass fertiliser and fine chemical industries in which threads of fluid are made and controlled Presentations were made in the areas of pinch off for inviscid and viscous threads of fluid recoil effects after droplet formation and the control of instability by forced vibration ii Dynamic wetting The motion of three phase contact lines which are formed at the junction between two fluids and a solid plays an important role in fluid mechanics **MARINE 2011, IV International Conference on Computational Methods in Marine Engineering** Luís Eça,Eugenio Oñate,Julio García-Espinosa,Trond Kvamsdal,Pål Bergan,2013-03-19 This book contains selected papers from the Fourth International Conference on Computational Methods in Marine Engineering held at Instituto Superior T cnico Technical University of Lisbon Portugal in September 2011 Nowadays computational methods are an essential tool of engineering which includes a major field of interest in marine applications such as the maritime and offshore industries and engineering challenges related to the marine environment and renewable energies The 2011 Conference included 8 invited plenary lectures and 86 presentations distributed through 10 thematic sessions that covered many of the most relevant topics of marine engineering today This book contains 16 selected papers from the Conference that cover CFD for Offshore Applications Fluid Structure Interaction Isogeometric Methods for Marine Engineering Marine Offshore Renewable Energy Maneuvering and Seakeeping Propulsion and Cavitation and Ship Hydrodynamics The papers were selected with the help of the recognized experts that collaborated in the organization of the thematic sessions of the Conference which guarantees the high quality of the papers included in this book *Chebyshev and Fourier Spectral Methods* John P. Boyd,2001-12-03 Completely revised text focuses on use of spectral methods to solve

boundary value eigenvalue and time dependent problems but also covers Hermite Laguerre rational Chebyshev sinc and spherical harmonic functions as well as cardinal functions linear eigenvalue problems matrix solving methods coordinate transformations methods for unbounded intervals spherical and cylindrical geometry and much more 7 Appendices Glossary Bibliography Index Over 160 text figures *Free-Surface Flow* Nikolaos D. Katopodes,2018-10-31 Free Surface Flow Computational Methods presents a detailed analysis of numerical schemes for shallow water waves It includes practical applications for the numerical simulation of flow and transport in rivers and estuaries the dam break problem and overland flow Closure models for turbulence such as Reynolds Averaged Navier Stokes and Large Eddy Simulation are presented coupling the aforementioned surface tracking techniques with environmental fluid dynamics While many computer programs can solve the partial differential equations describing the dynamics of fluids many are not capable of including free surfaces in their simulations Provides numerical solutions of the turbulent Navier Stokes equations in three space dimensions Includes closure models for turbulence such as Reynolds Averaged Navier Stokes and Large Eddy Simulation Practical applications are presented for the numerical simulation of flow and transport in rivers and estuaries the dam break problem and overland flow **Numerical Methods and Advanced Simulation in Biomechanics and Biological Processes** Miguel Cerrolaza,Sandra Shefelbine,Diego Garzón-Alvarado,2017-12-28 Numerical Methods and Advanced Simulation in Biomechanics and Biological Processes covers new and exciting modeling methods to help bioengineers tackle problems for which the Finite Element Method is not appropriate The book covers a wide range of important subjects in the field of numerical methods applied to biomechanics including bone biomechanics tissue and cell mechanics 3D printing computer assisted surgery and fluid dynamics Modeling strategies technology and approaches are continuously evolving as the knowledge of biological processes increases Both theory and applications are covered making this an ideal book for researchers students and R D professionals Provides non conventional analysis methods for modeling Covers the Discrete Element Method DEM Particle Methods PM MessLess and MeshFree Methods MLMF Agent Based Methods ABM Lattice Boltzmann Methods LBM and Boundary Integral Methods BIM Includes contributions from several world renowned experts in their fields Compares pros and cons of each method to help you decide which method is most applicable to solving specific problems *Discontinuous Finite Elements in Fluid Dynamics and Heat Transfer* Ben Q. Li,2005-12-20 Over the past several years significant advances have been made in developing the discontinuous Galerkin finite element method for applications in fluid flow and heat transfer Certain unique features of the method have made it attractive as an alternative for other popular methods such as finite volume and finite elements in thermal fluids engineering analyses This book is written as an introductory textbook on the discontinuous finite element method for senior undergraduate and graduate students in the area of thermal science and fluid dynamics It also can be used as a reference book for researchers and engineers who intend to use the method for research in computational fluid dynamics and heat transfer A good portion of this book has been used

in a course for computational fluid dynamics and heat transfer for senior undergraduate and first year graduate students It also has been used by some graduate students for self study of the basics of discontinuous finite elements This monograph assumes that readers have a basic understanding of thermodynamics fluid mechanics and heat transfer and some background in numerical analysis Knowledge of continuous finite elements is not necessary but will be helpful The book covers the application of the method for the simulation of both macroscopic and micro nanoscale fluid flow and heat transfer phenomena Computational Modeling for Fluid Flow and Interfacial Transport Wei Shyy,2014-06-10 Practical applications and examples highlight this treatment of computational modeling for handling complex flowfields A reference for researchers and graduate students of many different backgrounds it also functions as a text for learning essential computation elements Drawing upon his own research the author addresses both macroscopic and microscopic features He begins his three part treatment with a survey of the basic concepts of finite difference schemes for solving parabolic elliptic and hyperbolic partial differential equations The second part concerns issues related to computational modeling for fluid flow and transport phenomena In addition to a focus on pressure based methods this section also discusses practical engineering applications The third and final part explores the transport processes involving interfacial dynamics particularly those influenced by phase change gravity and capillarity Case studies employing previously discussed methods demonstrate the interplay between the fluid and thermal transport at macroscopic scales and their interaction with the interfacial transport

Scientific and Technical Aerospace Reports ,1995 **Boundary Element Methods in Nonlinear Fluid Dynamics** P.K. Banerjee,L. Morino,1990-05-31 This volume demonstrates that boundary element methods are both elegant and efficient in their application to time dependent time harmonic problems in engineering and therefore worthy of considerable development Applied Mechanics Reviews ,1973 **NBS Special Publication** ,1980 **Hydraulic Research in the United States and Canada, 1978** Pauline H. Gurewitz,1980

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