OPTIMAL CONTROL OF LINEARIZED COMPRESSIBLE NAVIER–STOKES EQUATIONS

Shirshendu Chowdhury[1] and Mythily Ramaswamy[1]

Abstract. We study an optimal boundary control problem for the two dimensional unsteady linearized compressible Navier–Stokes equations in a rectangle. The control acts through the Dirichlet boundary condition. We first establish the existence and uniqueness of the solution for the two-dimensional unsteady linearized compressible Navier–Stokes equations in a rectangle with inhomogeneous Dirichlet boundary data, not necessarily smooth. Then, we prove the existence and uniqueness of the optimal solution over the control set. Finally we derive an optimality system from which the optimal solution can be determined.

Mathematics Subject Classification. 49J20, 49K20, 35Q30, 76N25.

1. Introduction

The Navier–Stokes equations for a viscous compressible isentropic fluid in $\Omega \subset \mathbb{R}^N$ is

$$
\left.
\begin{aligned}
\frac{\partial \rho}{\partial t}(t,x) + \operatorname{div}[\rho(t,x)\boldsymbol{v}(t,x)] &= 0, \\
\rho(t,x)\left[\frac{\partial \boldsymbol{v}}{\partial t}(t,x) + (\boldsymbol{v}(t,x)\cdot\nabla)\boldsymbol{v}(t,x)\right] &= -\nabla p(t,x) + \mu\triangle\boldsymbol{v}(t,x) + (\lambda+\mu)\nabla[\operatorname{div}\,\boldsymbol{v}(t,x)], \\
p(t,x) &= a\rho^\gamma(t,x), \quad t>0,\ x \in \Omega,
\end{aligned}
\right\}
\tag{1.1}
$$

where $\rho(t,x)$ is the density of the fluid, $\boldsymbol{v}(t,x) = (v_1(t,x),\ldots,v_N(t,x))$ denotes the velocity vector in $\mathbb{R}^N$ and $p(t,x)$ denotes the pressure. Note that the second equation of (1.1) componentwise is

$$
\rho\left(\frac{\partial v_i}{\partial t} + \boldsymbol{v}\cdot\nabla v_i\right) = -\frac{\partial p}{\partial x_i} + \mu\triangle v_i + (\lambda+\mu)\frac{\partial}{\partial x_i}[\operatorname{div}\,\boldsymbol{v}],\, i=1,2,\ldots,N.
$$

Throughout this paper, we follow this same notational convention and use bold script to denote vectors and product spaces. The viscosity coefficients μ, λ are assumed to be constant satisfying the following thermodynamic restrictions: $\mu > 0$, $\lambda + \mu \geq 0$ and the constants $a > 0$, $\gamma > 1$.

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Numerical Solution Of The Incomprebible Navierstokes Equations Vol 113

Santo Banerjee,Asit Saha

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Projection and Quasi-Compressibility Methods for Solving the Incompressible Navier-Stokes Equations ,2013-11-11 Projection methods had been introduced in the late sixties by A Chorin and R Teman to decouple the computation of velocity and pressure within the time stepping for solving the nonstationary Navier Stokes equations Despite the good performance of projection methods in practical computations their success remained somewhat mysterious as the operator splitting implicitly introduces a nonphysical boundary condition for the pressure The objectives of this monograph are twofold First a rigorous error analysis is presented for existing projection methods by means of relating them to so called quasi compressibility methods e g penalty method pressure stabilzation method etc This approach highlights the intrinsic error mechanisms of these schemes and explains the reasons for their limitations Then in the second part more sophisticated new schemes are constructed and analyzed which are exempted from most of the deficiencies of the classical projection and quasi compressibility methods this book should be mandatory reading for applied mathematicians specializing in computational fluid dynamics J L Guermond Mathematical Reviews Ann Arbor   **Incompressible Flow** Ronald L. Panton,2024-01-31 Incompressible Flow The latest edition of the classic introduction to fluid dynamics This textbook offers a detailed study of fluid dynamics Equal emphasis is given to physical concepts mathematical methods and illustrative flow patterns The book begins with a precise and careful formulation of physical concepts followed by derivations of the laws governing the motion of an arbitrary fluid the Navier Stokes equations Throughout there is an emphasis on scaling variables and dimensional analysis Incompressible flow is presented as an asymptotic expansion of solutions to the Navier Stokes equations with low Mach numbers and arbitrary Reynolds numbers The different physical behaviors of flows with low medium and high Reynolds number are thoroughly investigated Additionally several special introductory chapters are provided on lubrication theory flow stability and turbulence In the Fifth Edition a chapter on gas dynamics has been added Gas dynamics is presented as Navier Stokes solutions for high Reynolds Number at arbitrary Mach number with a perfect gas as the fluid The existence of several excellent and free compressible flow calculators on the internet has been used in the presentation and the homework With this chapter the textbook becomes a survey of the entire field of fluid dynamics Readers of the Fifth Edition of Incompressible Flow will also find New content treating wind turbines Examples and end of chapter problems to reinforce learning MATLAB codes available for download Incompressible Flow is ideal for undergraduate and graduate students in advanced fluid mechanics classes and for any engineer or researcher studying fluid dynamics or related subjects   **Computational Fluid Dynamics Review 1998 (In 2 Volumes)** Mohamed M Hafez,Koichhi Oshima,1998-11-20 The first volume of CFD Review was published in 1995 The purpose of this new publication is to present comprehensive surveys and review articles which provide up to date information about recent progress in computational fluid dynamics on a regular basis Because of the multidisciplinary nature of CFD it is difficult to cope with all the important

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problems This book presents the state of the art on the solution of viscous flow using boundary elements and discusses different current approaches which have been validated by numerical experiments Chapter 1 of the book presents a brief review of previous work on viscous flow simulation and in particular gives an up to date list of the most important BEM references in the field Chapter 2 reviews the governing equations for general viscous flow including compressibility The authors present a compre hensive treatment of the different cases and their formulation in terms of boundary integral equations This work has been the result of collaboration between Computational Mechanics Institute of Southampton and Massa chusetts Institute of Technology researchers Chapter 3 describes the gen eralized formulation for unsteady viscous flow problems developed over many years at Georgia Institute of Technology This formulation has been extensively applied to solve aer09ynamic problems

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