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

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

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

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

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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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,2013-07-18 The most teachable book on incompressible flow now fully revised updated and expanded Incompressible Flow Fourth Edition is the updated and revised edition of Ronald Panton s classic text It continues a respected tradition of providing the most comprehensive coverage of the subject in an exceptionally clear unified and carefully paced introduction to advanced concepts in fluid mechanics Beginning with basic principles this Fourth Edition patiently develops the math and physics leading to major theories Throughout the book provides a unified presentation of physics mathematics and engineering applications liberally supplemented with helpful exercises and example problems Revised to reflect students ready access to mathematical computer programs that have advanced features and are easy to use Incompressible Flow Fourth Edition includes Several more exact solutions of the Navier Stokes equations Classic style Fortran programs for the Hiemenz flow the Psi Omega method for entrance flow and the laminar boundary layer program all revised into MATLAB A new discussion of the global vorticity boundary restriction A revised vorticity dynamics chapter with new examples including the ring line vortex and the Fraenkel Norbury vortex solutions A discussion of the different behaviors that occur in subsonic and supersonic steady flows Additional emphasis on composite asymptotic expansions Incompressible Flow Fourth Edition is the ideal coursebook for classes in fluid dynamics offered in mechanical aerospace and chemical engineering programs   Finite Element Methods for Flow Problems Jean Donea,Antonio Huerta,2003-06-02 In recent years there have been significant developments in the development of stable and accurate finite element procedures for the numerical approximation of a wide range of fluid mechanics problems Taking an engineering rather than a mathematical bias this valuable reference resource details the fundamentals of stabilised finite element methods for the analysis of steady and time dependent fluid dynamics problems Organised into six chapters this text combines theoretical aspects and practical applications and offers coverage of

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