VISCOUS AND INVISCID STABILITY OF MULTIDIMENSIONAL PLANAR SHOCK FRONTS

K. ZUMBRUN AND D. SERRE

ABSTRACT. We explore the relation between viscous and inviscid stability of multi-dimensional shock fronts, by studying the Evans function associated with the viscous shock profile. Our main result, generalizing earlier one-dimensional calculations, is that the Evans function reduces in the long-wave limit to the Kreiss–Sakamoto–Lopatinski determinant obtained by Majda in the inviscid case, multiplied by a constant measuring transversality of the shock connection in the underlying (viscous) traveling wave ODE. Remarkably, this result holds independently of the nature of the viscous regularization, or the type of the shock connection. Indeed, the analysis is more general still: in the overcompressive case, we obtain a simple long-wave stability criterion even in the absence of a sensible inviscid problem.

An immediate consequence is that inviscid stability is necessary (but not sufficient) for viscous stability; this yields a number of interesting results on viscous instability through the inviscid analyses of Erpenbeck, Majda, and others. Moreover, in the viscous case, the Kreiss–Sakamoto–Lopatinski determinant is seen to play the key role of a "generalized Fredholm solvability condition," determining the spectral expansion about zero of the linearized operator about the wave, and thereby the transverse propagation of signals along the front. This expansion is in general not analytic, due to accumulation of essential spectrum, but rather has conical structure. A consequence, as in the inviscid case, is that stability is typically stronger for systems than for scalar equations. In the indeterminate, "tangent" case (Majda's "weak stability"), we provide an appropriate higher order correction.

§1. Introduction

Consider a system of viscous conservation laws,

$$(1.1) \qquad u_t + \sum_j f^j(u)_{x_j} = \sum_{j,k}(B^{jk}(u)u_{x_k})_{x_j},$$

$u, f^j \in \mathbb{R}^n$, $B \in \mathbb{R}^{n \times n}$, $x \in \mathbb{R}^d$, and a planar shock solution

$$(1.2) \qquad u(x,t) = \bar{u}(x_1 - st), \qquad \lim_{z \to \pm\infty} \bar{u}(z) = u_{\pm}.$$

Stability Of Multi Dimensional Shock Fronts

Sylvie Benzoni-Gavage,Denis Serre

Stability Of Multi Dimensional Shock Fronts:

   The Stability of Multi-Dimensional Shock Fronts Andrew Majda,1983 A systematic study of the linearized stability of multi dimensional shock front solutions of a system of hyperbolic conservation laws is developed   *Multi-dimensional Hyperbolic Partial Differential Equations* Sylvie Benzoni-Gavage,Denis Serre,2007 Authored by leading scholars this comprehensive text presents a view of the multi dimensional hyperbolic partial differential equations with a particular emphasis on problems in which modern tools of analysis have proved useful It is useful to graduates and researchers in both hyperbolic PDEs and compressible fluid dynamics   *Shocks, Singularities and Oscillations in Nonlinear Optics and Fluid Mechanics* Ferruccio Colombini,Daniele Del Santo,David Lannes,2017-04-25 The book collects the most relevant results from the INdAM Workshop Shocks Singularities and Oscillations in Nonlinear Optics and Fluid Mechanics held in Rome September 14 18 2015 The contributions discuss recent major advances in the study of nonlinear hyperbolic systems addressing general theoretical issues such as symmetrizability singularities low regularity or dispersive perturbations It also investigates several physical phenomena where such systems are relevant such as nonlinear optics shock theory stability relaxation and fluid mechanics boundary layers water waves Euler equations geophysical flows etc It is a valuable resource for researchers in these fields   ,   *Hyperbolic Systems of Balance Laws* Alberto Bressan,Denis Serre,Mark Williams,Kevin Zumbrun,2007-05-26 This volume includes four lecture courses by Bressan Serre Zumbrun and Williams and a Tutorial by Bressan on the Center Manifold Theorem Bressan introduces the vanishing viscosity approach and clearly explains the building blocks of the theory Serre focuses on existence and stability for discrete shock profiles The lectures by Williams and Zumbrun deal with the stability of multidimensional fronts   *Mathematical Analysis of Shock Wave Reflection* Shuxing Chen,2020-09-04 This book is aimed to make careful analysis to various mathematical problems derived from shock reflection by using the theory of partial differential equations The occurrence propagation and reflection of shock waves are important phenomena in fluid dynamics Comparing the plenty of studies of physical experiments and numerical simulations on this subject this book makes main efforts to develop the related theory of mathematical analysis which is rather incomplete so far The book first introduces some basic knowledge on the system of compressible flow and shock waves then presents the concept of shock polar and its properties particularly the properties of the shock polar for potential flow equation which are first systematically presented and proved in this book Mathematical analysis of regular reflection and Mach reflection in steady and unsteady flow are the most essential parts of this book To give challenges in future research some long standing open problems are listed in the end This book is attractive to researchers in the fields of partial differential equations system of conservation laws fluid dynamics and shock theory   Hyperbolic Problems: Theory, Numerics and Applications Eitan Tadmor,Jian-Guo Liu,Athanasios E. Tzavaras,2009 The International Conference on Hyperbolic Problems Theory Numerics and Applications HYP2008 was held at the University of Maryland from June 9 13

2008 This book the first in a two part volume contains nineteen papers based on plenary and invited talks presented at the conference _Multi-dimensional Shock Front for Transonic Flow Equations_ Enrique Alberto Thomann,1985 _Analytical Approaches to Multidimensional Balance Laws_ Olga S. Rozanova,2006 It is difficult to overestimate the importance of mathematical investigation of balance laws They arise in many areas of physics mechanics chemistry biology social sciences In this collective book we concentrate in particular on the equations of continuous medium and related to them As a rule they are very complicated in their primitive form An important feature of such equations is a possible formation of singularities even in initially smooth solution within a finite time The structure of the singularities can be very complex A natural step in the approach to this problem is the transition despite the three dimensionality of our world to spatially one dimensional model Significant progress has been achieved in this direction Unfortunately the methods of the one dimensional theory as usual cannot be adapted to a case of many spatial variables However there are many attempts to deal with multidimensional problems We would like to present some of them All of the papers are written by outstanding experts representing various schools in mathematics and mechanics Each paper is organised as follows it contains an elementary as far as it is possible introduction to a problem a brief review of previously published results and then original results of the authors are presented **The Mathematics of Shock Reflection-Diffraction and von Neumann's Conjectures** Gui-Qiang G Chen,Mikhail Feldman,2018-02-27 This book offers a survey of recent developments in the analysis of shock reflection diffraction a detailed presentation of original mathematical proofs of von Neumann s conjectures for potential flow and a collection of related results and new techniques in the analysis of partial differential equations PDEs as well as a set of fundamental open problems for further development Shock waves are fundamental in nature They are governed by the Euler equations or their variants generally in the form of nonlinear conservation laws PDEs of divergence form When a shock hits an obstacle shock reflection diffraction configurations take shape To understand the fundamental issues involved such as the structure and transition criteria of different configuration patterns it is essential to establish the global existence regularity and structural stability of shock reflection diffraction solutions This involves dealing with several core difficulties in the analysis of nonlinear PDEs mixed type free boundaries and corner singularities that also arise in fundamental problems in diverse areas such as continuum mechanics differential geometry mathematical physics and materials science Presenting recently developed approaches and techniques which will be useful for solving problems with similar difficulties this book opens up new research opportunities **Hyperbolic Problems: Theory, Numerics, Applications** Thomas Y. Hou,Eitan Tadmor,2012-12-06 The International Conference on Hyperbolic Problems Theory Numerics and Applications was held in CalTech on March 25 30 2002 The conference was the ninth meeting in the bi annual international series which became one of the highest quality and most successful conference series in Applied mathematics This volume contains more than 90 contributions presented in this conference including plenary presentations by A Bressan P Degond R LeVeque T P Liu B

Perthame C W Shu B Sj green and S Ukai Reflecting the objective of series the contributions in this volume keep the traditional blend of theory numerics and applications The Hyp2002 meeting placed a particular emphasize on fundamental theory and numerical analysis on multi scale analysis modeling and simulations and on geophysical applications and free boundary problems arising from materials science and multi component fluid dynamics The volume should appeal to researchers students and practitioners with general interest in time dependent problems governed by hyperbolic equations

Advances in the Theory of Shock Waves Heinrich Freistühler,Anders Szepessy,2012-12-06 In the field known as the mathematical theory of shock waves very exciting and unexpected developments have occurred in the last few years Joel Smoller and Blake Temple have established classes of shock wave solutions to the Einstein Euler equations of general relativity indeed the mathematical and physical con sequences of these examples constitute a whole new area of research The stability theory of viscous shock waves has received a new geometric perspective due to the work of Kevin Zumbrun and collaborators which offers a spectral approach to systems Due to the intersection of point and essential spectrum such an ap proach had for a long time seemed out of reach The stability problem for in viscid shock waves has been given a novel clear and concise treatment by Guy Metivier and coworkers through the use of paradifferential calculus The L 1 semi group theory for systems of conservation laws itself still a recent development has been considerably condensed by the introduction of new distance functionals through Tai Ping Liu and collaborators these functionals compare solutions to different data by direct reference to their wave structure The fundamental prop erties of systems with relaxation have found a systematic description through the papers of Wen An Yong for shock waves this means a first general theorem on the existence of corresponding profiles The five articles of this book reflect the above developments *Handbook of Mathematical Fluid Dynamics* S. Friedlander,D. Serre,2004-11-20 The Handbook of Mathematical Fluid Dynamics is a compendium of essays that provides a survey of the major topics in the subject Each article traces developments surveys the results of the past decade discusses the current state of knowledge and presents major future directions and open problems Extensive bibliographic material is provided The book is intended to be useful both to experts in the field and to mathematicians and other scientists who wish to learn about or begin research in mathematical fluid dynamics The Handbook illuminates an exciting subject that involves rigorous mathematical theory applied to an important physical problem namely the motion of fluids Nonlinear Conservation Laws and Applications Alberto Bressan,Gui-Qiang G. Chen,Marta Lewicka,Dehua Wang,2011-04-19 This volume contains the proceedings of the Summer Program on Nonlinear Conservation Laws and Applications held at the IMA on July 13 31 2009 Hyperbolic conservation laws is a classical subject which has experienced vigorous growth in recent years The present collection provides a timely survey of the state of the art in this exciting field and a comprehensive outlook on open problems Contributions of more theoretical nature cover the following topics global existence and uniqueness theory of one dimensional systems multidimensional conservation laws in several space variables and approximations of their solutions

mathematical analysis of fluid motion stability and dynamics of viscous shock waves singular limits for viscous systems basic principles in the modeling of turbulent mixing transonic flows past an obstacle and a fluid dynamic approach for isometric embedding in geometry models of nonlinear elasticity the Monge problem and transport equations with rough coefficients In addition there are a number of papers devoted to applications These include models of blood flow self gravitating compressible fluids granular flow charge transport in fluids and the modeling and control of traffic flow on networks

Mathematical Problems of Classical Nonlinear Electromagnetic Theory Frederick Bloom,2020-11-29 A survey of some problems of current interest in the realm of classical nonlinear electromagnetic theory **Multidimensional Hyperbolic Problems and Computations** James Glimm,Andrew J. Majda,2012-12-06 This IMA Volume in Mathematics and its Applications MULTIDIMENSIONAL HYPERBOLIC PROBLEMS AND COMPUTATIONS is based on the proceedings of a workshop which was an integral part ofthe 1988 89 IMA program on NONLINEAR WAVES We are grateful to the Scientific Commit tee James Glimm Daniel Joseph Barbara Keyfitz Andrew Majda Alan Newell Peter Olver David Sattinger and David Schaeffer for planning and implementing an exciting and stimulating year long program We especially thank the Work shop Organizers Andrew Majda and James Glimm for bringing together many of the major figures in a variety of research fields connected with multidimensional hyperbolic problems A vner Friedman Willard Miller PREFACE A primary goal of the IMA workshop on Multidimensional Hyperbolic Problems and Computations from April 3 14 1989 was to emphasize the interdisciplinary nature of contemporary research in this field involving the combination of ideas from the theory of nonlinear partial differential equations asymptotic methods numerical computation and experiments The twenty six papers in this volume span a wide cross section of this research including some papers on the kinetic theory of gases and vortex sheets for incompressible flow in addition to many papers on systems of hyperbolic conservation laws This volume includes several papers on asymptotic methods such as nonlinear geometric optics a number of articles applying numerical algorithms such as higher order Godunov methods and front tracking to physical problems along with comparison to experimental data and also several interesting papers on the rigorous mathematical theory of shock waves **Pseudo-Differential Operators** Heinz O. Cordes,Bernhard Gramsch,Harold Widom,2006-11-15 **Asian Mathematical Conference, 1990 - Proceedings Of The Conference** Zhong Li,Kar Ping Shum,Chung-chun Yang,Le Yang,1992-03-31 *Variational Approach to Hyperbolic Free Boundary Problems* Seiro Omata,Karel Svadlenka,Elliott Ginder,2022-11-28 This volume is devoted to the study of hyperbolic free boundary problems possessing variational structure Such problems can be used to model among others oscillatory motion of a droplet on a surface or bouncing of an elastic body against a rigid obstacle In the case of the droplet for example the membrane surrounding the fluid in general forms a positive contact angle with the obstacle and therefore the second derivative is only a measure at the contact free boundary set We will show how to derive the mathematical problem for a few physical systems starting from the action functional discuss the mathematical theory and introduce

methods for its numerical solution The mathematical theory and numerical methods depart from the classical approaches in that they are based on semi discretization in time which facilitates the application of the modern theory of calculus of variations   Fifth International Congress of Chinese Mathematicians Lizhen Ji,2012 This two part volume represents the proceedings of the Fifth International Congress of Chinese Mathematicians held at Tsinghua University Beijing in December 2010 The Congress brought together eminent Chinese and overseas mathematicians to discuss the latest developments in pure and applied mathematics Included are 60 papers based on lectures given at the conference

This book delves into Stability Of Multi Dimensional Shock Fronts. Stability Of Multi Dimensional Shock Fronts is an essential topic that must be grasped by everyone, ranging from students and scholars to the general public. The book will furnish comprehensive and in-depth insights into Stability Of Multi Dimensional Shock Fronts, encompassing both the fundamentals and more intricate discussions.

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   - Chapter 4: Stability Of Multi Dimensional Shock Fronts in Specific Contexts
   - Chapter 5: Conclusion

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6. In chapter 5, the author will draw a conclusion about Stability Of Multi Dimensional Shock Fronts. This chapter will summarize the key points that have been discussed throughout the book.
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