

## Shape optimization by the homogenization method

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**Summary.** In the context of shape optimization, we seek minimizers of the sum of the elastic compliance and of the weight of a solid structure under specified loading. This problem is known not to be well-posed, and a relaxed formulation is introduced. Its effect is to allow for microperforated composites as admissible designs. In a two-dimensional setting the relaxed formulation was obtained in [6] with the help of the theory of homogenization and optimal bounds for composite materials. We generalize the result to the three dimensional case. Our contribution is twofold: first, we prove a relaxation theorem, valid in any dimensions; secondly, we introduce a new numerical algorithm for computing optimal designs, complemented with a penalization technique which permits to remove composite designs in the final shape. Since it places no assumption on the number of holes cut within the domain, it can be seen as a topology optimization algorithm. Numerical results are presented for various two and three dimensional problems.

*Mathematics Subject Classification (1991):* 65K10

### 1. Introduction

Shape optimization is a major issue in structural design. One of the most challenging aspects of shape optimization is what structural engineers refer to as the layout, or topology, optimization. Classical methods of shape optimization, based on boundary motion, are ill equipped to capture the possible topological complexity of the shape because the required smoothness assumptions on the boundary of the material domain do not permit hole punching, although it is widely acknowledged that creating holes (i.e., changing the topology) may drastically improve the performance of a candidate optimal shape.

# Shape Optimization By The Homogenization Method

**Grégoire Allaire, Eric Bonnetier, Gilles Francfort, François Jouve (auteur en mathématiques).)**



## **Shape Optimization By The Homogenization Method:**

*Shape Optimization by the Homogenization Method* Grégoire Allaire, Eric Bonnetier, Gilles Francfort, François Jouve (auteur en mathématiques), 1995      Shape Optimization by the Homogenization Method Grégoire Allaire, 2012-07-11 This book provides an introduction to the theory and numerical developments of the homogenization method Its main features are a comprehensive presentation of homogenization theory an introduction to the theory of two phase composite materials a detailed treatment of structural optimization by using homogenization a complete discussion of the resulting numerical algorithms with many documented test problems It will be of interest to researchers engineers and advanced graduate students in applied mathematics mechanical engineering and structural optimization      **Shape Optimization,**

**Homogenization and Optimal Control** Volker Schulz, Diaraf Seck, 2018-09-05 The contributions in this volume give an insight into current research activities in Shape Optimization Homogenization and Optimal Control performed in Africa Germany and internationally Seeds for collaboration can be found in the first four papers in the field of homogenization Modelling and optimal control in partial differential equations is the topic of the next six papers again mixed from Africa and Germany Finally new results in the field of shape optimization are discussed in the final international three papers This workshop held at the AIMS Center Senegal March 13 16 2017 has been supported by the Deutsche Forschungsgemeinschaft DFG and by the African Institute for Mathematical Sciences AIMS in Senegal which is one of six centres of a pan African network of centres of excellence for postgraduate education research and outreach in mathematical sciences

**Topological Derivatives in Shape Optimization** Antonio André Novotny, Jan Sokołowski, 2012-12-14 The topological derivative is defined as the first term correction of the asymptotic expansion of a given shape functional with respect to a small parameter that measures the size of singular domain perturbations such as holes inclusions defects source terms and cracks Over the last decade topological asymptotic analysis has become a broad rich and fascinating research area from both theoretical and numerical standpoints It has applications in many different fields such as shape and topology optimization inverse problems imaging processing and mechanical modeling including synthesis and or optimal design of microstructures fracture mechanics sensitivity analysis and damage evolution modeling Since there is no monograph on the subject at present the authors provide here the first account of the theory which combines classical sensitivity analysis in shape optimization with asymptotic analysis by means of compound asymptotic expansions for elliptic boundary value problems This book is intended for researchers and graduate students in applied mathematics and computational mechanics interested in any aspect of topological asymptotic analysis In particular it can be adopted as a textbook in advanced courses on the subject and shall be useful for readers interested on the mathematical aspects of topological asymptotic analysis as well as on applications of topological derivatives in computation mechanics      Applied Shape Optimization for Fluids Bijan Mohammadi, Olivier Pironneau, 2010 Contents PREFACE ACKNOWLEDGEMENTS 1 Introduction 2 Optimal shape design 3

Partial differential equations for fluids 4 Some numerical methods for fluids 5 Sensitivity evaluation and automatic differentiation 6 Parameterization and implementation issues 7 Local and global optimization 8 Incomplete sensitivities 9 Consistent approximations and approximate gradients 10 Numerical results on shape optimization 11 Control of unsteady flows 12 From airplane design to microfluidic 13 Topological optimization for fluids 14 Conclusion and perspectives INDEX

*Geometric Partial Differential Equations - Part 2* Andrea Bonito, Ricardo Horacio Nochetto, 2021-01-26 Besides their intrinsic mathematical interest geometric partial differential equations PDEs are ubiquitous in many scientific engineering and industrial applications They represent an intellectual challenge and have received a great deal of attention recently The purpose of this volume is to provide a missing reference consisting of self contained and comprehensive presentations It includes basic ideas analysis and applications of state of the art fundamental algorithms for the approximation of geometric PDEs together with their impacts in a variety of fields within mathematics science and engineering About every aspect of computational geometric PDEs is discussed in this and a companion volume Topics in this volume include stationary and time dependent surface PDEs for geometric flows large deformations of nonlinearly geometric plates and rods level set and phase field methods and applications free boundary problems discrete Riemannian calculus and morphing fully nonlinear PDEs including Monge Ampere equations and PDE constrained optimization Each chapter is a complete essay at the research level but accessible to junior researchers and students The intent is to provide a comprehensive description of algorithms and their analysis for a specific geometric PDE class starting from basic concepts and concluding with interesting applications Each chapter is thus useful as an introduction to a research area as well as a teaching resource and provides numerous pointers to the literature for further reading The authors of each chapter are world leaders in their field of expertise and skillful writers This book is thus meant to provide an invaluable readable and enjoyable account of computational geometric PDEs

Optimization of Structural Topology, Shape, and Material Martin P. Bendsoe, 2013-03-14 In the past the possibilities of structural optimization were restricted to an optimal choice of profiles and shape Further improvement can be obtained by selecting appropriate advanced materials and by optimizing the topology i e finding the best position and arrangement of structural elements within a construction The optimization of structural topology permits the use of optimization algorithms at a very early stage of the design process The method presented in this book has been developed by Martin Bendsoe in cooperation with other researchers and can be considered as one of the most effective approaches to the optimization of layout and material design

Optimal Design through the Sub-Relaxation Method Pablo Pedregal, 2016-09-01 This book provides a comprehensive guide to analyzing and solving optimal design problems in continuous media by means of the so called sub relaxation method Though the underlying ideas are borrowed from other more classical approaches here they are used and organized in a novel way yielding a distinct perspective on how to approach this kind of optimization problems Starting with a discussion of the background motivation the book broadly

explains the sub relaxation method in general terms helping readers to grasp from the very beginning the driving idea and where the text is heading In addition to the analytical content of the method it examines practical issues like optimality and numerical approximation Though the primary focus is on the development of the method for the conductivity context the book s final two chapters explore several extensions of the method to other problems as well as formal proofs The text can be used for a graduate course in optimal design even if the method would require some familiarity with the main analytical issues associated with this type of problems This can be addressed with the help of the provided bibliography

**Shell Structures, Theory and Applications** Wojciech Pietraszkiewicz, Czeslaw Szymczak, 2005-09-22 Shells are basic structural elements of modern technology Examples of shell structures include automobile bodies domes water and oil tanks pipelines ship hulls aircraft fuselages turbine blades loudspeaker cones but also balloons parachutes biological membranes a human skin a bottle of wine or a beer can This volume contains full texts of over 100 papers presented by specialists from over 20 countries at the 8th Conference Shell Structures Theory and Applications 12-14 October 2005 in Jurata Poland The aim of the meeting was to bring together scientists designers engineers and other specialists in shell structures in order to discuss important results and new ideas in this field The goal is to pursue more accurate theoretical models to develop more powerful and versatile methods of analysis and to disseminate expertise in design and maintenance of shell structures Among the authors there are many distinguished specialists of shell structures including the authors of general lectures I V Andrianov Ukraine V A Eremeyev Russia A Ibrahimbegovic France P Klosowski Poland B H Kröplin Germany E Ramm Germany J M Rotter UK and D Steigmann USA The subject area of the papers covers various theoretical models and numerical analyses of strength dynamics stability optimization etc of different types of shell structures their design and maintenance as well as modelling of some surface related mechanical phenomena

*Variational Analysis and Aerospace Engineering* Aldo Frediani, Bijan Mohammadi, Olivier Pironneau, Vittorio Cipolla, 2016-12-27 This book presents papers surrounding the extensive discussions that took place from the Variational Analysis and Aerospace Engineering workshop held at the Ettore Majorana Foundation and Centre for Scientific Culture in 2015 Contributions to this volume focus on advanced mathematical methods in aerospace engineering and industrial engineering such as computational fluid dynamics methods optimization methods in aerodynamics optimum controls dynamic systems the theory of structures space missions flight mechanics control theory algebraic geometry for CAD applications and variational methods and applications Advanced graduate students researchers and professionals in mathematics and engineering will find this volume useful as it illustrates current collaborative research projects in applied mathematics and aerospace engineering

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