Preface

The aim of this book is to present numerical optimization methods in structural design to students in engineering courses at final undergraduate level or in the first year of a postgraduate study. For others in industry or elsewhere who may be new to these highly practical techniques, the book can bridge the gap between familiar design practice and some of the advanced texts on optimization theory. While the specific application is to structural design, the principles involved can be applied far more widely. A 'how to do it' approach is followed throughout the book, with less emphasis at this stage on mathematical derivations. Extensive use is made of the 'Solver' optimization tool in Microsoft Excel[1], because of its ready availability. This provides an ideal means of illustrating the methods presented, how to set up an optimization problem and to demonstrate the usefulness of optimization techniques in general. With practice in the use of Solver, use of optimization modules in more extensive computer packages should present little difficulty.

The spreadsheet programs provided with this book are, in the earlier chapters, principally illustrations of optimization methods. In later chapters, these are of a more practical nature, in particular for reinforced shell structures and for the design of composite laminates. These topics are chosen to reflect the ever-increasing demand for lightweight structures in many branches of engineering. Weight reduction is not only to reduce operational costs, but also to offset the high cost of many modern, high-performance metallic materials and composites. Detailed instructions are given for use of the spreadsheets and on the use of Solver. Exercises, with solutions where appropriate, are provided with each chapter, many of them making some other use of Solver or further use of the spreadsheets. These are intended to give practice in setting up an optimization problem and generally to explore the characteristics of the optimization process. Many of the examples in the book, throughout the text and in the spreadsheets, will be seen to have a distinct aerospace flavour, this being simply a reflection of the author's main field of work over many years.

[1]Microsoft and Excel are registered trademarks of the Microsoft Corporation.

The early chapters of the book show the relationship between formal optimization and the traditional methods of design, it not being the intention to replace existing methods but rather to supplement them with an additional weapon in the armoury of the designer. Strength-to-weight ratios, limits of feasibility and the concept of structural efficiency are discussed. Classical optimization is then introduced, together with the Lagrange multiplier, fundamental to the discussion of numerical optimization methods in the following chapters. Numerical methods are introduced in sufficient detail to enable the reader to appreciate the processes taking place in some of the highly sophisticated 'black box' optimization routines in advanced computer packages. It is not the intention to describe these numerical methods in the detail necessary to enable the reader to program them efficiently, this being a task primarily for the programming specialist. The generalized reduced gradient method and the genetic algorithm, two of the methods available in Solver, are given due attention, the latter in a later chapter in the context of composite laminates. The remaining chapters of the book are devoted to applications—reinforced shell structures, with the design of a box beam and an aircraft fuselage section, as well as some extended discussion of the design of composite laminates. For these topics, relevant methods of analysis are covered in sufficient detail before proceeding to specific optimization problems and spreadsheet programs for their solution. Composite laminates are of particular interest because of the special problem introduced by the discrete nature of the individual plies of the laminate and because of the freedom to optimize the lay-up to match the application. A final chapter is given to optimization with finite element analysis, for which some special methods are necessary.

The level of knowledge required to follow the text is no more than in a usual engineering course. No specific demands are made, and the text should remain largely accessible to those from other disciplines, sufficient information being given 'to proceed from this point'. However, it is assumed that the reader already has a working knowledge of Microsoft Excel, with some Visual Basic, and also is familiar with matrix notation. With a less mathematical bias, he might in the first place go rather superficially over Chaps. 4 and 5 and with no experience of finite element methods might be tempted to miss Chap. 9. No attempt is made at completeness in the book, but rather to provide a sound understanding of basic principles and a good start for further study. For this, a list of further reading is included (reflecting perhaps more the author's personal choice). Specific reference to research papers is limited to where this is of particular relevance. For a more comprehensive reference list, the reader should turn to the several excellent, more advanced books on optimization theory included amongst the references at the end of each chapter.

This book is based on lectures given at Delft University of Technology in the Netherlands, while the author was professor of aircraft structures. He hopes that the reader will enjoy a study of optimization methods as much as he has and will be able to put them to good use in further study and engineering practice.

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