

ELSEVIER AEROSPACE ENGINEERING SERIES

Aircraft Structures for Engineering Students

Fourth Edition



T.H.G. Megson



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for engineering students

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T. H. G. Megson



ELSEVIER

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Preface

During my experience of teaching aircraft structures I have felt the need for a textbook written specifically for students of aeronautical engineering. Although there have been a number of excellent books written on the subject they are now either out of date or too specialist in content to fulfil the requirements of an undergraduate textbook. My aim, therefore, has been to fill this gap and provide a completely self-contained course in aircraft structures which contains not only the fundamentals of elasticity and aircraft structural analysis but also the associated topics of airworthiness and aeroelasticity.

The book is intended for students studying for degrees, Higher National Diplomas and Higher National Certificates in aeronautical engineering and will be found of value to those students in related courses who specialize in structures. The subject matter has been chosen to provide the student with a textbook which will take him from the beginning of the second year of his course, when specialization usually begins, up to and including his final examination. I have arranged the topics so that they may be studied to an appropriate level in, say, the second year and then resumed at a more advanced stage in the final year; for example, the instability of columns and beams may be studied as examples of structural instability at second year level while the instability of plates and stiffened panels could be studied in the final year. In addition, I have grouped some subjects under unifying headings to emphasize their interrelationship; thus, bending, shear and torsion of open and closed tubes are treated in a single chapter to underline the fact that they are just different loading cases of basic structural components rather than isolated topics. I realize however that the modern trend is to present methods of analysis in general terms and then consider specific applications. Nevertheless, I feel that in cases such as those described above it is beneficial for the student's understanding of the subject to see the close relationships and similarities amongst the different portions of theory.

Part I of the book, 'Fundamentals of Elasticity', Chapters 1–6, includes sufficient elasticity theory to provide the student with the basic tools of structural analysis. The work is standard but the presentation in some instances is original. In Chapter 4 I have endeavoured to clarify the use of energy methods of analysis and present a consistent, but general, approach to the various types of structural problem for which energy methods are employed. Thus, although a variety of methods are discussed, emphasis is placed on the methods of complementary and potential energy. Overall, my intention has been to give some indication of the role and limitations of each method of analysis.

Part II, 'Analysis of Aircraft Structures', Chapters 7–11, contains the analysis of the thin-walled, cellular type of structure peculiar to aircraft. In addition, Chapter 7 includes a discussion of structural materials, the fabrication and function of structural components and an introduction to structural idealization. Chapter 10 discusses the limitations of the theory presented in Chapters 8 and 9 and investigates modifications necessary to account for axial constraint effects. An introduction to computational methods of structural analysis is presented in Chapter 11 which also includes some elementary work on the relatively modern finite element method for continuum structures.

Finally, Part III, 'Airworthiness and Aeroelasticity', Chapters 12 and 13, are self explanatory.

Worked examples are used extensively in the text to illustrate the theory while numerous unworked problems with answers are listed at the end of each chapter; S.I. units are used throughout.

I am indebted to the Universities of London (L.U.) and Leeds for permission to include examples from their degree papers and also the Civil Engineering Department of the University of Leeds for allowing me any facilities I required during the preparation of the manuscript. I am also extremely indebted to my wife, Margaret, who willingly undertook the onerous task of typing the manuscript in addition to attending to the demands of a home and our three sons, Andrew, Richard and Antony.

T.H.G. Megson

Preface to Second Edition

The publication of a second edition has given me the opportunity to examine the contents of the book in detail and determine which parts required alteration and modernization. Aircraft structures, particularly in the field of materials, is a rapidly changing subject and, while the fundamentals of analysis remain essentially the same, clearly an attempt must be made to keep abreast of modern developments. At the same time I have examined the presentation making changes where I felt it necessary and including additional material which I believe will be useful for students of the subject.

The first five chapters remain essentially the same as in the first edition except for some minor changes in presentation.

In Chapter 6, Section 6.12 has been rewritten and extended to include flexural-torsional buckling of thin-walled columns; Section 6.13 has also been rewritten to present the theory of tension field beams in a more logical form.

The discussion of composite materials in Chapter 7 has been extended in the light of modern developments and the sections concerned with the function and fabrication of structural components now include illustrations of actual aircraft structures of different types. The topic of structural idealization has been removed to Chapter 8.

Chapter 8 has been retitled and the theory presented in a different manner. Matrix notation is used in the derivation of the expression for direct stress due to unsymmetrical bending and the 'bar' notation discarded. The theory of the torsion of closed sections has been extended to include a discussion of the mechanics of warping, and the theory for the secondary warping of open sections amended. Also included is the analysis of combined open and closed sections. Structural idealization has been removed from Chapter 7 and is introduced here so that the effects of structural idealization on the analysis follow on logically. An alternative method for the calculation of shear flow distributions is presented.

Chapter 9 has been retitled and extended to the analysis of actual structural components such as tapered spars and beams, fuselages and multicell wing sections. The method of successive approximations is included for the analysis of many celled wings and the effects of cut-outs in wings and fuselages are considered. In addition the calculation of loads on and the analysis of fuselage frames and wing ribs is presented. In addition to the analysis of structural components composite materials are considered with the determination of the elastic constants for a composite together with their use in the fabrication of plates.

Chapter 10 remains an investigation into structural constraint, although the presentation has been changed particularly in the case of the study of shear lag. The theory for the restrained warping of open section beams now includes general systems of loading and introduces the concept of a moment couple or bimoment.

Only minor changes have been made to Chapter 11 while Chapter 12 now includes a detailed study of fatigue, the fatigue strength of components, the prediction of fatigue life and crack propagation. Finally, Chapter 13 now includes a much more detailed investigation of flutter and the determination of critical flutter speed.

I am indebted to Professor D. J. Mead of the University of Southampton for many useful comments and suggestions. I am also grateful to Mr K. Broddle of British Aerospace for supplying photographs and drawings of aircraft structures.

T.H.G. Megson
1989

Preface to Third Edition

The publication of a third edition and its accompanying solutions manual has allowed me to take a close look at the contents of the book and also to test the accuracy of the answers to the examples in the text and the problems set at the end of each chapter.

I have reorganised the book into two parts as opposed, previously, to three. Part I, Elasticity, contains, as before, the first six chapters which are essentially the same except for the addition of two illustrative examples in Chapter 1 and one in Chapter 4.

Part II, Chapters 7 to 13, is retitled Aircraft structures, with Chapter 12, Airworthiness, now becoming Chapter 8, Airworthiness and airframe loads, since it is logical that loads on aircraft produced by different types of manoeuvre are considered before the stress distributions and displacements caused by these loads are calculated.

Chapter 7 has been updated to include a discussion of the latest materials used in aircraft construction with an emphasis on the different requirements of civil and military aircraft.

Chapter 8, as described above, now contains the calculation of airframe loads produced by different types of manoeuvre and has been extended to consider the inertia loads caused, for example, by ground manoeuvres such as landing.

Chapter 9 (previously Chapter 8) remains unchanged apart from minor corrections while Chapter 10 (9) is unchanged except for the inclusion of an example on the calculation of stresses and displacements in a laminated bar; an extra problem has been included at the end of the chapter.

Chapter 11 (10), Structural constraint, is unchanged while in Chapter 12 (11) the discussion of the finite element method has been extended to include the four node quadrilateral element together with illustrative examples on the calculation of element stiffnesses; a further problem has been added at the end of the chapter.

Chapter 13, Aeroelasticity, has not been changed from Chapter 13 in the second edition apart from minor corrections.

I am indebted to, formerly, David Ross and, latterly, Matthew Flynn of Arnold for their encouragement and support during this project.

T.H.G. Megson
1999

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Preface to Fourth Edition

I have reviewed the three previous editions of the book and decided that a major overhaul would be beneficial, particularly in the light of developments in the aircraft industry and in the teaching of the subject. Present-day students prefer numerous worked examples and problems to solve so that I have included more worked examples in the text and more problems at the end of each chapter. I also felt that some of the chapters were too long. I have therefore broken down some of the longer chapters into shorter, more 'digestible' ones. For example, the previous Chapter 9 which covered bending, shear and torsion of open and closed section thin-walled beams plus the analysis of combined open and closed section beams, structural idealization and deflections now forms the contents of Chapters 16–20. Similarly, the Third Edition Chapter 10 'Stress Analysis of Aircraft Components' is now contained in Chapters 21–25 while 'Structural Instability', Chapter 6 in the Third Edition, is now covered by Chapters 8 and 9.

In addition to breaking down the longer chapters I have rearranged the material to emphasize the application of the fundamentals of structural analysis, contained in Part A, to the analysis of aircraft structures which forms Part B. For example, Matrix Methods, which were included in 'Part II, Aircraft Structures' in the Third Edition are now included in Part A since they are basic to general structural analysis; similarly for structural vibration.

Parts of the theory have been expanded. In Part A, virtual work now merits a chapter (Chapter 4) to itself since I believe this powerful and important method is worth an in-depth study. The work on tension field beams (Chapter 9) has become part of the chapter on thin plates and has been extended to include post-buckling behaviour. Materials, in Part B, now contains a section on material properties while, in response to readers' comments, the historical review has been discarded. The design of rivetted connections has been added to the consideration of structural components of aircraft in Chapter 12 while the work on crack propagation has been extended in Chapter 15. The method of successive approximations for multi-cellular wings has been dropped since, in these computer-driven times, it is of limited use and does not advance an understanding of the behaviour of structures. On the other hand the study of composite structures has been expanded as these form an increasing part of a modern aircraft's structure.

Finally, a Case Study, the design of part of the rear fuselage of a mythical trainer/semi-aerobatic aeroplane is presented in the Appendix to illustrate the application of some of the theory contained in this book.