concepts of flexible structures, but instead appears to be a cursory overview of different types of satellite missions. (2) The author mentions in his preface that he provides a 'practical engineering approach', which I consider to be lacking. Apart from a couple of end-of-chapter case studies, there are limited examples throughout; the author could produce a better learning experience by cutting back on the theory and expanding the number of examples and how to apply the theory.

In conclusion, this book would be suitable for people with a strong theoretical background which needed to complement their knowledge from other sources. A positive aspect of this book is the variety of provided references at the end of each chapter, giving readers a wide range of sources for further information.

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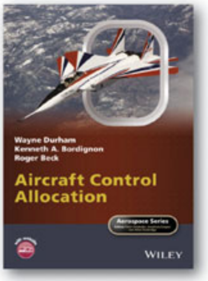

Aircraft Control Allocation

W. Durham *et al.*

John Wiley and Sons, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK. 2017. 281pp. Illustrated. £88.95. ISBN 978-1-118-82779-6.

This is a well-produced and well-presented book with an attractive front cover depicting the NASA NF-15B research aircraft. The content describes the state-of-the-art application of aircraft control allocation to the design of Flight Control Systems (FCS) for advanced technology combat aircraft.

The subject has been a topic of research for 20 years or more and has been evaluated in flight test programmes in the USA. Most recently, it has been demonstrated on the X-35B experimental aircraft and the content of this book builds on the experiences of those flight test development programs.

This book emphasises application rather than theory and the authors all have relevant 'real world' experience to underpin the material. Durham was previously a navy test pilot, Bordignon worked on the X-35B program and Beck is a flight mechanics specialist. Today, Durham and Bordignon are both university academics.

Aircraft control allocation is concerned with the simultaneous independent actuation of multiple control effectors to control roll, pitch and yaw moments directly. Required control moments are computed by the FCS and the commands provide the input to the control allocation algorithm. The problem confronting the designer is how to select an appropriate mix of control effectors to provide the required level of control redundancy and how to reconfigure the control algorithm following effector failure or saturation. Other important design issues concern the limitations of computer frame rate and effector actuator slew rate characteristics and their intrusion on handling qualities. The opening chapter gives a good overview of the justification for control allocation and outlines the approach to controller design, which is the subject matter of the following chapters.

The authors emphasise from the outset that the solution of the multiple redundant controller structure design is not necessarily unique so the design procedure is concerned with achieving an acceptable solution which may, or may not, be optimal. This book is about the choice of design procedure and the demonstration of successful solutions. The authors also emphasise that they are not mathematicians and that their work is concerned with the application of existing mathematical models and the interpretation and visualisation of the applicable flight physics. Since numerous design procedures are discussed, the authors are careful to explain the advantages and disadvantages of each, leaving the reader to draw his own conclusions about relevance.

Chapters 2 and 3 deal with Aircraft Control and Control Laws, respectively. The material provides the familiar mathematical foundations on which the control allocation algorithm is constructed. Naturally, the emphasis is on the dynamics of control effectors and how they relate to the equations of motion of the aircraft. The role of the FCS flight control laws is summarised briefly since the choice of controller structure does not necessarily have a large impact on control allocation design. However, for the purposes of the application discussed in the book, an FCS with a dynamic inversion control law is specified. Together, these two chapters give an excellent descriptive overview of the control-response properties of the augmented aircraft.

Chapter 4 sets out the case for control allocation and introduces the ideas and mathematical notation used in the design procedure. A brief overview of the 'problem' is given with reference to the real-world limitations of the control actuators and of the aerodynamic control effectors.

The geometry of control allocation is set out in Chapter 5. This describes a notation in which the multi-dimensional control space is represented by a geometrical diagram. The concept maps the vector of each control effector into the space representing the control moment, and this enables visual representation of the amplitude boundaries for all the effectors allocated to the controller. For two and three vector representations, the diagrams are easily interpreted. For higher order control vectors, typically order seven or more, the interpretation becomes difficult and complex. However, mathematical procedures have been devised to automate this aspect of

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the design using the tools and techniques of state space modelling.

The remaining chapters of the book are concerned with various examples of allocation design procedures. Chapter 6 gives an overview of a number of design procedures and illustrates their application to the two- and three-moment problem. It is also a comparative survey of the design methods, since all have been evaluated in piloted flight simulation exercises. Chapter 7 discusses the more familiar constraints on control of the computational frame rate, typically 0.01 s in modern FCS. In particular, adverse handling qualities can arise when the frame delay is too long and when the effector actuators are driven to rate limiting.

Chapter 8 provides an overview of FCS design in the context of control allocation and it does this with a simplified example of the application to a dynamic inversion control algorithm. Unfortunately, there appear to be some minor errors in this chapter. The second time history in Fig.8.8 should be labelled 'pitch rate' not 'roll rate'. Also, the general form of the transfer function given in equation 8.8 describes sideslip response properties and the appropriate lateral-directional notation should be used in its description. As written, it is misleading; for example, $T_{\theta 2}$ is an important longitudinal response characteristic describing incidence lag, whereas ω_2 is presumably determined by the roll mode time constant, but this is not clear from the limited information given. The use of an unambiguous notation together with an improved explanation of how the control gains influence the familiar aircraft response dynamics would help here.

It is also acknowledged that oversimplification of the model results in linear response properties which are relatively easy to optimise by feedback control. Real aircraft, especially those to which this technology is directed, do not have uniformly linear properties, and 'controller tuning' is required to achieve a workable control solution. It would also help if an explanation of the 'tuning' process was included in the discussion. For example, what is 'tuning' attempting to achieve and how are the controller gains adjusted to meet the objectives? The chapter concludes with a design example to illustrate the addition of a control allocation controller to the simplified system model set out earlier in the chapter.

Finally, Chapter 9 is entirely concerned with lessons learned from the application of control allocation to the NASA X-35B research aircraft. Most usefully, this discusses the problems, advantages and disadvantages discovered in developing the FCS in a real hardware environment as well as in simulation. The essential topics include failure due to effector actuator saturation, structural coupling, aircraft recovery after a system failure and the constraints of real-time computation. The challenges embrace multiple redundant system architecture design, control axis prioritisation, authority limiting, effector bandwidth, aircraft stability and handling qualities. This is supported by MATLAB/Simulink model software which may be downloaded from the publisher's website.

This book would appear to fill a gap in the market and it has the advantage that its authors bring firsthand experience to an interesting but complex subject. It is helpful that MATLAB/Simulink software for most of the examples in the book may be downloaded from the publisher's website.

The earlier chapters are well presented and give a good overview of what control allocation means and how it is designed. However, it is evident that the quality of the discussion in later chapters of the book is rather patchy. Some of the explanatory material is lacking in descriptive precision and mathematical rigour, and would benefit from more considered presentation. In particular, it would help if the controller design decisions are supported with some explanation as to how these are expected to influence flying qualities.

However, these are minor criticisms and the book should appeal to postgraduate researchers and to engineers engaged in advanced flight control system design and evaluation.

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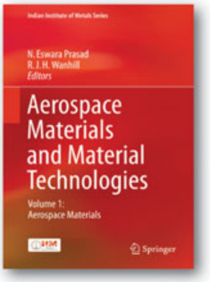

Aerospace Materials and Material Technologies. Vol.1: Aerospace Materials

Edited by N. E. Prasad and R. J. H. Wanhill

Springer. 2017. 586pp. Illustrated. £139.99. ISBN 978-981-10-2133-6.

This highly informative reference source is the latest in a series, inspired and approved by the Indian Institute of Metals. The work is offered in two volumes; Volume 1 addresses chemical/physical/mechanical compositions and properties. Volume 2 (to be reviewed at a later date) deals with material technologies, processing, testing, structural design and special evolving techniques.

Volume 1 Part 1, 'Metallic Materials', covers all important aerospace metals from light alloys to high temperature refractory materials.

Prized for low density, Mg alloys – discussed in Chapter 1 'Magnesium Alloys' – are widely used for casting secondary structures such as gearbox casings. Wrought alloys are also available and were used