Book Reviews

Aircraft and Rotorcraft System Identification: Engineering Methods with Flight Test Examples

M.B. Tischler and R.K. Remple

American Institute of Aeronautics and Astronautics, 1801 Alexander Bell Drive, Suite 500, Reston, VA 20191-4344, USA. 2006. 523pp. Illustrated. $83.95 (AIAA members), $119.95 (non-members). ISBN 1-56347-837-4.

System identification for rotorcraft is, in general, considered a subject in its own right, separate from the process as applied to fixed wing aircraft. This is due, in part, to the relative complexity of rotorcraft dynamics. Until recently, no textbooks were available that focused on rotorcraft system identification in detail. However, this changed with the publication of this book Aircraft and Rotorcraft System Identification: Engineering Methods with Flight Test Examples, written by Mark Tischler and Robert Remple. The lead author is well known in the field of system identification through his research at the U.S. Army Aeroflightdynamics Directorate at Ames, California. He is also the author of the successful software programme Comprehensive Identification from Frequency Responses (CIFER).

The book concentrates on the frequency-response method for system identification developed by Dr Tischler over the past 20 years and encapsulated in the CIFER software package. The focus is very much on the practical nature of system identification, with many examples and case studies presented through out the text. The student version of CIFER accompanies the book to assist in this, although readers should be aware this version of the software operates in Linux rather than Windows.

The first four chapters are predominantly taken up with introductory material. After an opening chapter discussing the principles and history of frequency domain system identification in general, chapter 2 introduces the various elements which comprise the frequency-response method. An example of the technique as applied to the XV-15 Tilt-Rotor is also presented. In fact, data from the XV-15 is cleverly used as an example throughout the book, the notion being that aspects of both fixed-wing and rotorcraft system identification can be demonstrated using the one aircraft. Chapter 3 then contains a more detailed description of the XV-15 case study and, if nothing else, gives an interesting insight into the vehicle's flight mechanics. Another example case, which is used continually in the text, is that of a simple pendulum and this is also discussed in chapter 3. CIFER is the subject of the fourth chapter, which provides a brief overview of its operation.

Details of the hands-on side of system identification begin with chapter 5, which discusses the collection of data from flight tests. This is followed by a chapter covering data consistency and reconstruction. The material in chapters 5 and 6 is general in the sense that the outlined concepts hold no matter which system identification technique is applied. However, from chapter 7 onwards, the focus returns to the unique frequency-response approach. Chapters 7 to 10 describe the steps necessary to perform non-parametric modelling, in which the aircraft's input-output behaviour is characterised, rather than its equations of motion. Firstly, the theory for single input/single output systems is outlined before the discussion turns to the multiple input/multiple output case. There is also a chapter dedicated to the identification of open-loop airframe dynamics from flight test data in which feedback control has been engaged. The analysis is extended to parametric identification, in which numerical estimates of the stability and control derivatives are obtained, in chapters 11 to 13. Two forms of parametric modelling are considered: transfer function and state space representations. The verification of the identified mathematical models is then considered in chapter 14.

The final chapter of the book is a specialist section describing higher-order modelling of coupled rotor/fuselage dynamics. This is an extension of the state space theory given earlier in the text to account for effects such as blade flapping, lead-lag dynamics and coning-inflow dynamics. The discussion is, again, backed up with results from flight tests, this time of the Kaman SH-2G.

As the emphasis of this book is on the applied aspects of system identification, for me, this book was enjoyable to read. It contains of a wealth of practical descriptions and examples, using data from a range of rotorcraft, as well as UAVs. It is worth noting, however, that this publication may not appeal to those seeking an in-depth theoretical discussion on the subject. The authors have, though, included as much mathematical description as is necessary and sources which cover the underlying theories are clearly cited. The minimal theoretical treatment in this text means that readers new to the subject may prefer a book in which the balance between theory and practice is more even. This may be found in either Flight Vehicle System Identification: A Time Domain Methodology by Ravindra V. Jategaonkar or Aircraft System Identification: Theory and Practice by Vlasilav Klein and Eugene A. Morelli. Conversely, engineers already actively involved in system identification are likely to find this text worthwhile and it will also be a great resource for anyone interested specifically in the process for helicopters and rotorcraft.

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Flight Vehicle System Identification: a Time Domain Methodology. Progress in Aeronautics and Astronautics series Vol 216

R. V. Jategaonkar

American Institute of Aeronautics and Astronautics, 1801 Alexander Bell Drive, Suite 500, Reston, VA 20191-4344, USA. 2006. 534pp. Illustrated. $79.95 (AIAA members), $104.95 (non-members). ISBN 1-56347-836-6.

Since its use in the analysis of flight test data began in the late 1960s, many institutes have been actively involved in researching the science of aircraft system identification. In recent years, however, few organizations have been as prominent in the field as the Institute of Flight Systems at DLR in Germany. This is in no small part due to the efforts of Ravindra Jategaonkar, who has published extensively on various aspects of the subject. So, when the American Institute of Aeronautics and Astronautics decided to publish three books on aircraft system identification in August 2006, it came as no surprise that one of the texts was written by Dr Jategaonkar.

As the title suggests, this book focuses on system identification techniques formulated in the time domain and the aim is to provide as much mathematical detail of the methods as is necessary while, at the same time, offering advice on the practical aspects of the subject based on the author's considerable experience. The book is also accompanied by an array of MATLAB software tools, along with some real flight test data, which are intended to illustrate the author's arguments and give the reader a practical understanding of the subject.

The book begins by outlining the principles of system identification as applied to dynamic systems in general before discussing the reasons why mathematical models of aircraft dynamics are required. After a brief historical review of the subject, the author then introduces the systematic approach to aircraft system identification used today. This is termed the 'Quad-M' process, which comprises the selection of manoeuvres designed to excite the vehicle's various modes of motion, measurement of the aircraft's response using a suitable instrumentation system, the method of data analysis chosen to estimate the numerical values of the parameters within the equations of motion and selection of an appropriate structure for the mathematical model.

The majority of chapter 2 is primarily concerned with the first of the Quad-M concepts – manoeuvre design. The mathematics behind the two common approaches to the problem –

https://doi.org/10.1017/S0001924000087182 Published online by Cambridge University Press

namely optimal input design and multistep input design – are described, with the author helpfully using illustrations to make his point wherever possible. An overview of the motion variables required for the analysis and guidelines for choosing appropriate sensors to measure these variables are also given. This rest of the chapter contains an interesting account of the practical aspects of flight testing, with the author describing his own experiences and highlighting possible pitfalls in the procedure.

While the third chapter is short in length, the material it covers is crucial for the chapters which follow. The aim of this section is to introduce various forms of the mathematical models that can be used to describe aircraft dynamics, with the emphasis being on state space representations and nonlinear equations. In particular, the author calls attention to modifications which have to be applied to the equations when faced with issues arising due to practical problems with flight test data. These include extensions of the model structure to account for systematic errors in the measurement of motion variables and control inputs, as well as the presence of time delays.

The core of the text considers the time domain parameter estimation techniques used to obtain numerical values for the parameters within the equations of motion. The first three algorithms to be developed are the output error method, filter error method and equation error method, which can all be used post-flight to analyse the measured data. Chapter 7 turns its attention to approaches for real-time, or recursive, parameter estimation, including techniques based on the extended Kalman filter. The subsequent two chapters focus on more specialised topics, with chapter 8 discussing the use of artificial neural networks and chapter 9 describing parameter estimation for unstable aircraft. It is in chapters 4 to 9 that the virtue of including companion software really becomes apparent. The opportunity to implement the various techniques utilising real flight test data allows the user a greater insight into the application of each algorithm. The link between theory and practice is further enhanced by the fact that the author has painstakingly annotated every key equation in the MATLAB files with the corresponding equation number as given in the book. This is particularly advantageous for the Filter Error Method, which is by far the most complex algorithm used for aircraft parameter estimation.

Chapter 10 returns to the issue of instrumentation by describing the data compatibility check, or flight path reconstruction, used to remove systematic errors from the measurements and verify their kinematic consistency. Although this step is carried out prior to the parameter estimation phase, the author delays its discussion until after the chapters covering parameter estimation, as the procedure utilises the output error method or the extended Kalman filter explained earlier.

After a chapter detailing how the parameter estimates can be validated, the final section provides a collection of interesting case studies from DLR in which system identification has been applied. These include the modelling of wake vortex encounters, analysis of unsteady aerodynamic effects and the identification of the Phoenix reusable launch vehicle demonstrator.

Overall, this is a first-rate book, which should appeal to those new to the field as well as anybody already actively involved in the subject area. The author has managed to strike a delicate balance between a theoretical and a practical treatment of the subject. Mathematical descriptions of the various techniques are detailed but concise. At the end of each discussion, the author goes out of his way to comment on which methods, based on his experience, have worked well in practice and the inclusion of the software tools enhances the value of this publication no end. On top of this, it is clear that a huge amount of effort has gone into the preparation of the material, and this ultimately makes the book an enjoyable read.

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Aircraft System Identification: Theory and Practice

V. Klein and E.A. Morelli

American Institute of Aeronautics and Astronautics, 1801 Alexander Bell Drive, Suite 500, Reston, VA 20191-4344, USA. 2006. 484pp. Illustrated. $84.95 (AIAA members), $119.95 (non-members). ISBN 1-56347-832-3.

This text on aircraft system identification is based on the considerable experience of the authors at NASA Langley, which has been an eminent authority on the subject over the last three decades. Vladislav Klein is one of the best known names in the field having been responsible for many key developments in aircraft system identification. Eugene Morelli is also a renowned expert on the subject and has analysed various aircraft including the de Havilland Canada DHC-6 Twin Otter, the Tu144LL supersonic transport aircraft and the X-43A (Hyper-X).

The scope of the book is fixed-wing, rigid body aircraft dynamics and, as indicated by the title, the objective is to deliver an account of the subject's theory, while reinforcing the concepts using practical examples. To assist in conveying the practical aspects of the system identification to the reader, a MATLAB software toolset known System IDentification Programs for AirCraft (SIDPAC), written by Dr Morelli, is included in the publication. The flight test data from the case studies is also provided.

The opening two chapters, as would be expected, introduce the principles of aircraft system identification and provide a brief outline of the subject's history. The theoretical background is laid out with a discussion of the mathematical modelling of dynamic systems and system identification in general.

The focus on aircraft begins in earnest with chapter 3, which looks at the mathematical models used to describe aircraft dynamics. In 46 pages the authors have managed to concisely develop the mathematics, starting from Newton's Second Law of Motion, and cover a range of topics including the linearisation of the equations and modelling of unsteady aerodynamic effects. This chapter will be particularly useful for readers who, like me, are schooled in the British system of flight dynamics notation and less familiar with the notation used in the US.

Parameter estimation techniques, used to obtain numerical values for the derivatives within the equations of motion, are the topic of chapters 4 to 8. Firstly, a general introduction to estimation theory is given. This is followed by chapters describing time domain techniques based on regression analysis and maximum likelihood estimation. Chapter 7 then concentrates on frequency domain parameter estimation and chapter 8 discusses techniques for performing the process in real-time. The treatment of the theory in these chapters is thorough, with each of the methods derived from first principles as far as possible. At the same time, practical examples from the authors' experiences at NASA Langley are used to illustrate their arguments and the reader has the opportunity to repeat the analysis using the software and data provided. The pros and cons of each approach are also outlined in detail.

Having discussed the theoretical aspects of parameter estimation, the remainder of the book focuses mainly on the practical issues to ensure the measurements from the aircraft are of sufficient quality. Firstly, the design of flight tests to gather data is considered and covers the selection of suitable data acquisition systems and sensors, as well as the design of control surface inputs. The following chapter describes the data compatibility check. This is an important pre-processing step which is used to remove systematic errors from the measurements and ensure the data is kinematically consistent. Further methods of data analysis are then explored in chapter 11, with a focus on techniques for filtering, smoothing, interpolation and numerical differentiation. Software is again provided to carry