Conclusions

The nonlinear response of a laminated shell including transverse shear and collapse was studied. Offsetting the cutout increases stiffness and strength (compared to shells with a centered cutout). Transverse shear strain significantly influences the response of a laminated shell undergoing large rotations (in excess of 15 deg) and is greater with increased width and reduced circumferential boundary conditions. This indicates that an approach not including transverse shear is less conservative for large rotations due to the presence of large transverse shear strains.

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Book Review

Automatic Control of Aircraft and Missiles

John H. Blakelock, 2nd Ed., Wiley, New York, 1991, 646 pp., $74.95

This book is a second edition of a volume originally published in 1965. The first volume competed with books such as those by Etkin or Seckel in the areas of airplane dynamics and controls, but was somewhat unique in its inclusion of missile dynamics and control. This edition is apparently intended to update aspects of the first edition, particularly in the inclusion of modern control theory and pilot modeling. In this light, it partially competes with Roskam's text or Etkin's second book, or newer books incorporating a treatment of "modern" control such as that by Stengel, but again the inclusion of missiles sets it apart from books that consider only aircraft. The text seems to be at about the right level for a first-year graduate course in flight dynamics and controls, but would be hampered in this regard by the lack of suggested exercises.

The book is composed of 13 chapters and 10 appendices. Chapters 1-4 deal with the equations of motion for aircraft, the development of longitudinal and lateral autopilots, inertial coupling, and "adaptive" autopilots, and are largely unchanged from the first edition. This constancy is both good and bad. The autopilot designs are clearly presented in terms of "classic" root-locus procedures, with engineering tradeoffs well identified—a characteristic sadly lacking in many textbooks and almost always missing in modern control textbooks. The time history responses, however, appear to have been carried over, and could not be presented with orthogonal grids rather than those dictated by the analog computers apparently used for the first edition. In addition, the use of stability axes, while typical of practice during the time of the first edition, is largely eschewed today for most flight analyses because of large angles of attack in many applications of interest; also, dimensional derivatives, rather than the "classic" nondimensionalization used here, are often more appropriate.

To this reviewer, Chapters 2 and 4, which present several designs in exemplary fashion and include some new material in lateral autopilots, are particularly good. Less successful for today's audience, perhaps, is Chapter 6 on adaptive autopilots, which is carried over from the previous edition; the material here is over 20 years old, and has effectively been superseded.

Chapter 7, again largely carried over from the first edition, deals with missile dynamics and control, whereas Chapter 8 is new and presents guidance design information. Again the presentation of the concepts is clear, and the designs are understandable. Chapter 8, which was particularly instructive for this reviewer, includes bank-to-turn design information that is appropriate for modern missiles. Chapter 9, another new chapter, returns to the aircraft application for an integrated flight-fire-control system design, including both longitudinal and lateral dynamics plus those of a gimballed tracker and movable gun. This chapter is unique compared with most books on aircraft dynamics because of its presentation of this fairly complex integrated "real-world" design problem, and should be very useful for students in developing an understanding of how rapidly the complexities grow.

Chapter 9 is also unique in the book in that it introduces, in this context only, the use of digital design procedures into the analysis. The design is considered from both a "direct" digital point of view, which uses z transforms, and the "emulation" point of view, which is in the Laplace domain but includes a Pade approximation to represent the digital delay. The author considers the results for these two digital methods to be equivalent, for the example selected, but this assessment would not

always be correct. The comparison of time histories to step inputs, for example, as is done here, is not sensitive to many of the high-frequency differences that would be apparent in a frequency-domain comparison.

Even more important, the significant influence of delays and equivalent delays that digital systems introduce on control system and aircraft stability, either automatic or manual, is not discussed. Nonetheless, although the material is so compressed that a full understanding of the digital techniques would likely require reference to another text, this introduction to discrete design is certainly warranted. The only cavil is that it might in fact have been more useful in the earlier chapters, given the fact that today's aircraft all have digital flight control systems, and that a description of the importance of the overall delay should be added.

Chapter 10 is a new chapter dealing with multivariable control system design techniques. This reviewer did not find the new material as inclusive as desired, and the presentation was somewhat less clear than other chapters of the book. There is no detailed discussion of LQG/LTR or H-infinity techniques that are the current hot topics among modern control advocates, and in fact even the simpler LQR technique is only briefly mentioned. It is difficult to consider a discussion of multivariable control design procedures complete without at least some consideration of these approaches.

Likewise, although it is a relatively new (in terms of acceptance) procedure, the so-called QFT frequency-domain design technique is not discussed either. Instead, the author presents two completed designs, one of which requires reference to a different textbook (his Reference 5), and the other of which requires the use of a control systems design computer "package." The author attempts at the end of the chapter to relate one of these "MIMO" designs back to a design performed using more classical techniques earlier in the book, which is a laudable endeavor, but the MIMO design is only presented, rather than discussed, and so the comparison is not too useful.

Chapters 11 and 12 are from the first edition, and deal with flexibility and randomness, respectively. Again, both chapters are excellent introductions to the subjects. The structural chapter in particular, with its discussion of the "tail-wags-dog" zero and propellant sloshing aspects of missile control, is a good description for those new to this area.

Chapter 13, the final chapter, is another new one that endeavors to incorporate some aspects of pilot modeling, as did, for example, Etkin's second book. The description given of the cross-over pilot model pioneered by McRuer and Krendel, which started the modern era of pilot modeling, is very good if abbreviated, and the Paper Pilot optimization program of Anderson, although not used much currently, is also well described. The author does not, however, give proper credit to Kleinman, Baron, and Levison for the development of the "optimal control pilot model" first presented in 1970, opting instead to present an optimization procedure by Pollard (1975) and an example of the *application* of the optimal control model by Dillow and Picha (1975). More recent work by Hess on the so-called structural pilot model, and by Schmidt on the optimal control pilot model, is not included at all, and so the chapter cannot be considered a really up-to-date exposition of the subject. Nonetheless, it does provide a useful introduction, and ensures that the subject is at least considered as part of a design procedure.

In addition to the 13 chapters, 109 appendices are included to provide some of the needed background. For example, Appendix B on gyroscopes is excellent and unusual for a modern textbook, Appendix C incorporates the majority of the root-locus design procedure necessary to follow the designs in the book, Appendix D has a very limited discussion of basic aerodynamic theory but a good description of using the Air Force DATCOM to develop a mathematical model, and Appendix I describes the fire control problem.

In summary, *Automatic Control of Aircraft and Missiles* in its second edition promotes the good qualities of the first edition and incorporates some interesting new material in missile guidance and aircraft integrated flight/fire control design. Its strength is in the presentation of classical control design studies rather than more modern control synthesis procedures, but it does incorporate introductory material in digital control and pilot modeling to initiate an understanding of these important topics and lead the interested reader to publications that can provide a more detailed understanding of them.

J. Victor Lebacqz
NASA Ames Research Center