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Book Review

Automatic Flight Control Systems

Donald McLean, Prentice-Hall, New York, 1990, 593 pp., $52.40.

This is an introductory book on a complicated subject. It contains 15 chapters covering aircraft flight control systems (FCSs), dynamics and stability, structural flexibility, handling qualities, control system design methods, stability augmentation systems, attitude control systems, flight path control systems, active control systems (for gust and load alleviation and ride quality), helicopter FCSs, digital FCSs, and adaptive FCSs. The three appendices cover actuators and sensors, stability derivatives for seven generic aircraft at different flight conditions, and mathematical models of human pilots.

This book has many positive features. Some of these features include overall views of the subject and discussions of practical considerations in implementing control systems, as well as many good examples and problems using real aircraft data from Appendix B. The book provides coverage of the many types of control system modes and makes use of the dimensional form of the equations of motion (EOM). It also provides a good introduction to aeroelastic effects.

Some criticisms of this book include the following. First, advocating weighting all of the states in LQR synthesis is not always the best solution. More graceful control systems (smaller control amplitudes) are obtained by weighting only the controlled outputs and the controls. If some state exceeds desirable limits, redesigning that state with a weight added on is often a better solution.

Second, in synthesizing integral error feedback, it is better to add integral-error states and to start the design by weighting only these states and the controls in the quadratic performance index (p. 248). If some state or output exceeds desirable limits, redesigning it with weights added on is a good alternative.

Third, the discussion of model following seems somewhat naive. For example, the author tries to make all states have first-order lag behavior (p. 433).

Fourth, units are not always normalized so that one unit of each is of comparable importance to the designer (e.g., radians are big units, so it is better to use centiradians or degrees). Thus, small terms in the EOM do not always signify negligibility, and large terms do not always signify importance. Also, the units used in the tables are not always clear.

Fifth, in some places, the author takes an ad hoc view of control synthesis (i.e., feedback *this* to *that* to stabilize *this*) instead of discussing controllability of modes by different controls and observability of modes with different sensors.

Sixth, the distinction between vacuum deformation modes and aeroelastic modes is not clearly made (aerodynamic feedback of elastic deformation modifies the vacuum modes). The rigid-blade treatment of rotor flapping seems out of place in a chapter on structural flexibility.

Finally, this review noted the following minor errors:

1) Newton's laws are for particles, which have constant mass (neglecting relativistic effects), and so for variable mass airplanes (a collection of particles), it would be more correct on page 19 to write ($F = m\,dv/dt$) instead of [$F = d(mv)dt$].

2) As in many other texts, Euler's moment equations for a rigid body are incorrectly attributed to Newton.

3) There is an incorrect statement about eigensystems on page 236; a single zero eigenvalue has a distinct eigenvector. Also, coupled modes with identical poles have one eigenvector and distinct principal vectors. (Repeated poles may also correspond to uncoupled modes, each with their distinct eigenvector.)

4) The eigenvalues in Table 12.1 are incorrect; the real roots of the short period mode are missing, and the eigenvalues are not in complex conjugate pairs.

In summary, the book is a good introduction to flight control systems. Although there are some weak areas as described above, the book is to be commended for its overall coverage of the subject.

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