BOOK REVIEW

PRACTICAL DESIGN OF FLIGHT CONTROL SYSTEMS FOR LAUNCH VEHICLES AND MISSILES

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The book titled **"Practical Design of Flight Control Systems for Launch Vehicles and Missiles"** by Mr. N.V. Kadam and published by Allied Publishers is truly an unique and remarkable effort when compared to other recent books on this niche topic. This is mainly because the author has been able to arrive at an ideal blend between theory and practice. As the title of the book itself suggests, the major effort of the author has been directed towards sharing his vast practical experience and hands on knowledge gained during working with teams involved in the design, development and flight testing of flight control systems for both launch vehicles and missiles. More importantly, the author has been able to achieve this without compromising on the mathematical content and theoretical rigour.

The introductory first chapter gives a broad overview of the subject, and exposes the readers to various elements of the flight control system like control effectors, power sources etc, for both launch vehicles and missiles. It clearly outlines the different forces and moments acting on this class of flight vehicles, illustrates the importance of various coordinate frames and derives expressions required for transforming the forces and moments from one frame to the other. The chapter in addition to giving a brief description on the various types of missiles and launch vehicles in use, also discusses the differences in their design drivers, and highlights the importance of mission / trajectory planning for initial stages of controller design.

The second chapter on Generalised Equations of Motion deals with the derivation of a simple but comprehensive generalized dynamics model which forms the backbone for the six degrees of freedom trajectory simulation program. The formulation is extremely elegant and has several novel and appealing features. In addition to the standard rigid body dynamics, the model formulation discusses how the other higher order terms related to structural flexibility, propellant sloshing, gimbaled engine inertia effects etc. can be introduced without disturbing the basic structure of the standard six degree of freedom equations of motion. The discussion on the various elements introduced in this model formulation is thorough and each of the dynamic terms including the coupling effects is discussed in great detail. Further, since the translational, rotational and flexible mode terms are completed decoupled, the physical significance of the various terms is transparent to the designer, thereby greatly reducing the errors during subsequent validation. The coupling between the different effects is brought in through the external forces and moments, thereby reducing to a great extent the effort required for deriving the coupled mode model from the decoupled mode model and thus highlighting the novelty and overall elegance of the generalized model formulation.

Chapters 3 and 4 which forms the heart of the book, describes in great detail the theoretical background and the practical design aspects required for synthesising the flight control systems which has to function both within and outside the atmosphere. The different sections in Chapter 3 deals with the more general aspects related to configuration, sizing requirements, and estimation of actuator and autopilot bandwidths. The details covered include error resolution in terms of Euler angles and Quarternions and their protection logics, alternate control law structures for attitude and latax control, load relief and drift minimization, and control effectors / power plant sizing to ensure adequate control for various phases of the trajectory till the mission accomplishment. Towards the end of Chapter the best options for control during different phases of the trajectory including optimal blending of available resources for back up control are also described in detail.

In Chapter 4 the author describes the linear plant models used, the design objectives, and the steps involved in the actual synthesis of the autopilot loops using classical design techniques for both attitude and latax control. Extensive coverage is also given to issues related not only to the linear control of rigid body dynamics but other equally important higher order effects related to vehicle flexibility, propellant sloshing and gimbaled engine inertias. Various other factors which affect the overall stability and performance of the flight vehicle like sensor location, structural mode attenuation, sharing of control authority, thrust misalignment, disturbance effects due to stage separation, gain adaptation / scheduling, digital implementation etc. are also covered in sufficient depth. Finally, the chapter concludes with a section on the use of mathematical programming as a valuable tool for arriving at an improved initial compensator design, and then also goes on to describe the limitations of the methodology.

For both launch vehicles and missiles, on - off reaction control systems are used both in the powered phase and more widely in the coasting phase where there are no other control alternatives available. In Chapter 5 the author therefore discusses the various issues related to the design and analysis of different types of on off reaction control systems. This chapter is an invaluable contribution to the book since very limited information is available in open literature on this topic. The general tendency of designers to arrive at the control parameters is to use digital simulation in an iterative manner, however simulation does not give adequate insight into understanding the nonlinear limit cycle behaviour. After a brief introduction, the author describes an analytical method for deriving the design parameters as an alternate to digital simulation and for developing a better understanding into the limit cycle characteristics. The designs got using this technique are found to match well with those obtained from simulation. The discussions concentrate mainly on the out of atmosphere conditions where aerodynamic torque can be totally neglected and under two different disturbance torque scenarios. A brief summary is however given for conditions when aerodynamic moment is present and for a variable disturbance torque which is proportional to aerodynamic angle of attack.

Chapter 6 gives an overview of the different validation steps used for clearing the flight control system design and also describes the authors experience on several practical issues and problems which are likely to arise during flight trials and tests.

In all the chapters in addition to the discussions, derivations and equations the author has spent considerable effort in augmenting the text with simple line sketches, figures and data tables to provide the required clarity. Each of these chapters also has a list of references and several appendices at the end which contain useful model descriptions, computer programs, case studies etc. Last but not the least the author Mr. N.V. Kadam must be truly complimented for the monumental effort he has put into preparing this book which is ideally suited both for a practicing engineer in the field and for post graduate students of aerospace engineering.

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