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Book Review

Publishers are invited to send two copies of new books for review to Dr. I. Michael Ross, Code: AA/Ro, Department of Aeronautics and Astronautics, U.S. Naval Postgraduate School, 699 Dyer Road, Monterey, CA 93943.

Space Vehicle Mechanisms

Peter L. Conley, John Wiley & Sons, Inc., 1998, 816 pp., $125.00, ISBN 0-471-12141-X

The word "mechanisms" in the title of this book means generally the various subsystems that make up a spacecraft. This is a handbook for the systems engineer who is doing space vehicle design. Each chapter is written by a specialist.

The first nine chapters deal with materials. Chapters 1 and 2 describe stainless steel and beryllium and their mechanical properties, structural composites with micromechanic models for stiffness, and strength and thermal properties. Metallurgy of nuts and bolts and joint design with preloads are discussed. The subjects in the next two chapters include the metallurgy and engineering properties of the materials used in ball bearings and springs, solid lubricants along with friction and wear testing and the chemistry of liquid lubricants, and lubricating greases. Information includes an outline of properties of plastics and rubbers used in space vehicle mechanisms for sealing and insulation.

Pyrotechnic release devices (including explosive separation bolts, cutters, and pinpullers) are illustrated with detailed drawings. Several types of nonexplosive release mechanisms are also discussed. A very good chapter on ball bearings provides material on bearing geometry, bearing loads, kinematics, preloading, friction loss, bearing noise, and bearing failure showing examples of successful ball bearings using Draper's RWA and Honeywell's CMG designs.

Two chapters are devoted to permanent magnet motors such as DC brush motors and brushless motors. The chapter on stepper motors gives simple expressions for the rotor torque for multi-stator phases and the detent torque, as well as time-domain plots of the stepping dynamics. A following chapter deals with testing permanent magnet motors.

The chapters on position measurement devices for feedback control present information on optical encoders, resolvers, inductosyn transducers, and potentiometers. Unfortunately, the basic principles are not clearly explained and omit, for example, transfer function details on resolver harmonics. The analyst is better off looking up answers to problems in these areas in the manufacturer's manual. By contrast, the chapters on slipring assemblies and rotary transformers for signal and power transfer explain these subjects with great clarity.

An excellent chapter discusses deployment devices. Among the many topics in it are hinged and linear deployment devices, wire deployers, yo-yo despin devices, tethers, tubular and telescoping booms, coilable masts, flexible solar arrays, and wrap-ribbed antennas. It includes information on critical mechanisms for deployment such as spring and buckled elements, latches, dampers, cables, and sensors and describes testing methods for deployment devices.

The chapter on lubrication presents Hertzian contact theory, Reynold's equation and elasto-hydrodynamic lubrication as background information. It gives practical suggestions for selecting lubricants. The chapter on structural dynamics gives a broad overview of the subject on topics such as launch loading environments and load cycle analysis. Design guidelines for launch restraints, deployment systems and latchup loads are given. Shock design specifications and vibration testing by sine sweep and random vibrations, as well as modal survey testing are briefly described.

The discussion of spacecraft contamination includes transportation, modeling, and design-guidelines. An excellent chapter on spacecraft thermal design contains information on analytical modeling of the vehicle system, heat flux and heat transfer methods, as well as radiators and heat pipes, and thermal isolation. It also includes the techniques for controlling thermal environments by remote and local heaters. Another section concerns mechanism design for withstanding temperature gradients from very hot sun to very cold deep space.

Radiation and survivability are discussed in terms of orbital environments, relevant modeling of the vehicle, and designing and qualifying radiation-survivable space systems. A chapter on reliability deals with allocation for subsystems and functional margins between what a hardware can do and what it must do for success, building on a layman's definition of probability.

The discussion in the chapter on design validation by digital simulation is somewhat simplistic. Most organizations designing space vehicles use multibody dynamics codes that handle rigid and flexible components and use interfacing with graphic simulation such as Simulink or Matrixx. These tools model Dahl friction models or backlash and provide sophisticated integration algorithms for time-domain response of mechanisms.

A chapter on electrical interfaces includes electrical wiring and insulation damage, interconnect hardware, harness design and databases. The last chapter provides information on the pointing control subsystem and explains error budgets, payload versus vehicle control,

and momentum compensation. It also delineates system characteristics such as stiffness, damping, backlash, friction, and noise aliasing due to sampling.

The subtitle of the book is, "Elements of Successful Design." Design, of course, is a process in which details are vital, but this study lacks working details in a number of areas. Overall, on many topics Conley's volume includes the most important facts, but without details. Because of this, I cannot recommend this book for spacecraft design. In fairness to the authors, however, it must be said that *Space Vehicle Mechanisms* is conceived as a handbook, and a specialist in one field who wants to get a broad overview of other areas of spacecraft design may find this volume useful.

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