and slurry transport. For the longer term, the National Science Foundation is supporting a joint academic-industrial effort to develop undergraduate courses in particle technology. Four week-long workshops will be held in 1994 and 1995, each helping twenty-five engineering faculty build elements of particle technology into their courses. The teams are DuPont and Penn State University, 3M and the University of Minnesota, Dow and the University of Houston, and Westinghouse and the University of Pittsburgh.

HOW MIGHT YOU RESPOND?

First, in the academic tradition, take this quiz:

- *Have you included examples of the relationships between particle size distribution, state of agglomeration, and end-use properties in your lectures, in required reading, in labs, and in homework?*
- *Have your graduates learned enough about particulate operations to participate on a startup team without extensive additional training?*
- *Can your graduates design a dust collector, a slurry transport line, or a storage vessel for a cohesive powder?*
- *Can your graduates make a computer model for the behavior and control of a process involving particles?*
- *Are your graduates aware of the typical problems encountered in systems involving particles and do they know enough of the terminology to discuss the problem with a consultant in powder technology?*
- *Have your graduates learned the most meaningful parameters to monitor and what options exist for resolving typical problems?*

Options for enriching the curriculum include

- *Permitting students to take (and count as electives toward a degree) courses in other departments, such as mining engineering, which already have strong courses in particle technology.*
- *Assigning the chemical engineering department to focus exclusively on gas and liquid processes and starting a new department devoted exclusively to particle technology, as is done in Germany.*
- *Developing continuing education courses in particle technology to be taught on campus, at a local corporation site, at AIChE meetings, via satellite through the National Technological Institute, or at a "for-profit" training center such as the Center for Professional Advancement.*

We hope that this paper will inspire you to act. If you can educate engineers to function effectively in this area of critical need, the U.S. chemical industry will hold onto its substantial share of the world chemical market, enhance the employment opportunities for technologists and plant workers, and increase the support for academic research in particle technology.

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ChE book review

ANALYSIS AND DESIGN OF DISCRETE LINEAR CONTROL SYSTEMS

by Vladimir Kucera

Prentice Hall, 472 pages, $66 (1992)

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The subject of this book is the analysis and design of control systems for systems characterized by linear, constant coefficient, discrete-time models. It is assumed that the systems are perfectly modeled and unconstrained; the "modern control theory" approach [*ca.* 1960s with some recent (early 1980s) results] is used.

The intended audience for the book, as stated by the author, includes "the graduate student who intends to specialize in linear control and the practicing engineer or applied scientist who is interested in new perspectives of linear control theory. For the specialist, the book is intended as a reference and, hopefully, as an inspiration for further research." It is assumed that the reader has a background in abstract and linear algebra, linear system theory, and stochastic processes.

I liked the author's philosophy of placing bibliographical notes at the end of each chapter rather than disrupting the presentation of material with references. The text portion of each chapter is concisely written, with the bulk of the material dominated by mathematical equations. Beginning students may have trouble using this text for self-study since they will typically need more motivation and justification for the derivations.

Another aspect of the book that I liked were the problems at the end of each chapter. Short answers and more detailed solutions to all of these problems are provided in appendices. I found it odd that the author bothered to include the short answers section (eight

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NOMENCLATURE

a,b	Colburn j factor parameters
A	Heat exchange area
C	Para-hydrogen mole fraction
c_p	Heat capacity
d_H	Hydraulic diameter of one side of heat exchanger
d_p	Catalyst particle diameter
D_{eff}	Pore diffusivity inside catalyst pellet
E	Activation energy
E_p	Pore diffusion effectiveness factor
F	Flow rate
h	Heat transfer (film) coefficient
k	ortho→para-hydrogen rate constant
k_o	Preexponential (frequency) factor
k_t	Thermal conductivity
M	Molecular weight of H_2
N_{St},N_{Pr},N_{Re}	Stanton, Prandtl, and Reynolds numbers
P	Pressure
R	Universal gas constant
T	Temperature
U	Overall heat transfer coefficient
v	Linear flow velocity
W	Mass of catalyst
r	Density (unsubscripted →Hydrogen)
μ	Viscosity
Φ	Thiele modulus

Subscripts and Superscripts

c	Cold side of heat exchanger
e	Equilibrium
i	Inlet
o	Outlet
p	Catalyst particle
s	Surface of the catalyst
w	Warm side of heat exchanger

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REVIEW: Linear Control Systems

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pages) in addition to the detailed solutions (seventy-one pages).

Chapter 1 provides a concise review of the necessary mathematical background, including linear algebra, random sequences, matrices over rings, and matrix equations over rings. Thirty-two problems illustrate these concepts.

Chapter 2 reviews discrete-time linear systems theory, including converting differential equation models to discrete-time models. Included are the standard concepts of reachability, controllability, observability, constructability, stabilizability and detectability, input/output (transfer function) models, and invertibility. A number of the twenty-four problems provide nice illustrative examples of the techniques. Control problems include cattle population, inventory, ball and beam, antenna, aircraft, and stirred-tank concentration.

Chapter 3 introduces state feedback (including pole placement), deadbeat control, and the linear quadratic regulator. Results for both state-space and transfer-function models are presented. There are nine illustrative examples. A number of the twenty-two problems are extensions to problems in Chapter 2.

Chapter 4 covers state estimation, including the linear quadratic predictor (Kalman filter) and offers six illustrative examples and eighteen problems. Chapter 5 presents output feedback (including the linear quadratic compensator) in both state space and input/output forms. There are eight illustrative examples and twenty problems.

Chapters 3 through 5 cover control system design techniques which take an initial state to a desired final state. Chapter 6 develops control designs which achieve desired closed-loop relationships between setpoints or load disturbances and outputs. There are thirteen illustrative examples and twenty problems.

Faculty who are teaching advanced process control courses may want to use portions of this book for background material, particularly for the concise review of discrete-time linear system theory concepts. A number of the problems can serve as nice illustrations of the theory, in addition to the homework and example problems. I doubt, however, that any chemical engineering faculty will want to adopt this as a textbook since most advanced process control courses devote less than one quarter of a semester to the material covered in this text. Indeed, most courses cover the continuous time version of this material.

Graduate students taking optimal control courses may wish to use this text for supplementary material. The book should be available in any well-stocked university library but will not be necessary for most personal libraries. Despite the desires of the author, this text will not meet the needs of the practicing process control engineer. It will also be of limited use to faculty and students conducting process control research since important topics such as constraints and robustness are not covered at all. ❒