BOOK REVIEWS

Fundamental Process Control

By David M. Prett and Carlos E. Garcia, Butterworths, Stoneham, MA, 1988, 246 pp., $39.95.

It is rare that colleagues in the industrial practice of process control make the effort to publish an extended and coordinated account of the problems they face and their ideas for attacking them. This monograph, authored by two chemical engineers working in the petroleum refining and petrochemical industry, is one of those rarities. Their message to the process control community is that the effort and cost associated with operating and maintaining multivariable control systems in their industry demands a new approach to the design of those systems. The new systems must be free, they say, of "*ad hoc* fixups," ubiquitous in present-day designs and the cause of so much difficulty in the smooth and uninterrupted operation of complex process systems. A designer who would solve what they call the "fundamental control problem," would be guided by a rational and orderly sequence of procedures and would, they say, produce a control system design that addresses all the important practical realities of the process control task.

The authors forewarn the reader that he must have "a thorough grounding in both classical and modern control theory in order to grasp the material presented." Maybe! Those readers meeting the "reader prerequisites" may jump directly to Chapters 7 and 8 after having learned about the real issues in process control and the fundamental control problem formulation in Chapters 1 and 2. In those latter chapters, the reader will find that the authors propose using the model-predictive-control framework that has been evolving for the past two decades. Within this framework, they incorporate a process mathematical model (in the form of a dynamic matrix) *and* upper and lower bounds representing the uncertainty of the physically distinguishable parameters of that model. They claim that the resulting process representation is a key innovation.

With that model and a weighted quadratic objective function incorporating the amount that the process outputs differ from setpoints and a term representing control effort, they are able to determine the optimum set of control moves all the way up to some future time. That minimization has to be carried out respecting all the constraints on process variables. This is an essential part of the fundamental control problem formulation because the encounter of a process variable with a constraint changes the character of the control task. The constraints considered are really only upper and lower bounds on process input and output variables; no general functions of state variables are considered. The optimization calculation is really a "minimax" operation, in which one first finds the worst possible performance over the family of processes represented by the uncertainties; then the controller moves are calculated to minimize the objective function for this worst case.

Their design procedure is structured such that they first determine whether *any* controller can meet the performance criteria. If so, they move on to the second stage, in which a controller algorithm and tuning parameters have to be selected and evaluated. This combination of statement of control performance criteria, representation of model uncertainty, incorporation of bounds, and the two-level optimization procedure constitutes the authors' contribution in this monograph to the art and science of process control. In their words, it represents a "quantum step" beyond one of the most popular current methods.

To help the reader understand the thrust of their ideas and to show the relation to related methods, they describe in Chapters 4, 5 and 6, process representations, unconstrained control, and model predictive control—all linear. Control problems in the petroleum industry are illustrated through the use of a heavy oil fractionator example. Their model of this process consists of 35 transfer functions of first-order and dead time form representing the dynamic relations between five inputs and seven outputs. The model is used throughout to illustrate the character and behavior of the various control methods discussed. Throughout their entire treatment of these methods and their own method, the authors frequently restate their goal of dispensing with *ad hoc* methods. "Fixups" such as overrides, high and low select operators, variable structure Rube Goldbergs, and antiwindup devices are most emphatically dismissed as paraphernalia *non grata*.

To end this treatise on a futuristic plane, the authors, in collaboration with David B. Garrison, present a long chapter on the role of emerging technologies in the areas of artificial intelligence, expert systems, and neural networks.

The authors acknowledge that their work on the fundamental control problem is incomplete. For example, there is no theorem that proves the robustness of their version of the model-predictive control problem. They would like to use a control objective criterion that more directly focuses on practical criteria such as maximum overshoot and settling time. And there is a need for an optimization technique to treat problems with multiple objectives. All these and other "loose ends" the authors toss out to interested researchers as projects worthy of effort to firm up the foundations and to broaden the features of their approach. Indeed, it is the researchers who will be the most interested in this volume. Its value to them lies not merely with the proposed control system design method but also with the articulation of point of view and descriptions of the types of process operations problems now faced by the processing industries. Rarely have these been so clearly and forcefully presented in recent times by colleagues in industrial practice.

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Solid-Liquid Separation

Edited by Ladislav Svarovski, 3rd ed., Butterworths, Stoneham, MA, 1990, 716 pp., $95.

This book is remarkably and, in some cases, formidably comprehensive. In encyclopedic format, it deals with every solid-liquid separation method ever mentioned in the chemical engineering literature.

As its editor succinctly describes in the foreword, "The book comprises chapters on basic fundamentals, on principles and on equipment, as well as on various important aspects of solid-liquid separations such as filter aids, washing, flocculation, etc. The emphasis is on the use of equipment rather than on its design, although the latter is not ignored; consequently, the book will probably be most useful to chemical engineers and process engineers, particularly those in plant operation, plant design, or equipment testing and commissioning. I hope we have managed to strike a good balance between practical and academic considerations as both are equally important and cannot be separated."

In addition to the above-mentioned topics, the editor manages to include to a remarkable extent such subjects as flotation, membrane separations, high gradient magnetic separation, and the thermodynamics of solid-liquid separation.

Ten of the 23 chapters are written by the editor, Svarovski, who is an internationally recognized authority on the broad field of solid-liquid separation. He has a particular research interest in hydrocyclones, but is probably best known for his books and for the seminars or short courses he has been giving on solid-liquid separations for perhaps the last 30 years. The rest of the chapters are written by a mix of academics and industrialists. All are recognized experts in the specific fields covered. Professor Ives, for example, who wrote the chapter on deep bed filtration, has been recognized as the preeminent authority on the subject for as long as this reviewer can remember.

As might be expected in a book written by many authors, there are some different viewpoints and emphases in the various chapters. Academic authors tend to place more emphasis on elaborating theories and mathematical models, while industrial practitioners tend to go further into engineering and process aspects. Also there are some differences in the skill with which the subjects are organized and presented. However, all are reasonably well written, and most are very well written indeed. All are comprehensive and clearly authoritative.

At this point comments will be made on a couple of local items in the book.

Sedimentation devices act as classifiers when the feed solids are not flocculent. Some fractions of fines below a cut-off size do not settle into the underflow and thus escape into the overflow. Hydrocyclones, DSM screens, and, to a considerable extent, solid bowl centrifuges deflocculate solids and act as classifiers even on flocculated feeds. Classification theory, although not named as such, is covered in a chapter titled "Efficiency of Separation of Particles from Fluids." In it certain separation processes are described using combinations of separators. One combination, however, is given special attention in a separate chapter.

A combination often encountered in practice is the use of a solid bowl centrifuge to further dewater the underflow from a gravity thickener. The overflow from the solid bowl, which contains escaping fines, is returned to the thickener feed. This recirculation of fines can, and in practice too often does, lead to disaster. Fines build up in the circuit until the thickener becomes overloaded. This problem is treated at length in a chapter titled "Problems with Fine Particle Recirculation." Every process designer should be aware and mindful of this problem, but, to the best of the reviewer's knowledge, it is not covered elsewhere in the literature. Its treatment here is an indication of how comprehensive the coverage of the field is in the book.

Overall, the book is so strong and well written that it seems like nitpicking to focus on weakness in one part of a chapter. The review of the theory in the chapter on gravity thickening (which is the reviewer's field of interest) contains several misconceptions, some of which are inherited from the literature. These misconceptions regarding theory do not detract from the bulk of the chapter, dealing with test procedures for determining thickener specifications, with thickener designs, and with applications. In these more practical aspects, the chapter is remarkably sound and comprehensive.

To justify criticism of the theoretical treatment the following misconceptions and/or shortcomings are noted. The description of the zones that form in batch settling derives from the speculations of Comings et al. (1954). It is inconsistent with flux theories, notably that of Kynch (1952), which have since been developed. The well-known "first decreasing rate" segment of a settling plot is now conceived to result from successive arrival at the suspension-supernatant interface of free-settling Kynch zones having ever increasing concentrations and ever decreasing settling rates. The effect of initial concentration on the shape of settling plots is also now explained on the basis of the flux theory.

Contrary to what is asserted, the work by Coe and Clevenger did not concern "the settlement of noncolloidal particles as initially discrete units." Their method would not be relevant to such classifying suspensions, and their experimental work was done with strongly flocculating materials.

It is also asserted on the basis of one paper in the literature that "although the Coe-Clevenger and Talmage-Fitch methods for designing thickener dimensions from batch settling tests provide a useful tool for obtaining acceptable estimates, they are not nearly concise or precise enough for continuous thickener design." This is true enough. There is at this time *no* theoretically sound and empirically