

MIXING MECHANICS



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A mixing resource

In this month's column, I'm going to tell you about a mixing resource that you might want to add to your reference bookshelf if you conduct any kind of mixing or blending in your plant. *Handbook of Industrial Mixing: Science and Practice*, edited by Edward L. Paul, Victor A. Atiemo-Obeng, and Suzanne M. Kresta (John Wiley & Sons, 2003) is a weighty tome of 1,440 pages containing mountains of both theoretical and practical information. It's accompanied by a CD-ROM that has 50 video clips and animations of various mixing applications. The book recently was named best new PSP engineering book by the Professional/Scholarly Publishing (PSP) division of the Association of American Publishers.

Sponsored by the North American Mixing Forum, an organization of mixing professionals in both industry and academia, the book has 22 chapters written by various authors. Each chapter contains some sections focusing on theory and others focusing on practice.

The book editors' mixing credentials are impressive: Paul had more than 35

years experience in process development at Merck & Co. Inc. before retiring. Atiemo-Obeng is a scientist in The Dow Chemical Co.'s engineering science and market development department. Kresta is a University of Alberta, Edmonton, professor in the chemical and materials engineering department. As for the chapter authors, Kresta told a university publication that "Everybody who's anybody in the field has written a definitive chapter. We have 46 contributors with a combination of more than 1,000 years of mixing-engineering experience."

The comprehensive mixing handbook has chapters on both liquid mixing and solids mixing. Of most importance to powder mixing are Chapter 8, "Rotor-stator mixing devices"; Chapter 10, "Solid-liquid mixing"; and Chapter 15, "Solids mixing." (For information on other handbooks that focus more heavily on powder mixing, see "More powder mixing references," later in this column.) Other chapters in this book include "Residence time distributions," "Mechanically stirred vessels," "Mixing and chemical reactions," "Heat transfer," "Mixing in the fine chemicals and pharmaceutical industries," "Mixing in the pulp and paper industry," and "Role of the mixing equipment supplier."

Focus on powder mixing

This is the only book I've seen that devotes a full chapter to the rotor-stator. Chapter 8, "Rotor-stator mixing devices" (26 pages), gives a good overview of the rotor-stator mixer and its application. The authors are

Atiemo-Obeng and Richard V. Calabrese of the University of Maryland. The chapter's first section covers rotor-stator mixer characteristics and discusses example applications. Section 2 discusses geometry and design configurations. Section 3 covers hydrodynamics and talks about batch mixer power draw and pumping capacity. Section 4 explores process scaleup and design considerations, and section 5 discusses mechanical design considerations.

Chapter 10, "Solid-liquid mixing" (40 pages), is authored by Atiemo-Obeng, W. Roy Penny of the University of Arkansas, and Piero Armenante of the New Jersey Institute of Technology. After an introduction in section 1, the chapter's second section discusses the hydrodynamics of solid suspension and distribution. This includes settling velocity and drag coefficient, the effect of particle shape and orientation to flow, the effects of solids concentration, and states of suspension. Section 3 covers measurements and correlations for solid suspension and distribution, including just-suspended speed in stirred tanks; the effect of fluid viscosity, solids loading, and fluid particle size; and vessel and impeller geometry and scale. It includes a good discussion of floating solids dispersion. Section 4 covers mass transfer in agitated solid-liquid systems and the effect of impeller speed. Section 5 discusses selection, scaleup, and design issues for solid-liquid mixing equipment. This section has a good list of tips for lab or pilot-plant experimentation.

Chapter 15, "Solids mixing" (101 pages), is divided into two parts: "Part A: Fundamentals of solids mixing" and "Part B: Mixing of particulate solids in the process industries." Authors are Fernando J. Muzzio, Albert Alexander, Chris Goodridge, Elizabeth Shen, and Troy Shinbrot of Rutgers University and Konanur Manjunath, Shrikant Dhodapkar, and Karl Jacob of The Dow Chemical Co.

Part A covers ideal mixtures versus real mixtures, powder sampling, scale of scrutiny, and statistical methods,

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granular mixing, mixing mechanisms (including freely flowing materials, weakly cohesive powders, and demixing), batch mixers and the mechanisms of tumbling and convective mixers, and selection and scaleup of solids batch mixing equipment.

Part B covers mixture characterization and sampling, selecting batch and continuous mixers, mixer fundamentals and mechanics (including mixing and segregation mechanisms and mixer classification), continuous solids mixing, and mixer scaleup and testing.

While the bulk of the book is on liquid mixing, it provides a good mixing overview. References are extensive and will lead you to good sources of additional information. Like many first editions, the book contains some minor errors and omissions. An example occurs on page 483, which refers to Figure 8.1 (a), (b), (c), and (d); however, there is no (d) in the figure.

More powder mixing references

Since only a small portion of *Handbook of Industrial Mixing* covers powder mixing, I recommend that you consult other literature or references when you need in-depth information about your dry application. I recommend the following:

Robert F. Conley, *Practical Dispersion — A Guide to Understanding and Formulating Slurries*, Wiley-VCH Publishers, 1996 (on mixing powders into liquids).

N. Harnby, M.F. Edwards, and A.W. Nienow, *Mixing in the Process Industries*, second edition, Butterworth-Heinemann, 1997 (20 percent of the book focuses on powder-to-powder mixing).

Martin Rhodes, ed., *Principles of Powder Technology*, John Wiley & Sons, 1990 (90 percent focuses on powder-to-powder mixing).

I also recommend *Powder and Bulk Engineering's Best of Mixing and Blending Plus Agglomeration*, CSC Publishing, 1991.² **PBE**

Reference

1. Find more information at www.engineering.ualberta.ca/kresta.cfm.
2. Available for purchase on PBE's Web site, www.powderbulk.com, or by contacting PBE at 1155 Northland Drive, St. Paul, MN 55120, 651-287-5607, fax 651-287-5650 (mwatt@cscpub.com).

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