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"Advances in Industrial Mixing: A Companion to the Handbook of Industrial Mixing"

Edited by Suzanne M. Kresta (University of Alberta, Canada), Arthur W. Etchells III (DuPont, USA), David S. Dickey (MixTech, Inc, USA) and Victor A. Atiemo-Obeng (The Dow Chemical Company, USA), John Wiley and Sons Inc, Hoboken, New Jersey, USA, 2016, 1044 pages, ISBN: 978-0-470-52382-7, £160.00, €192.00, US$200.00

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"Advances in Industrial Mixing" is an updated version of the "Handbook of Industrial Mixing" (1). The unchanged text of the "Handbook of Industrial Mixing" is provided electronically (on the accompanying DVD), and only the new or substantially revised contents are provided in the hard copy.

The order of the chapters in the "Handbook of Industrial Mixing" is retained in the new version. New contents are added in new subsections. There are 10 chapters with additional sections:

- 1b 'Mean Age Theory for Quantitative Mixing Analysis'
- 2b 'Update to Turbulence in Mixing Applications'
- 3b 'Microstructure, Rheology, and Processing of Complex Fluids'
- 5b 'CFD modelling of Stirred Tank Reactors'
- 6a 'Mechanically Stirred Vessels'
- 6c 'Vessel Heads: Depths, Volumes, and Areas'
- 7b 'Update to Mixing in Pipelines'
- 7c 'Introduction to Micromixers'
- 9b 'Laminar Mixing Processes in Stirred Vessels'
- 13b 'Scale-up Using the Bourne Protocol: Reactive Crystallization and Mixing Example'
- 14b 'Heat Transfer in Stirred Tanks – Update'
- 21b 'Magnetic Drives for Mixers'

Section 1b introduces the concept of tracer mean age and local residence time distributions (RTD). RTD theory does not consider the spatial distribution of tracer concentration and cannot define the local mixing states inside the mixing system. The essence of the mean age theory is a spatial distribution of time-integrated local mean age. The transport equation of the mean age is similar to the Navier-Stokes (NS) equation, so can be solved using computational fluid dynamics (CFD). The relationship between the mean age theory and the residence time theory is described. In comparison with the RTD, the advantage of the mean age theory is its ability to quantify the state of local mixing in a flow system.

Section 2b updates the turbulence length scales and turbulence dissipation from new experimental data from different mixing systems. The interaction between turbulence and both solids (lifting of solid particles from the tank bottom) and gases (break-up of bubbles) is briefly discussed.

In Section 3b, complex rheology of different types of fluids are described. The relationship between the rheology of multiple complex fluids (shear-thinning fluid, shear-thickening fluid, viscoelastic fluid) and scales from microstructure (polymers, nanoparticles) to macroscale (powders) is scrutinised.

The current status of CFD, including both advantages and limitations, is examined in Section 5b. The effects of mesh type, mesh size, discretisation schemes on predicted flow and turbulence diffusion are described. It raises the question of how to select laminar or different turbulence models for transitional flows. Modelling multi-phase flows is limited with regard to both incorporating accurate models and high computing resources, and further development is therefore required.

In Section 6b, the flow pattern provided in the "Handbook of Industrial Mixing" is expanded to include the effects of more factors on mixing: effects of liquid volume, off bottom clearance, bottom shape, viscosity, baffles, impeller diameter, impeller off-set and angle shafts. Section 6c discusses the contribution of tank head, head volume and areas on the liquid height and liquid volume and how to include them in the calculation of liquid volume and height.

Section 7b focuses on mixing in pipelines, covering some modest progress in this area, for example the development of compact turbulent mixers to obtain a high degree of radial uniformity. Low-pressure drop mixer development for laminar flow (Sulzer SMX mixers) and low-pressure drop mixer development for turbulence flow (orifice-style mixers) are described. New methods for liquid-liquid and gas-liquid dispersions in laminar, transitional and turbulent flow are provided. Micromixers are preferable for high rate of heat and mass transfer applications, and when specific product properties are requested. A fundamental description of mixing and transport in micromixers is provided in Section 7c.

Section 9b presents blending highly viscous fluids in laminar or low transitional regimes where viscous forces are dominant. The complexities of rheology cause blending challenges regardless of mixing device. A broad range of laminar mixing equipment is reviewed, such as open impellers, close-clearance impellers and multiple impellers. Power numbers for different non-Newtonian fluids in laminar and low transitional regimes are analysed. Various experimental measurements for characterisation are explored, including particle image velocimetry (PIV), laser Doppler anemometry (LDA), planar laser-induced fluorescence (PLIF) and electrical resistance tomography (ERT). Modelling approaches such as finite element method (FEM) and finite volume method (FVM) are also briefly introduced. For mixing systems of high aspect ratio of liquid height and tank diameter, multiple impellers are usually installed but may result in the generation of segregated zones. An approach of reversal rotation is introduced to eliminate this.

An example of a reaction with particles produced in a continuous process is analysed to solve the problem of smaller particle generation in Section 13b. This example is used to show why moving from batch to continuous processing causes a smaller-sized product.

In Section 14b, additional correlation and calculation examples are provided for heat transfer in stirred tanks. The original "Handbook of Industrial Mixing" covered fundamental heat transfer, heat transfer geometries and heat transfer coefficient correlations. This volume adds a few specific aspects of heat transfer, for example overall heat transfer coefficient calculations. A detailed calculation for a jacketed stirred tank is explained using an example.

Section 21b introduces different types of magnetic mixers such as laboratory magnetic stirrers, top-entering magnetic mixer drivers, and bottom-entering magnetic mixer drivers. The magnetic mixers are more advantageous for high-pressure, toxic applications and pharmaceutical applications.

Instead of adding new material in a subsection in the chapter, as mentioned above, Chapter 10, on solid-liquid mixing is completely revised to include a significant expansion and update. For example, besides the traditional Zwietering method for calculating the minimum agitator speed, a new method is developed using more extensive data. Regarding the effect of solid physical properties, the impact of particle size distribution and shape, solid wettability and stickiness are included. Solid suspension with multiple impellers in vessels of different base shapes is also described.

Besides the above mentioned materials that are added into the chapters of the "Handbook of Industrial Mixing", this volume also includes six new chapters: Chapters 23–28.

Chapter 23 'Commissioning Mixing Equipment' gives instructions for commissioning new mixing equipment, including inspection, installation, operation and maintenance. Safety and risk management have become priorities in industry.

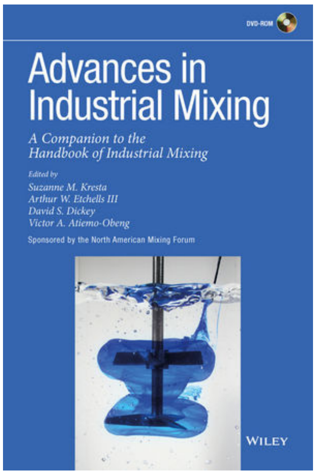
Chapter 24 'Mixing Safety' uses two case studies of incidents to discuss the practice of safety and risk management.

Chapter 25 'Mixing Issues in Crystallization and Precipitation Operations' describes the relationships between mixing and crystallisation and precipitation processes. In the crystallisation and precipitation operations, a number of factors need to be considered. Identifying the interactions between key mixing parameters with the crystallisation and precipitation processes, such as nucleation, growth and agglomeration, is crucial.

Chapters 26, 27 and 28 examine mixing in water, food and the pharmaceutical industry, respectively. Equipment types, calculation examples for treating drinking water, wastewater and sludge are given in Chapter 26. In Chapter 27, multiple types of mixers such as double-motion mixer and high-shear mixers are discussed for food mixing. Different types of food groups are briefly summarised. In the pharmaceutical industry, activities and equipment are required to be validated according to a regulatory agency. The validating issues need to be included in the mixing design. Chapter 28 discusses the concept of validation, and where mixing issues may occur.

Conclusion

In summary, "Advances in Industrial Mixing" provides an expansion to the "Handbook of Industrial Mixing" (1), including new developments in both experimental and numerical approaches and new methods developed based on more extensive data for assessing mixing quality. With regards to the issues raised in industry, a wide range of new materials are added in this volume, such as health and safety, and mixing in water, food and the pharmaceutical industry.



"Advances in Industrial Mixing: A Companion to the Handbook of Industrial Mixing"

Reference

1. "Handbook of Industrial Mixing: Science and Practice", eds. E. L. Paul, V. A. Atiemo-Obeng and S. M. Kresta, John Wiley and Sons Inc, Hoboken, New Jersey, USA, 2004

The Reviewer

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