other technical handbooks in composites and materials.

Gibson Batch
3M Corporation
St. Paul, MN 55144

Powder Technology Handbook

Edited by Koichi Iinoya, Keishi Gotah, and Ko Higoshitani, English Translation of Japanese handbook published in 1986, 2nd Ed., 1991.

This "sort of encyclopedia" is a rather unique and comprehensive guide to a wide-ranging technological and scientific field of world importance. Editing and translation are excellent. In nearly eight-hundred pages, this handbook introduces to English readers nearly 40 years of important Japanese research and development in the many subjects covered.

As in any other publication of this type, there are problems of classification, emphasis, and duplication; but, the three editors here appear to have maintained a reasonable balance and control. As an encyclopedia, 40 authors cover 70 items. They are classified into six divisions whose imbalance can be attributed to the specialized separation of sciences and technologies under this handbook umbrella. The titles of six divisions are: I. Particle Characterization and Measurement; II. Physical and Chemical Properties of Powder; III. Transport Phenomena and Related Topics; IV. Preparation of Powder; V. Powder Handling Operations; and VI. Instrumentation.

The oldest and most developed technologies (Powder Handling Operations Section) are described in about one-third of the text. Here, one finds varied items such as crushing and grinding, classification and separation, conveying and storage, crystallization and filtration, dewatering and drying, mixing and kneading, molding and firing in ceramic operations, thickeners and clarifiers, fluidized particle reactors. The next largest classification (Physical and Chemical Properties Section) is analytical. Here, newer measuring techniques, small-scale analysis, and physical-chemical modeling have revived interest in powder handling operations, which always have been a demand-art at very large scales. As an offshoot of new measuring techniques, these arts are becoming a modern technology for creating new materials at intermediate scales. In Section II, one finds items such as powder mechanics, adhesion and mechanical strength of sintered contacts, fluidity, permeation, adsorption, moisture content, rheology of slurries, electrical and magnetic properties, and vibrational and acoustic properties.

Nearly as large a section as Section II (Transport Phenomena and Related Topics Section) treats the more difficult actions and changes occurring where condensed-state particulates are used or formed in systems of commercial and environmental interest. Here, small-scale actions are magnified to anticipate what can become obvious at a large scale. A reader is introduced to items such as thermal and turbulent diffusion, agglomeration in fluids, impact and bounce, deposition and separation, condensation and vaporization, solution and dissolution, electrophoretic and optical phenomena, mechano-chemistry....all matters of new materials research and essential to development of new materials processing.

Three sections (Sections I, IV and VI) occupy text space not much more than action Section III. Section I is concerned primarily with small-scale geometry and distributed values of a major characterizing variable, particle size. Section IV treats more action items and can be considered an extention of Section III. Here, one finds aerosol generation, dispersion and sampling, electric charge control, coating and encapsulation, and specialized particulate generation by physical-chemical reactions. The final section (Instrumentation) concerns practical and standard test procedures for controlling powder processing.

Typical solid materials processes at particle sizes greater than 10^{-3}m have become today larger bulk processes with smaller particle sizes of 10^{-2}m. Now particle sizes of 10^{-6}m are handled routinely in fine chemicals manufacture. Super molecules of 10^{-9}-m size encapsulate larger particles and adhere to 10^{-8}-m pore walls of 10^{-4}-m catalysts constructed by sol-gel techniques. There is a continuum of scales between 10^{-10}m and 10^{-3}m, which appear to conceal states and actions as complex as one can easily observe in our technological landscape between 10^{-3}m and 10^{+3}m. This powder technology handbook should be of general use to the vocational classifications of mineral engineering, chemical engineering, environmental engineering, materials science, materials processing, ceramic engineering, soil mechanics, geoengineering, food processing, even activities as diverse as pharmaceutical manufacture (pills) and production of construction materials (cement and polymer composites).

William E. Ranz
Dept. of Chemical Engineering
and Materials Science
University of Minnesota,
Minneapolis, MN 55455

The Kinematics of Mixing: Stretching, Chaos, and Transport

By J. M. Ottino, Cambridge Texts in Applied Mathematics, 1989, 364 pp., $94.95 (Hard Cover), $39.95 (Soft Cover).

Until recently, methods to describe the operations of mixing, blending, or stirring of fluids have been based largely on deductions from dynamic equations expressing balances of mass and momentum. Usually the transport of mass by molecular diffusion and turbulent convective motions play key roles. The content of this book, however, is based on another method that introduces the notion of chaos in a low-dimensional dynamical system as the descriptive framework. The development relies on a correspondence between the motion of fluid in physical space and the trajectory of points in the phase space of a general dynamical system. Accordingly, the concept arises of producing chaotic particle trajectories in a deterministic flow field by passive convection. Thus, molecular diffusion certainly yields mixing, although the process is slow and turbulent flows yield fast mixing. However, there are many mixing problems in chemical engineering, planetary science, and other fields for which neither molecular diffusion nor turbulence is responsible for the mixing that occurs. For example, diffusion is absent in the mixing of fluids that are insoluble in each other. In the case of very viscous fluids, the energy cost of producing turbulent motions is uneconomic and is avoided. If the substance to be blended contains long-chain polymers, turbulence may be further undesirable as the accompanying large deformation rates could break the polymeric molecular bonds.

This book, containing much original work of the author, is unique in providing a unified treatment of relationships between chaotic behavior and problems of fluid mixing. The point of view adopted in the author's words is: "from a kinematical viewpoint fluid mixing is the efficient stretching and folding of material lines and surfaces..., and that stretching and folding is the fingerprint of chaos."

The author provides prototypes for a broad class of problems with the expectation that the prototype analysis will yield insights of importance in practical applications such as the design of mixing devices and the understanding of mixing experiments. As an example, one prototype, termed "the blinking vortex flow" consists of two point vortices having the same sense of rotational direction that are separated by a fixed distance and blink on and off periodically. At any given time, only one of the vortices is on, and so the motion is made up of consecutive twist maps. One description of the mixing process that ensues is provided by Poincaré sections that by definition consist of maps of the locations of marker particles at fixed increments of time for particles that are released at different initial positions throughout the flow. Certain markers define time invariant streamlines occurring as closed loops of circular or peanut shape. In other zones, the positions of the markers between boundaries of streamlines vary chaotically indicating a tendency for all portions of the space in the zone to be visited by the marker over a period of time. Depending on a parameter that is proportional to the product of vortex strength and the time periodicity of the blinkers, the chaotic zones occupy a variable area of the map. At a critical value of the parameter, the whole space exhibits the chaotic condition. At subcritical conditions, a magnified section of the Poincaré section near the boundary between a regular zone and a chaotic zone exhibits a fine structure of islands that in theory repeats itself to finer scales *ad infinitum*. This overall picture is certainly a stimulating concept to keep in mind when devising solutions to mixing problems, or when interpreting experiments.

The author's quantitative framework is based on the continuum mathematical description. Symbolic vector and tensor notation is employed throughout thus yielding a compact description of the basic results. One finds the results of C. A. Truesdell, R. Aris, J. Serrin, and others who in the past have contributed scholarly works dealing with the classical kinematics of flow. The book holds interest as an encyclopaedic compendium of old and new kinematical results, described in the symbolic format. Concomitantly, the book orients the reader to the important results in the theory of dynamical systems including the topics of the phase space of Hamiltonian systems, Liapunov exponents, homoclinic and heteroclinic points, elliptic points, fractal construction, and so on. Aspects of some of these latter topics were developed early by H. Poincaré, G. D. Birkoff, and others, with modern work associated with names like M. Hénon, S. Smale, and R. M. May.

The book is written in nine chapters dealing with: flow, trajectories, and deformation; conservation equations, change of frame and vorticity; computation of stretching and efficiency; chaos in dynamical systems; chaos in Hamiltonian systems; mixing and chaos in time-periodic two-dimensional flows; mixing and chaos in three-dimensional and open flows; and diffusion and reaction in lamellar structures and microstructures in chaotic flows. An appendix treats Cartesian vectors and tensors in detail. A generous number of drawings and photographs are provided to illustrate the text, including a section of attractive color plates detailing mixing and chaos in laboratory and numerical experiments. The book has been produced with artistic feeling along with scientific understanding.

Reviewer finds the book and its subject matter inviting as it integrates disparate topics of theoretical physics and mathematics with engineering concerns of mixing. In this, the author is creating a new field of study. Concomitantly, a disappointment of the book is the frequency at which unfamiliar subject matter is introduced with clearly insufficient exposition. Isochoric flow is defined as a mathematical requirement that the Jacobian of the mapping of points in time is equal to unity, but no physical interpretation is provided. The concept of diffeomorphism is introduced in one sentence in a manner that virtually none of the book's intended readers as visualized by this reviewer will find intelligible. Other examples could be cited. Thus, the student of this subject must be prepared to dig deeper, and fortunately the relevant citations are provided.

It should be noted that the book treats low-Reynolds-number viscous flows with no goal of treating mixing in turbulent flows wherein the velocity field itself is chaotic. This is because the geometrical theory used throughout the book breaks down in such circumstances. Accordingly, this book is complementary to standard statistical mixing treatments or other approaches based on the analysis of dynamics.

In conclusion, this book has a number of unique and attractive features. The contents of the book constitute a trove of information that will be relished by the student of mixing. At this stage, the book must be considered as required reading for academic and industrial researchers in all disciplines involved with fluid mixing.

R. E. Rosensweig
Corporate Research Labs
Exxon Research & Engineering Co.
Annandale, NJ 08801