Paste Flow and Extrusion

By J. Benbow and J. Bridgwater, Oxford Series on Advanced Manufacturing, Oxford, 1993, 153 pp. (hard cover), $56.50.

This is a well produced and attractive slim book covering a topic of industrial importance. Paste flow and extrusion are involved in the manufacture of lead pencils, toothpaste, foodstuffs, catalyst's supports—such as monoliths—animal feedstocks, health care products and a host of pharmaceutical processes. The material covered is largely based on work by the two authors, and it is conveyed with a minimum of fuss, economically with no unnecessary information. If anything, the reader might get the feeling that the authors are holding back—a rare feat—in an effort to keep the level uniform.

The book is structured as follows. After the customary Introduction, there is an overview of paste extrusion and related processes, including methods of size enlargement. Chapter 3 focuses on types of extruders: rotary, ram, and screw. Chapter 4 is the most "theoretical" on fundamentals of paste flow (a bit of rheology here). Chapter 5 concerns laboratory evaluation methods, a quite practical chapter, and Chapter 6 with paste formulation. Chapter 7 deals with flow defects and phase migration—an area dear to polymer processing types involved in melt fracture and related issues, whereas Chapters 8 and 9 deal with die design and screw extruders (again both areas closely paralleled by polymer processing). Chapters 10 and 11 conclude the presentation with an overview and worked examples, respectively. The very last chapter places the book squarely in the category of a know-how book.

Nevertheless, a sense of research needs manages to come through and ideas for PhD topics abound (for example in Chapter 7). A few comments regarding overall placement of the area in a broader context might help. Even though this topic could be imagined as a natural continuation of concentrated suspensions—as currently practiced in the U.S. and U.K. fluid mechanical communities, it is clear that things in this area did develop in a very much independent fashion. Do not search for tensors in this work; in fact, a chemical engineering undergraduate should be able to follow most of it. Nor is it connected with physics of granular media, a topic enjoying somewhat of a resurgence within the physics community. In fact, the flavor that comes across is somewhat akin to that of polymer processing, as the topic was just starting to find its way into texts with J. M. McKelvey and others; polymer types will recognize some of the names in the bibliography and feel very much at home in the chapters dealing with extrusion.

Other connections are not hard to imagine, and research needs are not hard to grasp. Some are obvious; very little is known about dry and wet mixing. High shear mixing, breaking agglomerates, is also in need of more fundamental work. Surface fracture and all the instabilities resulting from extrusion seem to be of a descriptive level and behind what one might find in the fluid mechanics and polymer literature (e.g., M. M. Denn, *Annual Reviews of Fluids Mechanics*, **22**, 13, 1990). Rheology, and all the processing that goes along with it, die design et al. suggest fertile areas for work as well.

In short, this is a pithy book that will undoubtedly help its intended industrial audience and sparkle the imagination of academic researchers.

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Scaleup and Design of Industrial Mixing Processes

By Gary B. Tatterson, McGraw Hill, New York, 312 pp., 1994, $56.

Gary Tatterson is well known to the international mixing community through his attendance at Engineering Foundation conferences since the 1970s and at the AIChE meetings, and through his earlier book titled *Fluid Mixing and Gas Dispersion in Agitated Tanks*. In the Preface to this book, he names 24 industrialists in the U.S. and 13 academics from the U.S., Japan and Europe, whom he thanks for advice and opinions that have helped guide it. Two academics have been given further recognition: Richard Calabrese has had a dimensionless group named after him and John Smith, an impeller. However, what all of these people know is that Gary has a wicked and outrageous sense of humor; I think this explains this book which is a bit of a spoof.

The book has five chapters. The first deals with Basic Processing Concepts (51 pages), which has very few equations with only those for drop size being considered in any detail. It is here that the Calabrese number is introduced to account for the effect of viscosity on Sauter mean drop size (just defined here as mean drop size d_p). Without the correction for viscosity, the equations published by Calabrese and others give $d_p/D \alpha\ We_I^{-0.6}$ where We_I and D are the impeller Weber number and diameter, respectively. This relationship is then rearranged here to give $d_p \alpha (\epsilon_T)^{-0.6}$ for both stirred vessels and static mixers where ϵ_T is the specific energy dissipation rate or power per unit mass. No explanations are given as to how these equations are derived. Of course, they come from the application of Kolmogoroff's theory by which turbulent stresses causing breakup are derived and these are then balanced in the low viscosity case by interfacial tension. Kolmogoroff's theory, however, when applied correctly, gives $d_p \alpha (\epsilon_T)^{-0.4}$. Unfortunately, these equations are used frequently throughout the book.

Chapter 1 also introduces the "Smith impeller" (similar to the Chemineer CD6 or the Scaba 6SRGT). Though the impeller is strongly recommended, quantitative data (for example, its power number, flow number, or gassed power characteristics) are not given on any of the three occasions discussed.

Each chapter contains personal nuggets of wisdom or key points, many very amusing. For example, in Chapter 1 he says, "*Key Point*. All rules have exceptions and all exceptions may become common practice (Dickey, 1991)." Did Dave Dickey really say this in a private communication; if so, did he expect to be quoted!

Chapter 2 is called Power and Flow (52 pages). In it, some ten pages are devoted to "Rheology" and this important topic is also discussed in Chapter 5, Pitfalls in Process Translation and the Use of Analogies (38 pages). In Chapter 5, Process Myths, one finds, "Another myth is the importance of rheology. For the most part, rheology becomes fairly unimportant. Exceptions to this statement are well known since, in special cases, rheology controls everything," and again "Another process myth involves slurries as shear thinning materials. Slurries are generally shear thickening." The first statement seems to me to be less than helpful and the second, I think those people mentioned in the Preface would agree, is wrong!

Chapters 3 and 4 are Processes and Process Objectives (94 pages) and Process Translation (63 pages), respectively. One spoof (?) from Chapter 4 on Process Mixing Similarities, "A giraffe and an elephant are similar in that both have four limbs, one neck, one trunk (*sic*) and one head; however, don't make exact comparisons" sets the flavor. Also in Chapter 4, on two occasions, power P is related to torque T_o and speed N, once by the equation $P = T_o/N$ and once by $T_o = P/N$. Both are wrong; $P = 2\Pi N T_o$. The equation "$k_L a \alpha (N^3 D^2)^{0.74} (V_s)^{0.28}$" is given in Chapter 5. Perhaps tongue in cheek, this equation is taken to imply that $k_L a$ should increase by $D^{1.58}$ on scaleup, that is, by 38 for a linear scaleup of 10! What it really tells one, of course, is that at an equal specific energy dissipation rate and superficial gas velocity, V_s, $k_L a$ does not change with scale!

As a spoof, the book works and I hope readers get as much fun out of it as Gary must have done writing it. My worry is that many people won't see it that way. In the past, mixing, for reasons which we need not go into here, has often been considered less than academically respectable in spite of its enormous importance across the whole spectrum of the process industries. It is seldom taught adequately in universities and few of the "big names" have chosen to work in the area. I feel that, in recent years, the image has begun to change, partly through groups like the North American Mixing Forum (NAMF) which have brought academics and industrialists together, and partly through better quality research. This book will not improve the image of the subject or help change negative attitudes.

Let me finish with one more quote, "*Key Point*: One can assume that similar looking equipment will behave similarly. Exceptions to this rule will occur from time to time but not for the reasons one expects. Surprises occur." They certainly do!

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Macrotransport Processes

By H. Brenner and D. A. Edwards, Butterworth-Heinemann, Stoneham, MA, 1993, 714 pp., $75.

This is a welcome addition to a relatively sparse literature and offers a mathematically rigorous procedure to connect the microstructure to the macroscopic phenomenology in a variety of transport processes. The term *macrotransport processes* describes the fact that transport processes are modeled macroscopically, but by emphasizing the macroscopic character of the modeling equations it also implies that an inherently complex, heterogeneous system is studied, the microscopic structure of which is suitably abstracted. Indeed, the only difference between the macroscopic transport equations and those developed for a molecularly homogeneous medium more than 30 years ago (Bird et al., 1960, *Transport Phenomena*, Wiley) is in the fact that transport parameters are not directly associated with the molecular structure, but indirectly through the "mesoscopic" structure of the complex heterogeneous medium under study. It is exactly this association that forms the field of study of this treatise.

As transport phenomena involving complex media are encountered more and more frequently in chemical engineering applications, it becomes increasingly advantageous to replace laborious and time-consuming experimental procedures necessary to determine macroscopic transport parameters with *a-priori* theoretical calculations. Unfortunately most of the existing approaches are either highly approximate or specific to particular applications only. This textbook, however, presents a systematic procedure to obtain this information, which can be also used for a considerably wide variety of applications.

The general problem addressed here is the connection between the phenomenological diffusivity and the apparent velocity corresponding to the macroscopic description of an advective-diffusive transport process of a solute in a complex medium to the medium's inherent microstructure. It focuses on the generalized advection-dispersion problem where a Brownian tracer (typically but not necessarily limited to a material particle) is advected and simultaneously dispersed as it is introduced within a complex medium in flow motion. The defining characteristic of all applications is the presence of two different scales of coordinates, global and local, with the distinction between the two accomplished by the requirement that, within the time scale of interest, all local space has had the opportunity to be sampled by the tracer due to its random, Brownian motion. This permits focus on the global, not on the combined local plus global, description. However, variations taking place in the local space still affect the results in the global space (in particular they determine the macroscopic transport coefficients) and the transition from the microscopic to the macroscopic description needs to be performed in a careful fashion. This is accomplished in the book in a highly systematical and a mathematical manner. The followed procedure can also be visualized as an abstraction (or projection) from an accurate, but highly complicated and multidimensional, microscopic description to a more easily solvable and lower-dimensional macroscopic one.

This coarse-graining approach is necessary when several length and/or time scales are involved in a phenomenon. This is a common characteristic of a variety of flow applications, most of which are considered in this textbook ranging from chromatography to suspensions rheology and flow through porous media. Therefore, it is becoming increasingly important to systematically perform this "coarse graining" procedure and determine from "first principles" of phenomena involving complex media. To achieve this task rigorously in a variety of applications, even at the expense of relatively complicated mathematics, it is worthwhile to get familiar with it.

In the preface an analogy of the macrotransport processes to the Darcy's law description of flows through porous media is made. The key principles that are elaborated in the following chapters