Particulate Science and Technology

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by

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PREFACE

Unity in Diversity

An essay to integrate the field of particulate science and technology seems opportune. Concern with specialized interest areas results in slow and usually steady progress and is a comfortable situation to work in. However, particularity of interest constrains ideas, whereas a sound unifying concept knows no natural boundary. Our field is currently asking searching questions and seeking definitive answers to broaden our outlook. We are ready to see what the other person is up to, to learn from the observations of others, and profit by interrelating their ideas.

However, in a broader and more fundamental sense, most of us who work in the field of finely divided matter would assert that, collectively, our present knowledge is only a promise of what it will be. Further, we individually know so little of what we need to know and, to add to our troubles, we realize that new knowledge is being accumulated at a pace faster than we can injest on a regular diet of reading and study.

A rewarding approach to the problems inherent in mastering this diversity is to develop an appreciation for the wholeness of the field. Necessary specialized excursions can then be related to the whole-field view and fitted into a rational scheme of scientific explanation. This book is an attempt to provide a methodical whole-field view of fine particle science and technology. It in no way pretends to be exhaustive. There is a rich abundance of searching treatises on particular subjects available now to the specialist, so a general view both unifying the good work already accomplished and providing a comprehensive structure for guiding what is to come seems appropriate at this juncture.

Particulate science and technology is a fascinating field of study. I don't know anyone working in it who does not find it somewhat exciting. It is an ancient art and a baffling science simultaneously. I count myself among the lucky ones who wonder why matter in finely divided form behaves as it does.

INTRODUCTION

"There is a tide. . ."

UNDERDEVELOPED TECHNOLOGY

The science of the nature and behavior of fine particles, like an underdeveloped country surrounded on all sides by highly structured industrial states, looks wistfully at developed entities like physics, chemistry, mathematics, biology, material science, engineering sciences, and computer science, to mention but a few well-structured disciplines. As with all cases of underdevelopment, a great deal of "aid" from these technically advanced neighbors is needed if progress in fine particle science is to materialize. However, the drive to progress must be derived from the urgencies sensed by those already working in the field who have the wit and foresight to develop and implement the creative necessities.

In any field of human technical endeavor where progress is made there is an advantageous juxtaposition of three elements: industrial and commercial need, intellectual challenge, and the possibility of success. For the study of particulate matter all three elements now coexist in good measure, but they have only just come together. The efforts of many have made this conjunction possible and although it is unfair to mention some and omit others who have made their contributions, still it seems appropriate to mention some major contributors.[1-19]

In this century the sciences have been developing new knowledge at a frenetic pace in a direction predetermined by the discovery of electricity. The physicist has become interested in the very small and, with the engineer, in the macroscopic to the spectacularly large, and the chemist is concerned with structures ranging up to molecular sized units. This pattern of study has left the great middle ground of fine particles in a relatively unexplored condition. During the past 200 years, we have seen the armies of science in their inexorable advance on the relationships between the structure and properties of solids, liquids, and gases. It is now the turn of matter in finely divided form to be comprehended and exploited. We can only

guess why it has taken so long to reach this stage, but one can imagine that it may have something to do with the extreme difficulty of theoretical and experimental work in the area, the staggering diversity of particulate matter in finely divided form, and the glamor of the older established disciplines which enjoy a hard won prestige.

Within the last 20 years or so there have been signs of a gradually developing awareness and interaction among those concerned with particulate matter. Although we still have the ceramicists and the powder metallurgists, the pharmacists and the chemical engineers are still ploughing their own furrow, though they interact more with each other than ever before. This seems to be true on campus, in the meeting hall, and especially in industry. Perhaps the most public manifestation is in the start-up of the journal "Powder Technology" in the 1960's; in the change of name of the "International Journal of Powder Metallurgy" to that of "International Journal of Powder Metallurgy and Powder Technology" in the 1970's. Other evidence includes: the publishing of Orr's book on *Particulate Technology* by Macmillan in 1966, the holding of a workshop on "Fine Particle Technology" in 1975 (National Science Foundation)*, the publication of various series of texts on different aspects of particulate matter on both sides of the Atlantic, the founding of the Fine Particle Society and its aspiration to correlate and serve the needs of its members in this field, in Japan the foundation of the Research Association for Powder Technology, the establishment of the International Powder Institute, the formation of the International Fine Particle Research Institute, and the services of the Powders Advisory Center. We can conclude, therefore, that there are serious efforts being made to move in the direction of integration so that we can better focus on our needs and coordinate our energies to meet them.

The key to success lies in our educating ourselves. In Europe a number of research centers like Karlsruhe Erlangen, Bradford, and Loughborough and in Canada, Laurentian University, are studying and teaching. But in one major industrial enterprise of this world, the United States of America, there is no single institution devoted to the study of matter in finely divided form, although there are numerous individual students scattered throughout the country. Some have said that there is a pressing need for establishing an American institution, many others have nodded their assent, but to date none has been organized. Apparently, the greatest single obstacle to this development is not the lack of funds, but the absence of a developed

*Program Director, Dr. Morris Ojalvo

consensus of the whole field view and a realization of its potential long-term benefits to us all. This situation exists because of the lack of serious discussion about the problems inherent in formulating policy, developing structure, and implementing the former through the latter. *In essence, just how do we conjoin the academic with the industrial, and reward the components in such a diverse interdisciplinary field as particulate matter and at the same time avoid the production of a new breed of specialist who will fragment the very cohesion that is so vital and so assiduously being developed.*

RESEARCH AND DEVELOPMENT NEEDS

Our technological requirements for comprehending the state and behavior of particulate matter during the next decade have been admirably summed up in the NSF Workshop Report.[20] They fall into four main categories.

Particulate Properties and Structure

The description of particle shape by means of morphological analysis of particle profiles offers a promising way of expressing visual images mathematically in a variety of functional forms. The functions can then be related to the properties of the particulate matter. Fundamental investigations of particle surface phenomena are required to establish the basic geometric properties of particulate matter so that they may then be related to their physico-chemical properties. Coordinately, establishment of the relationships between surface, subsurface, and interior structures and particle properties must be another of the goals of fine particle research and development. There is also a major experimental challenge to learn more about the electrical, optical, thermal, and magnetic characteristics of fine particles. Further, as more and more industrial processing becomes automated, there is an increasing need for the on-stream testing-cum-monitoring of powder technology operations. This demand raises a further need for study in this area because we do not know enough about what technology there is available.

Particle-Fluid Separation

There is an urgent need for developing dynamic concepts about the methods for the separation of very fine particles (less than 0.5 micron) from gases. More direct approaches to the study of the structure of flocs and of agglomerates generally are necessary. In particular, there is a need to establish the pattern of relationships between the development and form of floc structures and the behavior of sedimentation, thickening, and dewatering processes at all of their stages. Moreover, developing methods for studying the behavior of individual particles in rheologically complex fluids as well as in their deposition on collecting surfaces is a prerequisite to understanding the mechanisms and improving the technology. The transmission of interparticle forces in changing conditions (e.g., the alteration of particle-fluid drag or the change of applied pressure level, etc.) and the way in which the particles become rearranged must be directly observed under carefully controlled experimental conditions if we are to master the complexities of the motion of particle sets in dynamic environments.

Particle Handling

The following quotation from Zenz is an eloquent indicator of the formidable nature of our problems in this area:[21] "As mundane as it might first appear, there is today no universally guaranteed design procedure for assuring that a bin filled with any powder will be able to be emptied whenever desired." A new approach to the problems of mixing and blending must take into account the complex properties of the particualte matter being handled. When particles are being moved, usually entrained in a fluid, their level of interaction with each other and with the carrier fluid and also with the system surfaces and measuring devices should be related to the basic properties of the particles, the fluid, and the overall system. Phenomena to be studied include bridging, flow, choking, saltation, resilience and elutriation, to name but a few.

Controls

Minimizing the deleterious effects of applying powder technology requires controls. In general these systems problems are extremely involved. Dealing with only single phase liquids (for example) is a sufficiently complex system control problem, but effectively controlling in detail the behavior of particulate matter in different situations (as outlined in the immediately preceding sections of this introduction) raises the difficulty of

our task to a high level. In brief, we have to adopt an overall systems approach which will take into account technical, economic, health, social, and political factors inherent in a given situation. Just a glance at some of the industrial hygiene and related journals reveals the extent and seriousness of the problems of minimizing unfavorable effects from the industrial use of fine particles.

ABOUT THIS BOOK

The general concept offered in this book and some of the more important conclusions and observations that I have developed during the course of its writing are stated and examined in Chapter 1. Chapter 2 emphasizes the primacy of the individual particle in particulate science and technology. Chapters 3 and 4 may be said to deal with PARTICULATE TECHNOLOGY; they describe the ways in which particles are formed, the various production methods associated with each, followed by a descriptive treatment of some of the standard processing steps for dealing with finely divided matter. The next three chapters deal with what might be appropriately termed PARTICULATE SCIENCE. In Chapter 5 there is a discussion of a number of descriptors with particular emphasis on fine particle statistical descriptors. Chapter 6 reviews some of the more recent work on particle shape characterization and particle size analysis. Chapter 7 examines the nongeometric properties of fine particles including optical, electrical, magnetic, thermal, and chemical properties, and relates them to various aspects of particle settling and diffusion.

The essential message of the final Chapter 8 is vital to all of those working in the fine particle field. Particulate hazards are insidious: if they don't blow you up or irreparably damage your health they may just ruin your landholding quietly and steadily. Some of what must be learned and some presently known means for protecting us against folly in the use of fine particles are explored. Fine particles should be treated with the greatest of respect.

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