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"Particle Technology and Engineering: An Engineer's Guide to Particles and Powders: Fundamentals and Computational Approaches"

By Jonathan Seville and Chuan-Yu Wu (University of Surrey, UK), Butterworth-Heinemann, an imprint of Elsevier, Oxford, UK, 2016, 294 pages, ISBN: 978-0-08-098337-0, £51.10, US$84.00, €60.16

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Introduction

The authors of this book, Professor Jonathan Seville and Professor Chuan-Yu Wu, are globally recognised experts in the field of particle technology. Professor Seville has a degree in Chemical Engineering from the Universities of Surrey and Cambridge, UK, with a strong background in the design and manufacturing of products for the pharmaceutical, home care and fast-moving consumer goods industries. Professor Wu has a degree in Chemical Engineering and a PhD from Aston University, UK, in finite element method (FEM) of particle impact problems from which he later moved to discrete element methods (DEM).

The book is intended to provide an initial overview of the field of particle technology by summarising the essential scientific fundamentals of particles and introducing the basic knowledge required for two computational approaches (DEM and FEM). It gives a wide ranging introduction to the fundamentals of particle mechanics and computational aspects for particulate systems. For more in-depth discussion, the authors refer the readers to other, more extensive, works.

The book is divided into three main sections:

- Part one: provides an overview of fundamental characteristics of particles and powders in bulk form and how they can be determined (Chapters 2 and 3)
- Part two: consists of three chapters and comprises the bulk of the book. This section describes the complexity of a surrounding phase: firstly, as single particle interactions (Chapter 4), then considering multiple particles in the gas phase (Chapter 5) and finally considering multiple particles in liquid (Chapter 6)
- Part three*:* Chapters 7 and 8 describe the fundamental mechanics of particle systems both at the bulk level and particle level. This provides the basics for an understanding of the last two chapters of the book (Chapters 9 and 10) which introduce two computational methods – DEM and FEM applied to particle technology.

Particle Characterisation

Chapters 2 and 3 examine the fundamental properties of bulk solids such as powder density, flowability, particle size and shape, surface area, compressibility and compactibility and the related experimental techniques which can be used to characterise these properties. The book underlines the importance for particle properties related to final product quality control and process monitoring purposes. Importantly, particle characterisation allows a better understanding of the correlations between bulk behaviour, product quality and process performance. Furthermore, the authors consider particle size measurements and the importance of their physical and statistical representation. Finally, an often overlooked issue in industry is how representative a sample is of a larger quantity. General rules to design and prepare a representative sample to obtain reliable measurements are presented. The general principles in this section should be useful for a new practitioner in the area of particle technology but should be considered golden rules for working in the particle technology field.

Interaction with a Surrounding Phase

The second part of the book focuses on multiphase flow of solids in fluids. Chapter 4 examines the interaction of a single solid particle immersed in a fluid. The analysis of the forces exerted on a single particle by the surrounding fluid and the estimation of the drag force coefficient are presented as a starting point for the calculation of the terminal velocity in either steady-state or under unsteady motion. The value of terminal velocity is one of the key parameters for the design of unit operations such as fluidised beds and solid separation systems.

Systems with multiple solid particles in contact with a continuous gas phase are considered in Chapter 5. Beginning with the gas-solid contact regimes and a list of application examples, the chapter continues with a well-presented description of the equations for pressure drop in packed beds and minimum fluidisation velocity. An entire section is dedicated to fluidisation and fluidisation regimes, with particular focus on bubbling beds and models for the prediction of bubble size and velocity (very important elements in mass and heat transport phenomena involving multiphase flow). Typical fluidisation behaviours are summarised by the established Geldart classification diagram. Then pneumatic conveying, a few rules of thumb and the most important variables to be considered when designing pneumatic conveying systems are presented.

The last part of Chapter 5 focuses on gas-solid separations and illustrates the operating principles for cyclones and filters. An example of cyclone scale-up (**Figure 1**) and a brief discussion of multi-cyclone systems are included.

A description of the rheology of suspensions is examined in the first part of Chapter 6. Different rheological behaviours can be exhibited by solid suspensions: this section summarises typical rheological responses and their fitting to models such as power-law types (for example shear thinning and shear thickening). Then a brief touch on pastes is presented by giving useful examples of paste characterisation and a list of common problems associated with paste extrusion. The last part of the chapter gives an outline of the agglomeration process and provides a schematic mechanism for wet agglomeration. This description aids understanding of the influence of several process

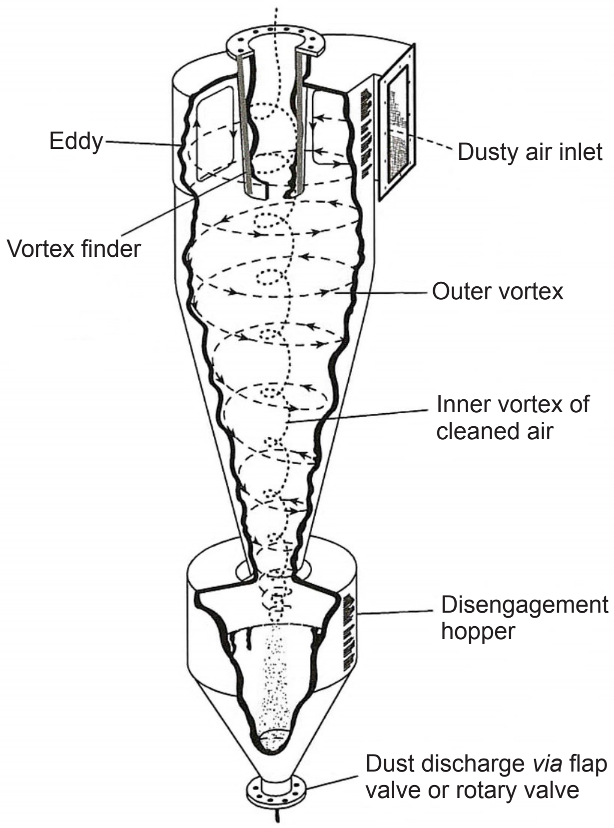


Fig. 1. An illustration of cyclone scale-up (Reprinted with permission from Elsevier/Butterworth-Heinemann, Copyright © 2016)

variables such as mixing intensity, liquid flow rate and droplet size.

Chapter 7 introduces powder bulk behaviour. Differences between bulk solid and fluid mechanics are illustrated and the concepts of powder failure, internal friction and wall friction are presented. One of the classic problems in bulk solid mechanics is stress analysis in storage vessels and the counterintuitive stress distribution in bulk solid containers is well presented. This analysis together with the Coulomb model for friction are the key elements for silo design. The discharge of storage hoppers is considered in the last part of the chapter. A comparison between flow patterns is provided together with the equations for calculating mass flow under different conditions. Further, transmission of stresses in powders during powder compaction is described with reference to tablet quality density.

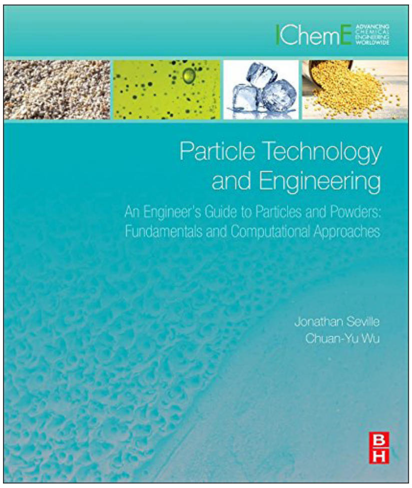
Computational Approaches

Chapter 8 illustrates the mathematics required to describe the particle-particle interactions influencing the mechanical behaviour for bulk solids. Both elastic and elastoplastic particles are considered for normal impacts, tangential loading, adhesive forces and capillary forces. This subject is not presented in complete mathematical detail, with full derivations of all the equations. The reader is given a good overview of the complexity of the impact analysis in the case of simple perfectly elastic impacts. In Chapter 9 the numerical DEM (that was originally developed in the field of soil mechanics and further developed for other disciplines) is introduced. The authors give an exhaustive description of the calculation cycle utilised by typical DEM algorithms and they conclude the chapter with a data analysis section. The DEM data post-processing analysis is a key step in the use of this numerical technique where the ultimate goal is to relate the microscopic interparticle phenomena to the macroscopic bulk behaviour of the material. The application of DEM is limited by the amount of plastic deformation that can be reliably represented. In situations where the plastic deformation of the particle is not negligible or for impact problems including contact of irregular shape particles, FEM has been used to model the state of stress inside the particle body. This different computational method is introduced in Chapter 10. Like DEM, this method was initially developed for other purposes but has more recently found wider application in different engineering disciplines including structural dynamics, heat transfer, fluid dynamics and aerodynamics. The potential and efficacy of the FEM is shown in two representative cases: the analysis of a normal impact between a sphere particle and a substrate and the continuum modelling of powder compaction. For both applications, if high stress levels and deformation are present DEM cannot be used to describe the problem since most of the energy will be dissipated in plastic deformation.

Conclusions

The book gives the reader a full but fairly approachable overview of the fundamentals of particle technology, reporting the current state of this field and providing perspectives on future challenges. A good overview of particle characterisation, the link between the microscopic and macroscopic properties and the future role of computational methods (DEM and FEM) in particle technology is provided in this book.

Particle technology is a broad subject and this text may be sufficient for the interests of a beginner and might awaken a sense of curiosity that will drive the reader to more exhaustive texts such as the Handbook of Powder Technology of which the latest volume was published in 2007 (1).



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Reference

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The Reviewers

Domenico Daraio is an EngD Student in Formulation Engineering at the University of Birmingham, UK, and he has a degree in Chemical Engineering from the University of Pisa, Italy. He is currently working on DEM modelling of milling systems to better understand how the energy input into the system is transferred at different scales.

Giuseppe Raso is a Marie Curie Early Stage Researcher at the University of Twente, The Netherlands, and the University of Edinburgh, UK. He graduated from the University of Calabria, Italy, in Chemical Engineering. His project involves the rheological study of wet powders and the application of DEM for the simulation of wet granular systems in industrial processes.

Michele Marigo is a Principal Scientist at Johnson Matthey Technology Centre, Chilton, UK. He obtained an undergraduate degree with a master's in Mechanical Engineering from the University of Padua, Italy, and a doctorate in Chemical Engineering (EngD) from the University of Birmingham. Michele's expertise includes materials science, particle engineering, discrete element modelling and finite element modelling.

