POWDER METALLURGY

& Particulate Materials Processing

by Randall M. German
Powder Metallurgy and Particulate Materials Processing

The Processes, Materials, Products, Properties, and Applications

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dedicated to
Carol, Laura, Ariana, and Angela
Powder metallurgy and particulate materials processing is abbreviated as P/M² and provide the focus for this book. These subjects include a variety of techniques to fabricate engineered products using principles ranging from materials synthesis to industrial engineering. The P/M² technologies create particles, control their attributes, consolidate the particles into shapes, and heat the shapes to a temperature where the particles bond into a strong product. Most of the shaping is applied to mass production applications, where the tool cavity is replicated over and over. Accordingly, each piece becomes economical because tooling, engineering, and equipment costs are spread over many parts. Many of the products have unique microstructure and performance attributes leading to a wide diversity of applications.

This book views P/M² from a perspective based on the laws of physics, chemistry, mechanics and dynamics, thermodynamics and kinetics, and chemical engineering. It is an outgrowth of the very successful book Powder Metallurgy Science (first edition 1984, second edition 1994). Although there is still a heavy emphasis on classic powder metallurgy (ferrous, nonferrous, refractory, cermets, hard materials or cemented carbides), there is now an interwoven treatment of composites, technical ceramics, and related material systems. The intent is to teach the generic principles associated with creating powders and fabricating engineered shapes from those powders; specific chemistries, applications, and engineering details are only used as illustrations. The book is both a text and reference. It is written for engineering students with a background in materials, metallurgy, ceramics, industrial engineering, mechanical engineering, engineering science, and engineered materials. However, it is also sufficiently basic that it can be used for industrial short courses and self-study.

The book is composed of 16 chapters, each divided into many small segments that can be consulted without reading the whole book. Chapter One provides a frame of reference. Chapters Two through Four focus on powder characterization, production, and microstructure control. Chapter Five considers adjustments to a powder for subsequent consolidation. Chapters Six through Eleven are the heart of the P/M² process. They focus on shaping, compaction, sintering, hot consolidation, and freeform processes. The balance of the book (Chapters Twelve through Sixteen) goes into finishing operations, characterization of the compact, testing and standards, material properties, designs, applications, and includes information on economics. Appendices are included with definitions, test standards, material properties, and answers to selected study questions. That organization provides both breadth and depth to the subject and sufficient reference information to allow subsequent study by the interested reader.
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He is a Fellow of APMI International and ASM International. His awards include the Tesla Medal, University of California (Davis) Distinguished Engineering Alumni Award, San Jose State University Award of Distinction, Nanyang Professorship (Nanyang Technological University), Penn State Engineering Society Outstanding and Premiere Research Awards, Metal Powder Industries Federation Distinguished Service Award, and Kuczynski and Samsonov Prizes of the International Team for the Science of Sintering.

Rand’s publication list exceeds 750 articles, 20 edited books, and he is co-inventor on 22 patents. His 12 books include Liquid Phase Sintering, Particle Packing Characteristics, Sintering Theory and Practice, Powder Metallurgy of Iron and Steel, Injection Molding of Metals and Ceramics (with A. Bose), and User’s Guide to Powder Injection Molding - Designs and Applications.

He lives in State College, Pennsylvania, with Carol, his wife; they have two married sons, Eric and Garth, who both live in California.
CHAPTER 1

INTRODUCTION

This chapter introduces powder processing to set the stage for the book and for understanding the scope of this technology. Historical aspects of the subject are introduced to illustrate the base of successful applications.

Outline
A. Frame of Reference
B. Definitions
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