

Manufacturing

*Design, Production, Automation,
and Integration*

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Preface

This book is a comprehensive, integrated treatise on manufacturing engineering in the modern age. By addressing the three important aspects of manufacturing—namely, design, production processes, and automation—it presents the state of the art in manufacturing as well as a careful treatment of the fundamentals. All topics have been carefully selected for completeness, researched, and discussed as accurately as possible, with an emphasis on *computer integration*. *Design* is discussed from concept development to the engineering analysis of the final product, with frequent reference to the various processes of fabrication. Numerous common fabrication processes (traditional and modern) are subsequently detailed and contextualized in terms of product design and automation. In the third part of the book, manufacturing control is discussed at the machine level as well as the system level (namely, material flow control in flexible manufacturing systems).

Although the book does discuss the totality of the *design* cycle, it does not present an exhaustive discussion of all manufacturing *processes* in existence. It emphasizes the most common types of metal processing, plastics processing, and powder processing, including modern processes such as laser cutting and numerous lithography-based methods. In the third part of the book, continuous control is not discussed in detail; students interested in automation are expected to have a basic knowledge of the topic. Discrete-

event control—a topic rarely introduced in manufacturing books—is addressed because of its vital importance in system control.

Although this book was written mainly for undergraduate and graduate students in mechanical and industrial engineering programs, its integrated treatment of the subject makes it a suitable reference for practicing engineers and other professionals interested in manufacturing. For the classroom setting, the book offers the following benefits: (1) providing the undergraduate-level instructor with the flexibility to include several advanced topics in a course on manufacturing fundamentals and (2) providing graduate students with a background of manufacturing fundamentals, which they may not have fully studied as undergraduates.

TEACHING MANUFACTURING ENGINEERING USING THIS BOOK

Although manufacturing practice in industry has evolved significantly over the past two decades, existing textbooks rarely reflect these changes, thus severely restricting the way manufacturing courses are taught. Most textbooks are still compartmentalized in the manner that manufacturing practice was in the distant past; namely, there are design books, process books, and automation books. In practice, manufacturing is a concurrent, integrated process that requires engineers to think simultaneously of all issues and their impact on one another. This book attempts to advance the teaching of manufacturing engineering, keeping pace with practice in industry while providing instructors with options for course development. Instructors can configure the book to be suitable for two consecutive (one-term) courses: one at an introductory undergraduate level (Fundamentals of Manufacturing Engineering) and one at an advanced level (Manufacturing Automation):

Fundamentals of Manufacturing Engineering

[Chapter 1: Competitive Manufacturing](#)

[Chapter 2: Conceptual Design](#)

[Chapter 3: Design Methodologies](#)

(Optional) [Chapter 4: Computer-Aided Design](#)

[Chapter 6: Metal Casting, Powder Processing, and Plastics Molding](#)

[Chapter 7: Metal Forming](#)

[Chapter 8: Machining](#)

[Chapter 9: Modern Manufacturing Techniques](#)

[Chapter 10: Assembly](#)

(Optional) [Chapter 11: Workholding—Fixtures and Jigs](#)

- (Optional) Chapter 12: Materials Handling
(Optional) Chapter 16: Control of Manufacturing Quality

Manufacturing Automation

- Chapter 1: Competitive Manufacturing
(Optional) Chapter 2: Conceptual Design
(Optional) Chapter 3: Design Methodologies
Chapter 4: Computer-Aided Design
Chapter 5: Computer-Aided Engineering Analysis and Prototyping
(Optional) Chapter 9: Modern Manufacturing Techniques
(Optional) Chapter 10: Assembly
(Optional) Chapter 11: Workholding—Fixtures and Jigs
(Optional) Chapter 12: Materials Handling
Chapter 13: Instrumentation for Manufacturing Control
Chapter 14: Control of Production and Assembly Machines
Chapter 15: Supervisory Control of Manufacturing Systems
Chapter 16: Control of Manufacturing Quality

CHAPTER HIGHLIGHTS

Chapter 1 focuses on major historical developments in the manufacturing industry in the past two centuries. The emergence of machine tools and industrial robots is discussed as prelude to a more in-depth review of the automotive manufacturing industry. Technological advancements in this industry have significantly benefited other manufacturing industries over the past century. Various manufacturing strategies adopted in different countries are reviewed as prelude to a discussion on the expected future of the manufacturing industry—namely, information technology–based manufacturing.

Chapter 2 emphasizes the first stage of the engineering design process: development of viable concepts. Concurrent engineering (CE) is defined as a systematic approach to the integrated design of products and their manufacturing and support processes. Identification of customer need is described as the first step in this process, followed by concept generation and selection. The importance of industrial design (including human factors) in engineering design is also highlighted. The chapter concludes with a review of modular product design practices and the mass manufacturing of such customized products.

Chapter 3 describes four primary design methodologies. Although these methodologies have commonly been targeted for the post–conceptual

design phase, some can also be of significant benefit during the conceptual design phase of a product—for example, *axiomatic design* and *group technology* during the conceptual design phase, *design for manufacturing/assembly/environment* during configuration and detailed design, and the *Taguchi method* during parametric design.

Chapter 4 begins with a review of geometric-modeling principles and then addresses several topics in computer-aided design (CAD), such as solid-modeling techniques, feature-based design, and product-data-exchange standards.

In **Chapter 5** a discussion of prototyping (physical versus virtual) serves as introduction to a thorough review of the most common computer-aided engineering (CAE) analysis tool used in mechanical engineering: finite-element modeling and analysis. Subsequently, several optimization techniques are discussed.

Chapter 6 describes three distinct fusion-based production processes for the net-shape fabrication of three primary engineering materials: casting for metals, powder processing for ceramics and high-melting-point metals and their alloys (e.g., cermets), and molding for plastics.

Chapter 7 describes several common metal-forming processes, focusing on two processes targeted for discrete-parts manufacturing: forging and sheet-metal forming. Quick die exchange, which is at the heart of productivity improvement through elimination of “waste,” is also briefly addressed.

Chapter 8 surveys nonabrasive machining techniques (e.g., turning and milling) and discusses critical variables for finding material removal rate, such as cutting velocity and feed rate. The economics of machining—which is based on the utilization of these variables in the derivation of the necessary optimization models—is also discussed in terms of the relationship of cutting-tool wear to machining-process parameters. A discussion of representative abrasive-machining methods is also included.

In **Chapter 9**, several (nontraditional) processes for material removal are reviewed in separate sections devoted to non-laser-based and laser-based fabrication. This leads to a discussion of several modern material-additive techniques commonly used in the rapid fabrication of layered physical prototypes.

Chapter 10 describes various methods used for joining operations in the fabrication of multicomponent products. These include mechanical fastening, adhesive bonding, welding, brazing, and soldering. The chapter concludes with a detailed review of two specific assembly applications: automatic assembly of electronic parts and automatic assembly of small mechanical parts.

In [Chapter 11](#), following the description of general workholding principles and basic design guidelines for jigs and fixtures, the use of such devices in manufacturing is discussed, in the form of dedicated or modular configurations. CAD techniques for fixture/jig development are briefly described.

In [Chapter 12](#), the focus is on the handling of individual goods (i.e., “unit loads”) with a primary emphasis on material-handling equipment, as opposed to facility planning and movement control. Industrial trucks (including automated guided vehicles), conveyors and industrial robots are reviewed as the primary mechanized/automated material-handling equipment. The automated storage and retrieval of goods in high-density warehouses, as well as the important issue of automatic part identification (including bar codes), are also discussed. The chapter ends with a discussion of automobile assembly.

[Chapter 13](#) describes the various sensors that can be used for automatic control in manufacturing environments. A brief introduction to the control of devices in the continuous-time domain precedes a discussion of pertinent manufacturing sensors: motion sensors, force sensors, and machine vision. A brief discussion of actuators concludes the chapter.

[Chapter 14](#) focuses on the automatic control of two representative classes of production and assembly machines: material-removal machine tools and industrial robotic manipulators, respectively.

[Chapter 15](#) describes two of the most successful discrete-event-system (DES) control theories developed by the academic community: Ramadge–Wonham automata theory and Petri nets theory. The chapter ends with a description of programmable logic controllers (PLCs), which are used for the autonomous DES-based supervisory control of parts flow in flexible manufacturing workcells.

[Chapter 16](#) addresses quality control with an emphasis on on-line control (as opposed to postprocess sampling), focusing on measurement technologies and statistical process-control tools. Inspection is defined and some common metrological techniques are presented. An overview of probability and statistics theories are presented as prelude to a discussion of statistical process capability and control. A discussion of ISO 9000:2000 concludes the chapter.

Beno Benhabib

Acknowledgments

Most books on manufacturing engineering—and this one is no exception—reflect the worldwide efforts of thousands of engineers and scientists who have, over the past century and even earlier, advanced the state of the art. Herein, that cumulative achievement is augmented by the knowledge and experience I have gathered over the past two decades. Although many individuals have helped me in my endeavors, the primary contributors are the dedicated graduate students and postdoctoral fellows whose work I have had the privilege of supervising over the past two decades at the University of Toronto:

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