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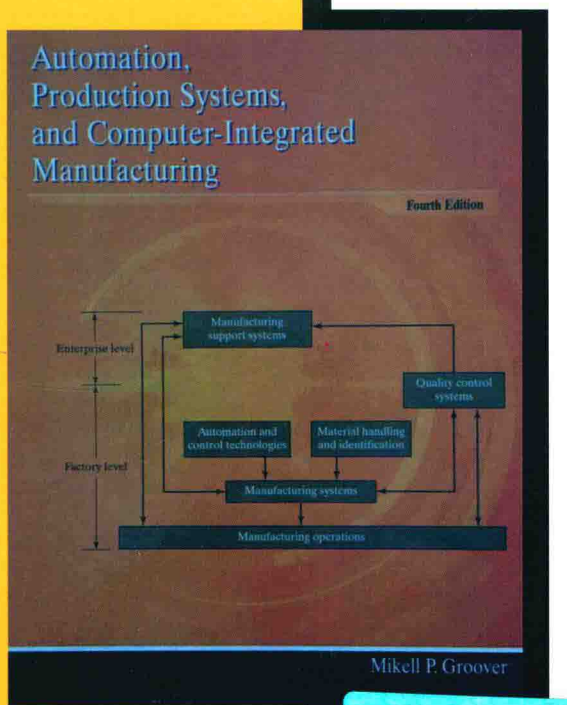
[美] Mikell P. Groover

自动化、生产系统与计算机集成制造（第4版）



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Automation, Production Systems, and Computer-Integrated Manufacturing

Fourth Edition

自动化、生产系统与计算机集成制造

（第4版）

[美] Mikell P. Groover

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Foreword

This textbook series is published at a very opportunity time when the discipline of industrial engineering is experiencing a phenomenal growth in China academia and with its increased interests in the utilization of the concepts, methods and tools of industrial engineering in the workplace. Effective utilization of these industrial engineering approaches in the workplace should result in increased productivity, quality of work, satisfaction and profitability to the cooperation.

The books in this series should be most suitable to junior and senior undergraduate students and first year graduate students, and to those in industry who need to solve problems on the design, operation and management of industrial systems.

Gavriel Salvendy

Department of Industrial Engineering, Tsinghua University

School of Industrial Engineering, Purdue University

April, 2002

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序　言

本教材系列的出版正值中国学术界工业工程学科经历巨大发展、实际工作中对工业工程的概念、方法和工具的使用兴趣日渐浓厚之时。在实际工作中有效地应用工业工程的手段将无疑会提高生产率、工作质量、合作的满意度和效果。

该系列中的书籍对工业工程的本科生、研究生和工业界中需要解决工程系统设计、运作和管理诸方面问题的人士最为适用。

加弗瑞尔·沙尔文迪
清华大学工业工程系
普渡大学工业工程学院（美国）
2002 年 4 月

Preface

This book has a history. It was originally published in 1980 as *Automation, Production Systems, and Computer-Aided Manufacturing*. Topics included automated flow lines, assembly line balancing, numerical control, CAD/CAM, control theory, process control, production planning, group technology, and flexible manufacturing systems. A revised edition was published in 1986 with a change in title to *Automation, Production Systems, and Computer-Integrated Manufacturing*. Additional topics included industrial robotics, programmable logic controllers, automated assembly systems, material handling and storage, automatic identification techniques, shop floor control, and the future automated factory. The second edition of the new title was released in 2000 with a 2001 copyright. Many of the topics remained the same as in the 1986 edition, but much of the material on control theory was eliminated. The book was reorganized substantially, and most of the chapters were rewritten to bring the technical subject matter up to date. The third edition was released in 2007 with a 2008 copyright. It contained expanded coverage of new and emerging technologies (e.g., radio frequency identification, Six Sigma, lean production, enterprise resource planning).

The basic objective of this new edition remains the same as in the previous editions: to provide up-to-date coverage of production systems, how they are sometimes automated and computerized, and how they can be mathematically analyzed to obtain performance metrics. The textbook is designed primarily for engineering students at the advanced undergraduate or beginning graduate levels in industrial, mechanical, and manufacturing engineering. It has all the features of an engineering textbook: equations, example problems, diagrams, quantitative end-of-chapter exercises, and technical descriptions that seem designed to baffle college students. The book should also be useful for practicing engineers and managers who wish to learn about automation and production systems technologies in modern manufacturing.

NEW TO THIS EDITION

In this fourth edition of the current title (fifth edition of the original 1980 book), I have consolidated and reorganized many of the topics and eliminated material that I felt is no longer relevant. Among the new topics and other changes in the book are those listed below. Items marked with an asterisk (*) relate to recommendations made by the reviewers (see Acknowledgments).

- In Chapter 3 (Manufacturing Metrics and Economics), many of the equations have been revised to make them more robust. A new section on cost of a manufactured part has been added.

- In Chapter 6 (Hardware Components for Automation and Process Control), new content has been added on electric motors, including linear motors and the conversion of rotary motion to linear motion.* Several new figures have been added in support of the new content.*
- In Chapter 7 (Computer Numerical Control), the appendix on APT has been removed because this method of programming has been largely replaced in industry by CAD/CAM part programming, coverage of which has been expanded in this new edition. In addition, the mathematical models of positioning control have been improved.
- In Chapter 8 (Industrial Robotics), two new robot configurations have been added and two configurations have been eliminated because they are no longer relevant.
- In Chapter 9 (Discrete Control and Programmable Logic Controllers), corrections and improvements have been made in the ladder logic examples.* A section on programmable automation controllers has been added.
- In Chapter 10 (Material Transport Systems), the section on AGVS technologies has been updated.
- In Chapter 11 (Storage Systems), the section on automated storage/retrieval systems has been updated and shortened.*
- In Chapter 12 (Automatic Identification and Data Capture), the section on radio frequency identification (RFID) has been expanded and updated.*
- In Chapter 14 (Single-Station Manufacturing Cells), coverage of CNC machining centers and related machine tools has been expanded.
- In Chapter 15 (Manual Assembly Lines), coverage of mixed-model assembly lines has been moved to an appendix, on the assumption that some instructors may not want to include this topic in their courses. A new section on batch-model assembly lines has been included in the appendix.
- In Chapter 16 (Automated Production Lines), coverage of transfer lines with internal parts storage has been moved to an appendix, on the assumption that some instructors may not want to include this topic in their courses.
- In Chapter 18 (Group Technology and Cellular Manufacturing), the organization of the text has been substantially revised. A new section on performance metrics in cell operations has been added. Coverage of parts classification and coding has been reduced, and the Opitz system has been relocated to an appendix.
- In Chapter 19 (Flexible Manufacturing Cells and Systems), sections on mass customization, reconfigurable manufacturing systems, and agile manufacturing have been added.
- In Chapter 20 (Quality Programs for Manufacturing), the DMAIC procedure in Six Sigma has been relocated to an appendix, on the assumption that some instructors may not want to cover the detailed methodology of Six Sigma. If they do, those details are in the appendix.
- In Chapter 22 (Inspection Technologies), the mathematical details of coordinate metrology have been relocated to an appendix. The section on machine vision has been updated to include recent advances in camera technology.

- In Chapter 23 (Product Design and CAD/CAM in the Production System), the section on CAD has been updated to be consistent with modern industrial practice.*
- In Chapter 25 (Production Planning and Control Systems), the section on work-in-process inventory costs has been eliminated, and the sections on MRP II and ERP have been upgraded.
- More than 50% of the end-of-chapter problems are new or revised. The total number of problems is increased from 393 in the third edition to 416 in this edition.
- An appendix has been added listing answers to selected end-of-chapter problems (answers to a total of 88 problems, or 21% of the end-of-chapter problems).*
- A total of 36 new or revised figures are included in this new edition, for a total of 278 figures. By comparison, the third edition has 293 figures, so the net change is a reduction of 15 figures. This is due to the removal of outdated and extraneous figures throughout the book and the elimination of the appendix on APT in Chapter 7.
- A list of abbreviations used in the book, located in the inside front cover, has been added for readers' reference.

SUPPORT MATERIALS FOR INSTRUCTORS

For instructors who adopt the book for their courses, the following support materials are available at the Pearson website, www.pearsonhighered.com. Evidence that the book has been adopted as the main textbook for the course must be verified.

- A ***Solutions Manual*** covering all review questions and problems
- A complete set of ***PowerPoint*** slides for all chapters

Individual questions or comments may be directed to the author at Mikell.Groover@Lehigh.edu or mpg0@Lehigh.edu.

ACKNOWLEDGMENTS

A number of changes in the book were motivated by responses to a survey that was conducted by the publisher. Some very worthwhile suggestions were offered by the reviewers, and I have attempted to incorporate them into the text where appropriate and feasible. In any case, I appreciate the thoughtful efforts that they contributed to the project, and I am sure that the book is better as a result of their efforts than it otherwise would have been. Participants in the survey were T. S. Bukkapatnam, Oklahoma State University; Joseph Domblesky, Marquette University; Brent Donham, Texas A&M University; John Jackman, Iowa State University; Matthew Kuttolamadom, Texas A&M University; Frank Peters, Iowa State University; and Tony Schmitz, University of North Carolina-Charlotte.

I also acknowledge the following individuals at Pearson Education Inc. for their support during this project: Holly Stark, Executive Editor; Clare Romeo, Program

Manager; and Sandra Rodriguez, Editorial Assistant. In addition, I am grateful for the fine job done by George Jacob at Integra Software Services who served as Program Manager for the project. He and the copy editors working with him were thorough and meticulous in their review of the manuscript (I take back all of the bad things I have ever said about copy editors throughout the nearly 40 years I have been writing textbooks).

Also, I am in gratitude to all of the faculty who have adopted the previous editions of the book for their courses, thus making those projects commercially successful for Pearson Education Inc., so that I would be allowed to prepare this new edition.

Finally, I wish to thank Marcia Hamm Groover, my wife, my PowerPoint slide expert, my computer specialist (I write books about computer-related technologies, but she is the one who fixes my computer when it has problems), and my supporter on this and other textbook projects.

ABOUT THE AUTHOR

Mikell P. Groover is Professor Emeritus of Industrial and Systems Engineering at Lehigh University, where he taught and did research for 44 years. He received his B.A. in Arts and Science (1961), B.S. in Mechanical Engineering (1962), M.S. in Industrial Engineering (1966), and Ph.D. (1969), all from Lehigh. His industrial experience includes several years as a manufacturing engineer before embarking on graduate studies at Lehigh.

His teaching and research areas include manufacturing processes, production systems, automation, material handling, facilities planning, and work systems. He has received a number of teaching awards at Lehigh University, as well as the Albert G. Holzman Outstanding Educator Award from the Institute of Industrial Engineers (1995) and the SME Education Award from the Society of Manufacturing Engineers (2001). His publications include over 75 technical articles and 12 books (listed below). His books are used throughout the world and have been translated into French, German, Spanish, Portuguese, Russian, Japanese, Korean, and Chinese. The first edition of *Fundamentals of Modern Manufacturing* received the IIE Joint Publishers Award (1996) and the M. Eugene Merchant Manufacturing Textbook Award from the Society of Manufacturing Engineers (1996).

Dr. Groover is a member of the Institute of Industrial Engineers (IIE) and the Society of Manufacturing Engineers (SME). He is a Fellow of IIE and SME.

PREVIOUS BOOKS BY THE AUTHOR

Automation, Production Systems, and Computer-Aided Manufacturing, Prentice Hall, 1980.

CAD/CAM: Computer-Aided Design and Manufacturing, Prentice Hall, 1984 (co-authored with E. W. Zimmers, Jr.).

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Fundamentals of Modern Manufacturing: Materials, Processes, and Systems, Fifth Edition, John Wiley & Sons, Inc., 2013.

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1.5 About This Book

The word *manufacturing* derives from two Latin words, *manus* (hand) and *factus* (make), so that the combination means *made by hand*. This was the way manufacturing was accomplished when the word first appeared in the English language around 1567. Commercial goods of those times were made by hand. The methods were handicraft, accomplished in small shops, and the goods were relatively simple, at least by today's standards. As many years passed, factories came into being, with many workers at a single site, and the work had to be organized using machines rather than handicraft techniques. The products

1

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