高等学校教材系列



# 机械设计

(第四版)(英文版)

Machine Elements in Mechanical Design

Fourth Edition



[美] Robert L. Mott 著 钱瑞明 缩编



電子工業出版社

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#### 内容简介

本书是美国Robert L. Mott 教授所著 Machine Elements in Mechanical Design (Fourth Edition) 的缩编版。缩编者在保持原书特色和风格的前提下,根据我国机械设计课程的教学要求,删去了原书中与我国其他先修课程重复的内容,将原书23章缩编为16章,并将计量单位转换为公制。缩编后的内容包括: 机械设计概论,带传动与链传动,齿轮传动与蜗杆传动,轴,轴联接件(键、联轴器、密封), 滚动轴承,滑动轴承,紧固件,弹簧,机座,离合器与制动器,设计大作业等。

本书可作为高等学校工科机械类专业机械设计课程的双语教学教材,也可供从事机械专业的教师、研究生或工程技术人员参考。

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## 缩编者序

"Machine Elements in Mechanical Design"—书是美国大学现行的机械设计教材,由美国代顿大学(University of Dayton)的罗伯特 L. 莫特(Robert L. Mott)教授编著,2004年出版了第 4 版。该教材共 3 篇 23 章, 另有 20 个附录,内容丰富生动,工程实践性强,被美国等多国高校广为采用,并被读者评价为五星级精品教材。该教材第 4 版主要特点有:

- 1. 每章以 "The Big Picture" 和 "You Are the Designer" 作为引言,介绍该章内容的工程背景和从设计角度需要考虑与解决的主要问题,以及学习该章后学生所具有的能力,由此激发学生的学习兴趣。
- 2. 介绍了大量的美国标准与计算方法,如常用材料、带、链、齿轮、滚动轴承、螺纹等,有 利于读者了解美国机械设计行业规范和技术数据,进行国际技术交流。
- 3. 例题丰富,求解步骤清晰,尤其是对于设计计算过程繁琐和需要反复试算的例题,采用了电子数据表格借助于计算机自动完成所有计算的方法,由此不仅简洁明了地展示了整个求解过程和步骤,提高了设计计算效率,而且也便于设计结果的分析和设计方案的优选。
- 4. 习题数量多,且紧密结合工程实际,最后一章给出了若干综合性设计大作业,有助于培养 学生的工程意识和综合设计能力。
- 5. 各章列出了很多扩展信息,如参考文献,行业、企业以及设计部门的网站地址等,为读者提供了进一步了解相关信息和获取设计资料的渠道。
- 6. 附有计算机辅助机械设计 MDESIGN 软件光盘, 学生可借助于该软件快速完成带传动、链传动、齿轮传动、轴、键、轴承、弹簧等的设计计算。

为了解和学习国外的教学理念与教材风格,满足我国机械设计课程双语教学的需要,电子工业出版社将 Machine Elements in Mechanical Design (Fourth Edition, 2004)作为精品教材加以引进。考虑到原书内容丰富,篇幅较大,电子工业出版社委托本人对其进行缩编,在保持原书特色和风格的前提下,根据我国机械设计课程的教学要求,删减部分内容,形成本缩编版。缩编版与原教材主要有以下不同:

- 1. 对于原书中与我国高校机械类本科专业其他先修课程相关的部分内容,作了章节的整体删除,如整章删除的有原书第3章(Stress and Deformation Analysis)、第4章(Combined Stresses and Mohr's Circle)、第6章(Columns)、第13章(Tolerances and Fits)、第17章(Linear Motion Elements)和第21章(Electric Motors and Controls);将原书第8章(Kinematics of Gears)8-4节(Spur Gear Nomenclature and Gear-Tooth Features)并人第9章,并将第8章其他节内容全部删除。
- 2. 原书例题、习题、参考文献和附录较多,结合我国机械设计课程的教学情况,缩编时作了部分删减。
  - 3. 鉴于当前网络搜索功能强大,全部删去了原书各章所列的网站地址。

- 4. 考虑到目前许多商用专业软件中已带有常用机械零件与传动的设计模块,故本缩编版未附原书所配 MDESIGN 光盘软件,并删去了原书中与此软件有关的内容。
  - 5. 将原书中的计量单位由英制转换为公制,转换时参考了原书的新加坡版本。

本缩编版共3篇16章,内容包括: 机械设计概论,带传动与链传动,齿轮传动与蜗杆传动,轴,轴联接件(键、联轴器、密封),滚动轴承,滑动轴承,紧固件,弹簧,机座,离合器与制动器,设计大作业等,涵盖了我国机械设计课程的主要内容。

本书语言流畅,通俗易懂,适应我国学生的英语水平和学习特点,是一本学习机械设计课程和进行机械设计双语教学的优秀教材。

东南大学机械工程学院 钱瑞明 2007年4月

## **Preface**

The objective of this book is to provide the concepts, procedures, data, and decision analysis techniques necessary to design machine elements commonly found in mechanical devices and systems. Students completing a course of study using this book should be able to execute original designs for machine elements and integrate the elements into a system composed of several elements.

This process requires a consideration of the performance requirements of an individual element and of the interfaces between elements as they work together to form a system. For example, a gear must be designed to transmit power at a given speed. The design must specify the number of teeth, pitch, tooth form, face width, pitch diameter, material, and method of heat treatment. But the gear design also affects, and is affected by, the mating gear, the shaft carrying the gear, and the environment in which it is to operate. Furthermore, the shaft must be supported by bearings, which must be contained in a housing. Thus, the designer should keep the complete system in mind while designing each individual element. This book will help the student approach design problems in this way.

This text is designed for those interested in practical mechanical design. The emphasis is on the use of readily available materials and processes and appropriate design approaches to achieve a safe, efficient design. It is assumed that the person using the book will be the designer, that is, the person responsible for determining the configuration of a machine or a part of a machine. Where practical, all design equations, data, and procedures needed to make design decisions are specified.

It is expected that students using this book will have a good background in statics, strength of materials, college algebra, and trigonometry. Helpful, but not required, would be knowledge of kinematics, industrial mechanisms, dynamics, materials, and manufacturing processes.

Among the important features of this book are the following:

- It is designed to be used at the undergraduate level in a first course in machine design.
- The large list of topics allows the instructor some choice in the design of the course. The format is also appropriate for a two-course sequence and as a reference for mechanical design project courses.
- Students should be able to extend their efforts into topics not covered in classroom instruction because explanations of principles are straightforward and include many example problems.
- 4. The practical presentation of the material leads to feasible design decisions and is useful to practicing designers.
- 5. The text advocates and demonstrates use of computer spreadsheets in cases requiring long, laborious solution procedures. Using spreadsheets allows the designer to make decisions and to modify data at several points within the problem while the computer performs all computations. See Chapter 5 on spur gears, Chapter 8 on shafts, and Chapter 13 on spring design.

- 6. References to other books, standards, and technical papers assist the instructor in presenting alternate approaches or extending the depth of treatment.
- 7. In addition to the emphasis on original design of machine elements, much of the discussion covers commercially available machine elements and devices, since many design projects require an optimum combination of new, uniquely designed parts and purchased components.
- 8. For some topics the focus is on aiding the designer in selecting commercially available components, such as rolling contact bearings, flexible couplings, belt drives, chain drives, clutches, and brakes.
- Computations and problem solutions use both the International System of Units (SI) and the U.S. Customary System (inch-pound-second) approximately equally. The basic reference for the usage of SI units is IEEE/ASTM-SI-10 Standard for Use of the International System of Units (SI): The Modern Metric System, which has replaced ASTM E380 and ANSI/IEEE Standard 268-1992.
- 10. Extensive appendices are included along with detailed tables in many chapters to help the reader to make real design decisions, using only this text.

### FEATURES OF THE FOURTH EDITION

The practical approach to designing machine elements in the context of complete mechanical designs is retained and refined in this edition. An extensive amount of updating has been accomplished through the inclusion of new photographs of commercially available machine components, new design data for some elements, new or revised standards, new end-of-chapter references, listings of Internet sites, and some completely new elements. The following list summarizes the primary features and the updates.

- The three-part structure that was introduced in the third edition has been maintained.
  - Part I (Chapters 1~3) focuses on reviewing and upgrading readers' understanding of design philosophies, the principles of strength of materials, the design properties of materials, and design for different types of loading.
  - Part II (Chapters 4~10) is organized around the concept of the design of a complete power transmission system, covering some of the primary machine elements such as belt drives, chain drives, gears, shafts, keys, couplings, seals, and rolling contact bearings. These topics are tied together to emphasize both their interrelationships and their unique characteristics. Chapter 10, Completion of the Design of a Power Transmission, is a guide through detailed design decisions such as the overall layout, detail drawings, tolerances, and fits.
  - Part III (Chapters 11~16) presents methods of analysis and design of several important machine elements that were not pertinent to the design of a power transmission. These chapters can be covered in any order or can be used as reference material for general design projects. Covered here are plain surface bearings, fasteners, springs, machine frames, bolted connections, welded joints, clutches, and brakes.
- 2. The Big Picture, You Are the Designer, and Objectives features introduced in earlier editions are maintained and refined. Feedback about these features from users, both students and instructors, has been enthusiastically favorable. They help

readers to draw on their own experiences and to appreciate what competencies they will acquire from the study of each chapter. Constructivist theories of learning espouse this approach.

- 3. Some of the new or updated topics from individual chapters are summarized here.
  - In Chapter 1, the discussion of the mechanical design process is refined, and several new photographs are added.
  - Chapter 3, Design for Different Types of Loading, is extensively upgraded and refined in the topics of endurance strength, design philosophy, design factors, predictions of failure, an overview of statistical approaches to design, finite life, and damage accumulation. The recommended approach to fatigue design has been changed from the Soderberg criterion to the Goodman method. The modified Mohr method is added for members made from brittle materials.
  - In Chapter 4, synchronous belt drives are added and new design data for chain power ratings are included.
  - Chapter 5, Spur Gear Design, is refined with new photographs of gear production machinery, new AGMA standards for gear quality, new discussion of functional measurement of gear quality, enhanced description of the geometry factor I for pitting resistance, more gear lubrication information, and a greatly expanded section on plastics gearing.
  - In Chapter 7, new information is provided for keyless hub to shaft connections of the Ringfeder<sup>®</sup> and polygon types, and the Cornay<sup>™</sup> universal joint. The extensive listing of Internet sites provides access to data for keys, couplings, universal joints, and seals.
  - Critical speeds, other dynamic considerations, and flexible shafts are added to Chapter 8, Shaft Design.
  - An all-new section, Tribology: Friction, Lubrication, and Wear, is added to Chapter 11, Plain Surface Bearings. More data on pV factors for boundary lubricated bearings are provided.
  - Refinements to Chapter 12, Fasteners, include the shear strength of threads, components of torque applied to a fastener, and methods of bolt tightening.

## **Acknowledgments**

My appreciation is extended to all who provided helpful suggestions for improvements to this book. I thank the editorial staff of Prentice Hall Publishing Company, those who provided illustrations, and the many users of the book, both instructors and students, with whom I have had discussions. Special appreciation goes to my colleagues at the University of Dayton, Professors David Myszka, James Penrod, Joseph Untener, Philip Doepker, and Robert Wolff. I also thank those who provided thoughtful reviews of the prior edition: Marian Barasch, Hudson Valley Community College; Ismail Fidan, Tennessee Tech University; Paul Unangst, Milwaukee School of Engineering; Richard Alexander, Texas A & M University; and Gary Qi, The University of Memphis. I especially thank my students—past and present—for their encouragement and their positive feedback about this book.

Robert L. Mott

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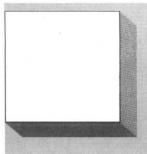
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**Answers to Selected Problems** 



## PART I

# Principles of Design and Stress Analysis

OBJECTIVES AND CONTENT OF PART I As you complete the first three chapters of this book, you will gain an understanding of design philosophies, and you will build on earlier-learned principles of strength of materials, materials science, and manufacturing processes. The competencies gained from these chapters are useful throughout the book and in general machine design or product design projects.

Chapter 1: The Nature of Mechanical Design helps you see the big picture of the process of mechanical design. Several examples are shown from different industry sectors: consumer products, manufacturing systems, construction equipment, agricultural equipment, transportation equipment, ships, and space systems. The responsibilities of designers are discussed, along with an illustration of the iterative nature of the design process. Units and conversions complete the chapter.

Chapter 2: Materials in Mechanical Design emphasizes the design properties of materials. Much of this chapter is probably review for you, but it is presented here to emphasize the importance of material selection to the design process and to explain the data for materials presented in the Appendices.

Chapter 3: Design for Different Types of Loading is an in-depth discussion of design factors, fatigue, and many of the details of stress analysis as used in this book.



## The Nature of Mechanical Design

### The Big Picture

### You Are the Designer

- 1-1 Objectives of This Chapter
- 1-2 The Mechanical Design Process
- 1-3 Skills Needed in Mechanical Design
- 1-4 Functions, Design Requirements, and Evaluation Criteria
- 1-5 Example of the Integration of Machine Elements into a Mechanical Design
- 1-6 Computational Aids in This Book
- 1-7 Design Calculations
- 1-8 Unit Systems

The Big Picture

## The Nature of Mechanical Design

#### **Discussion Map**

- To design mechanical components and devices, you must be competent in the design of individual elements that comprise the system.
- But you must also be able to integrate several components and devices into a coordinated, robust system that meets your customer's needs.

#### Discover

Think, now, about the many fields in which you can use mechanical design:

What are some of the products of those fields?
What kinds of materials are used in the products?
What are some of the unique features of the products?
How were the components made?

How were the parts of the products assembled?

Consider consumer products, construction equipment, agricultural machinery, manufacturing systems, and transportation systems on the land, in the air, in space, and on and under water.

In this book, you will find the tools to learn the principles of *Machine Elements in Mechanical Design*.

Design of machine elements is an integral part of the larger and more general field of mechanical design. Designers and design engineers create devices or systems to satisfy specific needs. Mechanical devices typically involve moving parts that transmit power and accomplish specific patterns of motion. Mechanical systems are composed of several mechanical devices.

Therefore, to design mechanical devices and systems, you must be competent in the design of individual machine elements that comprise the system. But you must also be able to integrate several components and devices into a coordinated, robust system that meets your customer's needs. From this logic comes the name of this book, *Machine Elements in Mechanical Design*.

Think about the many fields in which you can use mechanical design. Discuss these fields with your instructor and with your colleagues who are studying with you. Talk with people who are doing mechanical design in local industries. Try to visit their companies if possible, or meet designers and design engineers at meetings of professional societies. Consider the following fields where mechanical products are designed and produced.

- Consumer products: Household appliances (can openers, food processors, mixers, toasters, vacuum cleaners, clothes washers), lawn mowers, chain saws, power tools, garage door openers, air conditioning systems, and many others. See Figures 1–1 and 1–2 for a few examples of commercially available products.
- Manufacturing systems: Material handling devices, conveyors, cranes, transfer devices, industrial robots, machine tools, automated assembly systems, special-purpose processing systems, forklift trucks, and packaging equipment. See Figures 1–3, 1–4, and 1–5.
- Construction equipment: Tractors with front-end loaders or backhoes, mobile cranes, power shovels, earthmovers, graders, dump trucks, road pavers, concrete mixers, powered nailers and staplers, compressors, and many others. See Figures 1–5 and 1–6.