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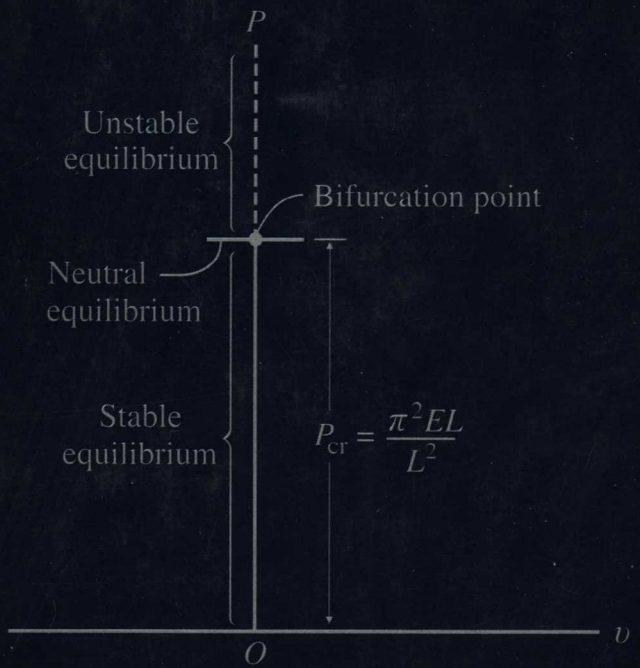
Mechanics of Materials
(原书第六版)

材料力学

[美]Russell C.Hibbeler 著

武建华 缩编



PEARSON Education

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Mechanics of Materials
ISBN: 0-13-191345-X

版贸核渝字(2006)第 65 号

图书在版编目(CIP)数据

材料力学/(美)希伯莱(Hibbeler, R. C.)著;
武建华缩编. —重庆:重庆大学出版社,2007. 8
书名原文:Mechanics of Materials
缩编国外精品教材
ISBN 978-7-5624-4141-0

Ⅰ. 材… Ⅱ. ①希…②武… Ⅲ. 材料力学—高等学校—教材 Ⅳ. TP301

中国版本图书馆 CIP 数据核字(2007)第 081663 号

Mechanics of Materials
材料力学 Cailiao Lixue
[美]R. C. Hibbeler 著 武建华 缩编

出 版 者:	重庆大学出版社	**地 址:**	重庆市沙坪坝正街 174 号重庆大学(A 区)内
网 址:	http://www.cqup.com.cn	**邮 编:**	400030
电 话:	(023)65102378 65105781	**传 真:**	(023)65103686 65105565
出 版 人:	张鸽盛		
责任编辑:	贾兴文	**版式设计:**	贾兴文
责任校对:	文 鹏	**责任印制:**	赵 晟
印 刷 者:	自贡新华印刷厂		
发 行 者:	全国新华书店经销		
开 本:	787×1092 1/16	**印张:**	35.75 **字数:** 1055 千
版 次:	2007 年 8 月第 1 版		2007 年 8 月第 1 次印刷
书 号:	ISBN 978-7-5624-4141-0		
印 数:	1—3 000		
定 价:	46.00 元		

缩编说明

本书是美国著名教授 Russell C. Hibbeler 所著教材《Mechanics of Materials》(第 6 版)的缩编本。

Hibbeler 教授的这本教材是当今最畅销的材料力学教材之一,不但在美国,在亚洲、欧洲都得到广泛使用。原书具有鲜明的特色,从 1991 年第 1 版到 2005 年第 6 版,可以看出内容变化跟随时代的进步和作者在丰富教学经验基础上对完美的追求:

1. 原书强调基础、强调应用。全书注重培养学生对基本概念、基本理论和基本方法的理解和掌握,同时强调理论与实际、理论与工程的结合,逐步引导学生增强发现问题、分析问题和解决问题的能力。

2. 原书易教、易学。每章前有"本章目的"(Chapter Objectives)作为导读,明确了本章要解决的问题。讲解重点突出,每章按重点分成几个单元,一次讲授一个单元,单元后列出本单元的"重点"(Important Points)和分析方法(Procedure for Analysis)。接着是各种类型的例题与相对应的习题。每章最后有本章复习(Chapter Review)。不但为教师备课和教学提供了方便,也便于学生学习、总结、记忆及检测。其中丰富的例题在解题方法和技巧上给学生开拓了思路。

3. 精美的插图和工程照片。作者用精美的插图和照片激发起读者的兴趣,帮助读者理解复杂抽象的概念,强化与工程实际的联系,体现了对读者形象化视觉需求潮流的满足。

4. 原书定位适中。所含内容与我国当前高等理工院校"材料力学"课程的教学要求非常接近,其章节安排与我国大多数"材料力学"教材基本相同。

为了更适合中国学生,我们对原书进行了缩编。对原书仅删去一小部分超出我国教学要求和不符合我国工程规范的小节(Sections),在原书中标有供选讲的星号(*),包括:

蠕变和疲劳引起材料的失效;各种基本受力下的非弹性变形;组合梁、曲梁;平面应变的莫尔圆;用不连续函数和面积矩法求梁的挠度;虚功原理及应用;中心和偏心荷载下柱子的设计(中心和偏心荷载下柱子的设计主要讲述了 AISC[美国钢结构协会]认可的经验公式,与我国《钢结构

设计规范》所用的柱子曲线完全不同)等。

本书对原书的1647个习题作了精心的挑选,删去了一些同类型的习题,减少了采用英制单位的和没有答案的习题,保留了783个习题,仍不失习题丰富的特点。全书的例题,除删去小节中的例题外,没有再删去。同时,给出了目录的中文翻译和附录中的英汉对照词汇表。

缩编后的教材,篇幅减少了1/3强,但是仍然保留了原书的风貌和特色,内容更接近我国教学的要求,是"材料力学"课程双语教学教材的最佳选择,适用于力学、土木、机械、动力、航空及材料等专业,也是工程技术人员不可或缺的参考书。

教材缩编过程中欠妥及不当之处,诚请读者批评指正。

重庆大学 武建华

2007年8月

Preface

This book is intended to provide the student with a clear and thorough presentation of both the theory and application of the fundamental principles of mechanics of materials. Understanding is based on the explanation of the physical behavior of materials under load and then modeling this behavior to develop the theory. Emphasis is placed on the importance of satisfying equilibrium, compatibility of deformation, and material behavior requirements.

Unique Features

The following is a list of some of the more important features of the text.

- Summaries. The "Procedure for Analysis", "Important Points", and Chapter Review sections provide a guide for problem solving and a summary of the concepts.
- Photographs. Many photographs are used throughout the book to explain how the principles of mechanics of materials apply to real world situations. In some sections they show how materials deform or fail under load in order to provide a conceptual understanding of the terms and concepts.
- Problems. The problems provide a balance between easy, medium, and difficult applications. In addition, some problems require solution by computer. Extra care has been taken in the presentation and solution of the problems, and all the problem sets have been reviewed and the solutions checked and rechecked to ensure both their clarity and numerical accuracy.
- Illustrations. Throughout this book, new four-color art has been added, including many photorealistic illustrations that provide a strong connection to the 3-D nature of engineering. We have also tried to use color to better illustrate complicated, abstract concepts, and better instruct and motivate today's more visual learners.

Contents

The subject matter is organized into 14 chapters. Chapter 1 begins with a review of the important concepts of statics, followed by a formal definition of both normal and shear stress, and a discussion of normal stress in axially loaded members and average shear stress caused by direct shear.

In Chapter 2 normal and shear strain are defined, and in Chapter 3 a discussion of some of the important mechanical properties of materials is given. Separate treatments of axial load, torsion, and bending are presented in Chapters 4, 5, and 6, respectively. In each of these chapters, both linearelastic and plastic behavior of the material are considered. Also, topics related to stress concentrations and residual stress are included. Transverse shear is discussed in Chapter 7, along with a discussion of thin-walled tubes, shear flow, and the shear center. Chapter 8 provides a partial review of the material covered in the previous chapters, in which the state of stress resulting from combined loadings is discussed. In Chapter 9 the concepts for transforming multiaxial states of stress are presented. In a similar manner, Chapter 10 discusses the methods for strain transformation, including the application of various theories of failure. Chapter 11 provides a means for a further summary and review of previous material by covering design applications of beams and shafts. In Chapter 12 various

methods for computing deflections of beams and shafts are covered. Also included is a discussion for finding the reactions on these members if they are statically indeterminate. Chapter 13 provides a discussion of column buckling, and lastly, in Chapter 14 the problem of impact and the application of various energy methods for computing deflections are considered.

Sections of the book that contain more advanced material are indicated by a star (*). Time permitting, some of these topics may be included in the course. Furthermore, this material provides a suitable reference for basic principles when it is covered in other courses, and it can be used as a basis for assigning special projects.

Alternative Method of Coverage. Some instructors prefer to cover stress and strain transformations first, before discussing specific applications of axial load, torsion, bending, and shear. One possible method for doing this would be first to cover stress and its transformation, Chapter 1 and Chapter 9, followed by strain and its transformation, Chapter 2 and the first part of Chapter 10. The discussion and example problems in these later chapters have been styled so that this is possible. Also, the problem sets have been subdivided so that this material can be covered without prior knowledge of the intervening chapters. Chapters 3 through 8 can then be covered with no loss in continuity.

Special Features

Organization and Approach. The contents of each chapter are organized into well-defined sections that contain an explanation of specific topics, illustrative example problems, and a set of homework problems. The topics within each section are placed into subgroups defined by titles. The purpose of this is to present a structured method for introducing each new definition or concept and to make the book convenient for later reference and review.

Chapter Contents. Each chapter begins with an illustration demonstrating a broad-range application of the material within the chapter. The "Chapter Objectives" are then provided to give a general overview of the material that will be covered.

Procedures for Analysis. Found after many of the sections of the book, this unique feature provides the student with a logical and orderly method to follow when applying the theory. The example problems are solved using this outlined method in order to clarify its numerical application. It is to be understood, however, that once the relevant principles have been mastered and enough confidence and judgment have been obtained, the student can then develop his or her own procedures for solving problems.

Photographs. Many photographs are used throughout the book to explain how the principles of mechanics apply to real-world situations.

Important Points. This feature provides a review or summary of the most important concepts in a section and highlights the most significant points that should be realized when applying the theory to solve problems.

Conceptual Understanding. Through the use of photographs placed throughout the book, theory is applied in a simplified way in order to illustrate some of its more important conceptual features and instill the physical meaning of many of the terms used in the equations. These simplified applications increase interest in the subject matter and better prepare the student to understand the examples and

solve problems.

Example Problems. All the example problems are presented in a concise manner and in a style that is easy to understand.

Homework Problems. Numerous problems in the book depict realistic situations encountered in engineering practice. It is hoped that this realism will both stimulate the student's interest in the subject and provide a means for developing the skill to reduce any such problem from its physical description to a model or a symbolic representation to which principles may be applied. Throughout the book there is an approximate balance of problems using either SI or FPS units. Furthermore, in any set, an attempt has been made to arrange the problems in order of increasing difficulty. The answers to all but every fourth problem are listed in the back of the book. To alert the user to a problem without a reported answer, an asterisk (*) is placed before the problem number. Answers are reported to three significant figures, even though the data for material properties may be known with less accuracy. Although this might appear to be a poor practice, it is done simply to be consistent and to allow the student a better chance to validate his or her solution. All the problems and their solutions have been triple checked for accuracy. A solid square (square icon) is used to identify problems that require a numerical analysis or a computer application.

Chapter Reviews. New chapter review sections summarize key points of the chapter, often in bulleted lists.

Appendices. The appendices of the book provide a source for review and a listing of tabular data. Appendix A provides information on the centroid and the moment of inertia of an area. Appendices B and C list tabular data for structural shapes, and the deflection and slopes of various types of beams and shafts. Appendix D, which is titled "Review for the Fundamentals of Engineering Exam," contains typical problems, along with their partial solutions, that are commonly used on FE exams. These problems may also be used for review and practice in preparing for class examinations.

Accuracy Checking. The edition has undergone rigorous accuracy checking and proofing of pages. Besides the author's review of all art pieces and pages, Scott Hendricks of Virginia Polytechnic Institute and Kurt Norlin of Laurel Technical Services rechecked the page proofs and together reviewed the entire Solutions Manual.

Supplements

- Instructor's Solutions Manual. An instructor's solutions manual was prepared and tyepset by the author. Like the textbook, it was triple accuracy checked.
- OneKey. OneKey is an on-line solution perfect for helping manage your class and preparing lectures, quizzes, and tests. Using OneKey, professors can quickly access electronic supplements for including complete art files and PowerPoint Slides. OneKey makes solutions available electronically (in single files for security), and helps you post only the solutions you choose at a site only accessible to your students. Please do not post these solutions at any unprotected site. Please contact your PH rep or engineering@prenhall. com, and we will be happy to show you how OneKey makes this task easy, flexible, and secure.

  To learn more about OneKey, visit www. prenhall. com/onekey, contact your local PH rep, or email engineering@prenhall. com.

Acknowledgments

Over the years, this text has been shaped by the suggestions and comments of many of my colleagues in the teaching profession. Their encouragement and willingness to provide constructive criticism are very much appreciated and it is hoped that they will accept this anonymous recognition. A note of thanks is given to reviewers of the previous several editions.

B. Aalami, *San Francisco State University*
R. Alvarez, *Hofstra University*
C. Ammerman, *Colorado School of Mines*
S. Biggers, *Clemson University*
R. Case, *Florida Atlantic University*
R. Cook, *University of Wisconsin—Madison*
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S. Schiff, *Clemson University*
C. Tsai, *Florida Atlantic University*
K. Walsh, *Arizona State University*
P. Kwon, *Michigan State University*
C. Lissenden, *Penn State University*
D. Liu, *Michigan State University*
T. W. Wu, *The University of Kentucky*
J. Hashemi, *Texas Tech University*
A. Pelegri, *Rutgers—The State University of New Jersey*
W. Liddel, *Auburn University at Montgomery*

A particular note of thanks is given to Scott Hendricks of Virginia Polytechnic Institute, who rigorously checked both the text and the Solutions Manual. I would also like to thank all my students who have used the previous edition and have made comments to improve its contents.

Lastly, I should like to acknowledge the assistance of my wife, Cornelie (Conny), during the time it has taken to prepare the manuscript for publication.

I would greatly appreciate hearing from you if at any time you have any comments or suggestions regarding the contents of this edition.

Russell Charles Hibbeler
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Average Mechanical Properties of Typical Engineering Materials[a]
(SI Units)

Materials	Density ρ (Mg/m³)	Modulus of Elasticity E (GPa)	Modulus of Rigidity G (GPa)	Yield Strength (ksi) σ_Y Tens.	Yield Strength (ksi) σ_Y Comp.[b]	Yield Strength (ksi) σ_Y Shear	Ultimate Strength (MPa) σ_u Tens.	Ultimate Strength (MPa) σ_u Comp.[b]	Ultimate Strength (MPa) σ_u Shear	% Elongation in 50 mm specimen	Poisson's Ratio ν	Coef of Therm. Expansion α (10^{-6})/℃
Metallic												
Aluminum Wrought Alloys — 2014-T6	2.79	73.1	27	414	414	172	469	469	290	10	0.35	23
Aluminum Wrought Alloys — 6061-T6	2.71	68.9	26	255	255	131	290	290	186	12	0.35	24
Cast Iron Alloys — Gray ASTM 20	7.19	67.0	27	–	–	–	179	669	–	0.6	0.28	12
Cast Iron Alloys — Malleable ASTM A-197	7.28	172	68	–	–	–	276	572	–	5	0.28	12
Copper Alloys — Red Brass C83400	8.74	101	37	70.0	70.0	–	241	241	–			
Copper Alloys — Bronze C86100	8.83	103	38	345	345	–	655	655	–			
Magnesium Alloys [Am 1004-T61]	1.83	44.7	18	152	152	–	276	276	152	1	0.30	26
Steel Alloys — Structural A36	7.85	200	75	250	250	–	400	400	–	30	0.32	12
Steel Alloys — Stainless 304	7.86	193	75	207	207	–	517	517	–	40	0.27	17
Steel Alloys — Tool L2	8.16	200	75	703	703	–	800	800	–	22	0.32	12
Titanium Alloys [Ti-6A1-4V]	4.43	120	44	924	924	–	1,000	1,000	–	16	0.36	9.4
Nonmetallic												
Concrete — Low Strength	2.38	22.1	–	–	–	12	–	–	–	–	0.15	11
Concrete — High Strength	2.38	29.0	–	–	–	38	–	–	–	–	0.15	11
Plastic Reinforced — Kevlar 49	1.45	131	–	–	–	–	717	483	20.3	2.8	0.34	–
Plastic Reinforced — 30% Glass	1.45	72.4	–	–	–	–	90	131	–	–	0.34	–
Wood Select Structural Grade — Douglas Fir	0.47	13.1	–	–	–	–	2.1[c]	26[d]	6.2[d]	–	0.29[e]	–
Wood Select Structural Grade — White Spruce	3.60	9.65	–	–	–	–	2.5[c]	36[d]	6.7[d]	–	0.31[e]	–

[a] Specific values may vary for a particular material due to alloy or mineral composition, mechanical working of the specimen, or heat treatment. For a more exact value reference books for the material should be consulted.

[b] The yield and ultimate strengths for ductile materials can be assumed equal for both ension and compression.

[c] Measured perpendicular to the grain.

[d] Measured parallel to the grain.

[e] Deformation measured perpendicular to the grain when the load is applied along the grain.

Average Mechanical Properties of Typical Engineering Materials[a]
(U. S. Customary Units)

Materials	Specific Weight γ (lb/in.^{3})	Modulus of Elasticity E (10^3) ksi	Modulus of Rigidity G (10^3) ksi	Yield Strength (ksi) σ_Y Tens.	Comp.[b]	Shear	Ultimate Strength (ksi) σ_u Tens.	Comp.[b]	Shear	% Elongation in 2 in. specimen	Poisson's Ratio ν	Coef of Therm. Expansion α (10^{-6})/°F
Metallic												
Aluminum Wrought Alloys — 2014-T6	0.101	10.6	3.9	60	60	25	68	68	42	10	0.35	12.8
Aluminum Wrought Alloys — 6061-T6	0.098	10.0	3.7	37	37	19	42	42	27	12	0.35	13.1
Cast Iron Alloys — Gray ASTM 20	0.260	10.0	3.9	–	–	–	26	97	–	0.6	0.28	6.70
Cast Iron Alloys — Malleable ASTM A-197	0.263	25.0	9.8	–	–	–	40	83	–	5	0.28	6.60
Copper Alloys — Red Brass C83400	0.316	14.6	5.4	11.4	11.4	–	35	0.35	9.80			
Copper Alloys — Bronze C86100	0.319	15.0	5.6	50	50	–	20	0.34	9.60			
Magnesium Alloys [Am 1004-T61]	0.066	6.48	2.5	22	22	–	40	40	22	1	0.30	14.3
Steel Alloys — Structural A36	0.284	29.0	11.0	36	36	–	58	58	–	30	0.32	6.60
Steel Alloys — Stainless 304	0.284	28.0	11.0	30	30	–	75	75	–	40	0.27	9.60
Steel Alloys — Tool L2	0.295	29.0	11.0	102	102	–	116	116	–	22	0.32	6.50
Titanium Alloys [Ti-6A1-4V]	0.160	17.4	6.4	134	134	–	145	145	–	16	0.36	5.20
Nonmetallic												
Concrete — Low Strength	0.086	3.20	–	–	–	1.8	–	–	–	–	0.15	6.0
Concrete — High Strength	0.086	4.20	–	–	–	5.5	–	–	–	–	0.15	6.0
Plastic Reinforced — Kevlar 49	0.0524	19.0	–	–	–	–	104	70	10.2	2.8	0.34	–
Plastic Reinforced — 30% Glass	0.0524	10.5	–	–	–	–	13	19	–	–	0.34	–
Wood Select Structural Grade — Douglas Fir	0.017	1.90	–	–	–	–	0.30[c]	3.78[d]	0.90[d]	–	0.29[e]	–
Wood Select Structural Grade — White Spruce	0.130	1.40	–	–	–	–	0.36[c]	5.18[d]	0.97[d]	–	0.31[e]	–

[a] Specific values may vary for a particular material due to alloy or mineral composition, mechanical working of the specimen, or heat treatment. For a more exact value reference books for the material should be consulted.

[b] The yield ahd ultimate strengths for ductile materials can be assumed equal for both ension and compression.

[c] Measured perpendicular to the grain.

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[e] Deformation measured perpendicular to the grain when the load is applied along the grain.

Contents

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