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机械工程设计

(注释版·原书第10版)

Shigley's

Mechanical Engineering Design

[美] 理查德 G.巴蒂纳斯 (Richard G. Budynas) 著
J.基斯 尼斯比特 (J. Keith Nisbett) 注释
朱殿华



机械工业出版社
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Dedication

To my wife, Joanne, my family, and my late brother, Bill, who advised me to enter the field of mechanical engineering. In many respects, Bill had considerable insight, skill, and inventiveness.

Richard G. Budynas

To my wife, Kim, for her unwavering support.

J. Keith Nisbett

Dedication to Joseph Edward Shigley

Joseph Edward Shigley (1909–1994) is undoubtedly one of the most well-known and respected contributors in machine design education. He authored or coauthored eight books, including *Theory of Machines and Mechanisms* (with John J. Uicker, Jr.), and *Applied Mechanics of Materials*. He was coeditor-in-chief of the well-known *Standard Handbook of Machine Design*. He began *Machine Design* as sole author in 1956, and it evolved into *Mechanical Engineering Design*, setting the model for such textbooks. He contributed to the first five editions of this text, along with coauthors Larry Mitchell and Charles Mischke. Uncounted numbers of students across the world got their first taste of machine design with Shigley's textbook, which has literally become a classic. Nearly every mechanical engineer for the past half century has referenced terminology, equations, or procedures as being from "Shigley." McGraw-Hill is honored to have worked with Professor Shigley for more than 40 years, and as a tribute to his lasting contribution to this textbook, its title officially reflects what many have already come to call it—*Shigley's Mechanical Engineering Design*.

Having received a bachelor's degree in Electrical and Mechanical Engineering from Purdue University and a master of science in Engineering Mechanics from the University of Michigan, Professor Shigley pursued an academic career at Clemson College from 1936 through 1954. This led to his position as professor and head of Mechanical Design and Drawing at Clemson College. He joined the faculty of the Department of Mechanical Engineering of the University of Michigan in 1956, where he remained for 22 years until his retirement in 1978.

Professor Shigley was granted the rank of Fellow of the American Society of Mechanical Engineers in 1968. He received the ASME Mechanisms Committee Award in 1974, the Worcester Reed Warner Medal for outstanding contribution to the permanent literature of engineering in 1977, and the ASME Machine Design Award in 1985.

Joseph Edward Shigley indeed made a difference. His legacy shall continue.

About the Authors

Richard G. Budynas is Professor Emeritus of the Kate Gleason College of Engineering at Rochester Institute of Technology. He has more than 50 years experience in teaching and practicing mechanical engineering design. He is the author of a McGraw-Hill textbook, *Advanced Strength and Applied Stress Analysis*, Second Edition; and coauthor of a McGraw-Hill reference book, *Roark's Formulas for Stress and Strain*, Eighth Edition. He was awarded the BME of Union College, MSME of the University of Rochester, and the PhD of the University of Massachusetts. He is a licensed Professional Engineer in the state of New York.

J. Keith Nisbett is an Associate Professor and Associate Chair of Mechanical Engineering at the Missouri University of Science and Technology. He has more than 30 years of experience with using and teaching from this classic textbook. As demonstrated by a steady stream of teaching awards, including the Governor's Award for Teaching Excellence, he is devoted to finding ways of communicating concepts to the students. He was awarded the BS, MS, and PhD of the University of Texas at Arlington.

前言

本书的写作目的

本书针对那些刚刚开始学习机械工程设计的学生，核心内容就是将工程实际中的零件设计规范与相应概念的基本发展状况相融合，引领学生逐渐熟悉零件的设计标准、规范及选用依据。因此，对于实现将学生逐步培养成设计工程师的目标，本书具有不可替代的作用。本书的写作宗旨如下：

- 涵盖关于机械设计的全部基础知识，包括设计过程，工程力学和工程材料，动载荷和静载荷作用下零部件失效形式的预防，及常用机械零部件的主要特征。
- 针对研究内容提供广泛应用的工程实例及相应解决方案。
- 鼓励、培养学生将设计和分析结合在一起，将基本概念和工程实践中的零件设计规范结合在一起。

新版特色

本书第 10 版对如下内容进行了修订和改进：

- 新增加第 20 章“几何尺寸和公差”。该章是机械设计中的一个重要主题。绝大多数制造企业在机器的设计、生产和质量控制过程中将尺寸和公差（GD&T）做为精确描述零件和装配体的一种标准化手段，但令人遗憾的是，许多机械工程师尚未充分地借助尺寸和公差的相关定义和概念来解读图样。

当几何尺寸和公差在制造业日益盛行之时，许多工程院校正在逐步淘汰复杂的制图课程，倾向于计算机辅助设计教学，后者随后转变为三维（3D）实体建模。在这种建模过程中，零件采用理想化尺寸构建。然而，在采用三维尺寸创建完美零件的这一能力培养过程中，往往缺少从生产和质检的角度来唯一和精确地描述零件的思想，这实在是令人感到惋惜！

要充分理解和掌握几何尺寸和公差方面的知识，就必须经过完整系统的课程学习或培训。一些工程师也许会从严格的培训计划中获益，然而所有的机械工程师都必须熟悉尺寸和公差方面的基本定义和概念。本书第 20 章的内容旨在为所有的机械设计师提供此方面必备的基础知识。

在一门课程中，教材附加章节的讲授会受到学时限制，为此，本书以适合学生自学的方式来编排附加章节。每章后面均附有习题，这些习题旨在检查学生对一些最基本概念的理解程度。教师可以将附加章节作为一项课后作业提供给学生，同时给予少量讲解或课后讨论，当然，每章中也提供了大量内容用于扩展讨论和演示。

- 在第 1 章“机械工程设计导论”中，在设计实践方面做了扩充。对设计要素进行了进一步阐述，同时，也对设计要素中的可靠度和失效概率间存在的统计学关系进行了描述。这与上一版中将设计过程中的统计学要素作为最后一章内容加以描述有所不同。“尺寸和公差”这一节的内容也进行了扩充，着重阐明对产品的尺寸和公差的确定是机械设计过程中至关重要的一部分内容。

- 新版中去除了上一版中“统计学计算”一章的内容。此章内容中与新版保持一致的相关统计学知识已包括在新版中有关统计学的相关章节中。同样，新版中删去了包含在上一版第 6 章“变载荷作用下的疲劳失效”中有关随机方法这一节内容，这样做的原因是基于读者反馈和作者的深入考虑：该

节包含了过多的内容和数据，这对解决那些简单的设计问题反而无益。

在第 11 章“滚动轴承”中，将韦布尔概率分布引入到轴承寿命计算过程中。

为了更好地与工程实际衔接，新版对每章后的习题进行了重新检查，以确保这些习题都已得到清晰描述。差不多一半的习题设计用于解决工程实际问题，新版的习题中也配置了许多开放性的题目以供读者去探索和设计。

与工程衔接

新版将继续彰显麦格劳-希尔与工程衔接的教育特色——提供作业布置和评价平台，借助此平台教师可轻松实现在线作业、测验和测试。学生们则可根据自己的进度安排进行在线学习以获得重要的技能锻炼机会。遗憾的是，使用本引进教材的国内读者，暂时无法进行在线学习。

麦格劳-希尔的 LearnSmart

麦格劳-希尔的 LearnSmart 是一个可以帮助学生快速高效学习的自适应学习系统。学生可借助此系统获得更多的知识以走向更大的成功。通过解答一系列自适应性问题，LearnSmart 能准确获知每个学生的学习水平，并为每个学生定制个性化学习计划，教师亦可通过该系统获知学生的学习动态。因此，可将该系统视为一个按等级分配作业的内在评价系统。读者可咨询当地的麦格劳-希尔销售代表获得重要信息，也可通过访问网址：www.mhlearnsmart.com 观看该系统演示。同样的，国内读者暂时也享受不到本项服务。

麦格劳-希尔的 SmartBook

借助智能自适应引擎 LearnSmart，麦格劳-希尔的 SmartBook 将为该系统的使用者提供绝无仅有的可持续性阅读体验。SmartBook 把学生已掌握的知识和尚未掌握的知识区分开来，不断地夯实学生最可能遗忘的基本概念，并为每个学生定制个性化的阅读内容。使用 SmartBook，可将阅读过程由被动的体验转变为一个充满活力的、令人振奋的过程。在这一过程中，学生将掌握更多的重要知识，为走入课堂做好充分的准备。SmartBook 包括功能强大的报告，这些报告囊括了学生学习所需的特定题目和学习目标。借助这些报告，教师可以洞察学生对书本知识的掌握情况，感受班级动态，提高课堂利用率，与学生单独互动并对学生成绩进行评估。

SmartBook 是如何工作的？每一个 SmartBook 包括四个组件：预览、阅读、练习和巩固练习。首先，通过预览每章内容和关键学习目标，学生们学习相关内容。接下来，根据 SmartBook 持续提供的自适应诊断结果，学生们被引导到他们最需要练习的主题进行阅读和练习，直到 SmartBook 引导他们进入巩固练习阶段，该阶段针对学生最可能忘记的重要内容进行加强练习，以保证重要的概念已被学生掌握和牢记。

麦格劳-希尔的 Create™

使用该功能可以帮助读者轻松实现章节重排、多资源内容衔接和快速上传读者自行编写的教学大纲、讲义等内容。可以借助 Create 查找成千上万本麦格劳-希尔的相关教材，编排适合自己风格的教材。该功能甚至可以通过挑选封面和在封面上添加署名、学校和课程信息的方式实现个性化教材展现。

教师可在网 (www.mcgrawhillcreate.com) 上体验麦格劳-希尔 Create™ 下的个性化教学定制过程。

在网站中 (www.mhhe.com/shigley) 还可看到如下媒体产品信息:

学生辅助学习内容

- 机械设计师工程基础 (FE) 考试题目。为学生提供交互性的习题及答案, 这些题目以自测题的形式提供给学生, 为参加 FE 考试做好充分准备。

教师辅助教学内容

- 解题手册。该手册向教师提供每章课后非设计类题目的习题答案。
- PowerPoint 幻灯片。这些幻灯片涵盖课程大纲内容, 包括本书中列出的所有的图、表和方程。教师可在这些幻灯片的基础上开展课堂讲解。
- C. O. S. M. O. S. 这是一个完整的在线组织式解题手册系统。教师可使用该系统进行常规作业的布置、小测验以及使用每章课后习题进行考试。

当然, 本项服务仅在美国本土提供, 其他教材引进国家暂时无法体验。

致谢

本书第 10 版出版之际, 作者谨向 50 年来一直致力于本书第 10 版及前 9 版出版工作的所有人员致以诚挚的谢意! 本书第 10 版编写过程中, 加州州立大学的 Peter J. Schuster 完成了本书的扩展部分, 高科技制造有限公司的 Glenn Traner 完成了本书第 20 章的绘图工作, 西英格兰大学的 Jędrzej Galecki 完成了原版书封面 CAD 模型的设计工作。参与本书审阅的全体人员包括亚利桑那州的 Kenneth Huebner、艾奥瓦州的 Gloria Starns、麦吉尔大学的 Tim Lee、密尔沃基工学院的 Robert Rizza、密西西比州立大学 Richard Patton、罗切斯特理工学院的 Stephen Boedo、伊利诺伊大学的 Om Agrawal、得克萨斯州农工大学的 Arun Srinivasa、阿尔伯塔大学的 Jason Carey、匹兹堡大学的 Patrick Smolinski 和弗吉尼亚理工大学的 Dennis Hong, 以及为本书在中国顺利出版而进行注释工作的天津大学朱殿华。在此, 作者对上述人员在参与本书出版过程中所做出的卓有成效的工作致以特别感谢!

符 号 说 明

$\mathcal{L}$	Life in hours
l	Length
M	Fundamental dimension mass, moment
$\mathbf{M}$	Moment vector
m	Mass, slope, strain-strengthening exponent
N	Normal force, number, rotational speed, number of cycles
n	Load factor, rotational speed, factor of safety
n_d	Design factor
P	Force, pressure, diametral pitch
PDF	Probability density function
p	Pitch, pressure, probability
Q	First moment of area, imaginary force, volume
q	Distributed load, notch sensitivity
R	Radius, reaction force, reliability, Rockwell hardness, stress ratio, reduction in area
$\mathbf{R}$	Vector reaction force
r	Radius
$\mathbf{r}$	Distance vector
S	Sommerfeld number, strength
s	Distance, sample standard deviation, stress
T	Temperature, tolerance, torque, fundamental dimension time
$\mathbf{T}$	Torque vector
t	Distance, time, tolerance
U	Strain energy
u	Strain energy per unit volume
V	Linear velocity, shear force
v	Linear velocity
W	Cold-work factor, load, weight
w	Distance, gap, load intensity
X	Coordinate, truncated number
x	Coordinate, true value of a number, Weibull parameter
Y	Coordinate
y	Coordinate, deflection
Z	Coordinate, section modulus, viscosity
z	Coordinate, dimensionless transform variable for normal distributions
α	Coefficient, coefficient of linear thermal expansion, end-condition for springs, thread angle
β	Bearing angle, coefficient
Δ	Change, deflection
δ	Deviation, elongation
ϵ	Eccentricity ratio, engineering (normal) strain
ε	True or logarithmic normal strain
Γ	Gamma function, pitch angle

γ	Pitch angle, shear strain, specific weight
λ	Slenderness ratio for springs
μ	Absolute viscosity, population mean
ν	Poisson ratio
ω	Angular velocity, circular frequency
ϕ	Angle, wave length
ψ	Slope integral
ρ	Radius of curvature, mass density
σ	Normal stress
σ'	Von Mises stress
$\hat{\sigma}$	Standard deviation
τ	Shear stress
θ	Angle, Weibull characteristic parameter
$\text{\$}$	Cost per unit weight
$\text{\$}$	Cost

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