Mechanical Engineering

Shigley's Mechanical Engineering Design,
Eighth Edition

Budynas–Nisbett

McGraw–Hill Primis

ISBN: 0–390–76487–6

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This book was printed on recycled paper.

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http://www.primisonline.com

111 0192GEN ISBN: 0–390–76487–6

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Preface

Objectives

This text is intended for students beginning the study of mechanical engineering design. The focus is on blending fundamental development of concepts with practical specification of components. Students of this text should find that it inherently directs them into familiarity with both the basis for decisions and the standards of industrial components. For this reason, as students transition to practicing engineers, they will find that this text is indispensable as a reference text. The objectives of the text are to:

- Cover the basics of machine design, including the design process, engineering mechanics and materials, failure prevention under static and variable loading, and characteristics of the principal types of mechanical elements.
- Offer a practical approach to the subject through a wide range of real-world applications and examples.
- Encourage readers to link design and analysis.
- Encourage readers to link fundamental concepts with practical component specification.

New to This Edition

This eighth edition contains the following significant enhancements:

- *New chapter on the Finite Element Method.* In response to many requests from reviewers, this edition presents an introductory chapter on the finite element method. The goal of this chapter is to provide an overview of the terminology, method, capabilities, and applications of this tool in the design environment.
- *New transmission case study.* The traditional separation of topics into chapters sometimes leaves students at a loss when it comes time to integrate dependent topics in a larger design process. A comprehensive case study is incorporated through standalone example problems in multiple chapters, then culminated with a new chapter that discusses and demonstrates the integration of the parts into a complete design process. Example problems relevant to the case study are presented on engineering paper background to quickly identify them as part of the case study.
- *Revised and expanded coverage of shaft design*. Complementing the new transmission case study is a significantly revised and expanded chapter focusing on issues relevant to shaft design. The motivating goal is to provide a meaningful presentation that allows a new designer to progress through the entire shaft design process – from general shaft layout to specifying dimensions. The chapter has been moved to immediately follow the fatigue chapter, providing an opportunity to seamlessly transition from the fatigue coverage to its application in the design of shafts.
- *Availability of information to complete the details of a design.* Additional focus is placed on ensuring the designer can carry the process through to completion.

By assigning larger design problems in class, the authors have identified where the students lack details. For example, information is now provided for such details as specifying keys to transmit torque, stress concentration factors for keyways and retaining ring grooves, and allowable deflections for gears and bearings. The use of internet catalogs and engineering component search engines is emphasized to obtain current component specifications.

- *Streamlining of presentation.* Coverage of material continues to be streamlined to focus on presenting straightforward concept development and a clear design procedure for student designers.

Content Changes and Reorganization

A new Part 4: *Analysis Tools* has been added at the end of the book to include the new chapter on finite elements and the chapter on statistical considerations. Based on a survey of instructors, the consensus was to move these chapters to the end of the book where they are available to those instructors wishing to use them. Moving the statistical chapter from its former location causes the renumbering of the former chapters 2 through 7. Since the shaft chapter has been moved to immediately follow the fatigue chapter, the component chapters (Chapters 8 through 17) maintain their same numbering. The new organization, along with brief comments on content changes, is given below:

Part 1: Basics

Part 1 provides a logical and unified introduction to the background material needed for machine design. The chapters in Part 1 have received a thorough cleanup to streamline and sharpen the focus, and eliminate clutter.

- *Chapter 1, Introduction.* Some outdated and unnecessary material has been removed. A new section on problem specification introduces the transmission case study.
- *Chapter 2, Materials.* New material is included on selecting materials in a design process. The Ashby charts are included and referenced as a design tool.
- *Chapter 3, Load and Stress Analysis.* Several sections have been rewritten to improve clarity. Bending in two planes is specifically addressed, along with an example problem.
- *Chapter 4, Deflection and Stiffness.* Several sections have been rewritten to improve clarity. A new example problem for deflection of a stepped shaft is included. A new section is included on elastic stability of structural members in compression.

Part 2: Failure Prevention

This section covers failure by static and dynamic loading. These chapters have received extensive cleanup and clarification, targeting student designers.

- *Chapter 5, Failures Resulting from Static Loading.* In addition to extensive cleanup for improved clarity, a summary of important design equations is provided at the end of the chapter.
- *Chapter 6, Fatigue Failure Resulting from Variable Loading.* Confusing material on obtaining and using the S-N diagram is clarified. The multiple methods for obtaining notch sensitivity are condensed. The section on combination loading is rewritten for greater clarity. A chapter summary is provided to overview the analysis roadmap and important design equations used in the process of fatigue analysis.

Part 3: Design of Mechanical Elements

Part 3 covers the design of specific machine components. All chapters have received general cleanup. The shaft chapter has been moved to the beginning of the section. The arrangement of chapters, along with any significant changes, is described below:

- *Chapter 7, Shafts and Shaft Components.* This chapter is significantly expanded and rewritten to be comprehensive in designing shafts. Instructors that previously did not specifically cover the shaft chapter are encouraged to use this chapter immediately following the coverage of fatigue failure. The design of a shaft provides a natural progression from the failure prevention section into application toward components. This chapter is an essential part of the new transmission case study. The coverage of setscrews, keys, pins, and retaining rings, previously placed in the chapter on bolted joints, has been moved into this chapter. The coverage of limits and fits, previously placed in the chapter on statistics, has been moved into this chapter.
- *Chapter 8, Screws, Fasteners, and the Design of Nonpermanent Joints.* The section on setscrews, keys, and pins, has been moved from this chapter to Chapter 7. The coverage of bolted and riveted joints loaded in shear has been returned to this chapter.
- *Chapter 9, Welding, Bonding, and the Design of Permanent Joints.* The section on bolted and riveted joints loaded in shear has been moved to Chapter 8.
- *Chapter 10, Mechanical Springs.*
- *Chapter 11, Rolling-Contact Bearings.*
- *Chapter 12, Lubrication and Journal Bearings.*
- *Chapter 13, Gears – General.* New example problems are included to address design of compound gear trains to achieve specified gear ratios. The discussion of the relationship between torque, speed, and power is clarified.
- *Chapter 14, Spur and Helical Gears.* The current AGMA standard (ANSI/AGMA 2001-D04) has been reviewed to ensure up-to-date information in the gear chapters. All references in this chapter are updated to reflect the current standard.
- *Chapter 15, Bevel and Worm Gears.*
- *Chapter 16, Clutches, Brakes, Couplings, and Flywheels.*
- *Chapter 17, Flexible Mechanical Elements.*
- *Chapter 18, Power Transmission Case Study.* This new chapter provides a complete case study of a double reduction power transmission. The focus is on providing an example for student designers of the process of integrating topics from multiple chapters. Instructors are encouraged to include one of the variations of this case study as a design project in the course. Student feedback consistently shows that this type of project is one of the most valuable aspects of a first course in machine design. This chapter can be utilized in a tutorial fashion for students working through a similar design.

Part 4: Analysis Tools

Part 4 includes a new chapter on finite element methods, and a new location for the chapter on statistical considerations. Instructors can reference these chapters as needed.

- *Chapter 19, Finite Element Analysis.* This chapter is intended to provide an introduction to the finite element method, and particularly its application to the machine design process.

- *Chapter 20, Statistical Considerations.* This chapter is relocated and organized as a tool for users that wish to incorporate statistical concepts into the machine design process. This chapter should be reviewed if Secs. 5–13, 6–17, or Chap. 11 are to be covered.

Supplements

The 8th edition of *Shigley's Mechanical Engineering Design* features McGraw-Hill's ARIS (Assessment Review and Instruction System). ARIS makes homework meaningful—and manageable—for instructors and students. Instructors can assign and grade text-specific homework within the industry's most robust and versatile homework management system. Students can access multimedia learning tools and benefit from unlimited practice via algorithmic problems. Go to aris.mhhe.com to learn more and register!
The array of tools available to users of *Shigley's Mechanical Engineering Design* includes:

Student Supplements

- *Tutorials—Presentation of major concepts, with visuals.* Among the topics covered are pressure vessel design, press and shrink fits, contact stresses, and design for static failure.
- *MATLAB® for machine design.* Includes visual simulations and accompanying source code. The simulations are linked to examples and problems in the text and demonstrate the ways computational software can be used in mechanical design and analysis.
- *Fundamentals of engineering (FE) exam questions for machine design.* Interactive problems and solutions serve as effective, self-testing problems as well as excellent preparation for the FE exam.
- *Algorithmic Problems.* Allow step-by-step problem-solving using a recursive computational procedure (algorithm) to create an infinite number of problems.

Instructor Supplements (under password protection)

- *Solutions manual.* The instructor's manual contains solutions to most end-of-chapter nondesign problems.
- *PowerPoint® slides.* Slides of important figures and tables from the text are provided in PowerPoint format for use in lectures.

List of Symbols

This is a list of common symbols used in machine design and in this book. Specialized use in a subject-matter area often attracts fore and post subscripts and superscripts. To make the table brief enough to be useful the symbol kernels are listed. See Table 14–1, pp. 715–716 for spur and helical gearing symbols, and Table 15–1, pp. 769–770 for bevel-gear symbols.

A	Area, coefficient
$\mathbf{A}$	Area variate
a	Distance, regression constant
$\hat{a}$	Regression constant estimate
$\mathbf{a}$	Distance variate
B	Coefficient
Bhn	Brinell hardness
$\mathbf{B}$	Variate
b	Distance, Weibull shape parameter, range number, regression constant, width
$\hat{b}$	Regression constant estimate
$\mathbf{b}$	Distance variate
C	Basic load rating, bolted-joint constant, center distance, coefficient of variation, column end condition, correction factor, specific heat capacity, spring index
c	Distance, viscous damping, velocity coefficient
CDF	Cumulative distribution function
COV	Coefficient of variation
$\mathbf{c}$	Distance variate
D	Helix diameter
d	Diameter, distance
E	Modulus of elasticity, energy, error
e	Distance, eccentricity, efficiency, Naperian logarithmic base
F	Force, fundamental dimension force
f	Coefficient of friction, frequency, function
fom	Figure of merit
G	Torsional modulus of elasticity
g	Acceleration due to gravity, function
H	Heat, power
H_B	Brinell hardness
HRC	Rockwell C-scale hardness
h	Distance, film thickness
$\hbar_{CR}$	Combined overall coefficient of convection and radiation heat transfer
I	Integral, linear impulse, mass moment of inertia, second moment of area
i	Index
$\mathbf{i}$	Unit vector in x-direction

J	Mechanical equivalent of heat, polar second moment of area, geometry factor
j	Unit vector in the y-direction
K	Service factor, stress-concentration factor, stress-augmentation factor, torque coefficient
k	Marin endurance limit modifying factor, spring rate
k	k variate, unit vector in the z-direction
L	Length, life, fundamental dimension length
LN	Lognormal distribution
l	Length
M	Fundamental dimension mass, moment
M	Moment vector, moment variate
m	Mass, slope, strain-strengthening exponent
N	Normal force, number, rotational speed
N	Normal distribution
n	Load factor, rotational speed, safety factor
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
R	Vector reaction force
r	Correlation coefficient, radius
r	Distance vector
S	Sommerfeld number, strength
S	S variate
s	Distance, sample standard deviation, stress
T	Temperature, tolerance, torque, fundamental dimension time
T	Torque vector, torque variate
t	Distance, Student's t-statistic, time, tolerance
U	Strain energy
U	Uniform distribution
u	Strain energy per unit volume
V	Linear velocity, shear force
v	Linear velocity
W	Cold-work factor, load, weight
W	Weibull distribution
w	Distance, gap, load intensity
w	Vector distance
X	Coordinate, truncated number
x	Coordinate, true value of a number, Weibull parameter
x	x variate
Y	Coordinate
y	Coordinate, deflection
y	y variate
Z	Coordinate, section modulus, viscosity
z	Standard deviation of the unit normal distribution
z	Variate of z

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
$\boldsymbol{\epsilon}$	Normal distribution with a mean of 0 and a standard deviation of s
ε	True or logarithmic normal strain
Γ	Gamma function
γ	Pitch angle, shear strain, specific weight
λ	Slenderness ratio for springs
$\boldsymbol{\lambda}$	Unit lognormal with a mean of l and a standard deviation equal to COV
μ	Absolute viscosity, population mean
ν	Poisson ratio
ω	Angular velocity, circular frequency
ϕ	Angle, wave length
ψ	Slope integral
ρ	Radius of curvature
σ	Normal stress
σ'	Von Mises stress
$\boldsymbol{\sigma}$	Normal stress variate
$\hat{\sigma}$	Standard deviation
τ	Shear stress
$\boldsymbol{\tau}$	Shear stress variate
θ	Angle, Weibull characteristic parameter
¢	Cost per unit weight
$	Cost