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MACHINE

（英文版 · 原书第8版）

机械零件设计（缩编版）

M. F. SPOTTS
（美）T. E. SHOUP 著
L. E. HORNBERGER
刘莹 李威 缩编

附赠光盘

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DESIGN OF MACHINE ELEMENTS

（美）M. F. SPOTTS　T. E. SHOUP　L. E. HORNBERGER　著

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SI PREFIXES

1000000 = 10^6 mega, M
1000 = 10^3 kilo, k
100 = 10^2 hecto, h
10 = 10 deka, da
0.1 = 10^{-1} deci, d
0.01 = 10^{-2} centi, c
0.001 = 10^{-3} milli, m
0.000001 = 10^{-6} micro, μ

lb or lbf, pound force
lbm, pound mass
psi, lb/in.^{2}
J, joule; newton-meter, Nm
W, watt; joule per sec, J/sec; Nm/sec
Pa, pascal; N/m^2
MPa, mega pascal; N/mm^2

An asterisk follows each number below that represents an exact definition. Numbers not followed by an asterisk are approximate representations of definitions or the results of physical measurements.

LENGTH

1 in. = 25.4* mm = 0.0254* m
1 ft = 304.8* mm = 0.3048* m
1 yd = 914.4* mm = 0.9144* m
1 mi = 5280 ft = 1760 yd = 1.609344* km
1 furlong = 220 yd = $\frac{1}{8}$ mi = 201.168* mi
1 rod = 16.5 ft
1 fathom = 6 ft

1 mm = 0.039370079 in.
1 m = 39.370079 in. = 3.280840 ft
1 m = 1.0936 yd
1 km = 0.62137 mi
1 micron = 0.000001 m = 0.001 mm
1 Angstrom = 0.0000001 mm

AREA

1 in.^{2} = 645.16* mm^2
1 ft^2 = 0.09290304* m^2
1 yd^2 = 0.83612736* m^2
1 mi^2 = 2.58998811* (km)^2
1 acre = $\frac{5280^2}{640}$ = 43560 ft^2
= (208.713 ft)^2
= 4046.856 m^2
= 0.4048656 hectares

1 mm^2 = 0.001550003 in.^{2}
1 m^2 = 1550.003 in.^{2}
= 10.76391 ft^2 = 1.19599 yd^2
1 km^2 = 0.38610 mi^2
1 hectare = (100 m)^2
= 2.471054 acres

VOLUME

1 in.^{3} = 16387.064* mm^3
1 ft^3 = 0.028316846592* m^3
1 yd^3 = 0.764554857984* m^3
1 gallon (US) = 231 in.^{3}
= 3.785411784* liter
1 qt (US) = $\frac{1}{4}$ gallon
= 0.946352946* liter
1 gallon (UK) = 277.42 in.^{3}
= 1.20095 US gallon = 4.54609 liter
1 bushel (US) = 2150.42 in.^{3}
= 1.24446 ft^3 = 0.03523907 m^3
1 barrel (42 US gallons) = 158.987 liters

1 mm^3 = 0.000061024 in.^{3}
1 m^3 = 1000 liters = 61023.74 in.^{3}
= 35.31467 ft^3
= 1.30795 yd^3
1 liter = 1.000 cc^3 = 61.02374 in.^{3}
= 0.264172 gallons = 1.056688 qt
1 cc = (10 mm)^3 = 1000 mm^3
1 liter = 1000 cc
= 1000000 mm^3
1 m^3 = (1000 mm)^3
= 1000000000 mm^3
= 1000 liters

FORCE

1 lb = 4.4482216N
= 444822.2dynes
1 poundal = 0.138255N

1 N = 100000dynes = 0.22480894 lb
1 dyne = 0.00001 N = 0.00000224809 lb

STRESS or PRESSURE

1 lb/in. = 175.12683N/m
1 lb/ft = 14.593903N/m
1 lb/in.^{2} = psi = 6894.7572N/m^2 (Pa)

1 N/m = 0.005710147 lb/in.
= 0.06852176 lb/ft
1 N/m^2 = 1 Pa
= 0.00014503774 lb/in.^{2}
= 0.02088543 lb/ft^2

1 lb/ft^2 = 47.880259N/m^2 (Pa)
1 atmosphere = 14.6959 lb/in.^{2} = 101325.0N/m^2 (Pa)
1 in. water (39.2 ℉) = 0.036126 lb/in.^{2} = 249.082N/m^2 (Pa)
1 ft. water (39.2 ℉) = 0.43352 lb/in.^{2} = 62.426 lb/ft^2 = 2988.98N/m^2 (Pa)

MASS

1 lbm = 0.45359237kg
1 slug = 32.17405 lbm = 14.593903kg
1 ton (short) = 2000 lb = 907.18474kg
1 ton (long) = 2240 lb = 1016.046909kg

1 kg = 2.2046226 lbm
1 kg = 0.06852176 slug

DENSITY

1 lbm/in.^{3} = 27679.905kg/m^3
1 lbm/ft^3 = 16.01846kg/m^3
1 slug/ft^3 = 515.379kg/m^3

1 kg/m^3 = 0.00003612729 lbm/in.^{3}
= 0.06242795 lbm/ft^3
= 0.001940321 slug/ft^3

WORK and ENERGY

1 in. lb = 0.1129848Nm (J) work
1 ft lb = 1.35582Nm (J)
1 Btu (59 ℉) = 777.9805ft lb = 1054.80Nm (J)
1 calorie (59 ℉) = 3.08729ft lb = 4.18580Nm (J)
1 Btu = 251.995calories

1 Nm = 1 J = 10^7 ergs = 8.850746in. lb
= 0.737562ft lb

POWER

1 hp = 550ft lb/sec = 0.7457kW (kN/sec, 1 kW = 1.3410hp)

MISCELLANEOUS

Free fall, g = 32.1740ft/sec^2 = 386.09in./sec^2 = 9.80665m/sec^2 acceleration
1 mi/gal = 0.425144km/liter, 1 km/liter = 2.352144mi/gal

国外高校优秀教材审定委员会

出版说明

随着我国加入WTO，国际间的竞争越来越激烈，而国际间的竞争实际上也就是人才的竞争、教育的竞争。为了加快培养具有国际竞争力的高水平技术人才，加快我国教育改革的步伐，国家教育部近来出台了一系列倡导高校开展双语教学、引进原版教材的政策。以此为契机，机械工业出版社陆续推出了一系列国外影印版教材，其内容涉及高等学校公共基础课，以及机、电、信息领域的专业基础课和专业课。

引进国外优秀原版教材，在有条件的学校推动开展英语授课或双语教学，自然也引进了先进的教学思想和教学方法，这对提高我国自编教材的水平，加强学生的英语实际应用能力，使我国的高等教育尽快与国际接轨，必将起到积极的推动作用。

为了做好教材的引进工作，机械工业出版社特别成立了由著名专家组成的国外高校优秀教材审定委员会。这些专家对实施双语教学做了深入细致的调查研究，对引进原版教材提出了许多建设性意见，并慎重地对每一本将要引进的原版教材一审再审，精选再精选，确认教材本身的质量水平以及权威性和先进性，以期所引进的原版教材能适应我国学生的外语水平和学习特点。在引进工作中，审定委员会还结合我国高校教学课程体系的设置和要求，对原版教材的教学思想和方法的先进性、科学性严格把关，同时尽量考虑原版教材的系统性和经济性。

这套教材出版后，我们将根据各高校的双语教学计划，及时地将其推荐给各高校选用。希望高校师生在使用教材后及时反馈意见和建议，使我们能够更好地为教学改革服务。

机械工业出版社

高等教育分社

序

目前，我国在全世界制造业中所起的作用日益加大，很多产品迅速在世界各国打开市场，这就要求从事机械设计和制造的人员更好地掌握英语并使用它与国外交流，了解外国的情况，这是十分重要的。有的学生虽然学习英语花费了不少时间，但是缺少专业英语的练习，因此很简单的专业名词也不知道，这是很大的浪费，也限制了这些学生的发展。因此出版一些英语教材，对于提高我国学生的英语和专业课水平都是十分有利和必要的。我在教授机械设计这门课程的一段时间中，选择了一些机械设计的英文教材让学生阅读，其内容包括机械零件的设计计算、结构设计、材料和热处理选择等。“弹簧”一章只讲英语教材，中文教材由学生自学。还曾经选择一些英文习题，要求学生先翻译成中文再做题。一个学期以后，学生很快掌握了专业英语的特点，他们用英语阅读专业书刊的能力有了明显的提高。

因此我认为出版一些英语教材的精选本，供教师和学生作为专业的英语教科书或教学参考书，对于提高我国学生的英语水平和机械设计专业的教学质量，是十分必要的。

本书是 M. F. Spotts、T. E. Shoup、L. E. Hornberger 等所著《机械零件设计》(Design of Machine Elements)第 8 版的缩编本。

在阅读了本书以后，我认为有以下特色：

1. 删去了大量我国机械设计课程不涉及的内容。原教材中有许多材料力学、金属材料、塑料零件设计等内容，而这些内容在我国另外开设有专门的课程，所以书中没有保留，并同时删去了有关的习题和例题。

2. 删去了一些与我国情况不适合的内容，如齿轮的计算方法和标准就与我国国家标准不同，对此也做了删减。

3. 本书保持了原教材的主要特色。原教材在结合工程设计、解决工程实际问题方面有不少有特色的内容，举出的应用实例较多，习题的数量大、类型多，对我们有较大的启发性

和引导作用。

以上措施，使本书的内容篇幅和价格更适合我国机械设计教学的实际情况，不失为一本较好的教学用书。

清华大学精密仪器与机械学系
吴宗泽
2007 年 7 月 4 日

Preface

We are pleased to publish this eighth edition of a text that has become a classic among the machine design community. This new edition contains a number of important improvements over the previous edition.

The example problems have been reformatted using a structured approach. This addition should make the logic of the example problems much easier to follow, and the authors recommend that the student of machine design adopt this structured approach in their work.

Most of the spreadsheet modules found in the previous edition have been upgraded and improved. In many cases the use of "drop-down menus" allows the user to switch between unit systems without the need to switch to a different module. Additionally, the spreadsheet modules now include command buttons to allow the user to view additional information of importance to their application. In one of the spreadsheets, the user can produce a scaled plot of the Mohr's Circle for a given state of two-dimensional stress. Some completely new spreadsheet modules have been added to allow a greater range of problems to be solved.

Perhaps one of the most important new features of this edition is the inclusion of a chapter on design with plastic materials. This chapter, written by L. E. Hornberger, a world-class leader in plastics design and recycling, provides an excellent overview of how plastic materials are having a strong positive influence on the design of machine elements. This new edition represents over 80 years of experience of its three authors in industry and in the classroom. As with any "work in process," we continue to welcome your helpful suggestions for improvement of this text.

As with any project of this magnitude, there are many people to thank for their suggestions, contributions, and helpful ideas. In particular we thank William L. Cleghorn, University of Toronto; Harvey Hoy, University of Wisconsin; Richard A. Hultin, Rochester Institute of Technology; Ronald L. Priebe, University of North Carolina Charlotte; and Tom Overman, Santa Clara University.

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Santa Clara University

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Introduction

Fundamentally, design is the process of problem solving. Problem solving is used by professionals from many different fields in the normal course of their work. In this chapter, we will look at the definition of design and how it fits into the overall scheme of problem solving. We will also look at the process one uses in implementing a design task. We will then discuss the computational tools that are helpful to the design analysis process. Finally, we will take a brief look at where one goes to acquire technical information to augment the design process.

I-1 Problem Solving and Design

Engineering is defined by ABET (the Accreditation Board for Engineering and Technology) as

> …that profession in which knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind.

What differentiates engineering from many other fields is that it attempts to go from theory into practice for the purpose of developing products and processes instead of merely observing the phenomena of that science or art. For example, a physicist studies and records findings in order to understand some phenomenon or physical process better. On the other hand, an engineer utilizes scientific information to make a particular process or product for use by consumers. ABET further defines the design portion of engineering activity as follows:

> Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences and math-