

时代教育·国外高校优秀教材精选



制造技术

——铸造、成形和焊接 (英文版·原书第2版)

Manufacturing Technology
— Foundry, Forming and Welding

(美) P N Rao 著



时代教育·国外高校优秀教材精选

制造技术

——铸造、成形和焊接

(英文版·原书第2版)

gzh 3080178 gzh 3080195
0219034

**Manufacturing Technology —
Foundry, Forming and Welding**

(美) P N Rao 著

机械工业出版社

P N Rao: Manufacturing Technology - Foundry, Forming and Welding

ISBN: 0-07-463180-2

Copyright© 1998 by The McGraw-Hill Companies, Inc.

Original language published by the McGraw-Hill Companies, Inc. All Rights reserved. No part of this publication may be reproduced or distributed in any means, or stored in a database or retrieval system, without the prior written permission of the publisher.

Authorized English language reprint edition jointly published by McGraw-Hill Education (Asia) Co. and China Machine Press. This edition is authorized for sale in the People's Republic of China only, excluding Hong Kong, Macao SAR and Taiwan. Unauthorized export of this edition is a violation of Copyright Act. Violation of this Law is subject to Civil and Criminal Penalties.

本书英文影印版由机械工业出版社和美国麦格劳-希尔教育出版(亚洲)公司合作出版。此版本仅限在中华人民共和国境内(不包括香港、澳门特别行政区及台湾)销售。未经许可之出口,视为违反著作权法,将受法律之制裁。未经出版者书面预先许可,不得以任何方式复制或抄袭本书的任何部分。

本书封面贴有 McGraw-Hill 公司激光防伪标签,无标签者不得销售。

北京市版权局著作权合同登记号:图字:01-2002-6641

图书在版编目(CIP)数据

制造技术:铸造、成形和焊接:第2版/(美)劳

(Rao, P. N.)著. —北京:机械工业出版社,2003. 1

(时代教育·国外高校优秀教材精选)

ISBN 7-111-11453-1

I. 制… II. 劳… III. ①铸造—工艺—高等学校—教材—英文②焊接工艺—高等学校—教材—英文
③锻造—弯曲成形—高等学校—教材—英文 IV. TG

中国版本图书馆CIP数据核字(2002)第107805号

机械工业出版社(北京市百万庄大街22号 邮政编码100037)

责任编辑:刘小慧 郑 玫

封面设计:鞠 杨 责任印制:付方敏

北京铭成印刷有限公司印刷·新华书店北京发行所发行

2003年2月第1版第1次印刷

787mm×1092mm 1/16·30.5印张·598千字

0 001—1 500册

定价:32.00元

凡购本书,如有缺页、倒页、脱页,由本社发行部调换

本社购书热线电话(010)68993821、88379646

封面无防伪标均为盗版

国外高校优秀教材审定委员会

主任委员：

杨叔子

委员（按姓氏笔画为序）：

王先逵	王大康	白峰杉	史荣昌	朱孝禄
陆启韶	张润琦	张策	张三慧	张福润
张延华	吴宗泽	吴麒	宋心琦	李俊峰
佘远斌	陈文楷	陈立周	单辉祖	俞正光
赵汝嘉	郭可谦	翁海珊	龚光鲁	章栋恩
黄永畅	谭泽光			

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，机械工业出版社拟于近期推出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，举办原版教材的教师培训，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，使我们更好地为教学改革服务。

机械工业出版社

2003 年 1 月

序

本书与 P N Rao 编著的《Manufacturing Technology — Metal Cutting and Machine Tools》构成完整的机械制造基础知识，都属于机械制造最基本的内容，是机械制造工程及自动化学科领域学生的必备知识。不论是按大学科培养计划还是专业培养计划中都有相应的课程与其相对应，在机械工程及其自动化的大学科培养计划中有“工程材料及成型技术”和“机械制造技术基础”两本教材与它相对应，而按专业培养计划中有“金属工艺学”或“机械制造基础”与之相对应，所以本书的内容几乎涉及到工科院校的每个学生。在国内出版的各种类型的“工程材料及成型技术”、“机械制造技术基础”、“金属工艺学”及“机械制造基础”教材都较多，但没有一本英文教材。采用此套书作为教材或教学参考书，或者作为机械工程的专业外语教材，有利于进行双语教学及促使学生掌握机械工程领域内最基本的相关英语专业词汇与术语。

本书内容相当于工程材料及成型技术、金属工艺学或机械制造基础的热加工部分，包括工程材料及其性能（含金属材料及热处理）、金属铸造生产过程（包括砂型铸造及特种铸造）、金属成形过程（热锻、冷冲及轧拉挤）和焊接生产四大部分，共 29 章。每章后都附有习题及参考书，便于学生复习检查。

本书可作为工程材料及成型技术和金属工艺学（热加工部分）或机械制造基础（热加工部分）的教材或参考书，亦可作为相关专业的专业外语教材。也可供从事机械制造的工程技术人员学习参考。

赵汝嘉

西安交通大学机械工程学院

2002 年 8 月

Preface to the Second Edition

The first edition of the book has received excellent reception from the teachers and students of engineering colleges. Originally the book was intended to comprehend analytical and design aspects of various manufacturing processes such that the students are able to correlate the conceptual subject details learnt in the classroom with their real-life applications. The success of the first edition broadly testifies to the acceptance of this concept by the teaching community.

Almost ten years have passed since the publication of the first edition of the book. In the intervening period, I had the good fortune of receiving plenty of suggestions from the users of the book in the form of new topics to be included and improvements, in a number of ways, to further expand the scope of the book. I tried to incorporate as many of them as possible, but some had to be deliberately omitted to conserve the flow of the material in the book and to maintain its reasonable size.

I wish to express my sincere thanks to the MARA Institute of Technology, Shah Alam, Malaysia where I am currently deputed on an assignment, for providing the necessary facilities and environment for undertaking the revision work.

I would welcome further suggestions regarding the coverage in the book, and would be happy to incorporate the suggested improvements in future editions to make the book more suitable to the changing curriculum needs of the subject, manufacturing technology.

P N RAO

Preface to the First Edition

This new book on manufacturing technology relates to its practice with as much of scientific aspects as possible. The study of manufacturing processes forms a core subject area for a majority of engineering students. In particular, this is an essential subject for all mechanical engineering students. But it is my experience that often the subject is taught with greater emphasis on the descriptive aspect rather than from a scientific and practical viewpoint. As a result, a fresh engineering graduate, on entering a manufacturing unit would be at a loss as to the means of correlating what he learned and what is required in practice. With this in mind, an attempt has been made to bring in as much of practice as possible into this book to make it more useful for engineering students.

This book is the outgrowth of material used by me for teaching two undergraduate courses relating to manufacturing processes. Whenever a process is described, the practical information, such as specifications, operating parameters and designing for the process, have all been highlighted. Each process is supplemented with simple illustrations, numerical calculations for the design process and a discussion of the results so obtained. A large number of well-labelled illustrations are provided to give the necessary insight into the process and its design.

After an introductory chapter, a short chapter is given to provide the necessary details of engineering properties as related to manufacturing processes. Three chapters have been devoted to the essential details of ferrous and nonferrous materials along with their heat treatment methods.

Another 11 chapters have been devoted to the technology of casting processes, wherein the sand casting process has been extensively dealt with from the technological viewpoint. In a concise form the available knowledge relating to the pattern, gating, risering and product design has been presented in these chapters. It is expected that an engineering student should be able to do a complete sand casting design from the information provided in this book.

Six chapters are devoted to the technological aspects related to metal forming processes, such as rolling, forging, extrusion and sheet metal operations. A good number of design examples as well as design exercises are provided wherever necessary.

Lastly, the welding and allied processes are covered in eight chapters, again giving a good amount of practical information. The emphasis is more on the commercial welding processes such as arc welding as well as the modern developments in welding processes.

SI units have been used throughout the book without exception. Countries all over the world have adopted these units because of the unambiguous representation of the various quantities. Hence it is imperative that engineering education should be done in SI units so that change-over takes place at the earliest and with least resistance. A brief introduction to SI units as related to the measurements used in this book has been provided in the appendix along with the essential data related to conversions from British or fps units to SI units.

References are provided at the end of each chapter which should be useful for those interested in studying further into the specific aspects. Also, a list of Indian Standards that are relevant for the subject under discussion has been provided at the end of each chapter. This information together with the numerous tables that are provided should help the practising engineer as well in the proper utilisation of the manufacturing processes.

I wish to express my sincere gratitude to Prof. U R K Rao, Prof. N K Tewari and Mr S Swaminathan who have provided constant encouragement to undertake this type of productive activity over a period of time. I am particularly thankful to Mr S Swaminathan and Prof U R K Rao for having taken the pains to review major portions of the manuscript and for giving useful suggestions for improvements. It is a pleasure to express heart-felt gratitude to my family members who have borne long hours of inconvenience during the preparation of the manuscript. I am indebted to the authorities of Indian Institute of Technology, New Delhi, for having allowed me to undertake this activity and provided the necessary facilities. Lastly, I wish to acknowledge the contributions made by many of my students over the past years during the teaching of the courses which enriched the book in many forms.

I am open to criticism and suggestions regarding the coverage in the book, and would welcome any helpful suggestions for improvement in future editions.

P N RAO



Contents

出版说明
序

Preface to the Second Edition
Preface to the First Edition

iv
v
vi
vii

- 1. **Introduction** 1
- 1.1 Manufacturing Processes 2
- 1.2 Breakeven Analysis 3
- References 8
- Questions 8
- Problems 8

part A

ENGINEERING MATERIALS AND THEIR PROPERTIES

- 2. **Engineering Properties and Their Measurement** 13
 - 2.1 Strength 13
 - 2.2 Hardness 14
 - 2.3 Ductility 18
 - 2.4 Toughness 19
 - References 20
 - Indian Standards 20
 - Questions 21
- 3. **Ferrous Materials** 22
 - 3.1 Iron 23
 - 3.2 Structure of Materials 23

3.3	Plain Carbon Steels	27	
3.4	Iron Carbon Equilibrium Diagram	29	
3.5	Cast Irons	31	
3.6	Other Alloying Elements	32	
3.7	Steel Designation	35	
	<i>References</i>	37	
	<i>Indian Standards</i>	38	
	<i>Questions</i>	38	
4.	Non-Ferrous Materials		40
4.1	Aluminium	40	
4.2	Copper	41	
4.3	Other Materials	42	
	<i>References</i>	43	
	<i>Indian Standards</i>	43	
	<i>Questions</i>	44	
5.	Heat Treatment of Metals		45
5.1	Transformation Curves	45	
5.2	Hardening	47	
5.3	Tempering	50	
5.4	Annealing and Normalising	52	
5.5	Case Hardening	53	
5.6	Heat Treatment of Non-Ferrous Alloys	55	
	<i>References</i>	56	
	<i>Indian Standards</i>	56	
	<i>Questions</i>	56	

part B

METAL CASTING PROCESSES

6.	Metal Casting Processes		61
6.1	History	61	
6.2	Advantages and Limitations	62	
6.3	Applications	62	
6.4	Casting Terms	62	
6.5	Sand Mould Making Procedure	64	
	<i>References</i>	65	
	<i>Indian Standards</i>	65	
	<i>Questions</i>	65	
7.	Patterns		67
7.1	Pattern Allowances	67	
7.2	Core Prints	73	

7.3	Elimination of Details	73	
7.4	Pattern Materials	74	
7.5	Types of Patterns	76	
7.6	Pattern Colour Code	80	
	<i>References</i>	80	
	<i>Indian Standards</i>	80	
	<i>Questions</i>	81	
	<i>Problems</i>	81	
8.	Moulding Materials		88
8.1	Moulding Sand Composition	89	
8.2	Testing Sand Properties	91	
8.3	Sand Preparation	96	
8.4	Moulding Sand Properties	97	
8.5	Indian Sands	102	
8.6	Other Sands	104	
8.7	Fluidity	107	
8.8	Types of Sand Moulds	109	
8.9	Moulding Machines	111	
	<i>References</i>	112	
	<i>Indian Standards</i>	112	
	<i>Questions</i>	113	
	<i>Problems</i>	114	
9.	Cores		115
9.1	Core Sands	116	
9.2	Carbon Dioxide Moulding	116	
9.3	Types of Cores	117	
9.4	Core Prints	119	
9.5	Chaplets	122	
9.6	Forces Acting on the Moulding Flasks	123	
	<i>References</i>	124	
	<i>Indian Standards</i>	124	
	<i>Questions</i>	125	
	<i>Problems</i>	125	
10.	Elements of Gating Systems		126
10.1	Elements of a Gating System	127	
10.2	Gates	129	
10.3	Casting Yield	132	
	<i>References</i>	133	
	<i>Questions</i>	134	
11.	Gating System Design		135
11.1	Pouring Time	136	
11.2	Choke Area	138	

11.3	Sprue	141	
11.4	Other Gating Elements	142	
11.5	Gating Ratios	144	
11.6	Slag Trap Systems	148	
	References	151	
	Questions	152	
	Problems	152	
12.	Risring Design		156
12.1	Caine's Method	157	
12.2	Modulus Method	159	
12.3	Naval Research Laboratory Method	163	
12.4	Feeding Distances	170	
12.5	Chills	170	
12.6	Feeding Aids	174	
	References	179	
	Indian Standards	180	
	Questions	180	
	Problems	180	
13.	Melting Practice		182
13.1	Cupola	182	
13.2	Charge Calculations	185	
13.3	Other Furnaces	188	
13.4	Ladles	189	
	References	190	
	Indian Standards	191	
	Questions	191	
	Problems	191	
14.	Casting Cleaning and Casting Defects		194
14.1	Fettling	195	
14.2	Defects in Castings	195	
	References	198	
	Questions	198	
15.	Product Design for Sand Castings		200
15.1	Designing for Economical Moulding	200	
15.2	Designing for Eliminating Defects	203	
15.3	Features to Aid Handling	210	
	References	211	
	Questions	211	
16.	Special Casting Processes		214
16.1	Shell Moulding	214	
16.2	Precision Investment Casting	217	

- 16.3 Permanent Mould Casting 219
- 16.4 Die Casting 220
- 16.5 Centrifugal Casting 225
- 16.6 Continuous Casting 227
- References* 227
- Indian Standards* 230
- Questions* 230

part C

METAL FORMING PROCESSES

- 17. Metal Forming Processes 233**
 - 17.1 Nature of Plastic Deformation 233
 - 17.2 Hot Working and Cold Working 234
 - References* 238
 - Questions* 239
- 18. Rolling 240**
 - 18.1 Principle 240
 - 18.2 Rolling Stand Arrangement 242
 - 18.3 Rolling Load 244
 - 18.4 Roll Passes 245
 - 18.5 Breakdown Passes 246
 - 18.6 Roll Pass Sequences 248
 - References* 250
 - Indian Standards* 253
 - Questions* 253
- 19. Forging 254**
 - 19.1 Forging Operations 254
 - 19.2 Smith Forging 255
 - 19.3 Drop Forging 255
 - 19.4 Press Forging 257
 - 19.5 Machine Forging 257
 - 19.6 Forging Defects 258
 - 19.7 Forging Design 259
 - 19.8 Drop Forging Die Design 265
 - 19.9 Upset Forging Die Design 272
 - References* 280
 - Indian Standards* 281
 - Questions* 281

20. Extrusion and Other Processes	284
20.1 Extrusion Principle	284
20.2 Hot Extrusion Processes	286
20.3 Cold Extrusion	287
20.4 Tooling for Cold Extrusion	289
20.5 Extruding Tubes	290
20.6 Wire Drawing	292
20.7 Rod and Tube Drawing	294
20.8 Swaging	295
20.9 Tube Making	296
References	297
Questions	298
21. Sheet Metal Operations	299
21.1 Press Tool Operations	299
21.2 Shearing Action	300
21.3 Shearing Operations	303
21.4 Drawing	309
21.5 Draw Die Design	311
21.6 Spinning	317
21.7 Bending	317
21.8 Stretch Forming	321
21.9 Embossing and Coining	322
References	323
Questions	323
Problems	324
22. Sheet Metal Die Design	327
22.1 Types of Dies	327
22.2 Die Construction	329
22.3 Punch Design	333
22.4 Pilots	340
22.5 Stripper and Stock Guide	342
22.6 Die Stops	344
22.7 Stock Strip Layout	346
22.8 Component Design for Blanking	349
22.9 Strip Development	350
22.10 Centre Line of Pressure	354
References	355
Indian Standards	355
Questions	356

part D**METAL FABRICATION PROCESSES**

23. Introduction to Fabrication Processes	361
23.1 Classification	361
23.2 General Considerations	362
<i>References</i>	366
<i>Indian Standards</i>	366
<i>Questions</i>	366
24. Gas Welding and Cutting	368
24.1 Principle	368
24.2 Oxy-Acetylene Welding Equipment	370
24.3 Oxy-Acetylene Welding Technique	371
24.4 Oxy-Hydrogen Welding	373
24.5 Gas Cutting	374
<i>References</i>	377
<i>Indian Standards</i>	377
<i>Questions</i>	378
25. Electric Arc Welding	379
25.1 Principle of Arc	379
25.2 Arc Welding Equipment	380
25.3 Electrodes	382
25.4 Manual Metal Arc Welding	384
25.5 Carbon Arc Welding	392
25.6 Inert Gas Shielded Arc Welding	393
25.7 Tungsten Inert Gas Welding (TIG)	394
25.8 Gas Metal Arc Welding (GMAW)	398
25.9 Submerged Arc Welding (SAW)	407
25.10 Other Arc Welding Processes	412
25.11 Arc Cutting	415
<i>References</i>	415
<i>Indian Standards</i>	416
<i>Questions</i>	417
26. Resistance Welding	419
26.1 Principle	419
26.2 Resistance Spot Welding	422
26.3 Resistance Seam Welding	425
26.4 Projection Welding	425
26.5 Upset Welding	428
26.6 Flash Welding	428
<i>References</i>	428

<i>Indian Standards</i>	429	
<i>Questions</i>	429	
27. Other Welding Processes		430
27.1 Thermit Welding	430	
27.2 Electro Slag Welding	431	
27.3 Electron Beam Welding	432	
27.4 Laser Beam Welding	434	
27.5 Forge Welding	435	
27.6 Friction Welding	435	
27.7 Diffusion Welding	436	
27.8 Explosion Welding	437	
<i>References</i>	437	
<i>Questions</i>	438	
28. Welding Design		439
28.1 Heat Input	439	
28.2 Heat Flow	441	
28.3 Distortions	446	
28.4 Defects in Welding	451	
<i>References</i>	454	
<i>Questions</i>	454	
<i>Problems</i>	454	
29. Brazing, Braze Welding and Soldering		456
29.1 Brazing	456	
29.2 Braze Welding	457	
29.3 Soldering	458	
<i>References</i>	459	
<i>Indian Standards</i>	459	
<i>Questions</i>	459	
<i>Appendix SI Units</i>		461
<i>Index</i>		465