时代教育·国外高校优秀教材精选

McGraw Hill Education

(美)P N Rao 著

MANUFACTURING TECHNOLOGY

VOLUME 1 THIRD EDITION

FOUNDRY, FORMING AND WELDING

制造技术

第1卷

铸造、成形和焊接

(英文版·原书第3版)

机械工业出版社
CHINA MACHINE PRESS

P N Rao
Manufacturing Technology Volume 1 Foundry, Forming and Welding
ISBN 0-07-008798-9

图书在版编目（CIP）数据

制造技术：第 3 版. 第 1 卷，铸造、成形和焊接：英文（美）拉奥（Rao, P. N.）著. —影印本. —北京：机械工业出版社，2010. 2
（时代教育：国外高校优秀教材精选）
ISBN 978-7-111-29067-4

Ⅰ. 制… Ⅱ. 拉… Ⅲ. 金属加工—高等学校—教材—英文 Ⅳ. TG-43

中国版本图书馆 CIP 数据核字（2009）第 209684 号

机械工业出版社（北京市百万庄大街 22 号 邮政编码 100037）
策划编辑：刘小慧 余 皞 责任编辑：刘小慧 余 皞
版式设计：霍永明 封面设计：张 静
责任印制：李 妍
北京铭成印刷有限公司印刷
2010 年 1 月第 2 版第 1 次印刷
184mm × 240mm · 31.5 印张 · 750 千字
标准书号：ISBN 978-7-111-29067-4
定价：54.00 元

凡购本书，如有缺页、倒页、脱页，由本社发行部调换
电话服务 网络服务
社服务中心：（010）88361066
销 售 一 部：（010）68326294 门户网：http://www.cmpbook.com
销 售 二 部：（010）88379649 教材网：http://www.cmpedu.com
读者服务部：（010）68993821 **封面无防伪标均为盗版**

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。

这本教材出版后，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，使我们更好地为教学改革服务。

机械工业出版社

2009年12月

序

由美国北依阿华大学(University of Northern lowa)工业技术系 P N Rao 教授所著的《制造技术　第1卷　铸造、成形和焊接》(*Manufacturing Technology Volume 1 Foundry, Forming and Welding*)和《制造技术　第2卷　金属切削和机床》(*Manufacturing Technology Volume 2 Metal Cutting and Machine Tools*)已经分别出版到第3版和第2版，它们已经被国外多所大学选为工程类本科学生学习制造技术的专业基础教科书。几年前，作为国外优秀原版教材，机械工业出版社引进出版了该书的前一个版本，国内部分高校已经采用它们作为“工程材料及成形技术”、“机械制造技术基础”或“制造工程基础(包括成形加工和切削加工)”等机械工程及自动化类专业核心课程的教材或主要教学参考书。该书的引进出版和教学应用，对于促进国内机械工程本科教学中更新教材、教学研究和双语教学等工作，产生了重要作用。

以使用本教材的教师和学生的反馈信息为基础，最新出版的这两卷书对第1卷的主要内容进行了大幅度的修订，也对第2卷的部分内容进行了调整和补充，从而使全书内容能够尽可能地反映出制造工艺与装备技术的新进展，使各章节内容更加简明和紧凑，从而更加便于教师和学生使用。

第1卷修订后将原来的29章内容重新组织改写为12章，删去了以前章节中一些重复的内容；重新绘制了部分示意图，使之更加清晰和易于学生理解；增加了有关抗拉试验、激光热处理、快速原型等10余处内容，重写了钎焊的全部内容。第2卷修订后各章标题变化不大，只是将原书中第14章“工艺规划”整个一章改写为“工装与夹具”，但在具体内容上，也进行了较大的修改和补充。第2章增加了介绍涂层硬质合金的内容，第3章加强了机床传动系统及作动器方面的内容，改写了第11章“特种加工”的内容，增加了水切割等新工艺方法，第15章对摩擦学方面的通用测量设备内容进行了更新。此外，该书还别开生面地在正文之前增加了“图示预览(Visual Walk-through)”，将该章主要内容组成，如教学目的、发展历史、图示范例、已解决的问题、小结、思考题和习题等，用图示和文字做了一个概要描述，这将帮助读者更好地利用该书各章节的内容。

通过以上修订、补充和改写，新版本制造技术的内容更加系统完整，文字更加简洁易读，图例更加清晰明了。

本书不失为一套适用于我国高校机械工程及自动化以及相关专业的优秀英文原版教材和教学参考书，也可作为相关专业的专业英语教材，并可供机械工程和制造工程领域的专业技术人员学习、参考。

刘　强

北京航空航天大学机械工程及自动化学院

国防科技工业高效数控加工技术研究应用中心

2009年5月22日

Preface to the Third Edition

The first two editions of this book have been well received by the teachers and students of engineering colleges. That proves the paradigm adopted by the author in developing this book as totally different from the other books in this area. Since the publication of the second edition, a number of suggestions have been received by the author about the improvements that could be done to the book. Many of the suggestions have been incorporated into this edition, which is explained below.

Many people felt that there are too many chapters in the book, and as a result of this division, there was a certain repetition experienced. Though there is some truth in this, the original intention was to make each chapter for a specific topic, which is convenient from the teaching point of view. However, since there is a need to conserve space, I have reorganised the original 29 chapters into 12 chapters and in the process the repetition experienced has been completely eliminated.

The modifications carried out in the chapters are the following:

- Many illustrations have been redrawn to improve clarity and ease of understanding by the students.
- Topics on tensile testing details, aluminium alloy properties table, laser heat treatment, rapid prototyping, simplified risering design, expanded furnace types, inoculation, degassing, ladles, permanent mould casting, vacuum die casting, low-pressure die casting and squeeze casting have been added.
- Brazing revised fully.

Two new chapters have been added after a careful examination of the syllabi of major universities. They are Chapter 11 on Powder Metallurgy and Chapter 12 on Plastic Processing. With this addition, the syllabi of major universities are fully covered and it is hoped that the book finds universal patronage as in the previous editions.

I wish to express my sincere thanks to my current employer, University of Northern Iowa, Cedar Falls, Iowa, USA, for providing an excellent environment and facilities which I could make use of in carrying out this stupendous task. I would also like to thank the following reviewers who took time out to review the book.

R K Gupta	Department of Mechanical Engineering Chandigarh Engineering College Nandran, Punjab
Rahul Caprihan	Faculty of Engineering Dayalbagh Educational Institute Dayalbagh, UP
P K Mishra	Mechanical Engineering Department MNNIT Allahabad, UP

Seshadri Bose	Department of Mechanical Engineering ABES Engineering College Ghaziabad, UP
Ravi Kant Jain	Prasad Institute of Technology Jaunpur, UP
S K Shah	Department of Mechanical Engineering Institute of Technology, BHU Varanasi, UP
R S Bharaj	Department of Mechanical Engineering Dr B R Ambedkar National Institute of Technology Jalandhar, Punjab
Madhukar Nagare	Department of Production Engineering VJTI, Mumbai, Maharashtra
A B Patel	Department of Mechanical Engineering Institute of Technology Nirma University of Science and Technology Gandhinagar, Gujarat
V R Iyer	Department of Mechanical Engineering Nirma University of Science and Technology Gandhinagar, Gujarat
V Ananda Krishnan	School of Mechanical Engineering Sastra Deemed University Thanjavur, Tamil Nadu
M Pradeep Kumar	Department of Mechanical Engineering College of Engineering Guindy, Tamil Nadu
K Natarajan	Department of Mechanical Engineering PSG College of Technology Coimbatore, Tamil Nadu
V S Senthil Kumar	Central Workshop Department of Mechanical Engineering Chennai
N S Das	Department of Mechanical Engineering C V Raman College of Engineering Bhubaneswar, Orissa
Tanmoy Mohanty	Mechanical Engineering Kalinga Institute of Industrial Technology Bhubaneswar, Orissa
A C S Kumar	Department of Mechanical Engineering JNTU College of Engineering Hyderabad, AP

It is a pleasure to work with the editorial staff at McGraw Hill Education India who made sure that the production comes with the highest quality in the shortest time to ensure the timely availability of the text.

As usual, 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 teaching of manufacturing technology.

P N Rao

Walkthrough

OBJECTIVES
Provides a quick look into the concepts that will be learned by the user.

2

Engineering Materials

Objectives

After completing the chapter the reader will be able to

- Understand the importance of the properties of engineering materials such as strength, hardness, ductility, and toughness
- Learn about the fundamentals of structure of engineering materials and how they control their properties
- Get the various details of the plain carbon steels and the variables that control their properties
- Understand the importance of different alloying elements in promoting the properties in alloy steels
- Learn different non-ferrous materials from the engineering standpoint
- Understand the heat-treatment process and learn about the various heat-treatment methods and their application

3.1 INTRODUCTION

Casting is one of the earliest metal-shaping methods known t o human beings. It generally means pouring molten metal into a refractory mould with a cavity of the shape to be made, and allowing it to solidify. When solidified, the desired metal object is taken out from the refractory mould either by breaking the mould or by taking the mould apart. The solidified object is called *casting*. This process is also called founding.

3.1.1 History of Casting Process

The casting process was probably discovered around c 3500 BC in Mesopotamia. In many parts of the world during that period, copper axes and other flat objects were turned out in open moulds made of stone or baked clay. These moulds were essentially in single piece. But in later periods, when round objects were required to be made, such moulds were split into two or more parts to facilitate the withdrawal of the round objects.

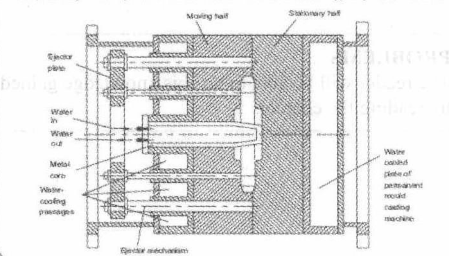
The Bronze age (c 2000 BC) brought far more refinement into the casting process. For the first time perhaps, a core for making hollow pockets in the objects was invented. These cores were made of baked clay. Also, the *cire perdue* or lost wax process was extensively used for making ornaments and fine work.

The casting technology has been greatly improved by the Chinese from around 1500 BC. Before that, there is no evidence of any casting activity found in China. They do not appear to have been greatly familiar with the *cire perdue* process nor used it extensively but instead specialized in multi-piece moulds for making highly intricate jobs. They spent a lot of time in perfecting the mould to the last detail so that hardly any finishing work was required on the casting made from the moulds. They probably made piece moulds

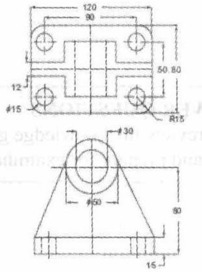
HISTORICAL PERSPECTIVE
Provides a brief perspective of historical developments related to the processes discussed.

WELL LABELED ILLUSTRATIONS
Provides a complete description of the object in question labeling the various parts to understand the function.

For making any hollow portions, cores are also used in permanent mould casting. The cores can be made out of metal or sand. When sand cores are used, the process is called semi-permanent moulding. The metallic core cannot be complex with undercuts and the like. Also, the metallic core is to be withdrawn immediately after solidification; otherwise, its extraction becomes difficult because of shrinkage. For complicated shapes, collapsible metal cores (multiple piece cores) are sometimes used in permanent moulds. Their use is not extensive because of the fact that it is difficult to securely position the core as a single piece as also due to the dimensional variations that are likely to occur. Hence, with collapsible cores, the designer has to provide coarse tolerance on these dimensions. A typical permanent mould is



4.2 Two castings are moulded in green sand. They differ in weight by a factor of 3.8 but they are both cubes. An experiment has shown that the lighter casting solidifies in 8.7 minutes. How much time would you estimate that it would take for the larger casting to solidify?



SOLVED PROBLEMS
Solved problems will help reader to review their understanding of the concepts discussed in the chapter.

SUMMARY
Provides the essence of the subject matter covered in the chapter.

Summary

Sand casting is not suitable for applications where large volumes of parts are to be produced or complex geometries are involved. For this purpose, a number of special casting methods are devised.

- Shell moulding is a special casting process used for specific applications that require higher quality castings with thin surface details. It uses resin-coated sand for making the mould that is strong and porous.
- Precision-investment casting utilizes an expendable pattern to create really complex objects without any parting line. This ensures very high precision and excellent properties.
- Permanent-mould casting utilizes a metallic mould to prepare the casting. This helps in lowering costs for mass production, at the same time ensuring a fine-grained structure with improved mechanical properties for the casting.
- Pressure die casting can be utilized for very complex shapes. This process uses a metallic die and the molten metal is injected at very high pressure ensuring the filling of very small cavities at a fast rate. The resulting casting is completely filled with smooth finish and fine-grained structure. It is very economical when produced in large volumes.
- Vacuum diecasting ensures the removal of entrapped air in the die inside the casting, thereby ensuring a sound casting.
- In centrifugal casting, the mould is rotated at high speed, which ensures that the slag and impurities in the molten metal are separated and removed effectively. This ensures that casting produced is sound. There are other variations in this process to cater to the different type of casting sizes and geometries produced.
- Continuous casting allows for the fast production of constant cross-section shapes in large volume

Questions

4.1. What are the various elements that comprise of the gating system?
4.2. Describe the objectives of gating systems in any casting.
4.3. What are the functions served by the pouring basin in a sand casting?
4.4 Give the sketch of a design of a pouring basin with an arrangement for trapping slag.
4.5. Explain why the sprue should be tapered.
4.6. What are the various methods available to a casting designer to reduce the momentum of the molten metal?
4.7. How can slag be trapped in a runner?

QUESTIONS
The reader will be able to test his knowledge gained by reading the chapter.

PROBLEMS
The reader will be able to test his knowledge gained by reading the chapter.

Problems

9.1. In a given arc-welding operation, the power source is at 20 V and current is at 300 A. If the electrode travel speed is 6 mm/s, calculate the cross-sectional area of the joint. The heat transfer efficiency is 0.80 and melting efficiency is 0.30. Heat required to melt the steel is 10 J/mm³.
9.2. In a resistance welding of a lap joint or two mild steel sheets of 1.5-mm thickness, a current of 10 000 A is passed for a period of 0.1 second. The effective resistance of the joint is 120 micro ohms. The density of steel is 0.00785 g/mm³ and heat required to melt is 1381 J/g. The joint can be considered as a cylinder of 5-mm diameter and 2.25-mm height. Calculate the percentage of heat distributed to the surroundings.
9.3. A projection welding of 3 spots is obtained with a current of 35 000 A for a period of 0.01 second. The effective resistance of the joint is 120 micro ohms. If the joint can be considered as a cylinder of 6-mm diameter and 2.5-mm height, calculate the heat distributed to the surroundings.
9.4. The arc welding of 6-mm steel plates in butt welding is being carried out at a welding speed of 9 mm/s. The welding transformer is set at 25 V and the current flowing is 300 A. Taking the arc efficiency as 0.85, calculate the temperature to which the plates should be preheated such that the critical cooling rate is kept below 6 °C/s at a temperature of 550 °C for satisfactory metallurgical quality.
9.5. Determine the appropriate welding speed to be used to weld 8-mm C50 steel plates when the power source is at 30 V and current at 325 A. The arc efficiency is 0.80 while the maximum cooling rate allowed is 6 °C/s at a temperature of 550 °C. The possible welding speeds are 6, 7, 8 and 9 mm/s.

3.14. Briefly discuss why draft allowance is important for patterns.
3.15. Describe the allowances given on pattern for shaking and distortion.
3.16. What is meant by core prints? Explain how they are to be provided.
3.17. What are the materials that are generally used for preparing patterns?
3.18. What are the specific applications for the following pattern materials: wood, metal and plastics?
3.19. What metals are generally used for making patterns? Explain the reasons for their selection.
3.20. What is meant by double-shrinkage allowance?
3.21. Name the various patterns that are normally encountered in foundry practice.
3.22. Name any two allowances provided on the pattern for a sand-casting and state the reasons why they are provided.
3.23. Explain where skeleton patterns are employed.
3.24. Which is the most widely used type of pattern? Describe its advantages.
3.25. What are the situations in which a single-piece pattern is advantageously used?
3.26. Sketch an example showing the cope and the drag type pattern.
3.27. Why is a loose piece pattern used? Give its problems.
3.28. Explain the use of a follow board pattern with a neat sketch.
3.29. Describe the pattern colour code normally used in foundries.
3.30. What properties are desirable of a moulding sand from the standpoint of sound castings?
3.31. Explain the importance of permeability of moulding sands.
3.32. State the essential ingredients of a moulding sand.
3.33. Explain the method of determining the moisture content in a moulding sand.
3.34. What is the role played by clay in a moulding sand? What is the method adopted for determining the clay content in a moulding sand?

MULTIPLE ANSWER QUESTIONS
Helps the reader to review the knowledge gained by reading the chapter and prepare for examinations.

Contents(目录)

1

Introductio

Objectives

After completing the chapter the reader will be able to

- Understand the importance of manufacturing for the mankind
- Know the different types of manufacturing processes
- Evaluate the feasibility of a particular process by carrying out the break-even analysis

1.1 MANUFACTURING PROCESSES

The benefits of civilisation which we enjoy today are essentially due to the improved quality of products available to us. The improvement in the quality of goods can be achieved with proper design that takes into consideration the functional requirement as well as its manufacturing aspects. The design process that would take proper care of the manufacturing process as well would be the ideal one. This would ensure a better product being made available at an economical cost.

Manufacturing is involved in turning raw materials to finished products to be used for some purpose. In the present age there have been increasing demands on the product performance by way of desirable exotic properties such as resistance to high temperatures, higher operating speeds and extra loads. These in turn would require a variety of new materials and its associated processing. Also, exacting working conditions that are desired in the modern industrial operations make large demands on the manufacturing industry.

Further, the economics of the manufacturing operation is a very important consideration. To be viable in the modern environment, a product has to be competitively priced besides having the functional and aesthetic appeal. Therefore, it is necessary for the engineer to give a proper thought to various aspects of manufacturing.

Manufacturing processes is a very fundamental subject since it is of interest not only to mechanical engineers but also to those from practically every discipline of engineering. It is so because engineering as a whole is meant for providing various materials for human consumption. For various products such as plant machinery required for chemical, civil, electrical, electronic, textile, etc., the manufacturing process forms a vital ingredient.

A detailed understanding of the manufacturing processes is thus essential for every engineer. This helps him appreciate the capabilities, advantages and also the limitations of the various manufacturing processes. This in turn helps in the proper design of any product required for him. Firstly, he would be able to assess the feasibility of manufacturing from his designs. He may also find out that there are more than one process available for manufacturing a particular product and so he can make a proper choice of the process which would require the lowest manufacturing cost and would deliver the product of desired quality. He may also modify his design slightly to suit the particular manufacturing process he chooses.

Manufacturing is defined by the Merriam Webster online dictionary as *to make into a product suitable to use*. Manufacturing remained as a craft till the first industrial revolution towards the end of the 18^{th} century with low volumes and single-piece productions. It required highly skilled craftsmen to individually produce the pieces and fit them when the assembly was required. This was a slow and expensive process, but in the absence of any machines, that was the only thing that was possible. The availability of the steam engine and coal-fire furnaces made the invention of a number of steam-power driven machinery to greatly increase the manufacturing capacity. A large number of inventions related to machine tools took place during this period and continued into the 19^{th} century. Towards the end of the 19^{th} century with the invention of electricity and better engineering materials, manufacturing operations became more productive. The developments in the automobiles at the beginning of the 20th century are instrumental in the growth of a variety of manufacturing methods and practices.

There are a large number of processes available to the engineer for manufacture. These processes can be broadly classified into four categories.

(a) Casting processes
(b) Forming processes
(c) Fabrication processes
(d) Material removal processes

1.1.1 Casting Processes

These are the only processes where liquid metal is used. Casting is also one of the oldest known manufacturing processes. It requires preparation of a cavity usually in a refractory material to resemble closely the final object to be made. Molten metal is poured into this refractory mould cavity and is allowed to solidify. The object after solidification is removed from the mould. Casting processes are universally used for manufacture of a wide variety of products. The principal process among these is sand casting where sand is used as the refractory material. The process is equally suitable for the production of a very small batch as well as on a very large scale.

Some of the other casting processes for specialised needs are

- shell-mould casting
- precision-investment casting
- plaster-mould casting
- permanent-mould casting
- die-casting
- centrifugal casting

1.1.2 Forming Processes

These are solid state manufacturing processes involving minimum amount of material wastage and faster production. In a forming process, the metal may be heated to a temperature, which is slightly below the solidus temperature and then a large force is applied such that the material flows and takes the desired shape. The desired shape is controlled by means of a set of tools called dies, which may be completely closed or partially closed during manufacture. These processes are normally used for large-scale production rates. These are generally economical and in many cases improve the mechanical properties too.

Some of the metal forming processes are

- rolling
- drop forging
- press forging
- upset forging
- extrusion
- wire drawing
- sheet metal operations

1.1.3 Fabrication Processes

These are secondary manufacturing processes where the starting raw materials are processed by any of the previous manufacturing processes described. It essentially, involves joining pieces either permanently or temporarily so that they would perform the necessary function. The joining can be achieved by either or both of heat and pressure and/or a joining material. Many of the steel structural constructions we see are first rolled and then joined together by a fabrication process.

Some of the processes of interest in this category are

- gas welding
- electric arc welding
- electric resistance welding
- thermit welding
- cold welding
- brazing
- soldering

1.1.4 Material Removal Processes

These are also secondary manufacturing processes where the additional unwanted material is removed in the form of chips from the blank material by a harder tool so as to obtain the final desired shape. Material removal is normally the most expensive manufacturing process because more energy is consumed and also, a lot of waste material is generated in the process. Still this is widely used because it delivers very good dimensional accuracy and good surface finish. It also generates accurate contours. Material removal processes are also called machining processes.

The various processes in this category are

- turning
- drilling
- shaping and planing
- milling
- grinding
- broaching
- sawing

All these manufacturing processes have been continuously developed so as to obtain better products at a reduced cost. Of particular interest is the development of computers and their effect on the manufacturing processes. The advent of computers has made a remarkable difference to most of the above manufacturing processes. They have contributed greatly to both automation and designing the process.

1.2 BREAK-EVEN ANALYSIS

An important responsibility of the engineer is to choose a manufacturing process, which makes the required quality of a product to the specifications and at the lowest cost possible. To fulfil both the conditions, one would have to do a break-even analysis of the various processes suitable for the production of the given object.