Materials and Processes

Third Edition
(in two parts)

PART A: MATERIALS

(Materials Engineering 2)

Edited by
James F. Young

Robert S. Shane

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Edited by

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Fairfield, Connecticut

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MARCEL DEKKER, INC. New York and Basel

Preface to the Third Edition

In this third edition we have built on the second edition and consciously focused on the contributions of materials science and materials engineering to the needs of students and practitioners of engineering. Defining design as a planned use of knowledge, we present here a road map to the materials and processes by which a design engineer can find the way to contemporary knowledge of materials and processes. For detailed information special sources of knowledge must be consulted. Our purpose is to point out the existence of such knowledge.

This is a newly written and revised edition of the classic textbook on materials and processes written by James F. Young for the General Electric engineering course and adopted worldwide for the education of engineers. It is about twice the size of the second edition. This reflects the rapid growth of materials science and the addition of several topics that we consider important to the education and practice of engineers.

Review questions have been deleted from the text in keeping with our belief that earnest teachers and students can devise such questions in line with their individual interests and emphasis.

Each contributing author is eminent in his field. Some contributors have a worldwide reputation; others are only known to the cognoscenti in their discipline. However, the presence of a contributor in this book is assurance that the late Mr. Young and I believed that the reader is getting authoritative information from the best available sources. Total responsibility for the final text is assumed by me and I would be grateful for any suggestions for improvement that any reader would care to give. However, my deepest thanks go to my friend, the late Mr. Young, and all the contributors who made this work possible.

Robert S. Shane

Preface to the Second Edition

The primary objective in preparing this revision has been to maintain the approach that motivated the first edition. That is, the emphasis has been placed on presenting a broad study of engineering materials and manufacturing processes from the viewpoint of the engineer. The acceptance gained by the first work has, it is believed, confirmed the need for this approach and its usefulness. The subject matter has been organized to provide for textbook and reference use by students and practicing engineers, particularly those having product development, design, production, processing, quality, and application responsibilities.

Other objectives sought in this revision are:

1. To expand the coverage of nonmetallic materials, constructional materials, and many materials and processes used in product industries.
2. To bring the presentation up to date with latest developments in physical metallurgy and chemistry, both in theory and in available materials.
3. To reorder the presentation to assist classroom use.
4. To add typical material property data and process tolerances which should promote the book's usefulness as a "starting" reference and aid development in the student of the "sense of proportion" so necessary to engineering.

Most of the chapters have been completely rewritten to accomplish these objectives. New chapters have been added on Metallographic Examination; Structure and Properties of Nonmetallic Materials; Rubber; Ceramics, Porcelain, and Glass; Miscellaneous Nonmetallic Materials; and Statistical Methods Useful in Quality Control. The old Heat Treatment chapter has been brought up to date and consolidated with chapters on Alloys, Iron and Steel, and Heat-Treating Processes to avoid duplication. Sections have been added on Tarnishing, Electric Contacts, and Nondestructive Testing, and the coverage has been expanded on many subjects, such as bearing metals, superalloys, nonferrous elements, blow molding, shell molding, and pressure welding.

Contact with first-edition users among the engineering colleges and experience with the new chapters in training programs of the General Electric Company have been utilized as a guide to the organization. In the study of metallic materials, properties are covered first and then specific materials available are reviewed in more detail. The nonmetallic materials are similarly covered. Manufacturing processes are grouped in the order typical of most fabrication. Since many first-edition users adopted some variation in the original

order to suit particular student groups and course objectives, the self-contained-chapter approach was continued to aid and encourage this practice, and textbook styling was emphasized.

Careful consideration was given to the possibility of separating the book into two volumes, because the study of materials is often separated from processing studies in engineering curricula. The single volume was retained, however, to provide for interchange in such courses; to aid reference use in more advanced courses, such as design courses; and particularly for reference use in engineering practice.

A study of the broad field covered by this book requires, of necessity, considerable condensation to achieve the present compact size. It has, therefore, been necessary, on occasion, to sacrifice preciseness for clarity of presentation and practicality. Bibliographies of many good works are listed with each chapter for those desiring more specialized treatments of the subjects. The tabular property data were selected to provide representative information on typical materials, with the hope that they may illustrate the general ranges available. This should aid the user in selecting types of materials for an application and then permit him to seek specific suppliers' data for his specification. It should also aid the student in achieving a sense of proportion for size, tolerance, and strength. Such data may not agree exactly with existing specifications or suppliers' guarantees, since the latter often deal with minimum values, and techniques among suppliers may provide materials differing from the representative values. Some trade names have been incorporated for convenience in identification. There is no intent to slight any source by its omission; any omissions have resulted from the physical impossibility of including all sources.

The book's wide scope requires dependence almost wholly on the contributions of specialists in the many fields represented. It is my hope that due acknowledgment of sources has been made with the material presented. I am also indebted to many experts in the General Electric Company, particularly the Research Laboratory, the Turbine Division Laboratory at Schenectady, N.Y., and the Household Refrigerator Laboratory at Erie, Pa., who read individual chapters and offered recommendations for technical accuracy and completeness; to contributors to individual chapters, including those who assisted in preparing portions drawn from the first edition, and, insofar as possible, their names have been incorporated with their work; to many professors who offered suggestions and criticisms; to the Metals Engineering Division Committee, ASME, for discussions and suggestions which have greatly assisted formation of the new edition; to my wife, Rita, who contributed much in companionship over a period of years, besides doing most of the typing and proofreading; and to Mrs. G. W. Snell and Miss C. Barr for assistance in typing and proofreading.

J. F. Young
December, 1953

Preface to the First Edition

This book has been written to present in one volume a broad study of the materials and manufacturing processes employed by the design engineer, and thus to provide information directly useful in the selection of materials for design. It is intended for convenient reference and for textbook use. It has therefore been organized for ease in classroom presentation and in such a manner that, it is hoped, will give the practicing engineer or designer an overall picture of the subjects discussed.

The problem of selecting the material for a piece of apparatus is no easy matter. One's first attempt at selection proves this quite convincingly. Plenty of information is available, but the real task is to find and evaluate that which has a bearing on the design. It is reasonable to assume that, if a material has the properties required in service, it is suitable, and so it may be selected. It soon becomes clear, however, that the material also must be available in the right form, and be such that it lends itself better than others to the available and desired method of processing. In addition, tne overall cost, including both of the material and of fabricating it, should represent the maximum value per dollar expended. And this combination can be obtained only when the product is both proportioned with respect to the material to be used and detailed to accommodate the method of processing.

The young engineer's training for design, which is largely obtained through working with more experienced engineers, should be preceded by some study of metallic and nonmetallic materials and of manufacturing methods. However, much of the available information on these subjects is not presented to suit the requirements of the design engineer. Data on metallic materials are presented largely from the metallurgist's viewpoint, and information on manufacturing methods usually tells how to accomplish the process and how to operate the equipment used. These approaches leave a rather broad gap in the design problem, a gap that it is hoped this book will bridge.

This textbook considers chiefly the materials and processes used in manufacturing electromechanical products. Sufficient metallurgy is included to enable the engineer to understand heat-treating practice and the effects of various processes on metallic materials. In the discussion of processes, enough detail for understanding the basic nature of each process is given; but—throughout—emphasis is laid on so designing the products that they can be easily processed. Materials and processes used only in building construction are not considered. Material-specifications systems and data have been left out also

because of their changing nature and the impossibility of covering adequately all sources of supply.

Many of the chapters have been written from lectures given in a general course in materials and processes conducted in the Advanced Engineering program of the General Electric Company. I am indebted to the many engineers whose lectures and papers have been used in the preparation of this book, and, insofar as practicable, their names appear at the head of those chapters prepared from their lectures or incorporating their work. I also wish to express my appreciation to Dr. A. R. Stevenson, Jr., to whom this book is dedicated, for the opportunity of preparing the book and for his encouragement; to Mr. E. E. Parker, Mr. E. R. Boynton, and Mr. J. E. Ryan, who served as the first supervisors of the general course and laid out the early lectures; to Mr. T. S. Fuller and Mr. E. R. Parker for their helpful suggestions and consultation; and to Miss F. E. Rist for her patience and good nature in typing the manuscript and in proofreading.

J. F. Young
January, 1944

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1

Introduction*

I. PURPOSE

A review of current engineering curricula in U.S. colleges and universities reveals little coverage of materials or their production processes. There are, of course, presentations on specific materials that are closely associated with each engineering field, and there are topical electives available to all engineering students. But none of the curricula in the major engineering institutions offers a broad review of the subjects of materials and processes on which design engineering depends. Filling this gap is one of the major driving forces in the preparation of this third edition of *Materials and Processes*.

Another major driving force stems from the role of the experienced engineer engaged in developing and applying technology to meet perceived needs. Design problems never emerge in neat packages in a single engineering discipline. Rather, they usually require application of knowledge and understanding from many areas of applied science and from the lore of modern engineering practice. An essential foundation for all design is material selection and adaptation of processes for production and fabrication. With the rapid evolution in materials engineering and process development that has occurred in the last few decades, the designer is now faced with many new alternatives. So, a major driving force has been to provide state-of-the-art discussions, and forecasts where possible, of the materials and processes knowledge a designer needs to select, prove, and specify materials and processes for a design.

A third driving force stems from the changing societal expectations and needs for technology, as reviewed in the next section.

II. TECHNOLOGY AND SOCIETY

The term "technology" is widely used but with differing meanings. Generally, technology connotes a competence or a capability. The differences relate to scope. The purist thinks of technology simply as knowledge of the applied sciences. The more pragmatic concept is to recognize technology as a body of knowledge of the applied sciences *together* with the lore of past experience and the facilities to produce the goods and services on which society and the economy depend. In this pragmatic view, technology is the totality of

*Contributed by JAMES F. YOUNG.