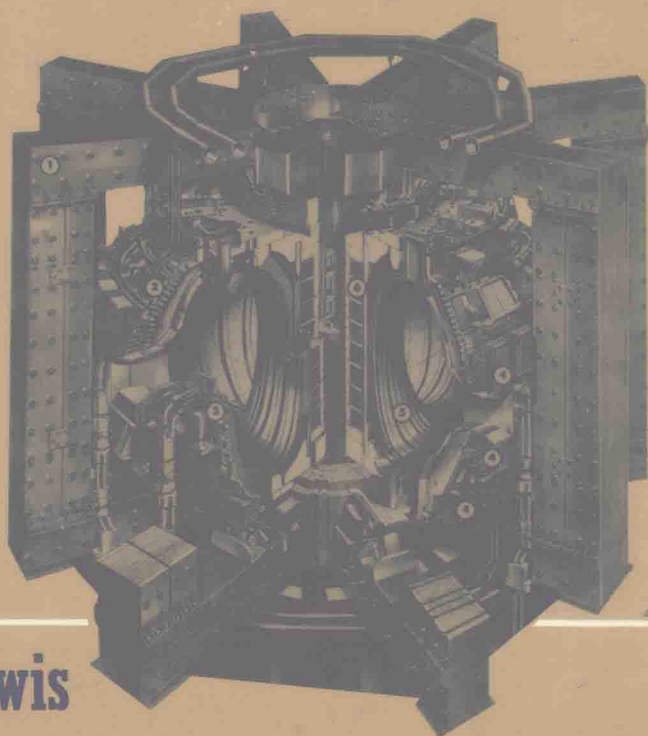


SELECTION OF
**ENGINEERING
MATERIALS**



Gladius Lewis

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OF
ENGINEERING
MATERIALS**

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PREFACE

My main acknowledgments go to the many students with whom I have interacted during the past decade on three continents while teaching and researching in the field of engineering materials and their applications. I appreciate, among many other things, their insight, probing questions, insatiable thirst for knowledge, and remarkable initiative. Many thanks also go to the following persons for their help in the “nut and bolts” aspects of converting a handwritten manuscript to a type-written, illustrated one: Barbara Moore and Ann Hester of the Department of Mechanical Engineering of the University of Alabama in Huntsville, Alabama; and Billie Bulmanski, Beth Caldwell, and Ann Brock of Memphis State University in Memphis, Tennessee. In addition, I am grateful for the permission given by various individuals and organizations to use a number of diagrams, photographs, and data sets. All such materials are clearly acknowledged in the text. An acknowledgments list of all proprietary products and the patent-holding companies is provided on page 565. Finally, I acknowledge the use of an enormous body of papers and documents published elsewhere. All information taken from these sources is clearly identified in the text, by means of numbers in brackets, corresponding to a reference list at the end of each chapter. My thanks go to all the authors of these referenced works.

INTRODUCTION

The most important decision in engineering is the proper selection of materials. That this is so is highlighted by the fact that all decisions regarding the manufacturing of engineering structures and components are predicated on proper selection of materials. Indeed, the combination of a proper material selection methodology and sound economic judgment is the cornerstone of the ability to transform an engineering idea from concept to implementation. The boldness or, as some may argue, the dogmatic nature of these remarks is meant to underscore the pivotal position that a course in the selection of engineering materials should occupy in the curricula of engineering degree programs. This is not the case at the present time.

Too many of today's engineering students and tomorrow's engineers are being wrongly or badly educated in this subject as a result of errors of omission and commission in the curriculum. Insufficient efforts are being made either to disabuse the minds of engineering students completely or to point out to them the limitations of the "old" approach to the selection of materials—that the process is largely empirical. In essence, that approach stressed the ability of engineers to draw on their fund of experience; but invariably, they tend to play it safe and prescribe the few materials that have been tested and proved or with which the engineers are most familiar. In addition, at the college level, courses

in such pertinent fields as materials science, mechanics of materials, and engineering design are not coordinated well enough for their symbiotic nature to be appreciated, thereby thwarting a cross-fertilized, coherent, holistic treatment.

In the past two decades or so, there has been a steadily growing realization that for optimum selection of materials, the engineer must be knowledgeable about the nature, properties, merits, and demerits of the widest spectrum of currently available materials as well as materials with near-term availability potential, in addition to being well grounded in the fundamentals of the mechanical aspects of design, environmental degradation of materials, manufacturing processes, quality control, salvage and recycling potential of materials, and so on. It is therefore necessary to present the material in this book as a synthesis of ideas from these and other subject areas. It is gratifying to note that in a small number of engineering colleges, such approaches are being taken in the teaching or development of the curriculum in this field.

This book is a contribution to the emerging “new approach” to the teaching and practice of material selection. The approach is, for a given application, to establish the link between the functional and material requirements and hence narrow the choice to a few candidate materials. On the basis of established criteria, either an unambiguous choice is made, or the compromises and/or dilemmas associated with the selection process are highlighted, leaving the final choice to the reader. It is useful to note here that when candidate materials are selected on the basis of so-called sizing material properties (properties that affect the final dimensions of the component, such as modulus of elasticity, fracture toughness, and density), the final choice is comparatively easier than when such selection is to be made on the basis of so-called discriminating material properties (properties that have little or no effect on the size of the component but are nonetheless important, such as ductility, oxidation resistance, and maximum reuse temperature).

The material in this book is divided into four parts. In Part I, some 30 case studies are examined, running the gamut of engineering applications from a vaulting pole to a flywheel as an energy storage unit in a ground vehicle and from the thermal protection system of the U.S. space shuttle to the wheels of a skateboard. The objective in this part is to present as well rounded a study as possible: definition or description of the case, establishment of service conditions, presentation of equations governing the mechanics of the system (where applicable), considerations relevant to the selection of suitable materials, candidate material choices, and a final evaluation of these materials, culminating in a recommendation.

Part II consists of a series of 58 questions and suggested answers on a wide range of materials applications, from the driveshaft of an automobile to a gas-cooled nuclear reactor and from a pyroelectric transducer to an ovenproof casserole. The objective in this part is to illustrate, by way of these suggested answers, both style and format for the presentation of information and ideas. It is not intended that these answers be taken as definitive; rather, it is hoped that they will be used as “springboards” for developing answers independently.

In Part III, the latest developments in the field of engineering materials and their applications are presented in 16 chapters. The objective in this part is to

give as comprehensive and panoramic a survey as possible. The chapters therefore cover trends in metals, ceramics, polymers, and composite materials. Of course, in a field as volatile as this one (as is evidenced in the explosion of developments in superconducting materials since February 1987), it is neither possible nor necessary to make the material in Part III encyclopedic. The best that can be hoped for is to capture the essence of research and developments results at the time of writing. (In the 24 months of preparation of the manuscript, some portions of Part III had to be updated no less than 10 times!)

The guiding principle in the presentation in Part III is a recognition of the key links between properties and uses of materials. Thus much space is devoted to details about the latest developments in materials from the viewpoint of their properties, advantages, and disadvantages. The intention is to present the information about these aspects, taken from as many sources as possible, in summarized form, thereby sparing the reader an agonizing journey through hundreds of journals and other publications.

Part IV presents 45 exercises in material selection for the student to tackle (ideally, under the guidance of a discriminating instructor).

It is useful to insert a number of caveats here, as far as an assessment of this book is concerned. First, it should be appreciated that access to detailed properties of many nonmetallic materials is not easy. As for raw material and fabrication cost data, these are mostly nonexistent in the open literature. To obtain them from vendors and/or user companies requires both Jobian patience and Herculean tenacity! Although various organizations are now earnestly trying to correct this deficiency in information sources (see Appendix A), much more needs to be known.

It is against this background of difficulty of obtaining cost data that a decision was made to forgo any exposition on the economics of materials selection. It is clearly an important element in any methodology (very rarely do the most economic solution and the best engineering solution to a given material selection problem coincide!). Also, it is important to recognize the fact that material properties differ in importance, depending on the application. Thus material property weighting factors must be assigned. This is by no means a trivial task and is clearly outside the ambit of this book. To underscore the fact that both cost and weighting factors are important in final material selection, a highly abbreviated and rudimentary treatment of them, for two named applications, is given in Appendix B. It is hoped that the reader with access to detailed cost and weighting factor information will apply these to any case of interest. (College professors using this book in a course might regard this exercise as *de rigueur* for their students).

The second caveat is to do with the intended readership. It is anticipated that at the college level, this book will be used in a capstone course at the senior undergraduate or first-year graduate level. These students would have the necessary background and preparation in subjects such as physics, chemistry, mathematics, mechanics of materials, materials science, thermofluids science, and electromagnetic theory. In other words, a certain minimum knowledge of relevant concepts in these courses is assumed.

The third caveat is, in fact, an extension of the second. This book is not intended to supplant existing texts on materials. Its main thrust is not the science

of materials (which would, presumably, have been thoroughly studied before embarking on a capstone course) but the applications of materials that are predicated on the science. In one sense, this book is intended to complement or supplement some existing texts; in another sense, it is a “first-generation” resource book on materials and their applications. That there are so few texts that this book can complement or supplement (even though “Choice of Materials” or “Selection of Materials” is a featured course in the curricula of many engineering colleges—see Appendix C) provides its *raison d’être*.

The fourth caveat is to do with the amount of detail given in the presentation of the engineering aspects of some of the case studies. This is deemed necessary in order to reinforce the notion that these are real engineering projects, not merely academic exercises. In addition, the inclusion of these details helps to “educate and inform” the reader who has no knowledge about these case studies or whose familiarity with them is, at best, perfunctory.

Finally, it should be appreciated that within the context and constraints of a book of this type, some aspects of material behavior in service, important as they are, will be treated only briefly. Examples of such aspects are fatigue, fracture, creep, corrosion, oxidation, wear, and erosion. Since the book is not intended to be exhaustive or even comprehensive but rather representative, and being cognizant of the intended readership, it is suggested that details of these aspects be obtained from other texts (see Appendix D).

It is my hope that this book will provide a real service for college students and will find a wider audience in the engineering community of practicing material engineers, machine element designers, and all people involved in the decision-making process regarding use of materials in the manufacturing and production engineering industries.

Gladius Lewis
Memphis, Tennessee

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