

Mechanical Engineers' Handbook

Second Edition

Edited by

MYER KUTZ

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For Arlene

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PREFACE TO THE SECOND EDITION

The two editions of this *Mechanical Engineers' Handbook* are separated by a dozen years. This length of time, especially when measured in cyber years, has dramatic consequences for a technical work that encompasses 78 chapters, each on a different topic.

This second edition of the *Handbook* has 26 entirely new chapters—a third of the book. Thirty-three chapters are revisions (42 percent of the book). Some revisions are by new authors and are so different from their predecessors that they could count as new chapters. Less than one-quarter of the book (19 chapters) is unchanged.

The new edition is the same length overall as the old. Twenty-five chapters from the first edition were deleted in order to make way for new material and because they were either obsolete or could be subsumed into new or revised chapters.

The new edition starts in a very different way than the first edition did. The separate section on digital computers is gone. There does not need to be such a section any longer, inasmuch as information on computers has been integrated into the contents of chapters where computers play an important role. The second edition opens with Chuck Drummond's revision of his chapter on the structure of solid materials. Other revisions in the materials section of the *Handbook* include chapters on aluminum (Seymour Epstein and colleagues at the Aluminum Association), nickel (Jim Hosier), magnesium (Bob Busk), and plastics and elastomers (Edward Peters). In addition, Carl Zweben provided a new version of the chapter on the important topic of composite materials.

In the years from 1986 to 1998, mechanical design entered a new era in which computers have played a larger and larger role. Virtual reality has become a new technology for mechanical engineers. The second edition of the *Handbook* has chapters on ergonomic design and electronic packaging, which the first edition did not have. New teamwork-based methods of product development have evolved, so the topic of concurrent engineering has a prominent place in this section of the *Handbook*.

All told, there are nine new chapters in the mechanical design section. A group of authors at the Concurrent Engineering Research Center—Cleetus, Jagannathan, Reddy, Srinivas, and Karinithi—contributed two chapters. Other new chapters include “Computer-Aided Design” by Emory Zimmers, “Virtual Reality” by Rajit Gadh and Tuskar Dani, “Ergonomic Factors in Design” by Bryce Rutter and Anne Becka, “Electronic Packaging” by Warren Fackler, and “Seal Technology” by Bruce Steinetz. In addition, Balbir Dhillon, who contributed to the first edition of the handbook, wrote two chapters for this edition—“Total Quality Management in Mechanical Design” and “Reliability in Mechanical Design.”

Many of the chapters covering mechanical design fundamentals have been revised. Frank Fisher revised his own “Stress Analysis” chapter. The Ravindran-Reklaitis duo

revised their own “Design Optimization” chapter. Steve Daniewicz has updated Jack Collins’ monumental “Failure Considerations” chapter. Bob Crane, with a new co-author, Theodore E. Matikis, updated his “Nondestructive Testing” chapter.

The authors of the chapters on systems and controls—Andy Sage, Preston White, and Bill Palm—all revised their chapters. Elmer Hixson and Eugene Ripperger revised their “Measurements” chapter.

A key section of the *Handbook* deals with manufacturing engineering. The nine chapters that make up this section in the second edition include four entirely new chapters and five revised chapters. This level of change is a result of new requirements in manufacturing. For example, just-in-time scheduling and a continuous flow in manufacturing processes require well-planned and well-designed manufacturing facilities. The increased use of composite materials has required more sophisticated manufacturing processes. In order to provide greater levels of quality, information systems must be linked directly to production processes. Cutting down on waste when production of a new part starts up requires off-line adjustments in tooling.

The organizers and authors of the majority of the chapters in the manufacturing engineering section—Magd Zohdi and Bill Biles—have again made a significant contribution to the *Handbook*. This time they have been joined by colleagues Dennis Webster and Thomas Ray. In addition, this section features new chapters by Gordon Lewis (“Engineering Design for Economic Production”) and Murray Roblin (“Fastening and Joining”), as well as a revision by Dell Allen of his “Classification Systems” chapter.

The section with the least amount of change involves energy and power. But even here there have been numerous major revisions and several important additions. Adrian Bejan revised his “Thermodynamics” chapter and provided a new chapter on “Exergy Analysis and Entropy Generation Minimization.” These authors revised their own chapters: Jim Keppler (“Coals, Lignite, Peat”), Peter Blair (“Geothermal Resources”), Joe Palen (“Heat Exchangers, Vaporizers, Condensers”), Allan Kraus (“Cooling Electronic Equipment”), Ronald Douglas Matthews (“Internal Combustion Engines”), and Len Wenzel (“Cryogenic Equipment”). These authors provided new versions of chapters written by others in the first edition: Bud Peterson (“Heat Transfer Fundamentals”), Harold Miller (“Gas Turbines”), and Dennis O’Neal (“Refrigeration”). Joe Fozsasz contributed a new chapter on air compressors. I have also included two chapters borrowed from another Wiley handbook: “Steam Turbines” (William G. Steltz) and “Hydraulic Systems” (Hugh R. Martin).

In the pollution control technology area, there are two entirely new chapters—one on air, by Andy Miller, the other on water, by Carl Brunner.

The final section of the *Handbook* deals with a variety of topics that concern mechanical engineers as their careers grow and mature. Few of these topics are static, and the section contains seven new chapters and three revisions. Among the new chapters are “Management Control of Projects” (Joe Maciariello and Calvin Kirby), “Managing People” (Hans Thamhain), “Detailed Cost Estimating” (Rod Stewart), “Total Quality Management and the Mechanical Engineer” (R. Alan Kemmerling and Jack ReVelle), “Registrations, Certifications, and Awards” (Jack ReVelle and Cynthia Scribner), and “What Engineers Need to Know about the Law” (Al Weinstein and Martin Chizek). Revisions include “Finance and the Engineering Function” (Bill Brett), “Patents” (David Burge), and “The Internet and Online Databases” (Bob Schwarzwald).

I am grateful to all of these authors. What I said in the Preface to the First Edition of the *Handbook* bears repeating: “The wonder is that I was able to obtain . . . articles from such a wide variety of authors. . . . All of them . . . have exhibited great dedication. Writing an article for a handbook is its own reward. A desire to impart information, knowledge, and experience to others for little personal gain is a truly wonderful thing.” I also want to thank my editor at Wiley, Bob Argentieri, who has been with this project from the beginning.

MYER KUTZ

New York, New York
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PREFACE TO THE FIRST EDITION

A handbook's contents portray the interests of the editor. As I pass back and forth over these chapters I find that they reflect my own career.

As an undergraduate in mechanical engineering at MIT I concentrated on mechanical design and actually thought, as I once told my father when he asked me how I intended to make a living, that I would be happy if someone would pay me to solve design problems. I was very young. While still an undergraduate I had a part-time job at the MIT Instrumentation Laboratory, where I did my Bachelor's thesis, *Design of a Bearing Torque Tester*. This was in the late 1950s, in the early days of such new and alternative materials as titanium and composites, covered in detail in this handbook, and when testing and failure analysis were much less sophisticated than they are today. (See the chapters on failure analysis and nondestructive testing.) As things turned out, however, when I went to work at the laboratory full-time, I found myself in a thermal design group working on temperature control for the guidance system of the Polaris missile. Most of my career as a mechanical engineer was focused on thermal design and temperature control. In fact, the title of my 1967 book was just that, *Temperature Control*. So the sections of this handbook on systems analysis, automatic control, thermodynamics, and heat transfer cover disciplines in which I was very much involved professionally throughout the 1960s. (I managed to employ systems engineering terminology in an article in *How Things Work in the Home*, published by Time-Life Books.)

Perhaps it was the Rockefellers' past identification with oil that suggested them as the topic for a book I wrote in the early 1970s (*Rockefeller Power*, published by Simon and Schuster in 1974), and possibly it is stretching the point to say that the chapters in this handbook on energy resources and power reflect what turned out to be a career transition. In 1976 I turned my professional activities to publishing as an acquisition editor for professional and reference books in mechanical engineering and related disciplines at Wiley. Among the most successful titles in my editorial program were books on manufacturing, products liability, patents, and occupational safety and health—all areas where I had no prior professional experience. Sales of these books demonstrated the needs of the marketplace, of course. I would be neglecting the concerns of many mechanical engineers if I did not include these topics in the handbook. Hence, the major sections on manufacturing and management.

More recently my professional life has focused on two major areas—computers and management. For several years I ran the Electronic Publishing Division at Wiley, with responsibility for distributing publications online via telecommunications. The chapters on computers, sources of mechanical engineering information, and online searching all reflect my concerns of this period.

As chairman of the Publications Committee of the American Society of Mechanical Engineers and, currently, as Executive Publisher of the Scientific and Technical

Division at Wiley, I have focused on financial matters. Several chapters of the handbook directly address this work. Worth noting here is that the ASME Board of Governors has identified the interaction of management with finance (and marketing) as being of key strategic importance.

In the past several decades, while my career was undergoing change, mechanical engineering was growing and evolving into a variety of different professions. This handbook, with its wide-ranging emphases, reflects this evolution—just as it must reflect the career growth and change of many mechanical engineers. It was Dick Zeldin, then head of Wiley's handbook program, who suggested that I undertake the editing of this handbook. At the outset, I intended it to be a one-volume updating of the old two-volume Kent's *Mechanical Engineers' Handbook*, which was first copyrighted in 1895. The most recent edition, the 12th, was published in 1950. It still continues to sell despite the fact that some of it is outdated and many topics that have become important over the past 35 years are not included. Not surprisingly, the 1950 edition of Kent contains little or nothing on computers and microprocessors, modern techniques of failure analysis, titanium, plastics and composites, modern techniques of nondestructive testing, group technology in manufacturing, computer integrated manufacturing, control systems design, modern financial techniques, safety engineering, online searching, energy, cogeneration, heat recovery, and nuclear power. The world of Kent, 12th edition, was a different world, a world in which engineering could afford large safety factors. Who cared how much anything weighed, or how much energy was consumed? So it is interesting to look back at the 12th edition and note the emphasis on steel. Steel must have been a relatively happy industry in the immediate postwar period—much happier than today. Obtaining an article on steel was an agonizing process. The industry is so demoralized, it seems, that when the Iron and Steel Institute moved from New York to Washington, it did not take along its library. I finally resolved the difficulty by borrowing part of the article that Wiley published in the Kirk-Othmer *Encyclopedia of Chemical Technology*.

Much of the 12th edition of Kent seemed to defy updating. How could you improve on the section on the efficiency of splices and knots? A revision of the chapter on woodworking (which was combined with a chapter on plastics molding) seemed better left in other hands—and in other publications.

In fact, the break between the 12th edition of Kent and a handbook edited in the 1980s was so severe that it seemed inappropriate to (1) attempt an updating, and (2) call a new mechanical engineers' handbook the 13th edition of Kent. I recommend, therefore, that you not clear space on your shelf for this volume by throwing out your old Kent, but that you keep both.

One thing you may not need the old Kent for, however, is its mathematical tables. With an inexpensive scientific calculator, most numbers you need are at your fingertips. You will not find mathematical tables in these pages. Why destroy forests to make paper for printing tables when ubiquitous microelectronics are so cheap and powerful?

They are changing the profession of mechanical engineering. In fact, CAD/CAM or CIM (computer integrated manufacturing), and robotics, for example, have made mechanical engineering a "hot field." So this handbook begins with chapters on computers and microprocessors (and, later, has a chapter on robots and computer-aided manufacturing).

This order was the recommendation of the handbook's editorial board. I am indebted to them for this wisdom—and for their good sense in confirming the subject

matter of the handbook. The final decision on what actually went into the handbook was mine alone—as were the choices of contributors. As it turned out, this was a massive undertaking. Although I have many connections within the mechanical engineering fraternity, not all of the 78 articles came easily. Some did not come forth at all, and I have had to borrow about 10 percent of the articles from other sources. These borrowings have been edited for this handbook, of course, often by the original authors.

The wonder is that I was able to obtain original articles from such a wide variety of authors. Some of them I knew because I had edited their books. Others were colleagues on ASME boards and committees. Others I found after exhaustive correspondence and telephone calls. All of them, no matter what their prior relationship to me, have exhibited great dedication. Writing an article for a handbook is its own reward. A desire to impart information, knowledge, and experience to others for little personal gain is a truly wonderful thing.

My thanks to colleagues Martin Grayson, Thurman Poston, Wiley's excellent production staff, particularly Ed Cantillon, Margaret Comaskey, Douglas Elam, and the unknown copyeditor and proofreaders. Thanks, too, to my secretary, Meryl Weiner, who put up with an awesome amount of last minute typing and organizational work. At this point, authors and editors generally mention spouses and other family members, thanking them for their patience and understanding. I have read hundreds of these citations to late nights in offices and Sunday afternoons spent with galleys spread over the dining room table. I know from personal experience that these statements are not pro forma; they are true, and they come from the heart. So does this: My wife Mandy deserves special thanks, particularly because this handbook was so long in the making.

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February 1986