

The Top Ten Books for Gear Engineers

Robert Errichello

Introduction

When I was new to gear engineering, I found the array of gear literature scarce, and the information scattered and conflicting. After investigating the materials available, I set the goal of creating an annotated listing of the references. There are many valuable resources, but for this article I have selected ten of the best. These references, in my opinion, are the most useful, and cover the scope while minimizing redundancy.

Dudley's Gear Handbook, 2nd ed., D. P. Townsend, ed. McGraw-Hill, 1991, 815 pages. It has been nearly thirty years since the first edition of the *Gear Handbook* was published. Over the years the *Gear Handbook* has served as a valuable resource for people who design, manufacture, and use gears. The second edition has been extensively revised and updated with two new chapters on gear vibration and noise.

The *Gear Handbook* shares the strengths and weaknesses of most handbooks in that it is comprehensive but condensed. Nevertheless, it is a convenient, single source for information on gears.

An important feature of the handbook is its extensive reference lists, which help gear researchers locate information.

The handbook comprises 24 chapters written by 26 contributors. With so many authors, some redundancy and inconsistencies are bound to occur. This is not necessarily a disadvantage though, because repetition and diverse opinions can help readers draw accurate conclusions.

Although the second edition is better organized than the first, the index is still too limited for easy access to information.

The *Gear Handbook* covers the fol-

lowing subjects in detail:

The theory of gearing, gear types and nomenclature, gear arrangements, gear tooth design, and detailed calculations of gear tooth geometry; Gear tolerances; Gear materials; Engineering drawings for manufacturing; Gear tooth loads; Gear and bearing load rating; Gear failures; Performance testing; Gear vibration and noise; Gear lubrication; Gear manufacturing including cutting, die processing, shaving, rolling, honing, and grinding; Bevel and hypoid gear manufacturing; Cylindrical and double-enveloping worm and worm gear manufacturing; Gear cutting tools; Gear inspection devices and procedures; and Tables of numerical data, including wire measurement data, trigonometric functions, involute functions, arc and chord data, and hardness testing data.

Fundamentals of Gear Design, R. J. Drago, Butterworths, 1988, 560 pages. Raymond Drago's book is a well organized, comprehensive treatment of gear theory, gear fabrication and inspection, gear failure and load capacity evaluation, and gear lubrication. Most chapters include extensive reference lists and bibliographies. I especially like the bibliography that is grouped by manufacturing method.

One of the strengths of *Fundamentals of Gear Design* is its emphasis on American Gear Manufacturers Association standards and practices. This is important because gear engineers should be aware of the excellent information available through AGMA.

The book contains good descriptions and illustrations of gear failure modes. However, I prefer the term



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"scuffing" over the author's terms, "frosting" and "scoring."

The chapter on variable, static, and low-cycle loading is unique for a gear text, because it treats both bending yield and contact yield analyses. The chapter also includes an analysis of subsurface stresses, which is useful for determining case depth for case hardened gears.

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Drago's discussion on gear lubricants is one of the best I have seen.

***Gear Drive Systems*, P. Lynwander, Marcel Dekker, 1983, 415 pages.** I like this book because it contains practical information for the gear engineer and for anyone else who is responsible for the specification and operation of gear systems.

Gear Drive Systems emphasizes the gearbox applications and discusses installation, operation, maintenance, troubleshooting, failure analysis, and economics. For the beginning gear engineer, there is a good overview of types and arrangements of gear drives, gear tooth geometry and kinematics, and gearbox load rating. Bearings, seals, lubrication systems, materials and heat treatment, and manufacturing methods are also covered.

Operators of gear drive systems will appreciate the chapter on gearbox installation, which discusses couplings and system alignment, and the chapter on gearbox operation, which discusses acceptance testing, initial startup, and condition monitoring. The last chapter covers maintenance and failure analysis.

***Maag Gear Book*, Maag Gear Company, 1990, 435 pages.** This book has been in great demand ever since the German version, *Maag-Taschenbuch*, was released in 1963. A revised edition of the German version came out in 1985, and the first English version *Maag Gear Book*, in 1990.

The *Maag Gear Book* gives a good overview of European practices and ISO methods for gear design and analysis, including gear geometry, load rating, application of gear drives, gear couplings, inspection, gear materials, and heat treatment.

The *Maag Gear Book* is well organized with helpful tables and graphs of data. The chapter on gear geometry gives the essential equations for gear tooth data and includes the best treatment I have seen on profile shift (addendum modification). The charts called "contact condition diagrams" will help the gear engi-

neer apportion the profile shift between the pinion and the gear so that specific sliding is reasonably controlled.

The chapter on load rating treats the ISO-Maag method for calculating pitting resistance and bending strength, and Maag's method for calculating scuffing resistance which is based on Blok's critical temperature criterion.

The chapter on gear drives discusses gear tooth profile and helix modifications, and the chapter on gear materials and heat treatment covers the selection and heat treatment of DIN steels.

An important feature of the book is the English, German, French, and Italian dictionary of gear geometry terms.

***The Geometry of Involute Gears*, J. R. Colbourne, Springer-Verlag, 1987, 532 pages.** This is the best textbook on gear geometry currently available. All the equations are derived from first principles and reduced to useful design algorithms. The clear, straightforward presentation makes complicated gear geometry seem simple. Part I covers spur gears, and Part II covers helical gears.

Colbourne gives a design procedure for internal gearsets that treats fillet interference, tip interference, axial and radial assembly, and manufacturing problems, such as tip trimming and cutter rubbing.

He explains gear cutting, including hobbing and shaping with pinion and rack cutters. Manufacturing engineers will be interested in his discussion of hobbing machines.

The last chapter covers calculating contact stress and bending stress in helical gear teeth, and suggests several improvements over AGMA procedures.

An important feature of the book is its many numerical examples which gear engineers will find helpful for checking their work and validating computer programs.

The Geometry of Involute Gears will be extremely useful to graduate students, practicing gear engineers, and gear researchers.

***Gears for Small Mechanisms*, W. O. Davis, N.A.G. Press Ltd., (London),**

2nd ed., 1970, 344 pages. One of the best ways to learn about involute gears is to study noninvolute gears. This book presents the theory of both involute and cycloidal gears. It covers the theory and practice of the design of very small gears, including friction and efficiency of tooth action. It also covers the design of tools for cutting and generating gear teeth and production and testing of gears used in watches, recording instruments, automatic control mechanisms, and similar devices.

Davis's book deals with the special problems presented by fine pitch gears that are not solved by scaling down copies of power transmission gears. The reader will gain an appreciation for the features and limitations of involute and

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cycloidal gearing. Extremes in the design of involute gears, for example, spur pinions with as few as three teeth, are also explored.

There are good discussions on the dynamic characteristics of gear trains, transmission error, and resonant vibration. Also included is the metrology of fine pitch gears, design of gear trains, and the estimation of gear tooth load capacity. Although the book is relatively old, most of the material is still relevant to current gear engineering.

***The Exact Over-Wire Measurement of Screws, Gears, Splines, and Worms*, W. F. Vogel, Wayne State University Press, 1973, 230 pages.** The indirect determination of gear tooth thickness by the measurement over wires (pins) or balls is a popular technique, and gear engineers should understand the theory and calculations underlying this method. It is especially important to understand the limitations of wire measurements; for example, odd-tooth helical gears cannot be accurately measured with only two wires. Vogel shows that they can be accurately measured with three wires under certain conditions, or with one wire with the gear

mounted on an arbor, or with two balls under certain conditions.

Vogel gives the derivation of the equations for the over-wire measurement of involute spur and helical gears. He also gives a complete general theory of wire and ball measurement that can be used for the exact measurement of general screws of either involute or noninvolute profiles.

Steel Selection - A Guide for Improving Performance and Profits, R. F. Kern and M. E. Suess, John Wiley, 1979, 445 pages. This book bridges the gap between metallurgical theory and real-world applications. Kern and Suess present guidelines for designing components to reduce distortion and avoid cracking during heat treatment, selecting alloys, and specifying heat treatment. They also explain how to produce gears, shafts, springs, and fasteners, and how to design against surface fatigue, bending fatigue, (high and low cycle), subcase fatigue, and scuffing.

All the major heat treatments are discussed, including through hardening and case hardening by carburizing, nitriding, and induction hardening.

The chapter on selecting steels for carburized gears emphasizes the importance of hardenability and gives guidelines for proper steel selection to obtain adequate case and core hardenability.

Written for engineers and shop personnel, *Steel Selection* is an excellent resource for the gear engineer.

The Influence of Microstructure on the Properties of Case-Carburized Components, G. Parrish, ASM, 1980, 236 pages. This book is a must for the gear engineer who designs carburized gears. It gives an in-depth discussion of the complexities and the significance of the following microstructural features: Internal oxidation, decarburization, carbides, retained austenite, grain size, microcracking, microsegregation, non-metallic inclusions, core properties and case depth, optimum case depth, tempering, refrigeration, grinding burns, residual stress, and shot peening.

The clear, concise writing makes the book a joy to read, and the contents make it a valuable resource for gear engineers, quality assurance personnel, and gear failure analysts.

Machinery Vibration - Measurement and Analysis, V. Wowk, McGraw-Hill, 1991, 358 pages. There has been a continuing trend toward higher speed mechanical systems, and a greater emphasis on reliability, efficiency, and controlling vibration. There have also been tremendous advances in the technology of vibration measurement in the past fifteen years. Because modern gearboxes must be reliable, efficient and quiet, it is imperative that gear engineers be knowledgeable in gear vibration.

Machinery Vibration is an excellent instructional tool for teaching how to take vibration measurements and interpret the results. The book is intended for operation and maintenance personnel and assumes that the reader has no prior knowledge of vibrations. However, an undergraduate course in vibration theory would be useful.

Wowk describes the basic concepts of vibration theory, including mass, stiffness, damping, amplitude, frequency, phase, time versus frequency domains, displacement, velocity, acceleration, steady state versus transient vibration, natural frequency, and resonance. He focuses on conventional instruments to measure machinery vibration, such as the fast Fourier transform (FFT) spectrum analyzer. Displacement, velocity, and acceleration transducers are discussed so that the reader will gain a working knowledge of the capabilities and limitations of each transducer.

Wowk also presents several interesting case histories that illustrate typical vibration problems, including imbalance, misalignment, resonance, cavitation and oil whirl, and excitation from gears, bearings, pumps, and motors.

After studying this book, the reader will have knowledge of the techniques and instrumentation required to solve common vibration problems. ■

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