# CRC Handbook of Lubrication (Theory and Practice of Tribology), Volume II, Theory and Design,

REVIEWED BY E. R. MAKI[1] AND R. C. ROSENBERG[1]

Volume II of the CRC Handbook of Lubrication is the second part of a two-volume series sponsored by the American Society of Lubrication Engineers. While Volume I deals with applications and maintenance, Volume II addresses theory and design.

The editor, E. R. Booser, has done a most capable job of coordinating and drawing on the expertise of the 38 authors who contributed the 33 chapters of this volume. He gives us the collective benefit of many viewpoints and perspectives in a well balanced and harmoniously written book. Each author is to be complemented for his individual effort. Because the field is so large, it is not possible to go into great depth on the individual topics. However, the text is quick in getting to the point without being boisterous. The essentials are here, as befits a handbook, but do not be too hasty as you may miss an important point. This is a handbook in the true sense of the word—a ready reference that brings one up to speed quickly.

There are three sections in Volume II:

Friction, Wear and Lubrication Theory
Lubricants and Their Application
Design Principles

Each of these sections is divided into orderly and concise treatments of the respective technical area and the reader soon becomes comfortable with the style and terseness of the text.

## Friction, Wear and Lubrication Theory

This section has 13 chapters. We are first introduced to the shape of surfaces as important to the tribologist. Then, we learn of their properties in terms of chemistry, physics, metallurgy, and mechanical nature.

Parts of these early chapters tend to address advanced research methods rather than the typical techniques used by practicing engineers. For example, in the section on the properties of surfaces, more space is used to discuss advanced techniques of surface analysis, such as LEED and AUGER electron spectroscopy, than the more commonly used scanning electron microscope techniques.

From the discussion of surfaces it is but a short step to friction and on to boundary lubrication. In these chapters the fundamentals of friction, lubrication and wear are discussed, terms are defined, and the important parameters are outlined.

Four chapters are devoted to the important principles of hydrodynamic lubrication. Those who want a comprehensive overview of the theory of fluid film lubrication will find that these pages fulfill this need. Of particular interest and potential future value are the straightforward presentations on turbulent film characteristics and the dynamic behavior of bearings. Those mystified by the transient behavior of viscous films will become comfortable with their characteristics after reviewing the chapter on squeeze films and bearing dynamics.

The subject of elastohydrodynamic lubrication is covered in one chapter. It begins with the basic concepts, moves on to treat both partial elastohydrodynamic lubrication and micro-elastohydrodynamic lubrication, and finally finishes with a brief discussion of its application to machine elements. This chapter provides some of the theoretical bases which are discussed in later chapters on rolling element bearings and gear performance.

The final chapters in this section are a discussion of wear. This area has been subdivided into four chapters including Metallic Wear, Nonmetallic Wear, Wear Coefficients, and Lubricated Wear. While there is some overlap in coverage, especially in the area of adhesive wear, this is unavoidable in the interest of maintaining continuity in each of the chapters. In general, the chapters on wear focus on the fundamental aspects of this complex phenomena rather than providing endless tables of wear data.

A difficulty with this section is that, while the title is Friction, Wear and Lubrication Theory, the actual chapters are ordered friction, lubrication and wear.

## Lubricants and Their Application

The 11 chapter section on Lubricants and Their Application includes topics ranging from liquids to solids to gases. In addition, coverage is given to processing fluids for metal working and the various methods of lubricant application.

Properties of liquid lubricants, greases, solid lubricants and gases are covered in the first four chapters of this section. The next chapter, Lubricating Oil Additives, seems misplaced and would have been better following the chapter on Liquid Lubricants. However, the total coverage is adequate to provide a first source of information about the various types of lubricants. Each chapter includes information relating to lubricant properties, applications, and the classification or specification systems that are commonly used.

The use of lubricants for metal processing by either deformation or cutting is treated in the next four chapters of this section. Tribological factors that affect these processes are covered in the first two chapters and the issues that influence cutting fluids and their stability are treated in the remaining two chapters.

The last two chapters in this section consider the methods of applying lubricants and their use in circulating oil systems. In typical handbook fashion they highlight the attributes of the various systems used for these functions and will give a novice designer the guidance needed to evaluate them.

## Design Principles

The third section has nine chapters which bring into practical focus the information presented in the prior two sections. It is here that one can assess the applicability of the theory by framing it within the guidelines provided by experienced tribologists. These chapters are well organized and presented. They would make excellent material for any course on mechanical design and would, if used in this manner, encourage many to make the correct decisions regarding tribology applications.

The first three chapters of this section provide information on the design of self-acting journal and thrust bearings, how to select materials for sliding bearings, and finally, how to evaluate bearing problems through damage analysis. Applications engineers should find these three chapters most useful in the pursuit of their activities.

Rolling element bearings and gears are given an overview. Each of these topics has sufficient complexity to well deserve the many books and articles available. It is not the intent of this publication to review all this prior technology. Read these chapters from the perspective of tribology and they will repay the effort many times over. They identify the areas of concern via a quick look.

Guidelines for shaft coupling, i.e., couplings and seals are presented in sufficient detail to assess serviceability of a particular geometry or design for a given application. It is unfortunate though, in the chapter on seals, that some emphasis was not placed on the issue of mating surface quality. In the case of elastomeric radial lip seals, their successul performance is as much dependent on providing a satisfactory running surface as it is on the selection of a lip material.

The final chapter in Design Principles deals with an approach to systems analysis. Although such procedures are not, in general, used among tribologists, this methodology

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has merit and the practitioner may well heed its signals to systemize the solution of lubrication problems.

Overall, this handbook is well organized with movement from general to more specific topics. It does, however, lack an overview and as such could be improved if there was a general introduction to the subject of tribology that would help the novice to find his way through this book. One problem noted during the review was that the Table of Contents is awkwardly placed on the twelfth page verso. A more prominent location, such as inside the front cover, would assist the reader in rapidly finding the subject of interest. On the other hand, the 24 page index at the end of the book is very complete and brings together subjects that are covered in several locations.

The use of SI units throughout is applauded, as is the attempt to use the ASLE nomenclature. The early chapters adhere to this nomenclature rigorously, but later chapters on lubricant properties and metal working processing do not. As an example, $\mu$ is viscosity in the fluid film sections and coefficient of friction in the metal working chapters.

This is an excellent reference volume which, in conjunction with its Volume I companion, will provide the user with an up-to-date set of tools to approach his tribology analysis and design issues. Most of the chapters provide adequate references to provide the reader with a ready source of additional information.

Although there may be individual points of technical conflict, the user will ultimately come to appreciate the content and presentation of this work. The quality of production is superior and there are few text errors. A prospective purchaser may expect this handbook to be a valuable first reference on the theory and practice of tribology or a durable and serviceable addition to an established, expanding collection.

**Polymers in Friction Assemblies of Machines and Devices: A Handbook edited by A. V. Chichinadze, Allerton Press Inc., 150 Fifth Ave., New York, N. Y., 10011, 1984, 280 pp.**

**REVIEWED BY N. S. EISS, JR.**[1]

The handbook consists of two parts, I Polymers for friction bearing (anti-friction polymers) and II Asbestos-polymer friction materials. Each part is an entity: Chapters, figures, equations, and references are numbered from one in each. The most valuable chapter of the handbook for the designer of plastic bearings is Part I Chapter 3, "Design of polymer friction bearings." In this chapter the topics of most interest are the evaluation of the heat-dissipation capability of assemblies, the determination of minimum permissable clearances, and the calculation of the reduction in clearance during operation. This chapter also includes a detailed tabular design method which could readily be programed on personal computers. A sample calculation is included with the presentation of the tabular method and additional sample calculations are included in Part I, Chapter 4.

The handbook makes specific recommendations of materials to use in thermoplastic friction bearings (TFB). In Chapter 1, mechanical, physical, thermal, and friction and wear properties are given for Soviet thermoplastics and "foreign" analogs of their materials. At the conclusion of Chapter 1, three thermoplastics are identified as perferred materials, Kapron (nylon), ATM-2 (Kapron with 55 percent coke and graphite as fillers) and SFD (acetal copolymer of formaldehyde with dioxalane). The latter two materials are less hygroscopic than the former and the ATM-2 material is recommended for assemblies with one-shot lubrication while the SFD is recommended for assemblies with periodic lubrication. Most of the example calculations are for bearings using the latter two materials although some calculations are made for Kapron bearings because of the materials' wide spread use in Russia. For restricted-lubrication, high-precision applications a metal fluoroplastic material (steel backing coated with porous copper or cermet impregnated with PTFE and $MoS_2$) is recommended; however, no sample calculations are included using this material.

In Chapter 3, a method for calculating the heat dissipation of a bearing running a steady state is presented. All design equations are presented without derivation and most references for these equations are in Russian. Hence, verification of the equations and assumptions made will be difficult. There is a serious notation problem in this section: The heat dissipation parameter is called $K_B$ (p. 69) and $K_{BB}$ (p. 75) and the only distinction is that the latter is called "parameter base value" when introduced and a relationship relating the two, $K_B = 0.75K_{BB}$ (p. 84), is also given. However, Fig. 42 is labeled $K_{BB}$ while Fig. 43 and 44 are labeled $K_B$ and all the called the heat-dissipation parameter.

In the section on calculating clearances, it is noted that the maximum reduction in clearance occurs during the transient heating before the housing has been heated. As in the previous section equations are presented without derivation and without references. The tabular design method in the next section refers to graphs of heat exchange coefficients, and heat dissipation factors previously presented as well as geometry and polymer property data. Some calculated results on load carrying capacity (PV) for Kapron, SFD, and ATM-2 are compared with measured data from a bench test and show the calculated values PV are 10–20 percent below the measured values.

Two major shortcomings which limit the usefulness of this handbook are the lack of an index and a table of nomenclature. While most symbols and acronyms are defined when first used, it is very inconvenient to search through the book for the first useage when the acronym is encountered later on in the book.

The major shortcoming of Part II is the emphasis on asbestos fillers for friction materials. In view of the evidence supporting the cause of cancer by asbestos materials and the subsequent efforts to remove asbestos from products, all of the data presented in this part has only historical interest for designers.

In Chapter 2 of Part II, 11 pages are a review of friction and wear theories. Design equations are presented in this chapter. Some equations are empirical, such as those for determining the total area of clutch facings, and are rendered useless by the absence of units to be used on the factors in the equation such as torque, work, and friction power.

Chapter 3 and 4 describe test apparatus and procedures for friction and wear testing of friction materials and give some physicomechanical, friction, and wear properties of asbestos polymer materials. The appendix outlines a method for calculating temperature in elements of antifriction and friction pairs. Most of the emphasis is on friction configurations, such as shoe on drum or ring against disk.

In summary, this handbook would be of interest to the plastic bearing designer who is familiar with methods for estimating bearing temperatures and clearances and is thus able to evaluate if the methods presented are applicable to his design. Designers who occasionally must design a plastic bearing will find this handbook very difficult to use because

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