英文版

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Wen Shizhu Huang Ping

摩擦学原理（第2版）

Principles of Tribology

Second Edition

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内 容 简 介

本书汇集摩擦学研究的最新进展及作者和其同事从事该领域的研究成果，系统地阐述摩擦学的基本原理与应用，全面反映现代摩擦学的研究状况和发展趋势。

全书共 21 章，由润滑理论与润滑设计、摩擦磨损机理与控制、应用摩擦学等 3 部分组成。除摩擦学传统内容外，还论述了摩擦学与相关学科交叉而形成的研究领域。本书针对工程实际中的各种摩擦学现象，着重阐述摩擦过程中的变化规律和特征，进而介绍基本理论、分析计算方法以及实验测试技术，并说明它们在工程中的实际应用。

本书可作为机械设计与理论专业的研究生教材以及高等院校机械工程各类专业师生的教学参考书，也可以供从事机械设计和研究的工程技术人员参考。

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Huang Ping is professor of the School of Mechanical and Automotive Engineering, South China University of Technology. He was born in Qiqihar City, Heilongjiang Province in 1957. He graduated from the Department of Engineering Mechanics, Tsinghua University obtaining his PhD degree in 1989, and worked in the State Key Laboratory of Tribology of Tsinghua University for seven years. He now serves as the director of the Design and Equipment Institute of South China University of Technology. He has published seven books and more than 160 articles. He won second prize in the National Natural Science Awards, third prize in the National Invention Awards and more than seven other provincial and ministerial scientific and technological progress awards. He won the national famous teacher award in 2011.

Second Edition Preface

This edition of *Principles of Tribology*, based on the first edition, is formed by revising the inadequacies of the original edition and its being improved in response to the hotspots of recent tribology research. Since the book was first published, the readers have offered various suggestions and opinions, and given the developments in tribology research, we thought it necessary to make this revision of the book.

Although one important task for this edition was to make some error corrections, it retains the basic framework of the first edition, with 21 chapters in three parts.

Also, in response to the rapid development of high-speed railways and the implementation of the lunar exploration project in China, rolling friction has become more important, so it is brought into a separate chapter (11). Although in the previous version, rolling friction was mentioned as a typical phenomenon of friction, we only gave some basic definitions. In Chapter 11, we give more detail on rolling friction definitions, rolling friction theories and stick-slip phenomena in rolling friction, as well as contact and heat generation of rolling friction between wheel and rail. In fact, rolling friction exists widely in transportation, automobile, machinery manufacturing, production and daily life, and it has functions which cannot be substituted by sliding friction.

Another new area of content in this edition is tribology research in MEMS (micro-electromechanical system) covered in Chapter 20. This includes the application of atomic force microscopy in tribology of MEMS, micro motor tribology research and micro analysis of wear mechanisms. This content is focused on recent tribology research and the rapid development of MEMS.

Also, ecological tribology, a hot topic in tribology research, has been introduced in Chapter 21. This chapter includes zero friction and superlubrication, green lubricating oil, friction-induced noise and its control, plus remanufacturing technologies and self-repairing technology. Ecological tribology research will become an important research direction for the future.

Of course, the new content is far more than just rolling friction, MEMS tribology and green tribology, but limited space here precludes more detailed coverage of the additions. We hope that the contents of the book will be more systematic and accurate in this edition.

We present our most sincere thanks to our colleagues and graduate students for their enthusiastic support, and to all the others who have provided help and made a contribution to the development of tribology research in general and this edition in particular.

March 2016

Wen Shizhu
Huang Ping

Preface

The formation and development of tribology as a practical subject is closely related to the requirements of social production and the progress of science and technology so that its research styles and research areas have been continuously evolving.

In the early 18th century, Amontons and Coulomb proposed the classic formulas of sliding friction after carefully studying a large number of friction tests and experiments. This was the early research style of tribology, based on experience.

At the end of the 19th century, Reynolds revealed the mechanism of viscous fluids according to bearing lubrication to derive the famous equation of the hydrodynamic lubrication: the Reynolds equation, which laid the theoretical foundation of lubrication. Therefore, it created a new research style based on continuum mechanics.

In the 20th century, due to production development, tribology research fields were further expanded. During the period, Hardy proposed the boundary lubrication theory, which was based on physical and chemical adsorption films of polar molecules of the lubricant on the surface. This promoted studies of lubricants and additives. Tomlinson explained the cause of solid sliding friction from the viewpoint of energy conversion in molecular motion. Furthermore, Bowden and Tabor established the adhesion friction theory based on the plowing effect. These achievements not only expanded the range of tribology, but prompted it to become a discipline involving mechanics, materials science, thermal physics and physical-chemistry, so as to create a multidisciplinary research style.

In 1965, the British Ministry of Education and Science published the report *Tribology and Research*. This was the first time that tribology had been defined as the science of the friction process. Since then, tribology as a separate discipline has been paid wide attention by industry and academia wordwide, and tribology research has entered a new period of development.

With in-depth theoretical and applied research, it is recognized that in order to effectively realize the potential of tribology in the economy, research has to evolve from the macro to the micro scale, from quality to quantity, from the static to dynamic and from single discipline to multidiscipline. At the same time, tribological research has gradually extended from the analysis of tribological phenomena to the analysis and control of them, or even to the control of tribological properties on a target. In addition, tribology research in the past mainly focused on equipment maintenance, but it has now changed to innovative design of mechanical products.

Modern science and technology, especially information science, materials science and nano-technology, plays a significant role in pushing the development of tribology. For example, because of the rapid development of computer science and numerical analysis, many complex tribological phenomena have been solved quite accurately with quantitative analysis. Therefore, the numerical methods used in lubrication simulation have pushed lubrication theory to consider a number of practical factors influencing the design of modern machinery. As another example, the electron microscope and micro-analytical instruments are now widely used for the analysis of worn surfaces to provide useful tools in studying the wear mechanism.

At the same time, the development of materials science has developed many new materials and surface treatment technologies so as to greatly promote research on the wear mechanism. The fields of modern wear have extended from metal materials to non-metallic materials, including ceramics, polymers and composites. Surface treatment technologies using physical, chemical and mechanical methods to modify the material properties of the surface have been the most rapidly developing area of tribology in recent years.

The development of nano-technology has generated a series of new disciplines, including micro- or nano-tribology. It occurs because tribological phenomena are closely related to the micro-structural changes and the dynamic behaviors of the surface and interface. Nano-tribology provides a new style from the macro to the atomic and molecular scales to reveal the mechanisms of friction, wear and lubrication so as to establish the relationship between the macroscopic properties and the micro structures of the material. These are the basic tribology mechanisms. The emergence of nano-tribology shows that tribology study has entered a new stage.

Furthermore, tribology is an interdisciplinary subject closely connected with other disciplines to form a new research field, which has distinctive features. Chemical tribology, biological tribology and ecological tribology appearing in recent years may become hot fields in future tribological research.

This book is based on the Chinese version previously published by Tsinghua University Press, which achieved recognition for its excellence as a scientific work by gaining a National Book Award.

In the book, we try as far as possible to reflect the whole picture of modern tribology and introduce new areas of tribological research and development trends. Obviously, the new areas currently are not yet well-known, so we will give a brief exposition for the reader to promote development of these areas. For the classical contents of tribology, we try to clearly state the basis of knowledge.

Because the scope of tribology is wide and the nature of a book is essentially limited, some defects or deficiencies may exist and we therefore welcome criticisms and corrections from readers.

During the writing of the book, we have cited many researches of scholars both domestic and international. We present our most sincere thanks to them as well as to the colleagues and graduate students at Tsinghua University for their enthusiastic support, help and contribution to the development of tribology research and to this book.

2011 Lunar New Year

Wen Shizhu
Huang Ping

Introduction

This book is a compilation of the current developments in the tribology research of the authors and their co-workers over a long period. It is a systematic presentation of tribology fundamentals and their applications. It also presents the current state and development trends in tribology research.

There are 21 chapters, consisting of three parts: I: lubrication theory and lubrication design, II: friction and wear mechanism and control, III: applied tribology. Beside the classical tribology contents, it also covers interdisciplinary areas of tribology. The book mainly focuses on the regularities and characteristics of tribological phenomena in engineering. Furthermore, it presents basic theories, numerical analysis methods and experimental measuring techniques as well as the applications of tribology.

The book is intended to be used as a textbook for senior-level or graduate-level students majoring in mechanical engineering or in related subjects in universities and colleges. It can also serve as a valuable reference for engineers and technicians in machine design and tribology research.

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