

英文版

温诗铸 黄平 著

Wen Shizhu Huang Ping

摩擦学原理 (第2版)

Principles of Tribology

Second Edition

清华大学出版社



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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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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 worldwide, 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.

Contents

About the Authors *xvii*
Second Edition Preface *xix*
Preface *xxi*
Introduction *xxiii*

Part I Lubrication Theory 1

1 Properties of Lubricants 3

1.1 Lubrication States 3

1.2 Density of Lubricant 5

1.3 Viscosity of Lubricant 7

1.3.1 Dynamic Viscosity and Kinematic Viscosity 7

1.3.1.1 Dynamic Viscosity 7

1.3.1.2 Kinematic Viscosity 8

1.3.2 Relationship between Viscosity and Temperature 9

1.3.2.1 Viscosity–Temperature Equations 9

1.3.2.2 ASTM Viscosity–Temperature Diagram 9

1.3.2.3 Viscosity Index 10

1.3.3 Relationship between Viscosity and Pressure 10

1.3.3.1 Relationships between Viscosity, Temperature and Pressure 11

1.4 Non-Newtonian Behaviors 12

1.4.1 Ree–Eyring Constitutive Equation 12

1.4.2 Visco-Plastic Constitutive Equation 13

1.4.3 Circular Constitutive Equation 13

1.4.4 Temperature-Dependent Constitutive Equation 13

1.4.5 Visco-Elastic Constitutive Equation 14

1.4.6 Nonlinear Visco-Elastic Constitutive Equation 14

1.4.7 A Simple Visco-Elastic Constitutive Equation 15

1.4.7.1 Pseudoplasticity 16

1.4.7.2 Thixotropy 16

1.5 Wettability of Lubricants 16

1.5.1 Wetting and Contact Angle 17

1.5.2 Surface Tension 17

1.6 Measurement and Conversion of Viscosity 19

1.6.1 Rotary Viscometer 19

1.6.2 Off-Body Viscometer 19

1.6.3	Capillary Viscometer	19
	References	21
2	Basic Theories of Hydrodynamic Lubrication	22
2.1	Reynolds Equation	22
2.1.1	Basic Assumptions	22
2.1.2	Derivation of the Reynolds Equation	23
2.1.2.1	Force Balance	23
2.1.2.2	General Reynolds Equation	25
2.2	Hydrodynamic Lubrication	26
2.2.1	Mechanism of Hydrodynamic Lubrication	26
2.2.2	Boundary Conditions and Initial Conditions of the Reynolds Equation	27
2.2.2.1	Boundary Conditions	27
2.2.2.2	Initial Conditions	28
2.2.3	Calculation of Hydrodynamic Lubrication	28
2.2.3.1	Load-Carrying Capacity W	28
2.2.3.2	Friction Force F	28
2.2.3.3	Lubricant Flow Q	29
2.3	Elastic Contact Problems	29
2.3.1	Line Contact	29
2.3.1.1	Geometry and Elasticity Simulations	29
2.3.1.2	Contact Area and Stress	30
2.3.2	Point Contact	31
2.3.2.1	Geometric Relationship	31
2.3.2.2	Contact Area and Stress	32
2.4	Entrance Analysis of EHL	34
2.4.1	Elastic Deformation of Line Contacts	35
2.4.2	Reynolds Equation Considering the Effect of Pressure-Viscosity	35
2.4.3	Discussion	36
2.4.4	Grubin Film Thickness Formula	37
2.5	Grease Lubrication	38
	References	40
3	Numerical Methods of Lubrication Calculation	41
3.1	Numerical Methods of Lubrication	42
3.1.1	Finite Difference Method	42
3.1.1.1	Hydrostatic Lubrication	44
3.1.1.2	Hydrodynamic Lubrication	44
3.1.2	Finite Element Method and Boundary Element Method	48
3.1.2.1	Finite Element Method (FEM)	48
3.1.2.2	Boundary Element Method	49
3.1.3	Numerical Techniques	51
3.1.3.1	Parameter Transformation	51
3.1.3.2	Numerical Integration	51
3.1.3.3	Empirical Formula	53
3.1.3.4	Sudden Thickness Change	53
3.2	Numerical Solution of the Energy Equation	54
3.2.1	Conduction and Convection of Heat	55
3.2.1.1	Conduction Heat H_d	55
3.2.1.2	Convection Heat H_v	55

3.2.2	Energy Equation	56
3.2.3	Numerical Solution of Energy Equation	59
3.3	Numerical Solution of Elastohydrodynamic Lubrication	60
3.3.1	EHL Numerical Solution of Line Contacts	60
3.3.1.1	Basic Equations	60
3.3.1.2	Solution of the Reynolds Equation	62
3.3.1.3	Calculation of Elastic Deformation	62
3.3.1.4	Dowson–Higginson Film Thickness Formula of Line Contact EHL	64
3.3.2	EHL Numerical Solution of Point Contacts	64
3.3.2.1	The Reynolds Equation	65
3.3.2.2	Elastic Deformation Equation	66
3.3.2.3	Hamrock–Dowson Film Thickness Formula of Point Contact EHL	66
3.4	Multi-Grid Method for Solving EHL Problems	68
3.4.1	Basic Principles of Multi-Grid Method	68
3.4.1.1	Grid Structure	68
3.4.1.2	Discrete Equation	68
3.4.1.3	Transformation	69
3.4.2	Nonlinear Full Approximation Scheme for the Multi-Grid Method	69
3.4.3	V and W Iterations	71
3.4.4	Multi-Grid Solution of EHL Problems	71
3.4.4.1	Iteration Methods	71
3.4.4.2	Iterative Division	72
3.4.4.3	Relaxation Factors	73
3.4.4.4	Numbers of Iteration Times	73
3.4.5	Multi-Grid Integration Method	73
3.4.5.1	Transfer Pressure Downwards	74
3.4.5.2	Transfer Integral Coefficients Downwards	74
3.4.5.3	Integration on the Coarser Mesh	74
3.4.5.4	Transfer Back Integration Results	75
3.4.5.5	Modification on the Finer Mesh	75
	References	76
4	Lubrication Design of Typical Mechanical Elements	78
4.1	Slider and Thrust Bearings	78
4.1.1	Basic Equations	78
4.1.1.1	Reynolds Equation	78
4.1.1.2	Boundary Conditions	78
4.1.1.3	Continuous Conditions	79
4.1.2	Solutions of Slider Lubrication	79
4.2	Journal Bearings	81
4.2.1	Axis Position and Clearance Shape	81
4.2.2	Infinitely Narrow Bearings	82
4.2.2.1	Load-Carrying Capacity	83
4.2.2.2	Deviation Angle and Axis Track	83
4.2.2.3	Flow	84
4.2.2.4	Frictional Force and Friction Coefficient	84
4.2.3	Infinitely Wide Bearings	85
4.3	Hydrostatic Bearings	88
4.3.1	Hydrostatic Thrust Plate	89
4.3.2	Hydrostatic Journal Bearings	90

4.3.3	Bearing Stiffness and Throttle	90
4.3.3.1	Constant Flow Pump	91
4.3.3.2	Capillary Throttle	91
4.3.3.3	Thin-Walled Orifice Throttle	92
4.4	Squeeze Bearings	92
4.4.1	Rectangular Plate Squeeze	93
4.4.2	Disc Squeeze	94
4.4.3	Journal Bearing Squeeze	94
4.5	Dynamic Bearings	96
4.5.1	Reynolds Equation of Dynamic Journal Bearings	96
4.5.2	Simple Dynamic Bearing Calculation	98
4.5.2.1	A Sudden Load	98
4.5.2.2	Rotating Load	99
4.5.3	General Dynamic Bearings	100
4.5.3.1	Infinitely Narrow Bearings	100
4.5.3.2	Superimposition Method of Pressures	101
4.5.3.3	Superimposition Method of Carrying Loads	101
4.6	Gas Lubrication Bearings	102
4.6.1	Basic Equations of Gas Lubrication	102
4.6.2	Types of Gas Lubrication Bearings	103
4.7	Rolling Contact Bearings	106
4.7.1	Equivalent Radius R	107
4.7.2	Average Velocity U	107
4.7.3	Carrying Load Per Width W/b	107
4.8	Gear Lubrication	108
4.8.1	Involute Gear Transmission	109
4.8.1.1	Equivalent Curvature Radius R	110
4.8.1.2	Average Velocity U	111
4.8.1.3	Load Per Width W/b	112
4.8.2	Arc Gear Transmission EHL	112
4.9	Cam Lubrication	114
	References	116
5	Special Fluid Medium Lubrication	118
5.1	Magnetic Hydrodynamic Lubrication	118
5.1.1	Composition and Classification of Magnetic Fluids	118
5.1.2	Properties of Magnetic Fluids	119
5.1.2.1	Density of Magnetic Fluids	119
5.1.2.2	Viscosity of Magnetic Fluids	119
5.1.2.3	Magnetization Strength of Magnetic Fluids	120
5.1.2.4	Stability of Magnetic Fluids	120
5.1.3	Basic Equations of Magnetic Hydrodynamic Lubrication	121
5.1.4	Influence Factors on Magnetic EHL	123
5.2	Micro-Polar Hydrodynamic Lubrication	124
5.2.1	Basic Equations of Micro-Polar Fluid Lubrication	124
5.2.1.1	Basic Equations of Micro-Polar Fluid Mechanics	124
5.2.1.2	Reynolds Equation of Micro-Polar Fluid	125
5.2.2	Influence Factors on Micro-Polar Fluid Lubrication	128
5.2.2.1	Influence of Load	128
5.2.2.2	Main Influence Parameters of Micro-Polar Fluid	129

5.3	Liquid Crystal Lubrication	130
5.3.1	Types of Liquid Crystal	130
5.3.1.1	Tribological Properties of Lyotropic Liquid Crystal	131
5.3.1.2	Tribological Properties of Thermotropic Liquid Crystal	131
5.3.2	Deformation Analysis of Liquid Crystal Lubrication	132
5.3.3	Friction Mechanism of Liquid Crystal as a Lubricant Additive	136
5.3.3.1	Tribological Mechanism of 4-pentyl-4'-cyanobiphenyl	136
5.3.3.2	Tribological Mechanism of Cholesteryl Oleyl Carbonate	136
5.4	Electric Double Layer Effect in Water Lubrication	137
5.4.1	Electric Double Layer Hydrodynamic Lubrication Theory	138
5.4.1.1	Electric Double Layer Structure	138
5.4.1.2	Hydrodynamic Lubrication Theory of Electric Double Layer	138
5.4.2	Influence of Electric Double Layer on Lubrication Properties	142
5.4.2.1	Pressure Distribution	142
5.4.2.2	Load-Carrying Capacity	143
5.4.2.3	Friction Coefficient	144
5.4.2.4	An Example	144
	References	145
6	Lubrication Transformation and Nanoscale Thin Film Lubrication	147
6.1	Transformations of Lubrication States	147
6.1.1	Thickness-Roughness Ratio λ	147
6.1.2	Transformation from Hydrodynamic Lubrication to EHL	148
6.1.3	Transformation from EHL to Thin Film Lubrication	149
6.2	Thin Film Lubrication	152
6.2.1	Phenomenon of Thin Film Lubrication	153
6.2.2	Time Effect of Thin Film Lubrication	154
6.2.3	Shear Strain Rate Effect on Thin Film Lubrication	157
6.3	Analysis of Thin Film Lubrication	158
6.3.1	Difficulties in Numerical Analysis of Thin Film Lubrication	158
6.3.2	Tichy's Thin Film Lubrication Models	160
6.3.2.1	Direction Factor Model	160
6.3.2.2	Surface Layer Model	161
6.3.2.3	Porous Surface Layer Model	161
6.4	Nano-Gas Film Lubrication	161
6.4.1	Rarefied Gas Effect	162
6.4.2	Boundary Slip	163
6.4.2.1	Slip Flow	163
6.4.2.2	Slip Models	163
6.4.2.3	Boltzmann Equation for Rarefied Gas Lubrication	165
6.4.3	Reynolds Equation Considering the Rarefied Gas Effect	165
6.4.4	Calculation of Magnetic Head/Disk of Ultra Thin Gas Lubrication	166
6.4.4.1	Large Bearing Number Problem	167
6.4.4.2	Sudden Step Change Problem	167
6.4.4.3	Solution of Ultra-Thin Gas Lubrication of Multi-Track Magnetic Heads	167
	References	169
7	Boundary Lubrication and Additives	171
7.1	Types of Boundary Lubrication	171
7.1.1	Stribeck Curve	171

7.1.2	Adsorption Films and Their Lubrication Mechanisms	172
7.1.2.1	Adsorption Phenomena and Adsorption Films	172
7.1.2.2	Structure and Property of Adsorption Films	174
7.1.3	Chemical Reaction Film and its Lubrication Mechanism	177
7.1.3.1	Additives of Chemical Reaction Film	178
7.1.3.2	Notes for Applications of Extreme Pressure Additives	178
7.1.4	Other Boundary Films and their Lubrication Mechanisms	179
7.1.4.1	High Viscosity Thick Film	179
7.1.4.2	Polishing Thin Film	179
7.1.4.3	Surface Softening Effect	179
7.2	Theory of Boundary Lubrication	179
7.2.1	Boundary Lubrication Model	179
7.2.2	Factors Influencing Performance of Boundary Films	181
7.2.2.1	Internal Pressure Caused by Surface Tension	181
7.2.2.2	Adsorption Heat of Boundary Film	182
7.2.2.3	Critical Temperature	183
7.2.3	Strength of Boundary Film	184
7.3	Lubricant Additives	185
7.3.1	Oily Additives	185
7.3.2	Tackifier	186
7.3.3	Extreme Pressure Additives (EP Additives)	187
7.3.4	Anti-Wear Additives	187
7.3.5	Other Additives	187
	References	189
8	Lubrication Failure and Mixed Lubrication	190
8.1	Roughness and Viscoelastic Material Effects on Lubrication	190
8.1.1	Modifications of Micro-EHL	190
8.1.2	Viscoelastic Model	191
8.1.3	Lubricated Wear	192
8.1.3.1	Lubricated Wear Criteria	193
8.1.3.2	Lubricated Wear Model	193
8.1.3.3	Lubricated Wear Example	193
8.2	Influence of Limit Shear Stress on Lubrication Failure	195
8.2.1	Visco-Plastic Constitutive Equation	195
8.2.2	Slip of Fluid-Solid Interface	196
8.2.3	Influence of Slip on Lubrication Properties	196
8.3	Influence of Temperature on Lubrication Failure	200
8.3.1	Mechanism of Lubrication Failure Caused by Temperature	200
8.3.2	Thermal Fluid Constitutive Equation	201
8.3.3	Analysis of Lubrication Failure	202
8.4	Mixed Lubrication	203
	References	207
	Part II Friction and Wear	209
9	Surface Topography and Contact	211
9.1	Parameters of Surface Topography	211
9.1.1	Arithmetic Mean Deviation R_a	211

9.1.2	Root-Mean-Square Deviation (RMS) σ or R_q	211
9.1.3	Maximum Height R_{\max}	212
9.1.4	Load-Carrying Area Curve	212
9.1.5	Arithmetic Mean Interception Length of Centerline S_{ma}	212
9.1.5.1	Slope \dot{z}_a or \dot{z}_q	213
9.1.5.2	Peak Curvature C_a or C_q	213
9.2	Statistical Parameters of Surface Topography	213
9.2.1	Height Distribution Function	214
9.2.2	Deviation of Distribution	215
9.2.3	Autocorrelation Function of Surface Profile	216
9.3	Structures and Properties of Surface	217
9.4	Rough Surface Contact	219
9.4.1	Single Peak Contact	219
9.4.2	Ideal Roughness Contact	220
9.4.3	Random Roughness Contact	221
9.4.4	Plasticity Index	223
	References	223
10	Sliding Friction and its Applications	225
10.1	Basic Characteristics of Friction	225
10.1.1	Influence of Stationary Contact Time	226
10.1.2	Jerking Motion	226
10.1.3	Pre-Displacement	227
10.2	Macro-Friction Theory	228
10.2.1	Mechanical Engagement Theory	228
10.2.2	Molecular Action Theory	229
10.2.3	Adhesive Friction Theory	229
10.2.3.1	Main Points of Adhesive Friction Theory	230
10.2.3.2	Revised Adhesion Friction Theory	232
10.2.4	Plowing Effect	233
10.2.5	Deformation Energy Friction Theory	235
10.2.6	Binomial Friction Theory	236
10.3	Micro-Friction Theory	238
10.3.1	“Cobblestone” Model	238
10.3.2	Oscillator Models	240
10.3.2.1	Independent Oscillator Model	240
10.3.2.2	Composite Oscillator Model	241
10.3.2.3	FK Model	242
10.3.3	Phonon Friction Model	242
10.4	Sliding Friction	243
10.4.1	Influence of Load	243
10.4.2	Influence of Sliding Velocity	244
10.4.3	Influence of Temperature	245
10.4.4	Influence of Surface Film	245
10.5	Other Friction Problems and Friction Control	246
10.5.1	Friction in Special Working Conditions	246
10.5.1.1	High Velocity Friction	246
10.5.1.2	High Temperature Friction	246
10.5.1.3	Low Temperature Friction	247
10.5.1.4	Vacuum Friction	247

10.5.2	Friction Control	247
10.5.2.1	Method of Applying Voltage	247
10.5.2.2	Effectiveness of Electronic Friction Control	248
10.5.2.3	Real-Time Friction Control	249
	References	250
11	Rolling Friction and its Applications	252
11.1	Basic Theories of Rolling Friction	252
11.1.1	Rolling Resistance Coefficient	252
11.1.2	Rolling Friction Theories	254
11.1.2.1	Hysteresis Theory	255
11.1.2.2	Plastic Deformation Theory	256
11.1.2.3	Micro Slip Theory	257
11.1.3	Adhesion Effect on Rolling Friction	258
11.1.4	Factors Influencing Rolling Friction of Wheel and Rail	260
11.1.5	Thermal Analysis of Wheel and Rail	262
11.1.5.1	Heat Transferring Model of Wheel and Rail Contact	262
11.1.5.2	Temperature Rise Analysis of Wheel and Rail Contact	264
11.1.5.3	Transient Temperature Rise Analysis of Wheel for Two-Dimensional Thermal Shock	268
11.1.5.4	Three-Dimensional Transient Analysis of Temperature Rise of Contact	269
11.1.5.5	Thermal Solution for the Rail	270
11.2	Applications of Rolling Tribology in Design of Lunar Rover	271
11.2.1	Foundations of Force Analysis for Rigid Wheel	271
11.2.1.1	Resistant Force of Driving Rigid Wheel	271
11.2.1.2	Driving Force and Sliding/Rolling Ratio of the Wheel	274
11.2.2	Mechanics Model of a Wheel on a Soft Surface	275
11.2.2.1	Wheel Sinking	276
11.2.2.2	Soil Deformation and Stress Model	276
11.2.2.3	Interaction Force between Wheel and Soil	277
11.2.3	Dynamic Analysis of Rolling Mechanics of Lunar Rover with Unequal Diameter Wheel	278
11.2.3.1	Structure with Unequal Diameter Wheel	278
11.2.3.2	Interaction model of wheel and soil	278
11.2.3.3	Model and Calculation of Movement for Unequal Diameter Wheel	280
	References	280
12	Characteristics and Mechanisms of Wear	282
12.1	Classification of Wear	282
12.1.1	Wear Categories	282
12.1.1.1	Mechanical Wear	282
12.1.1.2	Molecular and Mechanical Wear	283
12.1.1.3	Corrosive and Mechanical Wear	283
12.1.2	Wear Process	283
12.1.2.1	Surface Interaction	283
12.1.2.2	Variation of Surface	283
12.1.2.3	Forms of Surface Damage	284
12.1.3	Conversion of Wear	285
12.2	Abrasive Wear	285
12.2.1	Types of Abrasive Wear	285

- 12.2.2 Factors Influencing Abrasive Wear 286
 - 12.2.3 Mechanism of Abrasive Wear 289
 - 12.3 Adhesive Wear 290
 - 12.3.1 Types of Adhesive Wear 291
 - 12.3.1.1 Light Adhesive Wear 291
 - 12.3.1.2 Common Adhesive Wear 291
 - 12.3.1.3 Scratch 291
 - 12.3.1.4 Scuffing 291
 - 12.3.2 Factors Influencing Adhesive Wear 291
 - 12.3.2.1 Load 291
 - 12.3.2.2 Surface Temperature 292
 - 12.3.2.3 Materials 293
 - 12.3.3 Adhesive Wear Mechanism 294
 - 12.3.4 Criteria of Scuffing 296
 - 12.3.4.1 $p_0 U_s \leq c$ Criterion 296
 - 12.3.4.2 $WU_s^n \leq c$ 296
 - 12.3.4.3 Instantaneous Temperature Criterion 297
 - 12.3.4.4 Scuffing Factor Criterion 298
 - 12.4 Fatigue Wear 298
 - 12.4.1 Types of Fatigue Wear 298
 - 12.4.1.1 Superficial Fatigue Wear and Surface Fatigue Wear 298
 - 12.4.1.2 Pitting and Peeling 299
 - 12.4.2 Factors Influencing Fatigue Wear 300
 - 12.4.2.1 Load Property 300
 - 12.4.2.2 Material Property 302
 - 12.4.2.3 Physical and Chemical Effects of the Lubricant 302
 - 12.4.3 Criteria of Fatigue Strength and Fatigue Life 303
 - 12.4.3.1 Contact Stress State 303
 - 12.4.3.2 Contact Fatigue Strength Criteria 304
 - 12.4.3.3 Contact Fatigue Life 306
 - 12.5 Corrosive Wear 307
 - 12.5.1 Oxidation Wear 307
 - 12.5.2 Special Corrosive Wear 309
 - 12.5.2.1 Factors Influencing the Corrosion Wear 309
 - 12.5.2.2 Chemical-Mechanical Polishing 309
 - 12.5.3 Fretting 309
 - 12.5.4 Cavitation Erosion 310
 - References 312
- 13 Macro-Wear Theory 314**
- 13.1 Friction Material 315
 - 13.1.1 Friction Material Properties 315
 - 13.1.1.1 Mechanical Properties 315
 - 13.1.1.1.2 Anti-Friction and Wear-Resistance 315
 - 13.1.1.1.3 Thermal Property 316
 - 13.1.1.1.4 Lubrication Ability 316
 - 13.1.1.2 Wear-Resistant Mechanism 316
 - 13.1.1.2.1 Hard Phase Bearing Mechanism 316
 - 13.1.1.2.2 Soft Phase Bearing Mechanism 316
 - 13.1.1.2.3 Porous Saving Oil Mechanism 316