

CONTENTS

Foreword	xv
Preface	xvii
1 Introduction	1
1.1 Definition and History of Tribology / 1	
1.2 Industrial Significance of Tribology / 3	
1.3 Origins and Significance of Micro/Nanotribology / 4	
1.4 Organization of the Book / 6	
References / 7	
2 Solid Surface Characterization	
2.1 The Nature of Surfaces / 9	
2.2 Physico-Chemical Characteristics of Surface Layers / 11	
2.2.1 Deformed Layer / 11	
2.2.2 Beilby Layer / 11	
2.2.3 Chemically Reacted Layer / 11	
2.2.4 Physisorbed Layer / 13	
2.2.5 Chemisorbed Layer / 13	
2.2.6 Methods of Characterization of Surface Layers / 14	
2.3 Analysis of Surface Roughness / 15	
2.3.1 Average Roughness Parameters / 18	
2.3.2 Statistical Analyses / 25	
2.3.3 Fractal Characterization / 48	

- 2.3.4 Practical Considerations in Measurement of Roughness Parameters / 50
- 2.4 Measurement of Surface Roughness / 55
 - 2.4.1 Mechanical Stylus Method / 56
 - 2.4.2 Optical Methods / 61
 - 2.4.3 Scanning Probe Microscopy (SPM) Methods / 73
 - 2.4.4 Fluid Methods / 84
 - 2.4.5 Electrical Method / 84
 - 2.4.6 Electron Microscopy Methods / 85
 - 2.4.7 Analysis of Measured Height Distribution / 85
 - 2.4.8 Comparison of Measurement Methods / 86
- 2.5 Closure / 90
 - References / 93
 - Suggested Reading / 98

3 Contact between Solid Surfaces

99

- 3.1 Introduction / 99
- 3.2 Analysis of the Contacts / 101
 - 3.2.1 Single Asperity Contact of Homogeneous and Frictionless Solids / 101
 - 3.2.2 Single Asperity Contact of Layered Solids in Frictionless and Frictional Contacts / 115
 - 3.2.3 Multiple Asperity Dry Contacts / 127
- 3.3 Measurement of the Real Area of Contact / 154
 - 3.3.1 Measurement Techniques / 154
 - 3.3.2 Typical Measurements / 158
- 3.4 Closure / 162
 - References / 164
 - Suggested Reading / 168

4 Adhesion

169

- 4.1 Introduction / 169
- 4.2 Solid-Solid Contact / 170
 - 4.2.1 Covalent Bond / 174
 - 4.2.2 Ionic or Electrostatic Bond / 175
 - 4.2.3 Metallic Bond / 175
 - 4.2.4 van der Waals Bond / 177
 - 4.2.5 Free Surface Energy Theory of Adhesion / 177
 - 4.2.6 Polymer Adhesion / 184
- 4.3 Liquid-Mediated Contact / 185
 - 4.3.1 Idealized Geometries / 187

7 Wear

331

- 7.1 Introduction / 331
- 7.2 Types of Wear Mechanisms / 332
 - 7.2.1 Adhesive Wear / 332
 - 7.2.2 Abrasive Wear (by Plastic Deformation and Fracture) / 346
 - 7.2.3 Fatigue Wear / 360
 - 7.2.4 Impact Wear / 369
 - 7.2.5 Chemical (Corrosive) Wear / 379
 - 7.2.6 Electrical-Arc-Induced Wear / 381
 - 7.2.7 Fretting and Fretting Corrosion / 383
- 7.3 Types of Particles Present in Wear Debris / 385
 - 7.3.1 Plate-Shaped Particles / 385
 - 7.3.2 Ribbon-Shaped Particles / 387
 - 7.3.3 Spherical Particles / 388
 - 7.3.4 Irregular-Shaped Particles / 389
- 7.4 Wear of Materials / 390
 - 7.4.1 Wear of Metals and Alloys / 393
 - 7.4.2 Wear of Ceramics / 398
 - 7.4.3 Wear of Polymers / 404
- 7.5 Closure / 410
 - References / 415
 - Suggested Reading / 421

8 Fluid Film Lubrication

423

- 8.1 Introduction / 423
- 8.2 Regimes of Fluid Film Lubrication / 424
 - 8.2.1 Hydrostatic Lubrication / 424
 - 8.2.2 Hydrodynamic Lubrication / 425
 - 8.2.3 Elastohydrodynamic Lubrication / 427
 - 8.2.4 Mixed Lubrication / 427
 - 8.2.5 Boundary Lubrication / 428
- 8.3 Viscous Flow and Reynolds Equation / 428
 - 8.3.1 Viscosity and Newtonian Fluids / 428
 - 8.3.2 Fluid Flow / 434
- 8.4 Hydrostatic Lubrication / 444
- 8.5 Hydrodynamic Lubrication / 455
 - 8.5.1 Thrust Bearings / 457
 - 8.5.2 Journal Bearings / 471
 - 8.5.3 Squeeze Film Bearings / 493
 - 8.5.4 Gas-Lubricated Bearings / 496

- 8.6 Elastohydrodynamic Lubrication / 512
 - 8.6.1 Forms of Contacts / 514
 - 8.6.2 Line Contact / 515
 - 8.6.3 Point Contact / 522
 - 8.6.4 Thermal Correction / 523
 - 8.6.5 Lubricant Rheology / 525
- 8.7 Closure / 526
- References / 528
- Suggested Reading / 532

9 Boundary Lubrication and Lubricants 533

- 9.1 Introduction / 533
- 9.2 Boundary Lubrication / 534
 - 9.2.1 Effect of Adsorbed Gases / 537
 - 9.2.2 Effect of Monolayers and Multilayers / 539
 - 9.2.3 Effect of Chemical Films / 540
 - 9.2.4 Effect of Chain Length (or Molecular Weight) / 543
- 9.3 Liquid Lubricants / 544
 - 9.3.1 Principal Classes of Lubricants / 544
 - 9.3.2 Physical and Chemical Properties of Lubricants / 550
 - 9.3.3 Additives / 555
- 9.4 Greases / 556
- 9.5 Closure / 557
- References / 557
- Suggested Reading / 558

10 Micro/Nanotribology 560

- 10.1 Introduction / 560
- 10.2 SFA Studies / 562
 - 10.2.1 Description of an SFA / 563
 - 10.2.2 Static (Equilibrium), Dynamic, and Shear Properties of Molecularly Thin Liquid Films / 565
- 10.3 AFM/FFM / 575
 - 10.3.1 Description of AFM/FFM / 576
 - 10.3.2 Friction and Adhesion / 586
 - 10.3.3 Scratching, Wear, Local Deformation, and Fabrication/Machining / 599
 - 10.3.4 Indentation / 613
 - 10.3.5 Boundary Lubrication / 619
- 10.4 Atomic-Scale Simulations / 624

- 10.4.1 Interatomic Forces and Equations of Motion / 624
- 10.4.2 Interfacial Solid Junctions / 626
- 10.4.3 Interfacial Liquid Junctions and Confined Films / 628
- 10.5 Closure / 630
 - References / 633
 - Suggested Reading / 638

11 Friction and Wear Screening Test Methods

640

- 11.1 Introduction / 640
- 11.2 Design Methodology / 641
 - 11.2.1 Simulation / 641
 - 11.2.2 Acceleration / 642
 - 11.2.3 Specimen Preparation / 642
 - 11.2.4 Friction and Wear Measurements / 642
- 11.3 Typical Test Geometries / 646
 - 11.3.1 Sliding Friction and Wear Tests / 646
 - 11.3.2 Abrasion Tests / 649
 - 11.3.3 Rolling-Contact Fatigue Tests / 651
 - 11.3.4 Solid-Particle Erosion Test / 651
 - 11.3.5 Corrosion Tests / 651
- 11.4 Closure / 654
 - References / 654
 - Suggested Reading / 656

12 Tribological Components and Applications

657

- 12.1 Introduction / 657
- 12.2 Common Tribological Components / 657
 - 12.2.1 Sliding-Contact Bearings / 658
 - 12.2.2 Rolling-Contact Bearings / 659
 - 12.2.3 Seals / 662
 - 12.2.4 Gears / 665
 - 12.2.5 Cams and Tappets / 668
 - 12.2.6 Piston Rings / 669
 - 12.2.7 Electrical Brushes / 672
- 12.3 Microcomponents / 674
- 12.4 Material Processing / 679
 - 12.4.1 Cutting Tools / 679
 - 12.4.2 Grinding and Lapping / 684
 - 12.4.3 Forming Processes / 685
 - 12.4.4 Cutting Fluids / 685
- 12.5 Industrial Applications / 687