

CONTENTS

Plates fall between pages 14 and 15

INTRODUCTION	1
CHAPTER I. AREA OF CONTACT BETWEEN SOLIDS	5
MEASUREMENT OF SURFACE IRREGULARITIES AND SURFACE CONTOUR	5
Stylus methods	5
Optical interference [A]	6
Electron microscope [A]	8
Oblique sectioning	9
AREA OF CONTACT BETWEEN SOLIDS	10
Asperities of spherical shape	10
Effect of work-hardening	14
Asperities of conical and pyramidal shape	17
The area of real contact	19
Area of real and apparent contact	20
The effect of removing the load	22
ELECTRICAL RESISTANCE AS A MEASURE OF AREA OF REAL CONTACT	25
Effect of load on contact resistance	28
The contact of flat surfaces	30
CHAPTER II. SURFACE TEMPERATURE OF RUBBING SOLIDS	33
SURFACE TEMPERATURE OF SLIDING METALS	33
Calculation of surface temperature	33
Measurement of surface temperature	35
Temperature of sliding metals	37
Temperature of lubricated surfaces	40
Intermittent nature of surface temperature	41
Surface temperature and thermal conductivity	41
SURFACE TEMPERATURE OF NON-CONDUCTING SOLIDS	42
Temperature at which hot spots become visible	43
Thermal conductivity and the incidence of hot spots	44
Photographic recording of hot spots	46
Effect of grit on the incidence of hot spots	47
Influence of size and shape of slider	48
Measurement of transient hot spots [A]	49
A MORE EXACT CALCULATION OF THE SURFACE TEMPERATURE	52

CHAPTER III. EFFECT OF FRICTIONAL HEATING ON SURFACE FLOW	
POLISHING AND SURFACE FLOW OF SOLIDS [A]	58
Influence of melting-point	60
Mechanism of polishing	62
The action of a typical polisher	63
THE MECHANISM OF SLIDING ON ICE AND SNOW [A]	65
Pressure melting	65
Melting due to frictional heating	66
Formation of a water layer	66
Effect of temperature	67
Effect of thermal conductivity	68
Static and kinetic friction and the influence of speed	69
CHAPTER IV. FRICTION AND SURFACE DAMAGE OF SLIDING METALS	
THE MEASUREMENT OF FRICTION	73
The measurement of the temperature of stationary surfaces	75
Preparation of surfaces	77
THE FRICTION OF METALS	78
CHEMICAL AND RADIOACTIVE DETECTION OF METAL TRANSFER [A]	82
FRICTION AND SURFACE DAMAGE AT LIGHT LOADS [A]	83
EARLY THEORIES OF METALLIC FRICTION	87
CHAPTER V. MECHANISM OF METALLIC FRICTION [A]	
THE ROLE OF SHEARING AND PLOUGHING	90
The ploughing term	92
The shearing term	94
The shear strength of the metal junctions	97
Amontons's law	98
THE INTERDEPENDENCE OF SHEARING AND PLOUGHING	101
INTIMACY OF CONTACT AND THE INFLUENCE OF SURFACE FILMS	104
INTERMITTENT MOTION	105
LUBRICATING PROPERTIES OF THIN METALLIC FILMS	111
Friction as a function of track width	113
The limiting film thickness	114
Breakdown of the film	115
Wear of films	116
Effect of temperature	117
METALLIC FILMS AS LUBRICANTS	119

CHAPTER VI. ACTION OF BEARING ALLOYS [A]	122
COPPER-LEAD BEARING ALLOYS	123
Frictional behaviour of steel, copper, and lead	124
Thin films of lead on copper	124
Copper-lead alloys	125
Effect of wear on the friction	126
Effect of temperature on friction	128
Role of thin films in bearing alloys	129
Comparative behaviour of dendritic and non-dendritic alloys	130
WHITE-METAL BEARING ALLOYS	132
Lead-base alloys: structure and hardness	132
Unlubricated surfaces	134
Lubricated surfaces	136
The role of the matrix and the hard particles	136
Tin-base alloys: structure and hardness	137
Unlubricated surfaces	138
Lubricated surfaces	139
Comparison of lead-base and tin-base bearing alloys	139
SILVER-LEAD BEARINGS	140
EFFECT OF TEMPERATURE CHANGES ON BEARING ALLOYS	140
THE ROLE OF THE SOFT CONSTITUENT IN BEARING ALLOYS	142
CHAPTER VII. FRICTION OF CLEAN SURFACES: EFFECT OF CONTAMINANT FILMS	145
INFLUENCE OF SURFACE FILMS	145
Effect of adsorbed gases on metallic friction [A]	146
Influence of oxide films on friction [A]	149
INFLUENCE OF TEMPERATURE ON FRICTION OF CLEAN METALS	151
INFLUENCE OF INTERFACIAL POTENTIAL ON FRICTION	153
Effect of electrodeposited hydrogen and oxygen	153
Friction and surface tension	157
FRICTION OF GRAPHITE [A]	158
CHAPTER VIII. FRICTION OF NON-METALS	161
Crystalline solids [A]	161
Sapphire and diamond [A]	162
Carbon, graphite, and molybdenum disulphide [A]	163
Mica [A]	164
Plastics [A]	164
Frictional welding of plastics	166

CHAPTER VIII (<i>continued</i>)	
Tungsten carbide [A]	168
Glass [A]	168
Rubber [A]	169
Fibres [A]	169
SURFACE IRREGULARITIES AND THE FRICTION OF METALS	173
CHAPTER IX. BOUNDARY FRICTION OF LUBRICATED METALS	
FLUID LUBRICATION	176
BOUNDARY LUBRICATION BY LONG-CHAIN COMPOUNDS	178
Influence of chain length	178
Effect of temperature [A]	181
Fatty acids in solution	183
LUBRICATING PROPERTIES OF MONOLAYERS AND MULTILAYERS	184
Stearic acid films	185
Cholesterol films	188
Wear properties of lubricant layers	189
Minimum film thickness for effective lubrication [A]	189
LUBRICATING PROPERTIES OF SILICONES AND OF FLUORINATED HYDRO-CARBONS	191
INFLUENCE OF LOAD AND SPEED ON FRICTION OF LUBRICATED SURFACES	193
Effect of load	193
Friction of lubricated surfaces at very light loads	195
Effect of speed	196
CHAPTER X. MECHANISM OF BOUNDARY LUBRICATION	
IMPORTANCE OF CHEMICAL ATTACK	200
Lubricating properties of metallic soaps	203
STRUCTURE OF THE LUBRICATING LAYER: ELECTRON DIFFRACTION EXPERIMENTS [A]	207
MECHANISM OF SOAP FORMATION: INFLUENCE OF WATER [A]	211
INVESTIGATION OF SURFACE ADSORPTION BY RADIO-ACTIVE METHODS [A]	214
Fatty acids	215
Alcohols	215
Esters	215
ADSORPTION OF FATTY ACIDS, ALCOHOLS, AND ESTERS ON METALS [A]	216
MECHANISM OF BOUNDARY LUBRICATION [A]	219
CHAPTER XI. ACTION OF EXTREME PRESSURE LUBRICANTS	
LUBRICATION OF METALS BY COMPOUNDS CONTAINING CHLORINE	229
Chloride films	229

CONTENTS

xvii

Compounds containing chlorine	230
Importance of chloride formation	232
LUBRICATION OF METALS BY COMPOUNDS CONTAINING SULPHUR	233
Sulphide films	233
Sulphurized compounds	235
Importance of chemical attack and of nature of surface film	237
PHOSPHORUS ADDITIVES	238
REACTIVITY OF EXTREME PRESSURE ADDITIVES [A]	239
EXTREME PRESSURE LUBRICANTS IN THE CUTTING AND DRAWING OF METALS [A]	240
CHAPTER XII. BREAKDOWN OF LUBRICANT FILMS [A]	247
LUBRICATION BETWEEN THE PISTON RINGS AND CYLINDER WALL OF A RUNNING ENGINE	248
Effect of speed	248
Effect of viscosity and temperature	249
LUBRICATION BETWEEN A JOURNAL AND BEARING	250
Effect of load, speed, viscosity, and temperature	252
EFFECT OF TEMPERATURE ON LUBRICANT FILMS	254
CHAPTER XIII. NATURE OF CONTACT BETWEEN COLLIDING SOLIDS [A]	258
SPHERICAL SURFACES	258
Effect of variation in the yield pressure	261
The coefficient of restitution	264
Comparison of static and dynamic hardness	265
Time of impact	267
Temperature of impact	270
Effect of lubricant film	271
FLAT SURFACES	272
Pressure developed in the liquid film	275
Velocity of flow and rate of shear	279
Temperature developed in the liquid film	279
PRACTICAL IMPLICATIONS	281
CHAPTER XIV. THE NATURE OF METALLIC WEAR [A]	285
LOCAL ADHESION AND WEAR	285
WEAR-REDUCING PROPERTIES OF THIN METALLIC FILMS	287
CHEMICAL REACTION AND WEAR [A]	290
IMPORTANCE OF SURFACE OXIDATION	293
INFLUENCE OF LUBRICANT FILMS ON WEAR	295

CHAPTER XV. ADHESION BETWEEN SOLID SURFACES: THE INFLUENCE OF LIQUID FILMS	299
ADHESION OF HARD SURFACES: GLASS, PLATINUM, AND SILVER	299
Effect of surface roughness	302
Effect of humidity	303
Adhesion due to surface tension and viscosity	304
ADHESION OF SOFT METALS [A]	306
Effect of surface oxidation	309
Adhesion in the presence of lubricant films	310
ADHESION AND FRICTION [A]	312
 CHAPTER XVI. CHEMICAL REACTION PRODUCED BY FRICTION AND IMPACT [A]	315
INFLUENCE OF PRESSURE, OF SHEAR, AND OF SURFACE TEMPERATURE	315
EFFECT OF FRICTION ON PHOTOGRAPHIC PLATES	317
DECOMPOSITION OF EXPLOSIVES	317
Initiation by friction	317
Initiation by impact	318
Friction between particles	319
 APPENDIX. SOME TYPICAL VALUES OF FRICTION	322
 ADDENDA	328
AUTHOR INDEX	364
SUBJECT INDEX	366