

Contents

Preface	<i>page</i> xiii
List of principal symbols	xv
1 Hardness and indentation	
1. 1 The concept of hardness	1
1. 2 Dynamic effects	2
1. 3 Hertzian hardness and subsequent developments	4
1. 4 Proof testing	6
1. 5 Time and scale effects	8
1. 6 The punch test and local strain-hardening	10
1. 7 'Unworked indentation resistance' – 'strainless hardness'	11
1. 8 Friction and adhesion effects	13
1. 9 Rehbinder effect – influence of liquids	15
1.10 Mutual indentation tests	16
1.11 The Mallock test	17
<i>Bibliography</i>	21
2 Static cone and pyramid tests	
2. 1 Geometrical similarity of indentations	23
2. 2 Conical indenters	23
2. 3 Indentation 'shallowing' – depth measurements	24
2. 4 Indentation 'ridging' and 'sinking'	27
2. 5 Effect of cone angle and friction	29
2. 6 Strain-hardening in cone indentations	33
2. 7 The Rockwell test – 120° diamond 'cone'	35
2. 8 Pressure of fluidity – conical punching	37
2. 9 The pyramid indentation test	38
2.10 Ridging and sinking in pyramid tests	40
2.11 Effect of pyramid angle	41
2.12 Strain-hardening in pyramid indents	42
2.13 The Knoop elongated pyramid indenter	43
2.14 Effect of pyramid testing load	43
2.15 Micro-indentation testing	44
<i>Bibliography</i>	46
3 The static ball test	
3. 1 The Brinell test	47
3. 2 Depth measurements in the ball test	49
3. 3 Deformation of indenters	49

3. 4	Strain-hardenability and Meyer's equation	page 51
3. 5	Use of balls of different diameters	52
3. 6	'Meyer analysis' – use of concentric impressions	55
3. 7	Hardness comparisons by the ball test	56
3. 8	Strain-hardenability by other indentation tests	58
3. 9	Strain-hardening in ball indents	60
3.10	The 'Derived' hardness curve and the 90° cone test	62
3.11	Comparisons of indentation hardness scales	65
	<i>Bibliography</i>	66
4	Crystalline metals and the effects of deformation	
4. 1	Dislocations	68
4. 2	Strain-hardening	69
4. 3	Hardness and crystal grain size	71
4. 4	Scratch tests	72
4. 5	Orientation hardness of crystals	77
4. 6	The tensile test and indentation tests	79
4. 7	Tensile strain-hardening index	80
4. 8	The tensile-Brinell ratio	82
4. 9	Yield stress, hardness and work-hardening capacity	84
4.10	The cold-working of metals	86
4.11	The hardness of cold-worked crystals	91
4.12	Superhardening	95
4.13	Work-softening	95
4.14	Endurance limit, fatigue and hardness	96
4.15	Hardness of elastically-stressed metals	97
4.16	Hardness tests and forming properties	98
	<i>Bibliography</i>	99
5	Heat-treatment, alloying and hardness	
5. 1	Recovery and recrystallization of cold-worked metals	101
5. 2	Ageing effects after cold-working (Strain-ageing)	103
5. 3	Vacancy hardening in pure metals by quenching	105
5. 4	Hardness and allotropy (polymorphism)	105
5. 5	Alloy phase diagrams and hardness	107
5. 6	Annealed and cold-worked conglomerate alloys	109
5. 7	Solid solution hardening and softening	111
5. 8	Order hardening of solid solutions	115
5. 9	Radiation hardening	117
5.10	Electron compounds and intermediate phases	118
5.11	Electrodeposited metals and alloys	120

5.12	Impure metals and dispersion hardening	page 123
5.13	Age-hardening and phase diagrams	125
5.14	Austenitic steels and 'ausageing'	131
5.15	Martensitic hardening of steels and quench-ageing	132
5.16	Austempering	135
5.17	Hardenability and continuous-cooling transformation diagrams	138
5.18	Thermal-mechanical hardening – Ausforming	140
5.19	The tempering of steels	143
5.20	Hardness fluctuations during ageing and softening	145
5.21	Cutting tools and secondary hardening	146
5.22	High-carbon alloys – Cast irons	146
5.23	Spark-hardening and hardening in welded steels	148
	<i>Bibliography</i>	150
6	Dynamic tests and temperature effects	
6. 1	Effect of strain rate – Use of comparison pieces	153
6. 2	Volume of an indentation – Martel's system	154
6. 3	Rebound methods – The Scleroscope	154
6. 4	Dynamic work-hardening capacity	157
6. 5	Relations of scleroscope, ball and Rockwell C hardness	158
6. 6	Ballistic hammer for dynamic tests	159
6. 7	Bullet tests and explosive strain rates	161
6. 8	Sandblasting and 'Cloudbursting'	165
6. 9	Variation of static hardness with temperature	165
6.10	Creep effects in static indentation	172
6.11	Creep of soft alloys and hot alloys	176
6.12	Dynamic high temperature tests and hot-working	179
6.13	Ferrous alloys and the effect of temperature	182
	<i>Bibliography</i>	188
7	Hardness relations with other physical properties	
7. 1	Hardness and atomic bonding forces	191
7. 2	Hardness and elastic bulk modulus	193
7. 3	Hardness, Young's modulus and melting point	195
7. 4	'Hard metals' of high melting point	199
7. 5	Hardness, temperature and resistivity	200
7. 6	Hardness and magnetic properties	203
7. 7	Magnetic hardening and ageing	204
7. 8	Wear and abrasion	205
	<i>Bibliography</i>	216

8 Hardness apparatus and the test specimen	
8. 1 Examples of machines	<i>page</i> 208
8. 2 Portable machines	211
8. 3 Anvil effects	212
8. 4 Hot-hardness testing machines	213
8. 5 Standardization of the Vickers test	215
8. 6 Standardization of the Rockwell test	218
8. 7 Standardization of the Brinell test	221
8. 8 Selection, mounting and preparation of test specimens	223
8. 9 Hardness variations in cold-worked specimens	225
<i>Bibliography</i>	226
Name Index	231
Subject Index	234

PLATES 1-17

between pages 224 and 225