
Contents

Chapter 1. Damage	1
1.1. Definition	1
1.2. Damage variables	2
1.3. Effective stress	3
1.4. Principle of strain equivalence.	5
1.5. Experimental characterization of the damage.	6
1.5.1. Changes in mechanical characteristics	6
1.5.2. Modifications of the material	7
1.5.3. Wear rate	7
1.6. Models of the progression of the damage D	9
1.6.1. Dissipation	9
1.6.2. Types of damage	10
 Chapter 2. Ductile Fracture	17
2.1. Stages of ductile tearing	17
2.1.1. First step: damage by decohesion, cracking of inclusions, impurities, precipitates, cavity formation.	17
2.1.2. Second stage: growing cavities, formation of peduncles followed by necking, giving rise to ductile tearing	18
2.2. Linear ductile plastic damage during strain	20
2.3. Formation of cracks around inclusions or precipitates, cavities in ductile fracture	23
2.3.1. Formation of cracks from particles for Figure 2.5(b): the case of multiple metals	28
2.3.2. Aluminum–silicon alloy	29

2.4. Analysis of facies of ductile fractures of trichite and metals according to the purity and the state of the stresses	30
2.4.1. Whisker fracture (Cu and Fe).	30
2.4.2. Polycrystals CC and CFC in ductile fracture: influence of stress states and purity	33
2.4.3. Ductile fracture of steel test pieces without notches	34
2.4.4. Fracture of pure iron specimens	35
2.4.5. Ductile fracture of industrial copper specimens of purity 4N and 5N	36
2.4.6. Cases of zones of melted Fe, Cu (4N, 5N and industrial), aluminum (3N, 5N and industrial) – uniaxial and triaxial stresses	40
2.5. Relationship between the density of inclusions and ductility.	44
2.5.1. Sintered copper made up of particles	44
2.5.2. Alumina	46
Chapter 3. Sudden Fracture, Fracture Energy	53
3.1. Analysis of the fracture	53
3.2. Sudden fracture and energy criterion.	54
3.2.1. Energy balance causing the crack to advance	54
3.2.2. Obtaining G_c	56
3.2.3. Data for G_c and K_{Ic}	58
3.2.4. Examples of sudden fractures.	64
Chapter 4. Description and Modeling of Physical Mechanisms	73
4.1. Expansion of cracks	73
4.2. Calculation of r_p : the case of confined plasticity	74
4.3. Elastoplastic zone at the end of a crack	76
4.4. Stress and strain field at the end of the crack	77
Chapter 5. Fractures due to Cleavages and Intergranularity	81
5.1. Fractures from cleavages	81
5.1.1. Examples of fractures by cleavage.	82
5.1.2. Change of micromechanisms	84
5.2. Intergranular fracture	85
5.2.1. Fractures along interfaces, grain boundary	85
5.2.2. Intergranular brittle fracture.	86
5.2.3. Metal fracture transition parameter	87

5.2.4. Influence of the grain boundary	91
5.2.5. Cleavage strain of steels	92
5.2.6. Influence of the addition elements on the brittle–ductile transition	93
Chapter 6. Concentration of Stresses K_t	97
6.1. Introduction.	97
6.2. Measure of K_t	99
6.2.1. By extensometry gauges.	99
6.2.2. By photoelasticimetry	100
6.3. Solids with equal resistances.	101
6.4. Notching effect.	102
6.5. Reduction of the stress concentration factor: the case of notched objects.	104
6.6. Effect of notches under fatigue	105
6.7. Stress concentration values K_t : useful cases in practice	107
Chapter 7. The Intensity Factor of Stresses K	111
7.1. Introduction.	111
7.2. Fields of stresses and movements.	113
7.2.1. Mode I	113
7.2.2. Mode II.	115
7.2.3. Mode III	117
7.2.4. Values of K for flat cracked medium	118
7.2.5. Area at the bottom of the crack	121
7.2.6. Influence of the plastic zone undergoing cracking	124
7.3. Remarks regarding $K = \sigma \sqrt{\pi a}$	125
7.4. Values of the stress intensities K_I , K_{II} , K_{III} for the three modes: for cases related to the subject and useful cases in practice	126
7.4.1. Typical values of stress intensity factors K_I , K_{II} , K_{III}	126
7.4.2. Values of $K_I = f(\lambda) \cdot \sigma \sqrt{\pi a}$	131
Chapter 8. Fracture Zones in Photoelasticimetry	137
8.1. Photoelasticity	137
8.1.1. Primary stresses and isostatic lines	137
8.1.2. Birefringence by strain.	138
8.2. Propagation of light vibrations	139
8.2.1. Propagation of light in a vacuum.	139
8.2.2. Propagation of light in a transparent medium	140

8.2.3. Wave in a dielectric	141
8.2.4. Values of the constants C and K of photoelastic materials.	142
8.2.5. Choice of a photoelastic coating	144
8.2.6. Ellipsoid of the indices.	146
8.3. Photoelasticimetry.	149
8.3.1. Photoelasticimeter	149
8.3.2. Isochromatic lines, difference between the primary stresses	151
8.3.3. Example of physical parts under stresses: a three-dimensional case using the freezing method.	159
 Chapter 9. The Influence of Strain Speeds	 161
9.1. Types of dynamic loads	161
9.2. Examples of fast fractures	163
9.3. Damage, domain between necking and fracture, the case between FLCs and LCFF.	168
9.3.1. Definition	168
9.3.2. Large strains and damage	169
9.4. Forming limit curves: static stamping (under a press) and dynamic stamping (magnetoforming and electrohydroforming)	171
9.4.1. Measurement of strains	171
9.4.2. Description of an electrohydraulic (EH) test	172
9.4.3. Types of test pieces.	176
9.4.4. Example of LCFFs	177
9.5. Shock by intense pulsed magnetic field on aluminum alloys.	180
9.6. Test results	183
9.6.1. Strain trajectories, change of ε_1 according to ε_2 ; comparison of low and high speeds	184
9.6.2. Influence of strain speeds on FLCs, formability in static and dynamic states	187
9.6.3. Comparison of the values for necking Z and fracture F	189
 Chapter 10. Metal Fatigue	 197
10.1. Introduction	197
10.2. Endurance curve: plot of the endurance curve or Wöhler curve	197
10.3. Conventional endurance limit	199
10.4. Classification of fatigue tests.	201
10.4.1. Definition.	201
10.4.2. Tests in practice	203
10.4.3. Combined stress tests.	205

10.4.4. Application of a criterion in planar stress	212
10.4.5. Examples of influences on endurance	216
10.4.6. Influence of temperature	217
10.5. Physical aspects of fatigue	219
10.5.1. Physical mechanisms	219
10.5.2. Fatigue fracture surfaces, microscope images	222
10.5.3. Change of the streak spacing	223
10.5.4. Examples of micrograph images of fractures	224
10.6. Types of fatigue	225
10.6.1. Behavior of non-cracked parts under fatigue	226
10.6.2. Behavior of non-cracked parts under fatigue	230
10.7. Plasticity, fast fracture by fatigue: a case study	235
10.8. Propagation of corrosion cracks under fatigue-corrosion stress and influence of cycle frequencies	241
Chapter 11. Fracture of Composites	247
11.1. Fracture mechanisms	247
11.1.1. Unidirectional composite (UD)	247
11.1.2. Fracture of laminates	252
11.2. Criteria for fracture	254
11.2.1. Data describing the resistance of a UD or a fabric	254
11.2.2. Successive fractures of layers	256
11.2.3. Strength/stress ratio: coefficient of resistance R	256
11.2.4. Criteria for maximum stress and/or maximum strain	257
11.2.5. Quadratic criterion: in the stress space	259
11.2.6. Fracture envelopes	264
11.3. Design in primary strains	266
11.3.1. Principal stresses and strains	266
11.3.2. Constants of stresses and strains	267
11.3.3. Scaling of isotropes	268
Appendices	275
References	331
Index	335