

Contents

From the Preface to the Romanian edition	5
Preface to the English edition	7
1 Operating conditions and stresses imposed on aerospace materials	15
1.1 Operating conditions	15
1.1.1 Temperature levels	15
1.1.2 Surrounding medium	18
1.1.3 Electric and magnetic fields	18
1.1.4 Exposure to radiation and meteorites	18
1.1.5 Effects on the surrounding medium	19
1.2 Stresses imposed on aerospace vehicles	19
1.2.1 Mechanical stresses	19
1.2.2 Thermal stresses	20
1.2.3 Influence of chemical factors	20
1.2.4 Radiation effects	21
1.3 Specific materials and technologies	21
1.3.1 Materials for aerospace vehicles	21
1.3.2 Specific testing methods	22
1.3.3 Specific technologies	22
References	23
2 Structure and properties of materials	27
2.1 Structure of solids	27
2.1.1 Quantum approach to the structure of materials	27
2.1.2 Bonding forces in solids	33
2.2 Atomistic approach to the properties of materials	36
2.2.1 Conductivity	36
2.2.2 Mechanical properties	37
2.2.3 Thermoelastic effects	38
2.2.4 Anelasticity	41
2.2.5 Tribological behaviour	43
2.3 Crystalline structures	44
2.3.1 Geometry of metallic crystals	44
2.3.2 Crystalline aggregates of metals	48
2.4 Structural imperfections	48
2.4.1 Point defects	49
2.4.2 Line defects	50
2.4.3 Surface defects	62

2.5	Plastic deformation of polycrystalline materials	62
2.5.1	Strain-hardening of single crystals	63
2.5.2	Twinning	64
2.5.3	Strain-hardening of polycrystalline metals	65
2.5.4	Yield point	66
2.5.5	Bauschinger effect	67
2.5.6	Strain aging	68
2.5.7	Strain rate and temperature dependence	69
	References	73
3	Stresses and strains; rheological behaviour	75
3.1	Elasticity	75
3.1.1	Fundamental equations	75
3.1.2	Principal stresses and strains	81
3.1.3	Stress concentration	86
3.2	Rheological behaviour of materials	89
3.2.1	Mechanical models	90
3.2.2	General theories of deformation	94
3.3	Plastic flow laws	97
3.3.1	Maximum shear-stress criterion (Tresca)	97
3.3.2	Octahedral shear stress or the energy-of-distortion criterion (Maxwell-Huber-Hencky-von Mises)	98
3.3.3	Novozhilov treatment	100
3.3.4	Comparative analysis of plasticity criteria	101
3.3.5	General relations between stresses and strains	101
3.3.6	Deformation of ideally plastic materials	103
3.3.7	Influence of work-hardening	105
3.3.8	Mechanical work of plastic deformation	108
3.3.9	Influence of anisotropy	109
3.3.10	Numerical example of anisotropy effects	112
3.3.11	Current trends	115
	References	117
4	Tribological behaviour	119
4.1	Tribological properties of materials; specific systems	119
4.1.1	Fundamentals of friction phenomena	120
4.1.2	Dynamic tribological systems	122
4.2	Internal friction	125
4.2.1	Grain-boundary relaxation	126
4.2.2	Dislocation damping	127
4.2.3	Vibration damping by internal friction in spacecraft	127
4.3	External friction	131
4.3.1	High-speed behaviour of materials	131
4.3.2	High-temperature behaviour of materials	132
4.3.3	Effect of impact at supersonic speeds	135
4.3.4	Refractory and ablative materials	136
4.3.5	Friction and antifriction materials	138
4.4	Wear of materials	139
4.4.1	Hypotheses of dry wear	140
4.4.2	An oxidation hypothesis of steel wear	141

4.4.3	Fretting corrosion	142
4.4.4	Wear-resistant materials	144
4.5	Specific interactions between surfaces in contact	145
4.5.1	Alleviation of seizure through macrostructural means	145
4.5.2	Rheology of adhesives	147
4.6	Stress corrosion	149
4.6.1	Microstructural background of stress corrosion	150
4.6.2	Stress-corrosion cracking of aerospace materials	151
	References	153
5	Creep	157
5.1	Generalities	157
5.2	Structural mechanism of creep	158
5.2.1	Low-temperature creep	158
5.2.2	High-temperature creep	158
5.2.3	Diffusional creep	160
5.2.4	Creep fracture	161
5.2.5	Practical solutions resulting from structural considerations	163
5.2.6	Influence of irradiation on the creep mechanism	163
5.3	Stress-strain relationships	164
5.4	Anelastic effects and creep recovery	168
5.5	Mechanical aspects of the Bauschinger effect	173
5.6	Creep under various loading conditions	175
5.6.1	Multiaxial stress	175
5.6.2	Stationary creep under plane strain	178
5.6.3	Creep under alternating stress superposed on constant stress	179
5.6.4	Anelasticity and creep relaxation of a bolting element	181
5.6.5	Creep in a thin-walled cylinder	186
5.6.6	General creep relationships	188
5.7	Stress concentration in creep	190
5.7.1	Stress concentration around a cylindrical cavity	190
5.7.2	Concentration of stress around a circular hole in a thin plane disk	191
5.8	Creep of a rotating disk	193
5.8.1	Calculation methods	193
5.8.2	Example	194
5.8.3	Satisfying the boundary conditions	203
5.8.4	Choice of optimum number of intermediate radial positions	203
5.8.5	Suitable size for the time intervals	204
5.8.6	Generalization of hypotheses	204
5.8.7	Creep-calculation solutions in equation form	206
5.8.8	Actual trends	209
	References	210
6	Fracture	213
6.1	Basic concepts	213
6.2	Structural aspects of fracture	215
6.2.1	Modes of fracture	216

6.2.2	Shear fracture	220
6.2.3	Crack formation	221
6.3	Physical-mathematical models of fracture	223
6.3.1	Linear elastic behaviour	224
6.3.2	Elastic-plastic behaviour	232
6.4	Influence of geometric and environment factors on crack toughness	236
6.4.1	Influence of thickness	237
6.4.2	Influence of temperature	239
6.4.3	Influence of crack-tip root radius	240
6.5	Influence of complex loading and materials on fracture toughness	241
6.5.1	Mixed-mode fracture	241
6.5.2	Fracture of bimetals	242
6.6	Fracture arrest	243
6.6.1	Considerations regarding stresses and stress-intensity factors	244
6.6.2	Arrest techniques	247
6.7	Fracture design of structures	251
6.7.1	Design practices for rotating equipment	252
6.7.2	Design of aircraft with the aid of fracture-mechanics concepts	255
6.7.3	Numerical examples	259
6.8	Modern trends in the development of fracture-mechanics concepts	260
6.8.1	Development of theoretical aspects	261
6.8.2	Development of testing techniques	262
	References	263
7	Fatigue	269
7.1	Theories of fatigue	269
7.1.1	Nucleation of fatigue cracks	269
7.1.2	Fatigue-crack propagation	270
7.2	Utilization of material-mechanics principles in analysis of fatigue phenomena	271
7.2.1	Microstructural theories of fatigue	271
7.2.2	Correlations between fracture-mechanics concepts and fatigue	274
7.3	Statistical aspects of fatigue	278
7.3.1	Statistical theories of fatigue strength	278
7.3.2	Application of normal statistical laws in evaluating the behaviour of aerospace materials	281
7.4	Influence of environment on fatigue life	284
7.4.1	Stress concentrators and size effects	285
7.4.2	Effects of cyclic-stress frequency	291
7.4.3	Effects of corrosion	294
7.4.4	Cumulative stress effects	296
7.4.5	Relaxation of residual stresses and alleviation of stress concentration	298
7.4.6	Improvement of fatigue strength by various treatments and coatings	300
7.5	Fatigue-failure criteria	301
7.5.1	Crack-nucleation criterion	302
7.5.2	Crack-propagation criterion	303
7.5.3	Yield criterion	306

7.5.4	Application of fatigue criteria in design	307
7.5.5	Comparison of hypotheses on fatigue-crack growth with experimental results	308
7.5.6	Calculation example of fatigue strength by a crack-propagation criterion	310
7.6	Practical conclusions regarding aerospace materials	312
	References	312
8	Reliability of aerospace constructions	317
8.1	Reliability concepts	317
8.2	Significant factors for reliability estimation	318
8.3	Theoretical concepts on sensitivity to cyclic loading	318
8.3.1	Utilization of stochastic methods	318
8.3.2	Fatigue reliability	320
8.4	Life prediction	322
8.4.1	Interpretation of spectrum tests	322
8.4.2	Use of fracture-mechanics concepts in analysis and design of damage-tolerant structures	323
8.4.3	Use of fatigue criteria for life predictions of structures	327
8.5	Reliability of power plants	336
8.6	Actual trends	337
8.6.1	Material development	337
8.6.2	Design and damage tracking	337
	References	339
	Subject index	343