## Contents

Preface	v
Introduction	1
Chapter 1. The Fundamental Concepts of the Mechanics of a Solid Body	5
1. Tensors in three-dimensional Euclidian space	6
2. Contraction of tensors. Invariants	12
3. Mutual basis. Covariant and contravariant components of	
a tensor	16
4. Differential operations	22
5. Theory of deformation in a continuous medium	28
6. Theory of stress	31
7. Cartesian coordinates. Determination of displacements	34
8. Certain further properties of the stress tensor	37
9. Rate-of-deformation tensor. Invariants of deformation and	
rate of deformation tensors	45
10. An elastic body	49
11. An isotropic elastic body	54

viii CONTENTS

Chapter 2. Theory of Plasticity	59
12. The deformation theory of plasticity	60
13. Deformation theory with proportional loading	65
14. Drucker's postulate of work-hardening	68
15. Possible boundaries of applicability of the deformation	
theory of plasticity	71
16. Two-dimensional model of work-hardening body	77
17. Flow theory for a smooth loading surface. Isotropic work-	
hardening	86
18. Theory of flow with translational work-hardening	90
19. Singular surfaces of loading	92
20. Slip theory	98
21. Model of a plane body	103
22. Flow with a singular surface of loading	107
Chapter 3. Linear Viscoelastic Media	110
Chapter 5. Linear Viscociastic media	
23. The simplest viscoelastic body	111
24. More general differential deformation laws	117
25. The hereditary-elastic body	122
26. Conditions of a closed Volterra cycle	125
27. Singular heredity function	127
28. Exponential operators of arbitrary order	130
29. Multiplication theorem for $\mathcal{E}_{\alpha}$ -operators	133
30. Asymptotic formulae for $\mathcal{E}$ functions	137
31. The general problem of the theory of hereditary elasticity.	139
Volterra's principle	139
32. Application of Laplace transforms to problems of the	143
theory of hereditary elasticity	145
33. More general forms of kernels	151
34. Linear creep of concrete	151
35. Further applications of Volterra's principle	157
36. Simple dynamic problems	160
37. Complex moduli	160
38. Creep and relaxation functions	165
39. The moving load problem. Low speeds	103
40. Medium of a die along the boundary of a viscoelastic	169
medium	172
41. Some experimental results on creep in plastics	1/2

CC	NTE	NTS

CONTENTS	ix
Chapter 4. Creep of Metals. The Fundamental Experimental Facts	
and Phenomenological Theories	176
42. Fundamental information about creep	176
43. Empirical formulae for creep curves	178
44. Similarity of creep curves	182
45. Temperature dependence	187
46. Stress relaxation	192
47. Elementary creep theories	195
48. Ageing (time-hardening) theories	200
49. Hypothesis of the equation of state	206
50. Analytical expressions for the strain-hardening law	210
51. The relation between creep and relaxation according to the	
strain-hardening theory	216
52. Hereditary theory of creep	219
53. Experimental verification of the strain-hardening hypothe-	
sis with variable loads	224
54. Other creep investigations with variable loading on the	
basis of the strain-hardening hypothesis	229
55. Kinetic creep equations	234
56. Softening during creep	241
57. Creep and instantaneous plastic deformation	244
58. Short-term creep. The fundamental facts	249
59. Short-term creep. Dependence on rate	254
60. Creep in compression. Load reversal	257
61. Small deviations from the basic state	261
62. Dynamic creep	264
Chapter 5. Creep in a State of Complex Stress	267
63. Steady-state creep	268
64. Isotropic creep	270
65. Creep potential	273
66. Special forms of creep law	278
67. Working out the results of tests in combined tension and	
torsion	285
68. Quasilinear equations of steady-state creep	288
69. Anisotropic creep	297
70. Determination of anisotropy parameters	301
O. Determination of anticomorpy Parameters	

x CONTENTS

96. The Lagrange variational principle

71. Transient creep	304
72. Theory of deformation type creep	307
73. Flow theory	310
74. Generalisation of strain-hardening theory	313
75. Quasi-steady-state creep	315
76. Experimental verification of creep theory with complex	
stressed state. Early work	319
77. Creep with complex stress and constant load. Johnson's	
tests	322
78. Further analysis of Johnson's test results	330
79. Experimental studies of creep with complex stressed state	
(continued)	339
80. Namestnikov's investigations	345
81. Creep in a state of complex stress with variable loading	348
82. Stress relaxation in a state of complex stress	353
Chapter 6. Long Term Failure at High Temperatures	358
83. Fundamental information concerning long-term strength	358
84. Temperature-time dependence of long-term strength	361
85. Viscous failure	366
86. Failure accompanied by embrittlement	372
87. Mixed failure. Kachanov's hypothesis	375
88. More general hypothesis of failure. The brittle case	379
89. Mixed failure. Short-term creep	382
90. Failure with cyclic loading	387
91. The experimental study of long-term strength in a state of	
complex stress	390
92. The simplest criteria of long-term strength	393
93. General concepts of long-term failure in a state of complex	
stress	396
94. The possibility of constructing a more general theory of	
long-term failure	400
Chapter 7. Steady-State Creep. General Theory and Simple Exam-	
ples	403
95. Uniqueness in the small and stability	403

407

CONTENTS	XÌ
97. Castigliano's variational principle	410
98. Certain consequences of variational principles	411
99. Particular forms of the equations of steady-state creep	414
100. Modelling of steady-state and quasi-steady-state creep	418
101. Power law of creep. Theorem of Calladine and Drucker	419
102. Steady-state creep of bar type structures	424
103. Application of constant power dissipation surfaces to the	
calculation of bar type structures	433
104. The kinematic method of calculating bar type structures.	
Examples	437
105. Kachanov's method	443
hapter 8. Steady-State Creep. Bending and Torsion	445
106. Steady-state creep in pure bending	445
107. The general case of pure bending	453
108. Thin-walled sections of open profile	457
109. An approximate method of studying bending of thin-	
walled rods	462
110. Deformation of beams and frames in bending	467
111. Creep in torsion	474
112. Torsion of thin-walled rods of closed profile	479
113. Torsion of thin-walled rods of open profile	483
114. Variational methods of solving torsion problems	486
115. Bending and torsion of thin-walled rods of closed section	488
116. Bending of rods in the presence of a longitudinal force	491
117. Beam of ideal I-section	495
118. Simple problems of longitudinal force and transverse	
bending	498
hapter 9. Plane Axially-Symmetrical Problems of the Theory of	
Steady-State Creep	504
119. Fundamental equations of the plane problem	504
120. Thick-walled tubes	509
121. Pure bending of part of a circular cylinder	514
122. Rotating discs	522
123. Creep of a solid disc of constant thickness	524
<b>x</b>	

xii CONTENTS

124. Creep of a disc with a central hole	528
125. Direct numerical integration of the rotating disc creep	520
equations	530
126. Disc of equal strength	534
127. Disc design by the method of successive approximations	538
128. A further variant of the method of successive approxima-	544
tions	544
129. Stress concentration about a hole in a uniformly extended	£ 40
plate	548
130. Disc of hyperbolic profile loaded by radial forces	556
Charles and Challes	559
Chapter 10. Steady-State Creep of Plates and Shells	339
131. Bending of plates. Fundamental equations of the linear	
theory	559
132. Potentials of forces and moments. Fundamental equations	
of creep in plates	563
133. Partial linearisation of the equations of creep of a plate	566
134. Creep of plates in bending	570
135. Creep of circular plates by Mises type theory	574
136. The application of variational methods to the calculation	
of plates	581
137. Creep calculation of plates with the Tresca criterion	583
138. More complicated types of loading	588
139. Deflection of plates by a distributed load	590
140. Non-circular plates	593
141. Creep of shells	595
142. Theory of moment-free shells	597
143. Theory of moment-free shells. Determination of deforma-	
tions and displacements	601
144. Moment-free shells of rotation	605
145. Multi-layer shells with rigidly bonded layers	607
146. Two-layer model shell	612
147. Equations of the theory of shells	617
148. Technical theory of shells	620
149. The technical theory of creep of two-layer shells	627
150. Equations of axially symmetrical creep of a circular cylin-	
drical shell	632

ഹ	NI	F	NT	rc

xiii

151. Power creep law. Approximate investigation of the edge	
effect	636
152. A semi-infinite shell with hinged edge fixing	642
153. A semi-infinite shell with clamped edge	645
154. Extension of the technical theory to the case $T_{11} \neq 0$	648
155. A cylindrical shell compressed by an axial force	650
156. Edge effect in a cylindrical shell loaded with distributed	
pressure and an axial force	652
157. Approximate expressions for rate potential for an arbi-	
trary shell	654
·	
Chapter 11. Transient Creep	656
158. Application of the strain-hardening hypothesis to tran-	
sient creep calculations	656
159. Transient creep in bending	659
160. Numerical solution of the problem of transient creep of a	
beam	663
161. Transient creep of discs	669
162. Transient creep of discs. Cases 2, 3 and 4	674
163. Creep of a rotating cylinder and tube	679
164. Kachanov's variational principle in the theory of transient	
creep	684
165. The Wang and Prager variational principle	687
166. Approximate solution of relaxation problems. Shesteri-	
kov's method	691
167. Mixed variational principle	694
168. Application of the mixed variation principle to the prob-	
lem of bending	697
169. Bending of beams in creep with work-hardening	699
170. Transient creep of plates	703
171. A general device for investigating transient creep on the	
basis of strain-hardening theory	706
172. Application of ageing (time-hardening) theory to tran-	
sient creep calculations	709
173. Determination of time to failure	712
174. More accurate determination of the time to brittle failure	
of a rotating disc	715

xiv CONTENTS

Chapter 12. Geometrically Non-Linear Problems of Creep	722
175. Simple geometrically non-linear creep problems	722
176. A flexible cable	725
177. Deflection of beams with hinged fixed ends	727
178. Critical time of compression of a column	733
179. Allowance for instantaneous plastic deformation in deter-	
mining the critical time	741
180. Critical time of a column in compression. Further results	746
181. Mixed variational principles applied to buckling problems	752
182. Buckling of a column in compression. Application of va-	
riational method	754
183. Stability of arches	759
184. Certain investigations on the stability of shells in creep	765
185. Axially symmetric buckling of short cylindrical shells	768
186. Approximate method of solving buckling problems in	
non-linear formulation	771
187. Stability of a compressed visco-elastic rod	776
188. Stability of a compressed column of material that ob-	
serves the strain-hardening law	780
189. Nominal linearised criteria of stability	783
190. Application of linearised equations to the problem of	
buckling	789
191. Linearised equations of creep with work-hardening	791
192. Buckling of plates according to the linearised theory	794
Bibliography	797
Subject index	814