

Contents

Preface	6
1. Introduction	7
1.1 Basic concepts	7
1.1.1 External loads (forces)	7
1.1.1.1 Types of external forces	7
1.1.1.2 Static equilibrium of external loads	8
1.1.2 Internal forces; stress in general bodies under general loading conditions	8
1.1.3 Assumptions of solution	9
2. Tension and compression	11
2.1 Assumptions	11
2.2 Axially loaded bar	11
2.3 Normal stress	12
2.4 Stress on an oblique plane under axial loading	14
2.5 Deformation	15
2.6 Stress-strain curve (mechanical properties of materials)	16
2.6.1 Hooke's law	17
2.6.2 Mechanical characteristics of materials	18
2.6.3 Factor of safety; strength criterion; allowable stress; limit analysis	21
2.7 Application of Hooke's law to deformation computation	22
2.8 Poisson's ratio	23
2.9 Relative change in volume	24
2.10 Principle of superposition of stress and displacements	26
2.11 Various effects influencing the stress and strain assessment in an axially loaded bar	27
2.11.1 Variable load	27
2.11.2 Variable cross-section	29
2.11.3 Bars (cables) of uniform strength	30
2.12 Strain energy	31
2.12.1 Strain energy stored in rods stressed by various type of loading	33
2.12.2 Bars stressed by impact loading	34
2.13 Castigliano's theorem	35
3. Statically indeterminate uniaxial problems	38
3.1 Definition of statically indeterminate structures	38
3.2 General procedure applied when solving statically indeterminate problems	38
3.3 Bar attached to rigid supports	39
3.4 Parallel members connected with a rigid plate	42
3.5 Pin-connected frameworks	44
3.6 Problems involving temperature changes	45
3.7 Various types of statically indeterminate structures composed of uniaxially stressed members	47
3.7.1 Structures having geometric defects due to manufacturing inaccuracy	47
3.7.2 Statically indeterminate structure to the second degree	48
4. Frameworks, trusses; application of Castigliano's theorem	50
4.1 Statically determinate frameworks	50
4.2 Statically indeterminate frameworks	53
4.3 Pre-stressed trusses; truss with a cooled-down member	55
5. Stress and strain	59
5.1 Types of stress state	59
5.2 Uniaxial stress state; complementary shearing stresses	59
5.3 Plane stress; Mohr's circle	61
5.3.1 Stresses in an inclined plane	62

5.4 Mohr's circle for stress	63
5.5 Principal stresses and principal planes	65
5.6 Application of Mohr's circle to various types of stress analysis	66
5.6.1 3D analysis of stress	66
5.6.2 Particular cases of 2D analysis of stress	68
5.6.3 Uniaxial stress state from the standpoint of 3D analysis of stress	69
5.7 Stresses and strains in pure shear	70
5.8 Strain in the case of a 3D stress state; generalized Hooke's law	72
5.8.1 Multiaxial loading	72
5.8.2 Complex loading (a general stress condition)	73
5.8.3 Mohr's circle for plane strain	74
6. Strain energy	75
6.1 Introduction	75
6.2 Strain energy for a general stress state	75
6.2.1 Strain energy for shearing stresses	75
6.2.2 Strain energy for a general state of stress	76
7. Limit analysis; theories of elastic failure	80
7.1 Introduction	80
7.2 Theories of elastic failure	81
7.2.1 Uniaxial loading	81
7.2.2 General stress state	82
7.3 Theories of elastic failure for ductile materials	82
7.3.1 Maximum-shearing-stress criterion	82
7.3.2 Maximum-shear-strain-energy criterion	83
7.3.3 Comparison of Tresca's and HMH yield criteria	84
7.4 Graphical representation of the theories of elastic failure for ductile materials	85
7.4.1 Graphical representation of Tresca's criterion	85
7.4.2 Graphical representation of HMH criterion	85
7.5 Theories of elastic failure for brittle materials	87
7.5.1 Maximum-normal-stress criterion	87
7.5.2 Mohr's fracture criterion	88
7.5.3 Applicability of the criteria for brittle materials	90
7.6 Graphical representation of the theories of elastic failure for brittle materials	90
7.6.1 Graphical representation of maximum-normal-stress criterion	90
7.6.2 Graphical representation of Mohr's fracture criterion	91
7.6.3 Plotting of Haigh's limit and allowable figures	91
8. Torsion of circular shafts	92
8.1 Derivation of needed relations	92
8.1.1 Geometrical relations	92
8.1.2 Torsional stresses in the elastic range	93
8.1.3 Torsion formulas	94
8.2 Polar second moment of area (polar moment of inertia)	96
8.3 Strain energy in torsion and application of Castigliano's theorem	97
8.4 Statically indeterminate problems in torsion	98
8.5 Close-coiled helical springs subjected to axial load W	100
8.5.1 Types of stress in close-coiled helical springs	101
8.5.2 Deflection of close-coiled helical springs	102
8.5.3 Springs in series	103
8.5.4 Springs in parallel	104
9. Geometric characteristics of a cross-section	105
9.1 Centroids of plane areas	105
9.2 Second moments of area (moments of inertia of a plane area)	105
9.3 Products of inertia	106
9.4 Polar second moment of area (polar moment of inertia)	107
9.5 Properties of second moments of area	107

9.5.1 Parallel-axis theorem for second moments of area	107
9.5.2 Rotation of axes	108
10. Beams in bending	112
10.1 Basic concepts	112
10.1.1 Introduction	112
10.1.2 Types of beams, loads, and reactions	112
10.2 Shearing forces and bending moments	114
10.2.1 Method of sections	114
10.2.2 Relationships between loads, shearing forces, and bending moments	116
10.2.3 General comments	117
10.3 Stresses in beams	119
10.3.1 Bending formulas	119
10.4 Strain energy in bending	123
10.5 Shearing stress in beams (ordinary bending)	123
10.5.1 Distribution of the shearing stress in a beam with a rectangular cross-section	123
10.5.2 Distribution of the shearing stress in thin-walled open sections (shear centres)	126
10.5.3 Strain energy in shear	127
11. Deflections of beams	128
11.1 Introduction	128
11.2 Differential equation of the deflection curve	128
11.3 Application of Castigliano's theorem	129
11.3.1 Differentiation under the integral sign	129
11.3.2 Geometric interpretation of Mohr's integral (Verescagin's rule)	130
11.4 Influence coefficients; Maxwell's theorem of reciprocal displacements	132
11.4.1 Influence coefficients	132
11.4.2 Maxwell's theorem of reciprocal displacements	132
12. Statically indeterminate beams	134
12.1 General procedure for the solution of <i>SI</i> structures applied on beams	134
13. Combined loading	136
13.1 Introduction	136
13.2 Unsymmetric bending	136
13.3 Bars with axial loads	138
13.4 Bending and torsion	140
13.5 Torsion and tension (compression)	141
13.6 Bending and shear	142
14. Design for fatigue strength	143
14.1 Introduction	143
14.2 Fatigue strength; the <i>S-N</i> diagram	144
14.3 Endurance-limit modifying factors	145
14.4 Fluctuating stresses	147
14.4.1 Smith's and Haigh's fatigue diagrams	147
14.4.2 Safety factors for fatigue strength	149
14.5 Stresses due to combined loading	149
15. Thin-walled pressure vessels	151
References	153