

**Contents**

<b>Preface</b>	<b>6</b>
<b>1. Introduction</b>	<b>7</b>
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
<b>2. Tension and compression</b>	<b>11</b>
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
<b>3. Statically indeterminate uniaxial problems</b>	<b>38</b>
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
<b>4. Frameworks, trusses; application of Castigliano's theorem</b>	<b>50</b>
4.1 Statically determinate frameworks	50
4.2 Statically indeterminate frameworks	53
4.3 Pre-stressed trusses; truss with a cooled-down member	55
<b>5. Stress and strain</b>	<b>59</b>
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
<b>6. Strain energy</b> . . . . .	<b>75</b>
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
<b>7. Limit analysis; theories of elastic failure</b> . . . . .	<b>80</b>
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
<b>8. Torsion of circular shafts</b> . . . . .	<b>92</b>
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
<b>9. Geometric characteristics of a cross-section</b> . . . . .	<b>105</b>
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
<b>10. Beams in bending</b>	<b>112</b>
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
<b>11. Deflections of beams</b>	<b>128</b>
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
<b>12. Statically indeterminate beams</b>	<b>134</b>
12.1 General procedure for the solution of <i>SI</i> structures applied on beams	134
<b>13. Combined loading</b>	<b>136</b>
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
<b>14. Design for fatigue strength</b>	<b>143</b>
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
<b>15. Thin-walled pressure vessels</b>	<b>151</b>
<b>References</b>	<b>153</b>