

# Contents

<b>1 The Conventional Design Process</b>	<b>1</b>
1.1 Fully Stressed Design	3
1.1.1 Structure Made of Different Materials	7
1.1.2 Structure Under Alternative Loads	9
1.2 Strength-to-weight Ratio	12
1.2.1 Feasibility	15
1.3 Comparison of Layouts	16
1.3.1 Classification of Optimization Problems	19
1.4 Spreadsheet Program	21
1.4.1 ‘Seven-Bar Truss’	21
1.5 Summary	24
Exercises	25
References	28
<b>2 Optimality Criteria</b>	<b>29</b>
2.1 Circular Tube in Compression	30
2.1.1 Efficiency Formula	33
2.1.2 Material Limitation	38
2.2 Criterion for Maximum Stiffness	40
2.3 Spreadsheet Programs	44
2.3.1 ‘Circular and Square Tubes’	44
2.3.2 ‘Truss with Tubular Members’	48
2.4 Summary	50
Exercises	51
References	53
<b>3 The General Optimization Problem</b>	<b>55</b>
3.1 Box Beam Structure	56
3.1.1 General Form of Design Space	58

3.2	The Lagrange Multiplier Method . . . . .	61
3.2.1	Interpretation of Lagrange Multipliers . . . . .	67
3.3	Inequality Constrained Problems . . . . .	70
3.3.1	The Kuhn–Tucker Conditions . . . . .	73
3.4	Spreadsheet Program . . . . .	73
3.4.1	Eccentrically Loaded Column . . . . .	74
3.5	Summary . . . . .	78
	Exercises . . . . .	79
	References . . . . .	81
<b>4</b>	<b>Numerical Methods for Unconstrained Optimization . . . . .</b>	<b>83</b>
4.1	Unconstrained Optimization . . . . .	84
4.1.1	Steepest Descent Method . . . . .	85
4.1.2	Fletcher–Reeves Method . . . . .	90
4.1.3	Quasi–Newton Methods . . . . .	92
4.2	Line Search Methods . . . . .	94
4.2.1	Region Elimination and the Golden Section Method . . . . .	95
4.2.2	Polynomial Interpolation . . . . .	97
4.3	Spreadsheet Program . . . . .	100
4.3.1	‘Hooke and Jeeves Method’ . . . . .	100
4.4	Summary . . . . .	103
	Exercises . . . . .	105
	References . . . . .	106
<b>5</b>	<b>Numerical Methods for Constrained Optimization . . . . .</b>	<b>107</b>
5.1	Constraint-Following Methods . . . . .	108
5.1.1	Gradient Projection Method . . . . .	109
5.1.2	Generalized Reduced Gradient Method . . . . .	120
5.1.3	Other Methods for Constrained Optimization . . . . .	126
5.1.4	Substitution of Variables . . . . .	129
5.2	Penalty Function Methods . . . . .	129
5.2.1	Interior Penalty Function . . . . .	130
5.2.2	Exterior Penalty Function . . . . .	133
5.2.3	Augmented Lagrangian Penalty Function . . . . .	135
5.3	Spreadsheet Program . . . . .	138
5.3.1	‘Penalty Function Method’ . . . . .	140
5.4	Summary . . . . .	142
	Exercises . . . . .	143
	References . . . . .	145
<b>6</b>	<b>Optimization of Beams . . . . .</b>	<b>147</b>
6.1	Beam Cross Section . . . . .	148
6.1.1	Thin-Walled Beams . . . . .	150
6.1.2	Geometrically Similar Sections . . . . .	153

6.2	Optimum Spanwise Distribution . . . . .	154
6.2.1	Statically Determinate Beams . . . . .	155
6.2.2	Statically Indeterminate Beams . . . . .	158
6.3	Limit Design. . . . .	160
6.3.1	Yield Moment. . . . .	161
6.3.2	Limit Load . . . . .	163
6.4	Spreadsheet Programs. . . . .	168
6.4.1	'I-Section Beam' . . . . .	169
6.4.2	'Beam Under Lateral Load' . . . . .	173
6.5	Summary . . . . .	178
	Exercises. . . . .	179
	References. . . . .	181
<b>7</b>	<b>Reinforced Shell Structures . . . . .</b>	<b>183</b>
7.1	Bending Stress . . . . .	185
7.1.1	Effect of Yielding . . . . .	187
7.1.2	Modelling of Discrete Stiffeners . . . . .	189
7.2	Shear Stress . . . . .	192
7.2.1	Torsional Stiffness. . . . .	198
7.2.2	von Mises Criterion. . . . .	200
7.3	Buckling Formulae . . . . .	201
7.3.1	Buckling in Compression . . . . .	201
7.3.2	Buckling in Shear . . . . .	208
7.3.3	Efficiency Formula for a Compression Panel. . . . .	210
7.3.4	Shear Web Efficiency . . . . .	214
7.3.5	Post-buckled Shear Webs . . . . .	218
7.4	Spreadsheet Programs. . . . .	221
7.4.1	'Stiffened Panel' . . . . .	221
7.4.2	'Rectangular Box Beam' . . . . .	227
7.4.3	'Circular Fuselage Section' . . . . .	230
7.5	Summary . . . . .	235
	Exercises. . . . .	236
	References. . . . .	239
<b>8</b>	<b>Composite Laminates . . . . .</b>	<b>241</b>
8.1	Lamination Theory . . . . .	243
8.1.1	Transformed Stiffness Matrix . . . . .	245
8.1.2	Laminate Stiffness Coefficients . . . . .	247
8.1.3	Failure Criteria . . . . .	252
8.1.4	Change in Temperature. . . . .	256
8.1.5	Practical Restrictions on Lay-up . . . . .	258
8.2	Laminate Optimization . . . . .	259
8.2.1	Netting Analysis . . . . .	260
8.2.2	Iterative Redesign . . . . .	264

8.2.3	Numerical Optimization . . . . .	267
8.2.4	Genetic Algorithm. . . . .	270
8.3	Spreadsheet Program . . . . .	275
8.3.1	‘Composite Laminate’. . . . .	275
8.4	Summary . . . . .	278
	Exercises. . . . .	280
	References. . . . .	282
<b>9</b>	<b>Optimization With Finite Element Analysis . . . . .</b>	<b>283</b>
9.1	Sensitivity Analysis . . . . .	284
9.2	Reduction in Design Variables . . . . .	290
9.3	Spreadsheet Program . . . . .	291
9.3.1	‘Design Variable Linking’. . . . .	291
9.4	Summary . . . . .	294
	Exercises. . . . .	295
	References. . . . .	296
	<b>Appendix . . . . .</b>	<b>297</b>
	<b>Recommended Further Reading . . . . .</b>	<b>307</b>
	<b>Solutions to Selected Exercises . . . . .</b>	<b>309</b>
	<b>Index . . . . .</b>	<b>311</b>

Optimization Methods in Structural Design

Rothwell, A.

2017, XVI, 314 p. 113 illus., Hardcover

ISBN: 978-3-319-55196-8