

CONTENTS

1 INTRODUCTION	5
1.1 BASIC TERMS	5
1.2 LOADING	9
1.3 LOADING TYPES AND INTERNAL FORCES	10
2 ONE-DIMENSIONAL LOADING	13
2.1 DEFORMATION AND STRESS.....	13
2.2 TEST OF MATERIAL.....	14
2.2.1. Measurement of mechanical properties of material	15
2.3 STRAIN	17
2.4 DEFORMATION OF BAR DUE TO TEMPERATURE CHANGE	18
2.5 TRANSVERSAL DEFORMATION	19
2.6 STRENGTH AND DIMENSIONING OF BAR	19
2.6.1. Method of allowed stresses.....	20
2.6.2. Method of allowed loadings.....	21
2.6.3. Method of limit states	21
2.7 BAR UNDER SELFWEIGHT LOADING.....	22
2.7.1. Prismatic bar.....	22
2.7.2. Bar of constant strength	23
2.8 INDETERMINATE SYSTEMS.....	23
3 STRESSES, STRAINS AND HOOKES LAW	25
3.1 STRESS STATES	25
3.2 ONE-DIMENSIONAL STRESS STATE.....	26
3.2.1. Shear stresses.....	27
3.3 PLANE STRESS STATE	28
3.3.1. Principal stresses	30
3.3.2. Maximal shear stress	32
3.3.3. Mohr's circle for stress	32
3.4 THREE-DIMENSIONAL STRESS STATE	34
3.4.1. Principal stresses	34
3.4.2. Maximal shear stresses.....	36
3.5 DEFORMATIONS.....	37
3.5.1. Strains	37
3.5.2. Similarity of relations for stresses and strains.....	38
3.6 GENERALIZED HOOKE'S LAW	39
3.7 RELATIVE CHANGE OF VOLUME	40
3.8 PURE SHEAR	41
3.9 HOOKE'S LAW FOR SHEAR	42

4 ELASTIC POTENTIAL ENERGY	43
4.1 ELASTIC POTENTIAL ENERGY AND DENSITY OF POTENTIAL ENERGY FOR SIMPLE TENSION.....	43
4.2 ELASTIC POTENTIAL ENERGY FOR SHEAR	44
4.3 THREE-DIMENSIONAL STRESS STATE - DENSITY OF POTENTIAL ENERGY...	45
4.4 DENSITY OF ENERGY - SHAPE AND VOLUME CHANGES	45
5 STRENGTH THEORIES.....	47
5.1 YIELD AND FRACTURE CRITERIA FOR GENERAL LOADING STATES	47
5.2 RANKIN'S THEORY	47
5.3 SAINT-VÉNANT'S THEORY	48
5.4 GUEST'S THEORY OF MAXIMUM SHEAR STRESSES	48
5.5 BELTRAMI'S THEORY.....	49
5.6 HUBER – MISES – HENCKY THEORY.....	49
5.7 MOHR'S THEORY.....	50
5.8 GEOMETRIC REPRESENTATION OF STRENGTH THEORIES	51
5.9 USING OF STRENGTH THEORIES.....	51
6 CROSS-SECTION AREAS - GEOMETRIC CHARACTERISTICS	52
6.1 STATIC MOMENTS (LINEAR MOMENTS). COORDINATES OF CENTROID	52
6.2 MOMENTS OF INERTIA (SECOND MOMENT OF CROSS-SECTION AREA).....	53
6.3 PARALLEL AXIS THEOREM.....	54
6.4 MOMENTS OF INERTIA WITH RESPECT TO ROTATED AXES.....	55
6.4.1. Principal directions and principal inertial moments	56
6.5 RADIUS OF GYRATION AND ELIPSE OF MOMENTS OF INERTIA OF CROSS- SECTION AREA.....	57
6.6 SECTION MODULUS FOR BENDING AND TORSION	57
7 TORSION OF SIMPLE SHAFTS.....	59
7.1 TORSION AND TORSION MOMENT	59
7.2 STRESSES AND DEFORMATIONS.....	60
7.3 STRESS ANALYSIS AND PRINCIPAL STRESSES	62
7.4 STATICALLY INDETERMINATE SYSTEMS	63
7.5 ELASTIC POTENTIAL ENERGY	63
8 PLANE BENDING OF BEAM	64
8.1 BENDING IN PLANE	64
8.2 INTERNAL FORCES AND MOMENTS - BASIC RELATIONS.....	64
8.3 NORMAL STRESSES	66
8.4 SHEAR STRESSES	68
8.5 STRENGTH OF THE BEAM.....	71
8.6 POTENTIAL STRAIN ENERGY.....	72
8.7 DEFORMATION OF THE BEAM	73
8.7.1. Basic differential equation describing deformation.....	74

9 COMBINATION OF SIMPLE LOADINGS	76
9.1 THREE-DIMENSIONAL BENDING.....	76
9.2 SIMULTANEOUS BENDING AND AXIAL LOADING	78
9.3 ECCENTRIC COMPRESSION	78
9.3.1. Core of the cross-section area	79
9.4 SIMULTANEOUS BENDING AND TORSION.....	80
10 PRINCIPLE OF VIRTUAL WORK, ENERGY.....	82
10.1 PRINCIPLE OF SUPERPOSITION.....	82
10.2 WORK OF EXTERNAL FORCES	83
10.3 WORK OF INTERNAL FORCES	84
10.4 BETTI'S THEOREM	85
10.5 MAXWELL'S THEOREMS.....	86
10.6 CASTIGLIANO'S THEOREM.....	88
10.7 MOHR – MAXWELL THEOREM.....	88
11 STATICALLY INDETERMINATE SYSTEMS.....	90
11.1 SOLUTION OF INDETERMINATE SYSTEMS BY COMPARISON OF DEFORMATIONS.....	90
11.2 MÉNABRÉ'S THEOREM	91
11.3 CANONICAL EQUATIONS.....	92
12 CURVED AND CRANKED BEAMS AND FRAMES	94
12.1 CURVED AND CRANKED BEAMS AND FRAMES IN PLANE	94
12.1.1. Internal forces and moments.....	94
12.1.2. Internal force quantities in statically indeterminate beams and frames	95
12.1.3. Curved beams	96
12.1.4. Stresses and deformations.....	99
13 THIN-WALLED CYLINDRICAL SHELLS	101
13.1 BASIC TERMS	101
13.2 STRESSES IN THIN-WALLED CYLINDRICAL SHELLS.....	102
13.3 RINGS ON THIN-WALLED MEMBRANES	103
14 THICK-WALLED CYLINDRICAL VESSELS AND ROTATING DISCS	105
14.1 THICK-WALLED CYLINDRICAL VESSELS.....	105
14.2 ROTATING DISCS	108
14.2.1. Constant thickness.....	108
14.2.2. Constant strength	110
15 STABILITY OF SIMPLE STRUCTURAL MEMBERS.....	112
15.1 CRITICAL LOADING	112
15.2 CRITICAL FORCE – EULER THEORY	113

15.3 CRITICAL FORCE - EULER THEORY FOR VARIOUS BOUNDARY CONDITIONS	114
15.4 LOST OF STABILITY – BUCKLING.....	117
15.5 APPROXIMATION METHODS	119
15.5.1. Energy method	119
15.5.2. Method of Vianello.....	121
16 TRANSVERSAL AND AXIAL LOADING OF BARS.....	122
16.1 INTEGRATION OF DIFFERENTIAL EQUATION.....	122
16.2 ENERGY METHOD	123
16.3 METHOD OF HOWARD – CHENTSOV	125
17 DYNAMIC LOADING	128
17.1 STRESSES	128
17.1.1. Translational movement of body with acceleration	128
17.1.2. Rotating arm with constant cross-section area	129
17.1.3. Rotating arm with constant strength.....	130
17.1.4. Rotating ring	131
17.2 IMPACT	132
17.2.1. Impact in axial direction.....	132
17.2.2. Impact in torsion	135
17.2.3. Impact in bending	136
18 SHAPE AND FATIGUE STRENGTH	138
18.1 CLASSIFICATION OF PERIODIC HARMONIC LOADING	139
18.2 FATIGUE FRACTURE.....	140
18.2.1. Wöhler curve	141
18.2.2. Influence of middle stress to the fatigue limit	143
18.2.3. Influence of size of machine part to the fatigue limit in bending and torsion	144
18.3 INFLUENCE OF SHAPE TO FATIGUE LIMIT	145
18.4 INFLUENCE OF SURFACE QUALITY TO FATIGUE LIMIT	147
18.5 SAFETY COEFFICIENT FOR CYCLIC LOADING	148
18.6 SAFETY COEFFICIENT FOR COMBINED LOADING WITH FATIGUE	149
18.7 CUMULATION OF FATIGUE DAMAGE.....	151
LITERATURE.....	153