

Contents

1 Introduction. Elements of Crystal Plasticity

<i>K. Pöhlandt</i>	1
1.1 Survey	2
1.2 Concepts	2
1.3 Crystal Structure and Crystal Defects	5
1.4 Plastic Deformation	9
1.4.1 Gliding of Dislocations	9
1.4.2 Mechanical Twinning.	14
1.4.3 Sharp Yield Point and Strain Aging	14
1.5 Recovery and Recrystallization	17
1.5.1 Overview	17
1.5.2 Recovery.	18
1.5.3 Recrystallization.	19
1.5.4 Changes of Structure during Hot Forming	20
References to Chapter 1	22

2 Crystallographic Texture and Plastic Anisotropy

<i>H.-J. Bunge</i>	23
2.1 Structure of Polycrystalline Materials	26
2.2 Definition of Crystallographic Texture	27
2.2.1 Crystal Orientation	28
2.3 Experimental Determination of Textures.	30
2.4 Texture and Properties of Materials.	33
2.5 Plasticity of Polycrystalline Materials	36
2.5.1 The Taylor Model (Full-Constraints)	40
2.5.2 Special Plasticity Parameters.	47
2.5.3 Plasticity of Cubic Metals	50
2.5.4 Deformation Hardening.	51
2.5.5 Plasticity of Macroscopic Bodies	54
2.6 Parametrization of the Texture Function	54
2.7 Other Modes of Plasticity.	56
References to Chapter 2	57

3 Formability Testing

<i>K. Pöhlandt</i>	61
3.1 Introduction	63
3.2 Determination of Flow Curves.	63
3.2.1 Tensile Test	64
3.2.2 Upsetting Cylindrical Specimens	67
3.2.3 Plane Strain Upsetting Test	71
3.2.4 Upsetting Test at Elevated Temperatures	75
3.2.5 Torsion Test	76
3.2.6 Special Methods	84
3.2.7 Flow Curves of Sheet Metal	84
3.3 Plastic Anisotropy of Round Bars, Wire and Tubes	86
3.3.1 Introduction	86
3.3.2 General Terminology	88
3.3.3 Recommended Experimental Procedures	89
3.3.4 Metal Forming Processes and Relevant Parameters	93
3.4 Transferability of Results.	96
3.4.1 Basic Problem	96
3.4.2 Uncertainty of Experimentally Determined Flow Curves	97
3.5 Determining Forming Limits in Bulk Metal Forming	101
3.5.1 Concepts	101
3.5.2 The Term „Ductility“	103
3.5.3 The Forming Limit	104
3.5.4 Process Simulating Testing Methods	107
References to Chapter 3	108

4 Anisotropy of Sheet Metal

<i>D. Banabic</i>	119
4.1 Definition of the Anisotropy Coefficient.	122
4.2 Yield Criteria for Isotropic Materials	123
4.2.1 Tresca Yield Criterion	125
4.2.2 Huber-Mises-Hencky Yield Criterion	127
4.2.3 Drucker Yield Criterion	128
4.2.4 Hosford Yield Criterion	129
4.3 Quadratic Yield Criteria	129
4.3.1 Hill 1948 Yield Criterion	130
4.4 Non-quadratic Yield Criteria	135
4.4.1 Hill 1979 Yield Criterion	136
4.4.2 Bassani Yield Criterion	139
4.4.3 Hosford 1979 Yield Criterion	139
4.4.4 Early Yield Criteria by Barlat	141

4.4.5	Hill 1990 Yield Criterion	144
4.4.6	Hill 1993 Yield Criterion	147
4.4.7	Barlat 1991 Yield Criterion	150
4.4.8	Karafillis-Boyce Yield Criterion	152
4.4.9	The Yield Criteria by Barlat 1994 and 1996	157
4.4.10	Other Nonquadratic Yield Criteria	160
4.5	Yield Criteria Expressed in Polar Coordinates	163
4.5.1	Budiansky Yield Criterion.	163
4.5.2	Ferron Yield Criterion	164
4.6	Other Yield Criteria.	166
4.4	Recommendations for the Practice	166
References to Chapter 4.		168
5	Forming Limits of Sheet Metal	
<i>D. Banabic</i>	173
5.1	Introduction	173
5.2	Methods for Evaluating Sheet Metal Formability	179
5.2.1	Methods Based on Simulating Tests	179
5.2.2	Limit Dome Height Method	187
5.2.3	Methods Based on Mechanical Tests (Intrinsic Methods)	188
5.3	Forming Limit Diagram	189
5.3.1	Definition. History	189
5.3.2	Main Tests Used to Determine the FLD	192
5.3.3	Factors Influencing Forming Limit Diagrams	198
5.3.4	Theoretical Models for Calculating Forming Limit Diagrams	204
5.3.5	Use of Forming Limits Diagrams in Industrial Practice	205
References to Chapter 5		209
6	Workpiece Properties after Metal Forming	
<i>K. Pöhlandt</i>	215
6.1	Survey	215
6.1.1	Material Behavior during Machining after Metal Forming	216
6.1.2	Material Properties after Homogeneous Deformation	217
6.2	Strain Distribution in Workpieces	217
6.2.1	Visioplasticity Method	218
6.2.2	Hardness Distribution	219
6.3	Deformation-Induced Residual Stresses	221
6.3.1	Cold Bulk Metal Forming	222
6.3.2	Sheet Metal Forming	229

6.4	Corrosive Behavior of Sheet Metal Components	230
6.4.1	Survey	230
6.4.2	Austenitic Stainless Steels	231
6.4.3	CuZn Alloys	233
6.5	Fatigue Behavior of Extruded Components	235
6.5.1	Introduction	235
6.5.2	Ingot Steels	238
6.5.3	P/M Steels	242
6.5.4	Aluminum Alloy	244
6.5.5	Concluding Remarks	245
	References to Chapter 6	245
7	Simulation of Metal Forming	
<i>A. E. Tekkaya</i>	251
7.1	Introduction	252
7.2	Elements of Continuum Mechanics	253
7.2.1	Nonlinear Kinematics of Deformation	253
7.2.2	Axiom of Objectivity	257
7.3	Rigid-Plastic Explicit Methods	258
7.3.1	Rigid-Plastic Material Law	259
7.3.2	Markov's Variational Statement	260
7.3.3	Discretization: Penalty Factor Approach	261
7.3.4	Discretization: Lagrangian Multiplier Approach	263
7.3.5	Numerical Solution: Direct Iterative Method	265
7.3.6	Numerical Solution: Newton- (Raphson) Method	268
7.3.7	Static Explicit Solution Scheme	270
7.3.8	Thermomechanical Analysis	274
7.4	Elasto-Plastic Implicit Methods	276
7.4.1	Governing Variational Statement	276
7.4.2	Stress Update	279
7.5	Elasto-Plastic Explicit Methods	282
7.5.1	Introduction	282
7.5.2	Finite Element Equation of Motion	283
7.5.3	Computational Issues	284
7.5.4	Dynamic Relaxation	287
7.6	Applications	287
7.6.1	Introduction	287
7.6.2	Element Types	291
7.6.3	Meshing Issues	292
7.6.4	Bulk Forming Applications	293
7.6.5	Sheet Forming Applications	296
	References to Chapter 7	298

Appendix 1: Tables

<i>K. Pöhlandt</i>	303
A.1.1 Standards for Formability Testing	303
A.1.2 Comparative Designations of Materials	306
A.1.3 Mechanical Properties of Selected Steels	307
A.1.4 Conversion Factors of Units.	308

Appendix 2: Flow Curves of Common Metals

<i>K. Pöhlandt</i>	309
A.2.1 Experimentally Determined Flow Curves	309
A.2.2 Analytical Approximation	311
References to Appendix 2	314

Appendix 3: Theoretical Models of the FLD's

<i>D. Banabic</i>	317
A.3.1 Models Based on the Necking Theory	318
A.3.2 Models Based on the Theory of Sheet-Nonhomogeneity	320
A.3.3 Linear Perturbation Theory	324
A.3.4 Semiempirical Models	325
References to Appendix 3	326

Index	329
------------------------	-----