

Contents

Overview of Heavy Metals with page number references	1
1 Definitions and Test Methods	5
1.1 Flow stress	5
1.2 Plasticity	6
1.3 Deformation behaviour	8
1.4 Methods to determine the deformation behaviour	8
1.4.1 Overview and specifications	8
1.4.2 Test methods for simulation	12
1.4.3 Technological tests	20
1.4.3.1 Deep drawing test	20
1.4.3.2 Bending test	22
1.4.3.3 Rolling test	24
1.5 References	25
2 Flow stress	26
2.1 Influence of the chemical composition	26
2.1.1 Hot working	26
2.1.1.1 Basic relationships	26
2.1.1.2 Experimental and commercial materials	28
2.1.2 Cold working	37
2.1.2.1 Basic relationships	30
2.1.2.2 Influence of pre-treatment condition	40
2.1.2.3 Initial structure	34
2.2 Influence of forming conditions	44
2.2.1 Hot forming	44
2.2.1.1 Influence of the deformation temperature	45
2.2.1.2 Influence of strain	47
2.2.1.3 Influence of the strain rate	51
2.2.2 Cold forming	53
2.2.2.1 Degree of forming	53
2.2.2.2 Forming rate	54
2.2.2.3 Forming temperature	55
2.3 Modelling	57
2.3.1 Influence of chemical composition	57
2.3.2 Influence of forming conditions	59
2.3.2.1 Hot working	59
2.3.2.1.1 Modelling by means of the thermodynamic factors	59
2.3.2.1.2 Calculation using the activation energy of hot deformation	63
2.3.2.2 Cold deformation	65
2.3.2.2.1 Effect of the degree of deformation	65
2.3.2.2.2 Influence of degree of deformation, deformation temperature and deformation rate	67
2.4 References	69
3 Plasticity	71
3.1 Hot plasticity	71
3.1.1 Influence of the material	72
3.1.2 Material condition	75
3.1.3 Influence of temperature and strain rate	76
3.2 Cold plasticity	80
3.2.1 Factors influencing cold plasticity	80
3.2.2 Parameters of cold plasticity	80
3.2.3 Influence of the material	82
3.2.4 Temperature	83
3.2.5 Strain rate	84
3.2.6 Influence of the stress condition	86

3.3	Modelling of the plasticity in hot working	86
3.3.1	Modelling of the influence of the chemical composition	86
3.3.2	Influence of deformation conditions	87
3.3.2.1	Modelling of temperature influence	87
3.3.2.2	Modelling of the influence of strain rate	90
3.4	Calculation of the forming limit in hot rolling	90
3.5	Calculation of the forming limit in hot extrusion	91
3.6	References	93
4	Mechanical and physical properties	94
4.1	Mechanical properties after cold forming	94
4.1.1	Yield point and tensile strength	94
4.1.2	Elongation	95
4.2	Young's modulus	96
4.2.1	Definition and functional relationships	96
4.2.2	Temperature-dependent modelling of Young's modulus	99
4.3	Thermal conductivity	101
4.3.1	Characteristics of thermal conductivity	101
4.3.2	Calculation of thermal conductivity	103
4.4	Specific heat capacity	107
4.4.1	Definition and dependencies	107
4.4.2	Specific heat capacity calculation	108
4.5	Thermal expansion coefficient	110
4.5.1	Definition and factors of influence	110
4.5.2	Influence of temperature on the coefficient of expansion	112
4.6	Density	114
4.6.1	Definition and factors of influence	114
4.6.2	Modelling the temperature dependence	115
4.7	References	117
5	Data bank of deformation parameters	118
5.1	Introduction	118
5.1.1	Basis of the data bank	118
5.1.2	Hot and cold flow curves	118
5.1.2.1	Remarks on the data of flow stress	119
5.1.2.2	Extrapolation	120
5.1.3	Plasticity curves	120
5.1.4	Mechanical and physical properties	121
5.2	Copper- and Copper alloys	123
5.2.1	Pure Copper and low alloyed Copper	123
5.2.2	Copper – Zinc – alloys	168
5.2.3	Copper – Tin – alloys	254
5.2.4	Copper – Nickel – alloys	290
5.2.5	Copper – Aluminium – alloys	343
5.2.6	Copper – Silicon – alloys	375
5.3	Nickel – and Nickel – alloys	388
5.3.1	Pure Nickel and Nickel alloys with <10% alloy content	388
5.3.2	Nickel – Copper – alloys	415
5.4	Chemical resistant and elevated-temperature alloys	490
5.5	Heat resistant Nickel – Chromium – alloys	532
5.6	Zinc and Zinc alloys	562
5.7	Lead	579
5.8	Niobium and Niobium alloys	587
5.9	Tantalum	599
5.10	Uranium	604
5.11	Tungsten	607
5.12	Tin	612
5.13	Zircon and Zircon alloy	616
5.14	Nobel metals	623
5.14.1	Silver and Silver alloys	623
5.14.2	Gold and Gold alloys	642
5.14.3	Platinum and Platinum alloys	651
5.15	References	663