

Dipl.-Ing. Franz Marketz, Den Haag

**Computational
Micromechanics Studies of
Martensitic Transformation**

Reihe **5**: Grund- und Werkstoffe

Nr. **491**

Contents

1	Introduction	1
1.1	Aims and Scope of the Studies	1
1.2	Outline	2
1.3	Notation	5
2	Mechanical Effects	7
2.1	Non-thermoelastic Martensitic Transformation	8
2.2	Thermoelastic Martensitic Transformation	9
3	Principles of Martensitic Transformation	10
3.1	Kinematic Theory of Martensitic Transformation	10
3.2	Mechanics Aspects of Martensitic Transformation	12
3.3	Continuum-Thermodynamics Aspects	15
4	Modelling Martensitic Transformation I	20
4.1	Introduction	20
4.2	Basic Aspects on Martensitic Transformation	21
4.3	Modelling Framework	23
4.3.1	Levels of Consideration	23
4.3.2	Modelling Aspects on the Microlevel	23
4.3.3	Micro-Meso Approach	25
4.4	Micromechanical Models	28
4.4.1	Meso-Macro Approach	29
4.4.2	Axisymmetric Cone Model	31
4.4.3	Plate Models	33
4.5	Thermomechanical Framework	34
4.5.1	Gibbs Free Energy Formulation	34
4.5.2	Transformation Conditions	35

4.6	Numerical Results	38
4.6.1	Accommodation and Stress-Assisted Nucleation in a Microstress Field . .	38
4.6.2	A Quasistatic Modelling Approach to the Growth of Martensitic Variants	40
4.6.3	Transformation Progress in a Microstress Field	41
4.6.4	Concluding Remarks	45
4.7	Chapter 4 Figures	47
5	Thermodynamic Effect of Stress	70
5.1	Introduction	70
5.2	The Kinematic Aspects of Martensitic Transformation on the Mesoscale	72
5.3	Continuum-Thermodynamics Framework	74
5.4	The Maximum Mechanical Driving Force for Tridimensional Stress States	76
5.5	The Effect of Microstress on the Mechanical Driving Force	79
5.6	Implementation of the Magee-Effect into a Constitutive Equation for TRIP . . .	81
5.7	Concluding Remarks	85
5.8	Chapter 5 Figures	86
6	Modelling Martensitic Transformation II	98
6.1	Introduction	98
6.2	Martensitic Transformation as a Deformation Mechanism	99
6.3	Micromechanics and Martensitic Transformation	101
6.4	Problem Formulation	106
6.4.1	Plastic Constitutive Relations	107
6.4.2	Micromechanical Model	108
6.5	Results	109
6.5.1	Transformation-induced Microstress Distributions	109
6.5.2	Thermodynamic Forces along Interphase Boundaries	110
6.5.3	Stress-assisted Nucleation Tendency	111
6.6	Discussion	112
6.7	Chapter 6 Figures	114
7	Simulation of a TRIP-Experiment	127
7.1	Objective of the Numerical Study	127
7.2	Kinematic Aspects on TRIP	128
7.3	Continuum-Thermodynamics Framework	130
7.4	Transformation Kinetics on Macroscale and Microscale	132

7.5	Modelling Method and Results	133
7.6	Conclusion	135
7.7	Chapter 7 Figures	136
8	Modelling Variant Coalescence	140
8.1	Introduction	140
8.2	Kinematics of the $\beta_1 \rightarrow \gamma'_1$ transformation in Cu-Al-Ni	141
8.3	Continuum-Thermodynamics Framework	142
8.4	Modelling Variant Coalescence in Cu-Al-Ni	143
8.4.1	Modelling Framework	143
8.4.2	Micromechanical Model	145
8.5	Results and Discussions	146
8.6	Chapter 8 Figures	147
9	Summary	151
10	Appendices	158
10.1	Orthogonal Transformation Relations	158
10.2	Kinematics of the Invariant Plane Strain	160
10.3	Transformation Volume Change	161
10.4	Derivation of Stress-free transformation tensors for an Fe-30Ni alloy and a Cu-Al-Ni alloy	162
10.5	Finite-Element Modelling Method	166