

Contents

Contents	I
List of Figures	V
List of Tables	VII
1 Introduction and Motivation	1
1.1 Introduction	1
1.2 Motivation	4
2 Constitutive modeling of a polycrystalline material	9
2.1 Elasticity	10
2.2 Variation of elastic properties in crystals	13
2.3 Creep	15
2.3.1 General Remarks	15
2.3.2 Constitutive Equations Based on Creep Potential	17
2.3.3 Identification of creep parameters	22
2.3.4 Crystallographic approach	24
2.3.5 Comparison of both approaches	26
2.3.5.1 Comparison by the predicted creep strain rate	26
2.3.5.2 Creep properties variation in single crystal . .	30
3 Grain boundary sliding	35
3.1 Nature of the grain boundary sliding	35
3.2 Grain boundary sliding modeling	37

4	Creep cavitation	43
4.1	Overview of existing models	43
4.1.1	Cavitation due to diffusion processes	43
4.1.2	Cavitation models based on dislocation creep	44
4.1.3	Cavitation due to various mechanisms	45
4.2	Tvergaard's cavitation model	45
4.2.1	Cavity nucleation and growth equations	45
4.2.2	Creep strain rate evolution due to cavitation	47
4.3	Influence of cavities on the material behavior	48
5	Numerical implementation	53
5.1	Geometrical representation of polycrystal	53
5.2	Material model implementation	56
5.3	Calculation of averaged fields in the unit cell	57
5.4	Statistical analysis of the unit cell	58
5.5	Choice of the representative number of grains	61
5.6	Choice of the grain boundary region thickness	62
6	Tensile creep tests for polycrystalline copper at 550 °C	65
6.1	Choice of the specimen and test conditions	65
6.2	Experimental procedure	66
6.3	Experimental results	68
6.4	Validation of the secondary creep stage	68
6.5	Micrographs of copper under different applied stresses	70
7	Model application	73
7.1	Verification of the model by the separate creep region	73
7.1.1	Primary creep stage validation	73
7.1.2	Secondary creep stage verification	75
7.1.3	Tertiary creep stage verification	76
7.2	Non-proportional loading test	78
7.2.1	Continuum damage mechanics approach	78
7.2.1.1	Isotropic damage	78
7.2.1.2	Anisotropic damage	80
7.2.2	Non-proportional loading experiments	82
7.2.3	Non-proportional loading test of the unit cell	84
8	Conclusions and outlook	87
A	Derivation of elasticity equations in engineering constants	91

B	Micrographs of the copper specimens	95
C	Crystallographic planes and directions in copper crystal	99
	Bibliography	101