

Spis treści

Streszczenie.....	7
Summary	9
1. Introduction.....	11
2. Motivation.....	14
2.1. Strain localization simulations	14
2.1.1. Cellular Automata Finite Element model.....	17
2.1.1.1. Forging of the Bainitic steels	20
2.1.1.2. Forging of the CuCr alloys.....	24
2.2. Examples of the experimental investigation on strain localization.....	27
2.3. Conclusions	34
3. Multi scale modelling methods	35
3.1. Motivation	35
3.2. Classification of multi scale modelling methods	36
3.3. Multi scale models	37
3.4. Models based on Digital Material Representation.....	45
4. Aim of the work.....	52
5. Digital Material Representation (DMR).....	55
5.1. Topology of the microstructure	56
5.1.1. Voronoi tessellation	57
5.1.2. Cellular automata grain growth algorithm	60
5.1.3. Image processing.....	69
5.2. Properties of the microstructure	72
5.3. Connection of the digital microstructure with the commercial finite element software	75
6. Numerical simulations based on the basic DMR model.....	77
6.1. Uniform finite element meshes – case studies	77
6.1.1. Examples of DMR applications to single phase materials	77
6.1.2. Examples of DMR application to two phase materials	85
6.1.3. Examples of DMR application to single phase materials with inclusions	89
6.2. Nonuniform finite element meshes – case studies	93
6.3. Further improvements of the DMR system	98
7. The improvements of the DMR approach	100
7.1. The cellular automata model for phase transformation	100

7.1.1.	Nucleation	101
7.1.2.	Ferrite grain growth.....	102
7.1.3.	Strain localization analysis in the two phase DMR	107
7.2.	Crystal plasticity model	109
7.2.1.	Uniform field models	109
7.2.2.	Nonuniform field models	110
7.2.3.	Crystal Plasticity Finite Element Method (CPFEM)	111
7.3.	Multi scale model based on the DMR.....	120
8.	Practical applications of the DMR	125
8.1.	Numerical simulations of the deformation processes	125
8.1.1.	Numerical simulation of the levelling process.....	125
8.1.2.	An approach to manufacturing chain modelling in application to bolt production	128
8.2.	Numerical simulations of the thermal processes.....	133
8.2.1.	Numerical simulation of phase transformation after rolling	133
8.2.2.	Numerical simulation of static recrystallization after forging	135
8.3.	Numerical simulations of the micro forming process	138
9.	Discussion.....	142
9.1.	Summary	142
9.2.	Conclusions.....	144
9.3.	Future work	146
	Literature.....	147