

1	Introduction	1
1.1	Objective	2
1.2	Structure of the work	2
2	State of the art	4
2.1	Manufacturing processes for composites	4
2.2	Main sources and factors for process-induced distortions and residual stresses	5
2.3	Material models	8
3	Material characterisation – Single Components	17
3.1	Cure kinetics	18
3.2	Glass transition temperature	21
3.3	Density	22
3.4	Specific heat capacity	23
3.5	Thermal conductivity	26
3.6	Chemical Shrinkage	27
3.7	Mechanical behaviour during the curing process	30
3.8	Relaxation behaviour	36
4	Material characterisation – Composite	42
4.1	Heat of reaction	43
4.2	Density	43
4.3	Heat capacity	43
4.4	Thermal conductivity	44
4.5	Engineering constants	48
4.6	Thermal expansion	51
4.7	Chemical shrinkage	56
4.8	Relaxation behaviour	59
5	Formation of residual stress on the micro level	64
5.1	Model description	64
5.2	Results of the process simulation	66
5.3	Study - Effects of matrix nonlinearities on the formation of residual stresses	69
5.4	Study - Effects of micro residual stress / defects on the macro level	73
6	Formation of residual stress on the macro level	77

6.1	Simulation strategy	77
6.2	Thermal analysis module	79
6.3	Mechanical analysis module	79
6.3.1	Step 1 - Curing process	79
6.3.2	Step 2 - Tool removal	83
6.3.3	Post processing of the results	84
6.4	Validation test case 1	86
6.4.1	Experimental investigation	86
6.4.2	Numerical investigation	87
6.5	Validation test case 2	96
6.5.1	Experimental investigation	97
6.5.2	Numerical Investigation	98
6.6	Conclusion	103
7	Application - composite multi spar flap	104
7.1	Model description	105
7.2	Results	106
7.3	Sensitivity of influencing factors	117
7.4	Warpage compensation strategies	121
7.5	Conclusion	122
8	Further application based on non deterministic methods	123
8.1	Sensitivity analysis	124
8.1.1	Application 1 - Design of Experiment on material parameters	124
8.1.2	Application 2 - Design of Experiment on process parameters	127
8.2	Variability analysis	129
8.3	Process optimisation	132
8.4	Conclusion	135
9	Summary	136
10	Abbreviation	139
11	Notation	141
12	References	144
13	List of Figures	151