Table of contents

Acknowledgements	Ι			
Abstract				
Kurzfassung				
Publications				
Table of contents				
Catalogue of symbols used	XIII			
1 Introduction	1			
 1.1 Motivation 1.2 Objective 1.3 Structure of the work 	1 2 2			
2 State of the art	5			
 2.1 Fundamentals of composite sandwich structures 2.1.1 Definition 2.1.2 Application of composite sandwich structures 2.1.3 Materials and manufacturing 2.1.4 Fundamentals of sandwich theory 2.1.5 Failure modes of sandwich structures 2.2 Through-the-thickness reinforcement of foam core sandwich structures 2.2.1 Motivation and examples from the literature 2.2.2 Tied foam core technology 2.3 Impact behaviour of foam core sandwich structures 2.3.1 Impact failure modes 2.3.2 Analytical analysis of the impact response of foam core sandwich structures 	5 6 8 12 15 18 21 23 24 26 31			
3 Experimental characterisation of the Tied Foam Core-sandwich structure	33			
 3.1 Materials and manufacturing 3.2 Tested TFC-configurations 3.3 Damage analysis with X-ray computed tomography 3.4 Flatwise compression test 3.4.1 Literature review 3.4.2 Test description 3.4.3 Results and discussion 3.4.4 Analytical method to predict compressive modulus and compressive strength 3.5 Out-of-plane shear test 3.5.1 Literature review 3.5.2 Test description 3.5.3 Results and discussion 	 33 34 35 36 37 38 45 47 48 48 50 			

3.6 3.6.1 3.6.2 3.6.3 3.7 3.7.1 3.7.2 3.8	 TFC-sandwich indentation test Literature review Test description Results and discussion Core indentation test Test description Results and discussion Chapter summary 	54 55 55 56 59 60 61
4	Experimental analysis of the impact response of TFC-sandwich at low temperature	63
4.1 4.2 4.3 4.3.1 4.3.2 4.3.2 4.3.2 4.3.4	Literature review Low-velocity impact: test set-up Results and discussion Test results at room temperature Test results at -55 °C using carbon fibre pins Effects of the manufacturing process on impact damage at -55 °C Effects of the pin material on impact damage at -55 °C Chapter summary	 63 64 66 69 71 72 73
5	Numerical simulation of impact on TFC-sandwich structure	77
5.1 5.1.1 5.1.2 5.1.2 5.1.2 5.2.1 5.2.2 5.2.3 5.2.3 5.3.2 5.3.5 5.3.5 5.3.5 5.3.5 5.3.5 5.3.5 5.5.5.5 5.5.5.5 5.5.5.5 5.5.5.5 5.5.5.5.5 5.5.5.5.5.5.5.5.5.5.5.5.5.	Fundamentals of explicit simulation General aspects and basic equations Contact modelling with Abaqus Modelling the face sheet damage Modelling the crushing behaviour of the foam core Numerical simulation of impact on a curved foam core sandwich shell aerospace application Literature review Modelling approach Strain rate effects of the sandwich components Face sheet model validation Impact model validation: assembly level Impact model validation: sub-component level Numerical simulation of impact on TFC-sandwich structure Modelling approach Validation of the TFC-model Validation of the TFC-model Chapter summary	77 77 82 83 90 for 91 92 93 94 00 02 04 02 04 12 112 113 113
6	Summary and outlook 1	25
Refer	rences	29
List c	of figures	37
List of tables		40
A X	Appendix 1	41

A.1	Calculation of effective stiffnesses of sandwich panels	141
A.2	Results of the tensile test of the CFRP face sheet	141
A.3	Validation of the sandwich impact model	143