

TABLE OF CONTENTS

1. Introduction	1
1.1 Stiffened Composite Structures	1
1.2 Industrial Applications	3
1.2.1 Aerospace Applications	4
1.2.2 Aircraft Applications	5
1.2.3 Marine Applications	8
1.3 The Design of Stiffened Structures with Composite Materials	9
2. Failure Mechanisms (Modi) and Failure Prediction in Stiffened Composite Structures	11
2.1 Ply Failure	11
2.2 Delamination	15
2.3 Core Failure	18
2.4 Buckling	19
3. Computational Investigations of Stiffened Composite Structures	20
3.1 Investigated Configuration	20
3.2 Definition of a Risk Parameter	23
3.2.1 Onset of Delamination	23
3.2.2 Ply Failure	24
3.2.3 Matrix Cracking in the Neat Resin Core	25
3.3 Free Edge Effects in the Skin-Stringer Transition	26
3.3.1 3D-Finite Element Model	27
3.3.2 Deformations, Interlaminar Stresses, Onset of Failure	30
3.3.3 Parametric Study	44
3.3.3.1 <i>Fiber Orientation Angle</i>	44
3.3.3.2 <i>Transition Radius/Layer Thickness</i>	53
3.3.3.3 <i>Layer Materials</i>	61
3.3.3.4 <i>Core Materials</i>	69
3.4 Interlaminar Stresses in the Skin-Stringer Transition at Some Distance from Free Edges	78

3.4.1	Generalized Plane Strain Finite Element Approach	78
3.4.1.1	<i>GPS-Finite Element Model</i>	78
3.4.1.2	<i>Boundary Conditions for the GPS-Model</i>	79
3.4.2	Comparison of the 3D- and the Generalized Plane Strain Model	83
4.	Experimental Investigations	89
4.1	Acoustic Emission Technique	89
4.2	Test Specimen	92
4.3	Experimental Setup and Procedure	93
4.4	Finite Element Model of the Test Setup	95
4.5	Experimental Verification of the Failure Calculations	97
5.	Analysis Concept for Stiffened Composite Structures	114
5.1	Description of the Analysis Concept	114
5.2	Application of the Analysis Concept	115
5.2.1	Investigated Imperfect Stringer-Stiffened Wing Torsion Box	116
5.2.2	Finite Element Model – Overall Analysis	117
5.2.3	Finite Element Model – Local Analyses	119
5.2.4	Numerical Results of the Global Analysis	122
5.2.5	Numerical Results of the Detail Analyses	127
5.2.5.1	<i>Perfect Model</i>	127
5.2.5.2	<i>Prestressed Model</i>	128
6.	Conclusions	137
	References	139