

Contents

Nomenclature	ix
1 Introduction	1
1.1 Motivation	1
1.2 Structural design of stringer frame stiffened shell structures	3
1.3 Objectives and scope of the thesis	6
2 Theoretical fundamentals	9
2.1 Coordinate system	9
2.2 Bending perturbations of shells	9
2.3 Buckling phenomena of stiffened shell structures	11
2.4 Smeared stiffener theory	15
2.5 State of the art	16
2.5.1 Assessment of state-of-the-art calculation methods	17
2.5.2 Assessment of state-of-the-art frame sizing methods	20
3 Calculation of panel instability	27
3.1 Approach of a novel calculation procedure	27
3.2 Verification of the presented approach	36
3.2.1 Study structures	36
3.2.2 Verification computations	38
3.2.3 Evaluation of applicability	45
3.2.4 The influence of stiffness change on the prediction accuracy	54
3.3 Interim summary of results	57
3.4 Adjusted approach for the calculation of panel instability	59
3.4.1 Approach of the calculation procedure	59
3.4.2 Buckling and post-buckling calculation of the shell skin	63
3.4.3 Adjusted smeared stiffener theory	64
3.4.4 Panel instability calculation	65
3.4.5 Failure mode estimation	68
3.5 Verification of the adjusted approach	69
3.5.1 Study structures	69
3.5.2 Verification computations	70
3.6 Summary of results	81

4	Minimum stiffness criterion for frames	85
4.1	Discussion on the derivation of a criterion	85
4.2	The approach of determining a transition point between buckling modes	86
4.2.1	Determining the minimum substitute stiffness	87
4.2.2	Deriving a suitable frame cross section	90
4.3	The approach of matching critical loads of buckling phenomena	92
4.3.1	Determining global buckling	92
4.3.2	Determining the minimum stiffness	95
4.4	Verification of the minimum stiffness criteria	96
4.4.1	Study structures	96
4.4.2	Verification computations	97
4.4.3	Comparison of approaches	113
4.5	Summary of results	117
5	Structural design process for prospective stringer profile shapes	119
5.1	Proposed structural design process	120
5.2	Optimisation of a stiffened cylindrical shell structure	121
5.2.1	Study structure	122
5.2.2	Optimisation procedure	123
5.2.3	Evaluation of optimised shell designs	124
5.3	Summary of results	126
6	Summary, conclusion and outlook	129
	Bibliography	133
A	Appendix	145
A.1	Substitution of the potential energies	145
A.1.1	Inner potential energy	145
A.1.2	External potential energy for static calculation	147
A.1.3	External potential energy for stability calculation	148
A.2	The stiffness matrix and geometric stiffness matrix of the EPIANO finite element	148