

Table of Contents

Acknowledgements	i
Abstract	iii
Table of contents	vii
List of Figures	xiii
List of Tables	xxii
1. Introduction	1
1.1. Overview	1
1.2. Fibers	1
1.2.1. Carbon fibers	1
1.2.2 Glass fibers	4
1.3. Functionally Graded Materials	5
1.4. Orientation of laminates	7
1.5. Applications of composites	9
1.5.1. Aerospace industry	10
1.5.2. Automobiles	11
1.5.3. Construction industry	11
1.5.4. Marine industry	13
1.6. Manufacturing processes of fiber reinforced polymer materials	14
1.7. Mechanical behavior of composite plates	16
1.8. Concept of hybridization	17
1.9. Overview of plate theories	17

1.10. Failure criteria of composite plates	19
1.11. Buckling and Postbuckling response of functionally graded hybrid composite plates	22
1.11.1 Overview	22
1.11.2 Need for cutouts	24
1.12 The problem in a broad-sense	24
1.13 Outline of the thesis	25
1.14 Scope of the present investigation	26
2. Literature Review	27
2.1. Overview of the past work	27
2.2 Material characterization	27
2.3 Buckling and postbuckling response of composite plates	31
2.3.1 Uniaxial compressive loading	32
2.3.2 In-plane shear loading	34
2.3.3 Combined Uni-axial and In-plane shear loading	35
2.4 Boundary conditions	36
2.5 Gaps in Present Research	37
2.6 Objectives of the present study	37
3. Experimental Programs for Material Characterization of Hybrid Composites	38
3.1. Introduction	38

3.2. Fabrication of laminates	38
3.2.1. Plain laminated specimens	38
3.2.2. Hybrid laminated specimens	43
3.3. Experimental tests	45
3.3.1. Glass transition temperature test	47
3.3.2. Tensile test	47
3.3.2.1. Energy absorbed	48
3.3.2.2. Shear modulus	49
3.3.3. Compressive test	50
3.3.4. Flexural test	50
3.4. Results and Discussion	51
3.4.1. Tensile characteristics	52
3.4.1.1. CFRP laminates	52
3.4.1.2. GFRP laminates	59
3.4.1.3. Energy absorbed	64
3.4.1.4. Shear modulus	68
3.4.1.5. Failure modes	72
3.4.1.6. Strength, stiffness and failure strain	73
3.4.2. Compressive characteristics	78
3.4.2.1. CFRP laminates	78
3.4.2.2. GFRP laminates	83
3.4.2.3. Failure modes	88
3.4.2.4. Strength and failure strain	91
3.4.3. Flexural Characteristics	92

3.4.3.1. CFRP laminates	92
3.4.3.2. GFRP laminates	96
3.4.3.3. Failure modes	99
3.4.3.4. Strength, stiffness and failure strain	103
3.5. Concluding remarks	104
4. Buckling and Postbuckling Response of Hybrid Composite Plates under Uni-axial Compressive Loading	107
4.1. Introduction	107
4.2. Experimental and numerical approaches	108
4.2.1. Experimental approach	108
4.2.2. Numerical study	111
4.3. Results & Discussion	116
4.3.1. Experimental study	116
4.3.2. Numerical study	117
4.3.2.1. Buckling load	117
4.3.2.2. First ply failure load	123
4.3.3. Effect of cutouts	125
4.3.3.1. (0/90) _{4s} stacking sequence	128
4.3.3.1.1. Small size cutouts	128
4.3.3.1.2. Medium size cutouts	129
4.3.3.1.3. Big size cutouts	129
4.3.3.2. (-45/+45) _{4s} stacking sequence	132
4.3.3.2.1. Small size cutouts	133
4.3.3.2.2. Medium size cutouts	134
4.3.3.2.3. Big size cutouts	136

4.3.3.3. (-45/+45/0/90) _{2s} stacking sequence	137
4.3.3.3.1. Small size cutouts	137
4.3.3.3.2. Medium size cutouts	138
4.3.3.3.3. Big size cutouts	139
4.4. Concluding remarks	153
5. Buckling and Postbuckling Responses of Hybrid Composite Plates under In-Plane Shear Load	142
5.1. Introduction	142
5.2. Numerical approach	142
5.3. Verification of numerical model	147
5.4. Results and discussion	148
5.4.1. Critical buckling load	148
5.4.2. First ply failure load	152
5.4.3. Effect of direction of in-plane shear load	152
5.4.4. Effect of cutouts	153
5.4.5. Effect of stacking sequence	156
5.4.6. Effect of boundary conditions	181
5.5. Concluding remarks	192
6. Postbuckling Response of Functionally Graded Hybrid Composite Plates under Combined Uniaxial Compression and In-plane Shear Loads	195
6.1. Introduction	195
6.2. Verification	198
6.3. Numerical formulation	200
6.4. Results and discussion	203
6.4.1. Effect of stacking sequence	204
6.4.1.1. (0/90) _{4s} stacking sequence	204

6.4.1.2. (+45/-45) _{4s} stacking sequence	206
6.4.1.3. (+45/-45/0/90) _{2s} stacking sequence	209
6.4.2. Effect of cutout shape and size	209
6.4.3. Load interaction/Failure envelopes	218
6.5. Concluding remarks	225
7. Summary and Conclusions	227
7.1 Summary	227
7.2 Conclusions	227
7.3 Future scope of the present investigation	233
Bibliography	234
List of publications	244
Biographical notes	247