

Contents

Preface

Abbreviations and Symbols

Chapter 1

Introduction	1-85
1.1 Composites.....	2
1.1.1 Fibre reinforced composites	4
1.2. Matrices.....	5
1.2.1 Thermosetting and thermoplastic polymers	6
1.2.2 Polyester	7
1.2.3 Epoxy resin.....	11
1.2.4 Phenolic resin.....	12
1.2.5 Vinyl esters.....	12
1.2.6 Other thermosetting polymers	12
1.3 Synthetic fibres	13
1.3.1 Glass fibre	14
1.3.2 Carbon fibre	15
1.3.3 Kevlar fibre	15
1.3.4 Boron fibre	16
1.3.5 Other fibres.....	16
1.4 Natural fibres	17
1.4.1 Chemical composition	19
1.4.2 Properties	25
1.4.3 Advantages	27
1.4.4 Major issues related to natural fibres.....	29
1.4.4.1 Moisture absorption	29
1.4.4.2 Thermal stability	30
1.4.4.3 Biodegradation and photodegradation	31
1.5 Fibre/matrix interface	31
1.5.1 Methods to improve interfacial bonding	33
1.5.1.1 Physical modification	33
1.5.1.2 Chemical modification	35
1.6 Natural fibre reinforced polymer composites.....	39
1.6.1 Applications of natural fibre reinforced composites.....	44
1.7 Green composites.....	45

1.8	Cellulose nano composites.....	49
1.9	Synthetic fibre reinforced composites	51
1.10	Hybrid fibre composites	54
1.11	Motivation for the study.....	64
1.12	Scope and objectives	66
	References	71

Chapter 2

Materials and Experimental Procedures.....87-103

2.1	Materials	88
2.1.1	Pineapple leaf fibre (PALF).....	88
2.1.2	Glass fibre (GF).....	88
2.1.3	Polyester resin	89
2.1.4	Chemicals	89
2.2	Chemical modification of fibre surface	91
2.2.1	Silane treatment	91
2.2.2	Polystyrene maleic anhydride (PSMA) treatment	91
2.2.3	Sodium hydroxide treatment.....	91
2.2.4	Potassium permanganate (KMnO ₄) treatment.....	91
2.3	Solvatochromic measurements	91
2.4	Fourier transform infrared analysis (FTIR)	94
2.5	Optical microscopy studies	94
2.6	Composite processing	94
2.6.1	PALF/PER and GF/PER composites.....	94
2.6.2	Chemically modified PALF/PER composites	95
2.6.3	PALF/GF hybrid polyester composites	95
2.7	Scanning electron microscopy analysis	96
2.8	Mechanical property measurements	97
2.9	Hardness measurement	98
2.10	Dynamic mechanical analysis (DMA).....	98
2.11	Thermogravimetric analysis (TGA)	98
2.12	Thermophysical measurements.....	98
2.13	Water absorption studies	100
2.14	Ageing studies	101
2.14.1	Cold water immersion.....	101
2.14.2	Dimensional stability tests	102
2.14.3	Boiling water immersion.....	102
2.14.4	Thermal ageing	102
2.14.5	Soil burial test	103
2.14.6	Outdoor weathering studies	103
	References	103

Chapter 3	
Polarity Characteristics of PALF	105-126
3.1 Introduction	106
3.2 Results and Discussion	109
3.2.1 Effect of fibre treatment on polarity parameters	109
3.3 Conclusion	123
References	124
Chapter 4	
Mechanical Behaviour of PALF/GF Hybrid Composites	127-196
4.1 Introduction	128
4.2 Results and Discussion	130
4.2.1 PALF/PER composites	130
4.2.1.1 Tensile properties.....	130
4.2.1.2 Flexural properties	134
4.2.1.3 Impact strength	135
4.2.2 GF/PER composites.....	138
4.2.2.1 Tensile properties.....	138
4.2.2.2 Flexural properties	140
4.2.2.3 Impact strength	141
4.2.3 Chemically treated PALF/PER composites	143
4.2.3.1 Silane treatment	143
4.2.3.1.1 Methyl triethoxy silane	144
4.2.3.1.2 Vinyl tri (2-methoxy ethoxy silane)	145
4.2.3.1.3 γ - methacryloxy propyl trimethoxy silane.....	147
4.2.3.2 Sodium hydroxide treatment	150
4.2.3.3 Potassium permanganate treatment.....	151
4.2.3.4 Comparison of effectiveness of the various chemical treatments.....	151
4.2.4 Intimately mixed (IM) PALF/GF hybrid composites	151
4.2.4.1 Tensile properties.....	151
4.2.4.1.1 Effect of PALF/GF content ratio	151
4.2.4.1.2 Effect of fibre loading.....	159
4.2.4.2 Flexural properties	161
4.2.4.2.1 Effect of (PALF/GF) content ratio.....	161
4.2.4.2.2 Effect of fibre loading	162
4.2.4.3 Impact properties	163
4.2.4.3.1 Effect of (PALF/GF) content ratio.....	163
4.2.4.3.2 Effect of fibre loading	166
4.2.5 Layered hybrid composites.....	167
4.2.5.1 Trilayer GPG (Glass skin and PALF core) hybrid composites	167
4.2.5.1.1 Tensile properties	167

4.2.5.1.2 Flexural properties.....	176
4.2.5.1.3 Impact properties.....	179
4.2.5.2 Trilayer PGP and bilayer GP hybrid composite	181
4.2.5.2.1 Tensile properties	181
4.2.5.2.2 Flexural properties.....	183
4.2.5.2.3 Impact properties	183
4.2.6 Theoretical modelling	183
4.3. Conclusion	190
References	192

Chapter 5

Dynamic Mechanical Analysis of PALF/GF Hybrid Composites.....197-242

5.1 Introduction	198
5.2 Results and Discussion	200
5.2.1 PALF/PER composites.....	200
5.2.1.1 Effect of fibre aspect ratio.....	200
5.2.1.2 Effect of fibre content	204
5.2.2 GF/PER Composites	213
5.2.3 PALF/GF hybrid composites	218
5.2.3.1 Behaviour of intimately mixed composites.....	218
5.2.3.2 Effect of hybrid layering patterns	228
5.2.3.3 Cole-cole analysis	234
5.2.4 Theoretical modelling	235
5.3 Conclusion.....	238
References	239

Chapter 6

Thermal Properties of PALF/GF Hybrid Composites.....243-274

6.1 Introduction	244
6.2 Results and Discussion	248
6.2.1 Thermogravimetric analysis.....	248
6.2.1.1 Fibre characterisation.....	248
6.2.1.2 Polyester resin	256
6.2.1.3 PALF/PER composites.....	258
6.2.1.4. Chemically modified PALF/PER composites.....	261
6.2.1.5. PALF/GF hybrid composites	263
6.2.2 Thermophysical properties.....	265
6.2.2.1 Effect of change of GF/PALF ratio	265
6.2.2.2 Thermal conductivity and the first order model.....	267
6.3. Conclusion.....	270
References	270

Chapter 7	
Water Absorption Behaviour of PALF/GF Hybrid Composites.....	275-305
7.1	Introduction 276
7.2	Results and Discussion 278
7.2.1	Water uptake of PALF/GF hybrid polyester composites..... 278
7.2.2	Effect of chemical treatment..... 287
7.2.3	Kinetics of water absorption 291
7.2.4	Diffusion, sorption and permeation 292
7.2.5	Thermodynamic parameters 297
7.2.6	Theoretical modelling 299
7.3.	Conclusion 302
References 303
Chapter 8	
Environmental Behaviour of PALF/GF Hybrid Composites	307-345
8.1	Introduction 308
8.2	Results and Discussion 311
8.2.1	PALF/GF hybrid composites..... 311
8.2.1.1	Effect of humidity..... 311
8.2.1.1.1	Weight gain and thickness swelling..... 311
8.2.1.1.2	Tensile properties 312
8.2.1.1.3	Impact Properties 318
8.2.1.2	Thermal ageing 319
8.2.2.	Effect of PALF modification 324
8.2.2.1	Percentage Weightage 324
8.2.2.2	Tensile properties..... 326
8.2.2.3	Impact properties 329
8.2.2.4	Effect of thermal ageing 330
8.2.3.	Soil burial and outdoor weathering studies 331
8.2.3.1	PALF/GF hybrid composites..... 332
8.2.3.2	Effect of PALF modification 338
8.3	Conclusion 342
References 343
Chapter 9	
Conclusions & Future Scope of Work	347-357