

TABLE OF CONTENTS

Chapter No	Contents	Page No
1	Composites Material	1
	1.1. Introduction	1
	1.2. Definitions of Composites Materials	2
	1.3. Classification of Composite Material	4
	1.3.1. Classification of Composites Material on the Basis of Matrix Phase	4
	1.3.2. Classification of Composites Material on the Basis of Reinforcement or Dispersed Phase	5
	1.4. Matrix Phase (Primary Phase)	6
	1.4.1. Polymer Matrix Composites (PMC) or Polymer Matrix Materials	6
	1.4.2. Property of Thermosets & Thermo-Plastic (Matrix Phase)	9
	1.5. Thermo-plastic Polymer Matrix Phase	11
	1.5.1. Effect of Heat on the Matrix of Thermoplastic Polymer Composites	12
	1.6. Metal Matrix Composites (MMCs)	13
	1.6.1. Property of Metal Matrix Composites	16
	1.6.2. Application of Metal Matrix Composites	17
	1.7. Ceramic Matrix Composites (CMCs)	18
	1.7.1. Type of Silicon Carbide Fibers	20
	1.7.2. Aluminum Oxides Fiber	21
	1.8. Property of Ceramic Matrix Composites (CMCs)	22
	1.8.1. Advantages & Application of Ceramic Matrix Composites	23
	1.9. Carbon Matrix Composites (CAMCs)	23
	1.9.1. Advantage of Carbon – Carbon Composites	24

	1.9.2. Applications of Carbon–Carbon Composites	24
	1.10. Function of Matrix Phase	25
	1.11. Classification of Composites Material on the Basis of Reinforcement	25
	1.12. Fiber Reinforcing Material	26
	1.13. Reinforcement by Particles or Particulates	27
	1.13.1. Shape and Orientation of Dispersed Phase Inclusions	28
	1.14. Particle-Reinforced Metal Matrix Composites	28
	1.14.1. Titanium Carbide Particle-Reinforced with Steel	29
	1.14.2. Silicon Carbide Particle-Reinforced with Aluminium	29
	1.15. Fibre Reinforced Composites	30
	1.15.1. Fibre Reinforced or Fibre Dispersed Phase	31
	1.15.2. Fibrous Composites	36
	1.15.3. Long-fiber Reinforced Composites	36
	1.16. Manufacturing of Fibre Reinforced Composites	40
	1.17. Discontinuous - Short Fiber Reinforced Composites	42
	1.18. Discontinuous Fiber-Reinforced Metal Matrix Composites	42
	1.19. Short Fibre Composites	43
	1.19.1. Short Fiber - Rubber Composites	43
	1.20. Fibre Orientation	45
	1.21. Glass Fiber	46
	1.22. E – Glass	47
	1.23. S – Glass	47
	1.24. HS Glass Fibers	48
	1.25. CR – Glass Fibers	48
	1.26. C-glass Fibre	48
	1.27. R-glass Fibre	48
	1.28. D-glass Fibre	48
	1.29. Carbon Fibers	51
	1.29.1. Manufacturing of Carbon Fibers	51
	1.30. Aramid Fibres	54

1.31. Kevlar 49	54
1.32. Kevlar - 149	54
1.33. Nylon Fibers	55
1.34. Ceramic Fibers	57
1.35. Silicon Carbide based Fibers	58
1.36. Alumina based Fibers	59
1.37. Boron Fibers	59
1.38. Manufacturing of Boron Fiber	59
1.39. High-Density Polyethylene Fibers	60
1.40. Basalt Fibers	60
1.41. Extended Chain Polyethylene Fibers	60
1.42. Hybrid Composites	61
1.43. Green Composites	62
1.44. Bio - Composite Materials	63
1.45. Laminate Composites	64
1.46. Lamina with Continuous Long Fiber	64
1.47. Lamina with Discontinuous Fiber	65
1.48. Nano-composites	68
1.48.1. Polymer Nano-composites	69
1.49. Nano Clay Composites	69
1.50. Carbon Nano Fibers	70
1.50.1. Manufacturing of Carbon Nano-fibers	70
1.51. Carbon Nano-tubes	71
1.51.1. Single-walled Carbon Nanotube (SWCNT)	71
1.51.2. Multi-walled Carbon Nanotube (MWCNT)	71
1.51.3. Properties of Carbon Nanotube-polymer Composites	72
1.52. Natural Fiber Composites	73
1.53. Advantages & Disadvantages of Composites Material	75
1.54. Properties and Applications of Composite Materials	76
1.55. Properties of Polymer Matrix Composites	78

	1.55.1. Elastic and Strength Properties of Polymer Matrix Composites	79
	1.56. Physical Properties of Polymer Matrix Composites	82
	1.57. Fatigue Properties of Polymer Matrix Composites	83
	1.58. Creep and Creep Rupture of Polymer Matrix Composites	84
	1.59. Application of PMCs Composites Material	85
	1.59.1. Aircraft and Military Applications	85
	1.59.2. Space Applications	91
	1.59.3. Automotive and Transportation	92
	1.59.3.1. Body Components	92
	1.59.3.2. Chassis Components	92
	1.59.3.3. Engine Components	93
	1.59.4. Contribution of Polymer Matrix Composites in Sport Applications	94
	1.59.5. Marine Application of Polymer Composites Material	96
	1.59.5.1. Glass Fiber-reinforced Polyesters	96
	1.59.5.2. Kevlar 49-fiber Reinforced Composites	96
	1.59.5.3. Carbon Fiber-reinforced Epoxy	96
	1.60. Application of Polymer in Construction and Infrastructure	97
	1.61. Application of Polymer Composites in Corrosive Environments	99
	1.62. Application of Polymer Composites in Electrical & Electronics Field	99
	1.63. Application of Polymer Composites in Energy Field	99
	1.64. Property of Metal Matrix Composites	100
	1.65. Mechanical Properties of Continuous Fiber-Reinforced Metal Matrix Composites	101
	1.66. Physical Properties of Unidirectional Metal Matrix Composites	103
	1.67. Property of Discontinuous Fiber-reinforced Metal Matrix Composites	103

	1.68. Properties of Particle-Reinforced Metal Matrix Composites	104
	1.69. Mechanical Properties of Titanium Carbide Particle-reinforced Steel	104
	1.69.1. Mechanical Properties of Silicon Carbide Particle-reinforced Aluminium	105
	1.70. Physical Properties of Silicon Carbide Particle-reinforced Aluminium	106
	1.71. Mechanical Properties of Alumina Particle-Reinforced Aluminium	106
	1.72. Application of Metal Matrix Composite	107
	1.73. Property of Ceramic Matrix Composites	109
	1.74. Mechanical Properties of Ceramic Matrix Composites	111
	1.75. Physical Properties of Ceramic Matrix Composites	112
	1.75.1. Application of Ceramic Matrix Composite	112
	1.76. Carbon – Carbon Composites	113
	1.77. Mechanical Properties of Carbon Matrix Composites	114
	1.78. Physical Properties of Carbon Matrix Composites	115
	1.79. Application of Carbon Matrix Composite	116
	1.80. Applications of Bio-composites	117
	1.81. Applications of Advanced Composites	118
	1.82. Bonding in Composites Material	118
	1.82.1. Mechanical Bonding	118
	1.82.2. Dissolution and Wetting Bond	119
	1.82.3. Reaction Bond	119
	1.82.4. Oxide Bond	119
	1.82.5. Diffusion Bonding	120
	1.82.6. Plasma Spray Bonding	120
	1.82.7. Hot Rolling Bonding	120
	1.82.8. Mixed Bonding	120
	1.83. Failure Criteria of Composites Materials	120
	1.83.1. Fundamental of Failure	121

	1.83.2. Failure Criteria for Unidirectional Composite Material	121
	1.83.3. Quadratic Interaction Failure Criteria	122
	1.84. Tensile Properties of Composites Material	124
	1.85. Failure of Composites Due to Residual Stress	125
	1.86. Transverse Tensile Property of Composites Material	126
	1.87. Micro-mechanics of Composites	127
	1.88. Reinforcement Material	129
	1.88.1. Glass Fibers Reinforcing Material	131
	1.88.2. Carbon Fibers Reinforcing Material	133
	1.88.3. Boron Fibers Reinforcing Material	134
	1.88.4. Silicon Carbide Fiber Reinforcing Material	135
	1.88.5. Alumina Fiber Reinforcement Material	135
	1.89. Aramid Fibers	136
	1.90. High-Density Polyethylene Fibers	137
	1.91. Basalt Fibers	137
	1.92. Nylon Fiber Reinforcement Material	137
	1.93. Matrix Materials	139
	1.93.1. Polymer Matrix Materials	140
	1.93.2. Thermoplastic Resins Matrix	140
	1.94. Metal Matrix Material	142
	1.95. Ceramic Matrix	144
	1.96. Carbon Matrix Materials	144
	1.97. Composite Manufacturing Process	145
	1.97.1. Hand Lay-up Technique	145
	1.97.2. Spray-up Technique	147
	1.97.3. Bag-molding Process	148
	1.97.4. Filament Winding	150
	1.97.5. Conventional Filament-Winding Machine	152
	1.97.6. Numerical Control Filament Winding Technique	153
	1.98. Compression Moulding	155

	1.99. Injection Moulding	158
	1.99.1. Reaction Injection Molding (RIM)	159
	1.99.2. Reinforced Reaction Injection Molding	160
	1.100. Pultrusion Process	160
	1.101. Liquid Composites Moulding Process	163
	1.101.1. Resin Transfer Molding (RTM) Technique	164
	1.102. Automated Fibre Placement	167
	1.103. Additive Manufacturing	168
	1.104. Elastic Reservoir Moulding (ERM) Technique	168
	1.105. Tube Rolling	169
	Question for Discussion	170
	References	174
2	Introduction to Polymer Material	184
	2.1. Introduction	184
	2.1.1. Natural Polymers	184
	2.1.2. Synthetic Polymers	184
	2.2. Definition of Polymer	189
	2.3. Polymer a Class of Engineering Materials	191
	2.3.1. Polymer Material Used in Mechanical Engineering Field	192
	2.3.2. Polymer Material Used in Electrical Engineering Field	197
	2.3.3. Polymer Material Used in Civil Engineering Field	201
	2.3.4. Limitation of Polymer in Engineering Applications	203
	2.3.5. Application of Polymer in Medical Fields	203
	2.4. Comparative Study Among Metals, Ceramics & Polymers	205
	2.4.1. Metals	206
	2.4.2. Ceramics	209
	2.4.3. Polymer	211
	2.5. Classification of Polymer Materials	212
	2.5.1. Classification of Polymer on the Basis of Origin	213

	2.5.2. Classification based on the Structure of Polymers	214
	2.5.3. Classification of Polymer on the Basis of Thermal Behaviour	219
	2.5.3.1. Thermo-plastic Polymer	219
	2.5.3.2. Thermosetting Polymer	221
	2.5.4. Classification of Polymer on the Basis of Molecular Forces	222
	2.5.4.1. Elastomers	222
	2.5.4.2. Fibres	223
	2.5.4.3. Thermoplastic Polymers	224
	2.5.4.4. Thermosetting Polymers	224
	2.5.5. Classification of Polymer on Basis of Polymerization or Formation	224
	2.5.5.1. Addition Polymerization Technique	224
	2.6. Stages in Addition Polymerization	226
	2.7. Application of Addition Polymer	228
	2.8. Characteristics of Addition Polymer Technique	229
	2.9. Free Radical Polymerization	229
	2.10. Ionic Polymerisation	230
	2.11. Cationic Polymerization	230
	2.12. Anionic Polymerization	231
	2.13. Condensation Polymers	232
	2.14. Coordination Polymerization	236
	2.15. Co-polymerization	236
	2.16. Application of Condensation Polymer	237
	2.17. Characteristics of Condensation Polymerization Technique	238
	2.18. Molecular-weight & Molecular Weight Distributions	238
	2.19. Calculation of Number Average Molecular Weight	239
	2.20. Calculation of Weight Average Molecular Weight	240
	2.21. Calculation of Weight Distribution in Polymer	241
	2.22. Calculation of Weight Average Chain Length (WACL)	241

	2.23. End-group Analysis	242
	2.24. Property of Polymer Material	242
	2.24.1. Mechanical Property of Polymer	243
	2.24.2. Electrical Property of Polymer	249
	2.24.3. Physical Property of Polymer	253
	2.24.4. Optical Property of Polymer Material	258
	2.25. Application of Polymer Material	259
	2.26. Polymer Processing	263
	2.26.1. Extrusion Process	264
	2.26.2. Injection Molding Technique	266
	2.26.3. Compression Molding	267
	2.26.4. Transfer Molding	268
	2.26.5. Blow Molding Technique	269
	2.26.6. Vulcanization	269
	Miscellaneous	272
	2.27. Thermoplastics Compounds	272
	2.27.1. Polyethylene	272
	2.27.2. Nylon	273
	2.27.3. Nylon – 66	273
	2.27.4. Nylon – 11	274
	2.27.5. Polyvinyl Chloride (PVC)	275
	2.27.6. Polyester	275
	2.27.7. Teflon	278
	2.27.8. Polystyrene	278
	2.27.9. Polypropylene	279
	2.27.10. Acrylics (Poly-methyl-methacrylate)	279
	2.27.11. Acrylonitrile-butadiene-styrene (ABS)	280
	2.27.12. Polycarbonates	280
	2.27.13. Fluorocarbons	280
	2.27.14. Bakelite	281
	2.28. Thermosets Compound	283

	2.28.1. Melamine	283
	2.28.2. Epoxy Resins	284
	2.28.3. Phenolic	285
	2.29. Elastomers	286
	2.29.1. Buna – S	286
	2.29.2. Nitrile Rubber	287
	2.29.3. Butyl Rubber	287
	2.29.4. Thiokol	288
	2.29.5. Polyurethane	288
	2.29.5.1. Poly Urethanes Rubbers	288
	2.29.5.2. Polyurethane (Foam Condensation Polymer)	289
	2.29.6. Silicones	290
	2.29.6.1. Formation of Linear Silicones	291
	2.29.6.2. Formation of Cross-linked Silicones	291
	2.29.7. Manufacturing of Silicone Rubber	291
	2.29.8. Polyphosphazines	293
	2.29.9. Sodium Polyacrylate – Copolymer	294
	2.29.10. Sulphur based Inorganic Polymer	294
	2.29.11. Chalcogenide Glass (As_2S_3) _n	295
	Question for Discussion	295
	References	297
	Index	303