Table of Contents

Contents	**Page No.**
Certificates	ii-iv
Acknowledgment	v-vi
Table of Contents	vii-xiii
List of Figures	xiv-xix
List of Tables	xxi-xxii
Abbreviations/Symbols	xxiii-xxvii
Abstract	xxix-xxxii
Chapter 1 Introduction	1
1.1 Fundamentals of Composite Materials	1
1.2 Classification of Composite Materials based on Matrix Phase	5
1.2.1 Polymer Matrix Composites (PMCs)	5
1.2.1.1 Thermoplastic Polymers	6
1.2.1.2 Thermoset Polymers	6
1.2.2 Metal Matrix Composites (MMCs)	7
1.2.3 Ceramic Matrix Composites (CMCs)	8
1.3 Classification of Composite Materials based on Reinforcement Phase	8
1.3.1 Fiber-reinforced composites (FRC)	8
1.3.1.1 Continuous/long fiber composites	9
1.3.1.2 Discontinuous/short fiber composites	10
1.3.2 Particulate reinforced composites (PRC)	10
1.4 Synthetic Fiber-Reinforced Polymer Composites and Their Usage	11
1.5 Thesis organization	14

Chapter-2 Literature review 17

2.1 Synthetic fibers and Synthetic fiber-reinforced polymer composites 17

2.2 Importance of Nanoparticles and its interface in Polymer matrix composites. 21

2.2.1 Importance of Nanoparticles in Polymer matrix composites. 21

2.2.2 Importance of Interface in Polymer matrix composites. 26

2.3 Surface modification of fiber by chemical treatment and nanoparticle coating. 28

2.3.1 Surface modification of fiber by chemical treatment 28

2.3.2 Surface modification of fiber by nanoparticle coating. 31

2.3.2.1 Dip Coating Method: 31

2.3.2.2 Electrophoretic Deposition Method (EPD): 32

2.3.2.3 Spray Coating Method: 34

2.3.2.4 Chemical Grafting: 35

2.4 Fabrication method of fiber-reinforced polymer composites. 36

2.5 Physical and Mechanical properties of fiber-reinforced polymer composites. 41

2.6 Thermal and thermo-mechanical properties of fiber-reinforced polymer composites. 46

2.7 Tribological Properties of fiber-reinforced polymer composites 49

2.8 Analysis of the Frictional Properties of Fiber-reinforced Polymer Composites Using Machine Learning Techniques. 53

2.9 The Research gaps in existing literature based on the review of previous studies. 55

2.10 Objectives of the present work 56

Chapter- 3 Materials and Methodology 57

3.1 Matrix material 57

3.2 Fibers used in the present study 57

3.2.1 Aramid fiber 57

3.2.2 Carbon fiber 58

3.3 Nanoparticles used in the present study 59

3.3.1 Carbon nanotubes 59

3.3.2 Graphene oxide 59

3.4 Chemicals used in the present study 59

3.5 Functionalization of CNTs 60

3.6 Surface treatment of aramid fiber 61

3.6.1 Chemical treatment of aramid fiber 61

3.6.2 Coating of CNTs on aramid Fiber 61

3.7 Surface treatment of carbon fiber 62

3.7.1 Chemical treatment of Carbon fiber 62

3.7.2 Coating of CNTs, GO, and hybrid (CNTs/GO) on Carbon Fiber 62

3.8 Composite fabrication 63

3.8.1 Aramid fiber-reinforced epoxy composites 63

3.8.2 Carbon fiber-reinforced epoxy composites 64

3.9 Physical and thermal characterization of fibers and nanoparticles 65

3.9.1 Scanning electron microscopy (SEM) 65

3.9.2 Fourier transform infrared spectroscopy (FTIR) 65

3.9.3 Thermogravimetric analysis (TGA) 66

3.10 Physical, mechanical, thermal, and tribological tests of fiber-reinforced epoxy composites 67

3.10.1 Density calculation 67

3.10.2 Vickers Microhardness testing 67

3.10.3 Tensile testing 68

3.10.4 Flexural testing 68

3.10.5 Short beam shear test 69

3.10.6 Izod impact test 70

3.10.7 Thermal conductivity test 71

3.10.8 Tribological testing 71

3.10.8.1 Reciprocating wear test 71

3.10.8.2 Erosion wear test 72

3.11 Surface morphology tests 73

3.12 Taguchi experimental design 73

3.13 Machine Learning (ML) 75

Chapter- 4 Mechanical and tribological properties of CNTs coated aramid FREC 77

4.1. FTIR analysis 77

4.1.1. Infrared Spectroscopy of CNT 77

4.1.2. Infrared Spectroscopy of aramid Fiber 78

4.2. TGA analysis of aramid fiber and CNT-coated aramid fiber 79

4.3 Scanning electron microscopy (SEM) 81

4.4 Density calculation 83

4.5 Microhardness test 83

4.6 Tensile testing 85

4.7 Thermal conductivity 87

4.8 Tribological testing 89

4.8.1 Impact of CNT coating on the tribological properties of aramid fiber reinforced polymer composites 89

4.8.2. Impact of different parameters (frequency, normal load and temperature) on the friction properties of polymer composites 91

4.9 SEM analysis of worn surface 96

4.10 Summary 98

Chapter- 5 Mechanical and tribological properties of CNTs, GO, and (CNTs/GO) hybrid coated carbon FREC 101

5.1 FTIR analysis 101

5.1.1 Infrared Spectroscopy of CNT 101

5.1.2 Infrared Spectroscopy of Carbon Fiber 101

5.2 Thermogravimetric analysis of carbon fiber and Nanoparticles coated carbon fiber 102

5.3 Scanning electron microscopy (SEM) 104

5.4 Density calculation 105

5.5 Microhardness test 106

5.6 Tensile testing 107

5.7 Flexural testing 109

5.8 Short beam shear (SBS) test 111

5.9 Impact test 112

5.10 Thermal conductivity test 113

5.11 Tribological testing 114

5.11.1 Effect of GO, CNTs, and hybrid (GO/CNTs) coating on the tribological properties of CFRE composites. 114

5.11.2 Effect of load on friction coefficient of fiber-reinforced polymer composite. 117

5.11.3 Effect of sliding frequency on friction coefficient of fiber-reinforced polymer composite. 118

5.12 SEM analysis of worn surface 119

5.13 Summary 120

Chapter- 6 Erosive wear properties of CNTs, GO, and (CNTs/GO) hybrid coated carbon FREC using Taguchi orthogonal array 123

6.1 Erosion test 123

6.2 Experimented results of erosion wear test and Taguchi analysis 126

6.3 Analysis of variance (ANOVA) and the effects of factors 129

6.4 Impact of CNTs, GO, and hybrid (CNTs/GO) coating on the erosive wear properties of carbon fiber reinforced polymer composites. 131

6.5 SEM analysis of worn surfaces 132

6.6 Summary 137

Chapter- 7 Analysis of Frictional properties of CNTs coated aramid FREC using ML Techniques 139

7.1 Machine learning models 140

7.1.1 Artificial neural network (ANN) 141

7.1.2 Random Forest (RF) 143

7.1.3 Gradient boosting machine (GBM) 146

7.2 Collection of data 147

7.3 Data preprocessing 148

7.4 Parameter optimization 150

7.5 Model Performance Evaluation 150

7.6 Feature importance for predicting the Coefficient of friction 155

7.7 Summary 157

Chapter- 8 Conclusions 159

Future Scope 163

References 165

List of Publications 182