TABLE OF CONTENTS

STATUS OF THESIS i
APPROVAL PAGE ii
TITLE PAGE iii
DECLARATION iv
DEDICATION……...v
ACKNOWLEDGEMENT vi
ABSTRACT..... vii
ABSTRAK..... viii
LIST OF TABLES xiii
LIST OF FIGURES..... xiv
LIST OF ABBREVIATIONS……...xviii
NOMENCLATURES…….....xix

CHAPTER 1 - INTRODUCTION 1
1.1 Background 1
1.1.1 Historical Background of Neural Networks (NN) 2
1.1.2 NN Capabilities……..5
1.2 Defining a Limited Set of Stress Ratios..... 6
1.3 Problem Statement..... 7
1.4 Research Objectives...…….....7
1.5 Scope of Study.……8
1.6 Benefits……...9
1.7 Organization of Thesis.....9

CHAPTER 2 - LITERATURE REVIEW/THEORETICAL BACKGROUND 11
2.1 Fatigue Life Assessment of Composite Materials Using NN……...11
2.2 Composites.....15
2.2.1 Fiber and Matrix.....16
2.2.2 Laminated Composites.....18
2.2.2.1 Laminated Code.....19
2.2.2.2 Special Laminates 20

2.3 Fatigue of Composite Materials 21
2.3.1 Fatigue 21
2.3.2 Constant Amplitude Loading Fatigue 22
2.3.2.1 The S-N Diagram and Related Formulae.....24
2.3.2.2 Reliability Aspects of Fatigue Life Evaluation 27
2.3.3 Constant Life Diagrams (CLD) 28

CHAPTER 3 - MODELING USING NEURAL NETWORKS (NN).....32
3.1 NN Architecture 32
3.2 NN Modes of Training.....35
3.3 Problem Formulation of NN Learning 36
3.3.1 Generalization…….....37
3.4 Introduction to Multi-layer Perceptrons (MLP): Single-layer Perceptron.....38
3.4.1 Capability of Single-layer Perceptron.....41
3.4.2 Perceptron Learning Rule.....43
3.5 Multi-layer Perceptrons (MLP).....45
3.5.1 MLP Structure…….45
3.5.2 Activation Function.……46
3.5.3 Training Algorithm……..……49
3.5.3.1 Gradient Descent……49
3.5.3.2 Optimization Methods……51
3.5.3.3 Backpropagation…….....52
3.5.4 Bayesian Regularization..……55
3.5.5 The Levenberg – Marquardt Training Algorithm ……..57
3.5.6 Implementation……...58
3.5.6.1 Adaptation of Bayesian Framework within The Levenberg-Marquardt Algorithm…….58
3.5.6.2 Realization……61

CHAPTER 4 – MATERIALS AND METHODS.....62
4.1 NN Modeling Procedure.....62
4.2 Materials and Experimental Data 64
4.2.1 Material and Test Descriptions of Material I (E-glass/epoxy, [±45/04/±45/] lay-up).....64

4.2.2 Material and Test Descriptions of Material II (E-glass/polyester, [90/0/±45/0]s lay-up) 64
4.2.3 Material and Test Descriptions of Material III (AS4/PEEK, [0/+45/90/-45]2s lay-up) 65
4.2.4 Specimens Geometry.....66
4.3 NN Pre-processing…….....67
4.3.1 Forming The Training and Testing Data Sets……..67
4.3.2 Input Set and Data Normalization…….....68
4.3.3 Hidden Nodes Number……69

CHAPTER 5 - RESULTS AND DISCUSSION.....70
5.1 NN Fatigue Life Prediction.....70
5.1.1 Material I (E-glass/epoxy, [±45/04/±45/])……...72
5.1.2 Material II (E-glass/polyester, [90/0/±45/0]s)……..76
5.1.3 Material III (AS4/PEEK, [0/+45/90/-45]2s)……82
5.1.4 Evolution of Optimization, Regularization and NN Parameters during Iteration……....85
5.1.5 Sensitivity Analysis……..90
5.2 Assessing the Quality of the NN Prediction 91
5.3 The Effect of Fatigue Life Scatter on the NN Model Prediction……...…92

CHAPTER 6 - CONCLUSIONS AND RECOMMENDATIONS.....94
6.1 Conclusions……..94
6.2 Recommendations……95

REFERENCES.....96
APPENDIX A.....101