LIST OF FIGURES

Figure 1-1 A schematic drawing of (a) a biological neuron, and (b) a synapse..... 3

Figure 1-2 (a) McCulloch and Pitts' neuron model, and (b) unit step function..... 4

Figure 2-1 A schematic representation of CLD. 17

Figure 2-2 (a) Formation of a composite material from fibers and resin. (b) Types of composites.....20

Figure 2-3 (a) Lamina as basic building entity of laminate, in the form of unidirectional and braided. (b) A laminated composite.....22

Figure 2-4 The x, y, z laminate (global) coordinate system, the x1, x2, x3 ply (local) coordinate system and the ply angle θ 23

Figure 2-5 Stacking sequence description of $[45_3/0_4/90_2/60]$ lay-up 23

Figure 2-6 Typical constant amplitude cyclic loading waveform and its parameters.....27

Figure 2-7 Fatigue loadings at different load regimes or stress ratio-*R* conditions 27

Figure 2-8 Typical *S-N* curves.....29

Figure 2-9 Various *S-N* curve fits on semi-log plot to fatigue data taken from [40] 30

Figure 2-10 Scatterband in fatigue lives and fatigue strength.....31

Figure 2-11 Projection of *S-N* curves to form a CLD.....34

Figure 3-1 NN architectures (a) feed forward with one hidden layer (gray colored circles), and (b) recurrent network with hidden neurons.....35

Figure 3-2 Perceptron neuron with an *L*-element input vector and hardlimiter function. 39

Figure 3-3 The simplified schematic of a neuron model 40

Figure 3-4 A single-layer perceptron (a) its schematic (b) its simplified schematic.....41

Figure 3-5 Input vectors of (a) two classes (b) four classes, and (c) eight classes.43

Figure 3-6 A representation of boundary plane in a three-input space.....44

Figure 3-7 MLP with one hidden layer and multiple output.....46

Figure 3-8 MLP with one hidden layer and single output 47

Figure 3-9 Hyperbolic tangent activation function.....48

Figure 3-10 Logistic activation function 49
Figure 3-11 Bipolar sigmoid activation function 49
Figure 4-1 Flowchart of the NN modeling process 59
Figure 4-2 A schematic geometry drawing of test specimens of Materials I, II and III (a) top view, and (b) side view.....62
Figure 5-1 The NN training output for Material I with training set of R = 0.1 and -2 72
Figure 5-2 Fatigue life prediction by NN model for testing sets R = -0.5, -1, -2 and 10 using R = 0.1 and 0.5 as training set.....73
Figure 5-3 Fatigue life prediction by NN model for testing sets R = 0.1, -1, -2 and 10 using R = 0.5 and -0.5 as training set 73
Figure 5-4 Fatigue life prediction by NN model for testing sets R = 0.5, -0.5, -1 and 10 using R = 0.1 and -2 as training set 74
Figure 5-5 The *S-N* curves based on experimental data and as predicted by the NN model for R = 0.5.....75
Figure 5-6 The *S-N* curves based on experimental data and as predicted by the NN model for R = -0.5 75
Figure 5-7 The *S-N* curves based on experimental data and as predicted by the NN model for R = -1 76
Figure 5-8 The *S-N* curves based on experimental data and as predicted by the NN model for R = 10.....76
Figure 5-9 Fatigue life prediction by NN model for testing sets R = 0.7, 0.8, 0.9, -1, -2, 10 and -0.5 using R = 0.1 and 0.5 as training set 77
Figure 5-10 Fatigue life prediction by NN model for testing sets R = 0.5, 0.7, 0.8, 0.9, -2, 10 and -0.5 using R = 0.1 and -1 as training set 78
Figure 5-11 Fatigue life prediction by NN model for testing sets R = 0.5, 0.7, 0.8, 0.9, -1, -2 and -0.5 using R = 0.1 and 10 as training set 78
Figure 5-12 The *S-N* curves based on experimental data and as predicted by the NN model for R = 0.5.....80
Figure 5-13 The *S-N* curves based on experimental data and as predicted by the NN model for R = 0.7.....80
Figure 5-14 The *S-N* curves based on experimental data and as predicted by the NN model for R = 0.8.....81
Figure 5-15 The *S-N* curves based on experimental data and as predicted by

the NN model for R = 0.9.....81
Figure 5-16 The S-N curves based on experimental data and as predicted by the NN model for R = -1 81
Figure 5-17 The S-N curves based on experimental data and as predicted by the NN model for R = -2 82
Figure 5-18 The S-N curves based on experimental data and as predicted by the NN model for R = -0.5 82
Figure 5-19 Fatigue life prediction by NN model for testing sets R = 0.2, -0.3, -1 and 10 using R = 0.1 and -0.1 as training set. 83
Figure 5-20 The S-N curves based on Parametric Constant Life Method and as predicted by the NN model for R = 0.2 84
Figure 5-21 The S-N curves based on Parametric Constant Life Method and as predicted by the NN model for R = -0.3 84
Figure 5-22 The S-N curves based on Parametric Constant Life Method and as predicted by the NN model for R = -1 85
Figure 5-23 The S-N curves based on Parametric Constant Life Method and as predicted by the NN model for R = 10 85
Figure 5-24 The evolution of optimization parameter λ during the NN iteration for Material I 87
Figure 5-25 The evolution of regularization parameter α during the NN iteration for Material I 87
Figure 5-26 The evolution of regularization parameter β during the NN iteration for Material I 87
Figure 5-27 The effective number of parameters during the NN iteration for Material I.....88
Figure 5-28 The evolution of optimization parameter λ during the NN iteration for Material II 88
Figure 5-29 The evolution of regularization parameter α during the NN iteration for Material II 88
Figure 5-30 The evolution of regularization parameter β during the NN iteration for Material II 89
Figure 5-31 The effective number of parameters during the NN iteration for Material II 89
Figure 5-32 The evolution of optimization parameter λ during the NN iteration

for Material III.....89
Figure 5-33 The evolution of regularization parameter α during the NN iteration for Material III.....90
Figure 5-34 The evolution of regularization parameter β during the NN iteration for Material III.....90
Figure 5-35 The effective number of parameters during the NN iteration for Material III.....90
Figure 5-36 The sensitivity of the number of hidden nodes on the MSE values.....91