CONTENTS

Abstract i-ii

List of Figures vi-viii

List of Tables ix-x

Abbreviations xi

List of Symbols xii-xiii

Chapter 1 Introduction 1

1.1 Condition Monitoring and Fault Diagnosis of Gearbox 1

1.1.1 Importance of gearbox 1

1.1.2 Condition Monitoring and Fault Diagnosis 1

1.1.3 Condition Based Maintenance 3

1.1.4 Gear Faults 5

1.1.5 Vibration Transmission from Gear Faults 6

1.1.6 Importance of Vibration Signal and Analysis 8

1.2 Signal Processing Techniques 10

1.2.1 Time Domain 10

1.2.2 Frequency Domain 11

1.2.3 Cepstrum 13

1.2.4 Time – Frequency Domain 14

1.2.5 Time – Synchronous Averaging 15

1.2.6 Demodulation 16

1.3 Specimen Vibration Signatures of a Gear 17

1.4 Introduction to Artificial Neural Networks 19

1.5 Fault Diagnosis of Gearboxes – A Case Study 21
Chapter 2 Literature Review

2.1 Introduction 23
2.2 Experimental Laboratory Tests by Inducing Faults 24
2.3 Fault Modeling and Analysis 29
2.4 Automated Detection with ANN 37
2.5 Motivation for the Present Research Work 45

Chapter 3 Experimentation and Data Acquisition 48

3.1 Gearbox 49
3.2 Induced Gear Defects 51
3.3 Accelerometer 53
3.4 Fast Fourier Transform (FFT) Analyzer 55
3.5 Mounting of Sensing and Measuring Equipment 56
3.6 Methodology 58
3.7 Analysis of Vibration Amplitudes 70

Chapter 4 Extraction of Statistical Features 72

4.1 Statistical Features 72
4.2 Feature Extraction 74
4.3 Model Calculation for Extraction of Features 105
4.4 Analysis of Extracted Vibration Features 106

Chapter 5 ANN Based Fault Diagnosis System 114

5.1 A Single Neuron 115
5.2 Activation Functions or Transfer Functions 116
5.3 Single and Multi Layer Networks 118
5.4 Supervised Learning 120
5.5 Learning Rate 121
5.6 Hidden Layers and Hidden Layer Neurons          122
5.7 Neural Network Training                             123
5.8 Back Propagation Algorithm for ANN                    124
5.9 Designing ANN system for Fault Diagnosis           125

Chapter 6 Results and Discussion                      130
  6.1 Training and Testing of Fault Classification-
      System (5I-2O)                                           130
  6.2 Training and Testing of Fault Detection-
      System (5I-5O)                                          138

Chapter 7 Conclusions and Scope for Future Work         154
  7.1 Conclusions                                          154
  7.2 Scope for Future Work                                155

References                                              157

List of Publications Based on This Thesis               165

Conference Papers Based on This Thesis                  166