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Vibration-Based Structural Health Monitoring

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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ABSTRACT

Ageing and degradation of the infrastructures, especially critical infrastructures (such as power plants, high-rise buildings, long-span bridges, dams, airports, railway tracks, etc.) impose a major concern that affects national assets of each country and endangers public safety. On this point, structural health monitoring (SHM) potentially provides solution to the problem by evaluating the integrity of the infrastructures to determine their current health state. Basically, structural health monitoring deals with early warning on the state of health of infrastructures, localisation and quantification of damage in the structures and prediction of their remaining service life. This, consequently reduces asset management costs, effectively prolongs operational lifetime and ensures public safety. Hence, getting access to a robust paradigm to deal with aforementioned concerns is a major challenge introduced here. Despite high level of research activities in this field, few robust methods of indicating an adverse condition of a structure in service has been demonstrated as effective, which is the motivation for this research work.

The main objective of this study is to investigate a more robust scheme of damage identification, including damage detection and damage localisation, to overcome some of the shortcomings with the current methods. In this regard, firstly, a background on the existing methods is presented in Chapter 1 to evaluate the advantages and limitations with the current methods. According to the literature, frequency response-based damage identification methods are superior to conventional modal-based approaches as they are less error prone and provide abundance of information in a wide range of frequencies; hence, this study starts with developing a more robust frequency response function (FRF) – based damage identification method in Chapter 2 to detect and localise structural damage in single or multiple states. The novelty of the approach is implementation of two-dimensional discrete wavelet transform (2-D DWT) along with the second derivative of the reconstructed operational mode shapes obtained by FRFs to enhance the sensitivity of the approach to damage. Based on the numerical results of this stage, it can be concluded that the method's performance is quite acceptable once the level of undesirable noise is negligible; however, by increasing the level of uncertainty in the system, the performance of the method deteriorates. Therefore, to overcome this problem, the harmful effects of

measurement noise on FRFs are investigated in Chapter 3 and its undesirable effect is suppressed by employing a novel idea using Gaussian Kernel on FRFs. The numerical and experimental damage identification results obtained by the presented noise-suppression approach demonstrate its efficiency to cope with the issue of noise. At this stage, and although, the method is performing well, in terms of its sensitivity to damage as well as its robustness against noise, it still needs to be modified; in real-life applications the source of excitation is random and this important issue has not been taken into account in the methodology described in Chapter 3. Hence, in Chapter 4, the issue of stochastic systems is investigated and a novel spectral-based approach is presented to deal with the issue of random excitation in damage identification process. In this regard, the frequency distribution of the power spectral density of the time responses is analysed by introducing the spectral moments which represent some major statistical properties of a stochastic process. The efficiency of the approach is validated by several numerical case studies.

The method presented in Chapter 2 to Chapter 4 is a frequency-based approach and, therefore, raw time measured responses are first required for transfer from time domain into the frequency domain before further analysis. In some applications, it might be advantageous to deal with directly measured time responses without transferring them into the frequency domain. In this regard, in Chapter 5, a novel time series-based damage identification method is presented based on the idea of symbolic time series analysis. The main idea of the method is to generate the symbol sequences by mapping the time data from the state space into the constructed symbol space and then study any change in the statistical properties of the obtained symbol sequences by developing the probability vectors. This method is very easy to implement, is robust against noise and it has shown a considerable sensitivity to slight structural damage. The efficiency of the method is successfully demonstrated by several numerical and experimental investigations.

The scope of Chapter 1 to Chapter 5 of this thesis is mainly on structural damage identification; however, it might be of great interest to obtain a reliable and representative model of the structure considering the effects of structural damage. This is of considerable demand, as in many applications, it is required to estimate the serviceability and remaining life of a structure after damage occurrence. Because of this, the author explores the issue of finite element model updating in Chapter 6 to investigate how a reliable model of the structure can be obtained. A particular damage case is investigated and the idea of thin layer interface elements is introduced and implemented. It is demonstrated, that by updating the finite element model of the structure, using this technique, the reliability of the model significantly improves.

According to this journey from Chapter 1 to Chapter 6, more robust schemes of damage identification are developed and verified both in time and frequency domains; and, some future works are suggested by the author in Chapter 7 to conclude the work and motivate other researchers to pursue the work further.

LIST OF PUBLICATIONS BASED ON THIS RESEARCH

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TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION 18
1.1 BACKGROUND 18
1.2 LITERATURE REVIEW 22
1.2.1 NATURAL FREQUENCY 22
1.2.2 DAMPING 25
1.2.3 MODE SHAPES 26
1.2.4 FREQUENCY-RESPONSE FUNCTION 37
1.2.5 TIME SERIES DATA 47
1.3 CONCLUSIONS 54
CHAPTER 2: A NOVEL DAMAGE IDENTIFICATION METHOD USING FRFS 57
2.1 ABSTRACT 57
2.2 INTRODUCTION 58
2.3 METHODOLOGY 60
2.4 WAVELET ANALYSIS 64
2.4.1 INTRODUCTION 64
2.4.2 THE CONCEPT OF WAVELET TRANSFORM 65
2.4.1 DISCRETE WAVELET TRANSFORM 73
2.4.2 TWO-DIMENSIONAL WAVELET TRANSFORM 75
2.4.3 THE ISSUE OF BORDER DISTORTION 76
2.5 NUMERICAL INVESTIGATION OF DAMAGE DETECTION USING 2-D DWT 78
2.5.1 DAMAGE LOCALISATION RESULTS WITHOUT EXTENDING THE SHAPE SIGNALS IN NOISE FREE SITUATION 81
2.5.2 DEMONSTRATION WITH NOISE POLLUTED RESPONSES 82
2.5.3 DISCUSSION ON THE INFLUENCE OF SENSOR SPACING 85
2.6 CONCLUSION 87

■ CHAPTER 3: FRF-BASED DAMAGE LOCALISATION METHOD WITH NOISE SUPPRESSION APPROACH 88

3.1 ABSTRACT 88

3.2 INTRODUCTION 89

3.3 DAMAGE LOCALISATION METHOD WITH NOISE SUPPRESSION APPROACH 91

3.4 NUMERICAL INVESTIGATION OF DAMAGE LOCALISATION METHOD 95

3.4.1 GAUSSIAN NOISE 100

3.4.2 NON-GAUSSIAN NOISE WITH EXPONENTIAL DISTRIBUTION 102

3.4.3 NON-GAUSSIAN NOISE WITH LOG-NORMAL DISTRIBUTION 103

3.4.4 COLOURED NOISE 105

3.4.5 GAPPED-SMOOTHING METHOD 106

3.5 EXPERIMENTAL INVESTIGATION 107

3.6 EXPERIMENTAL RESULTS & DISCUSSION 109

3.7 SUMMARY AND DISCUSSION 113

■ CHAPTER 4: SPECTRAL-BASED DAMAGE LOCALISATION IN STRUCTURES UNDER AMBIENT VIBRATION 115

4.1 ABSTRACT 115

4.2 INTRODUCTION 116

4.3 PRELIMINARY CONCEPTS AND DEFINITIONS 118

4.4 PROPOSED DAMAGE DIAGNOSTIC SCHEME 121

4.4.1 SENSITIVITY ANALYSIS 124

4.5 NUMERICAL DEMONSTRATION 126

4.5.1 DESCRIPTION 126

4.5.2 NOISE-FREE DAMAGE SCENARIOS 132

4.5.3 NOISY DAMAGE SCENARIOS 133

4.5.4 RESULTS WITHOUT EXTENDING THE SHAPE SIGNALS 133

4.5.5 DISCUSSION ON THE INFLUENCE OF SENSOR SPACING 136

4.5.6 Conclusion 136

Chapter 5: Damage Localisation Based on Symbolic Time Series Analysis 138

5.1 Abstract 138

5.2 Introduction 139

5.3 A background on Symbolic Time Series Analysis (STSA) 141

5.4 Damage Localisation Based on Symbolic Time Series Approach 149

5.4.1 Reconstructing the time series data by employing discrete wavelet transform (DWT) 151

5.4.2 Partitioning the state space based on maximum entropy 153

5.4.3 Selection of alphabet size 156

5.4.4 Developing pattern vectors for damage localisation 157

5.5 Application 158

5.5.1 Demonstration (1): A time-variant multi-degree of freedom mechanical system 159

5.5.2 Demonstration (2): A Flexural Beam 163

5.5.3 Demonstration (3) : A 2-D Truss Structure 173

5.5.4 Demonstration (4) : A 3-D Truss structure 176

5.5.5 Experimental validation of the method 185

5.6 Conclusions 192

Chapter 6: Nonlinear Joint Model Updating in Assembled Structures 193

6.1 ABSTRACT 193

6.2 Introduction 193

6.3 Joint Interface Modelling 196

6.4 Experimental investigation 199

6.5 Finite element modelling 203

6.6 Application of Component Mode Synthesis (CMS) 205

6.7 Identification of joint Uncertain Parameters 208

6.8 CONCLUSION 214
CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS 216
REFERENCES 219

LIST OF FIGURES

Figure 2-1. Measured shape signals for a typical structure. 60
Figure 2-2. Sudden change in the spatial signal at damage location. 62
Figure 2-3. A 3-D representation of FRFs at all measured frequencies and locations. 62
Figure 2-4. Damage localisation results for a two-fixed-end beam with high level damage in the mid-span (a) Initial surface, z, the visualisation of damage line is possible only for limited frequency range (b) Normalised surface, z^*, the visualisation of damage line is possible for the whole frequency range. 64
Figure 2-5. (a) A stationary signal in time domain (b) Frequency spectrum of a stationary signal (d) A non-stationary signal in time domain (d) Frequency spectrum of a non-stationary signal. 67
Figure 2-6 (a) A non-stationary signal in time domain (b) Frequency spectrum of a non-stationary signal (c) STFT analysis of the signal by a narrow window (d) STFT analysis of the signal by a wide window. 69
Figure 2-7 The effect of translation and dilation on mother wavelet. 71
Figure 2-8. (a) A non-stationary signal in time domain, (b) CWT of a non-stationary signal. 72
Figure 2-9. (a) A non-stationary signal in time domain with translated Morlet with different translation values, (b) the Morlet wavelet coefficients. 73
Figure 2-10. Wavelet decomposition, *h* = low-pass decomposition filter, *g* = high-pass decomposition filter. 75
Figure 2-11. Extending the damage sensitive shape signal at arbitrary frequency coordinate. 77
Figure 2-12. Finite element model for a two-fixed –end beam, (a) Single State Low Level Damage (SLLD), (b) Single State High Level Damage (SHLD), (c) Multiple State Low Level Damage (MLLD), (d) Multiple State High Level Damage (MHLD). 79
Figure 2-13. Comparison between the beam in healthy state and damaged condition SLLD, (a) FRF based on receptance measurement, (b) First five natural frequencies. 80
Figure 2-14. Horizontal detail wavelet coefficients for four damage conditions, noise free situation without extending the shape signals (a) SLLD, (b) SHLD, (c) MLLD, (d) MHLD. 82
Figure 2-15. FRF in presence of WGN, solid line shows the healthy state and dashed line correspond to SHLD damage case, (a) 2% noise, (b) 5% noise. 84
Figure 2-16. Horizontal detail wavelet coefficients for four damage conditions, 2% noise, with extending the shape signals(a) SLLD, (b) SHLD, (c) MLLD, (d) MHLD. 85
Figure 2-17. Horizontal detail wavelet coefficients for four damage conditions, 5% noise, with extending the shape signals (a) SLLD, (b) SHLD, (c) MLLD, (d) MHLD. 85
Figure 2-18. Horizontal detail wavelet coefficients for four SHLD condition, 5% noise, with extending the shape signals, (a) 40 sensors, (b) 20 sensors. 86
Figure 3-1. 10% noise with different distributions in time domain (a) Normal distribution with $\mu = 0$ and $\sigma = 1$, (b) Exponential distribution with $\mu = 1$, (c) Log-normal distribution with $\mu = 0$ and $\sigma = 1$. 97
Figure 3-2. The effect of 10% noise in frequency domain, (a) Gaussian noise, (b) Colour noise. 98

Figure 3-3. The effect of noise suppression on simulated FRF at a typical DOF, 10% noise with exponential distribution in MHLD damage condition. 99
Figure 3-4. 10% Gaussian noise in (1) SLLD damage condition, (2) SHLD damage condition. (a) no noise removal, (b) noise is removed by moving average technique (c) noise is removed by Gaussian kernel.........101
Figure 3-5. 10% Gaussian noise in (1) MLLD damage condition, (2) MHLD damage condition. (a) no noise removal, (b) noise is removed by moving average technique (c) noise is removed by Gaussian kernel.........102
Figure 3-6. 10% non-Gaussian noise with exponential distribution in (1) MLLD damage condition, (2) MHLD damage condition. (a) no noise removal, (b) noise is removed by moving average technique (c) noise is removed by Gaussian kernel....................103
Figure 3-7. 10% non-Gaussian noise with Log-normal distribution in (1) MLLD damage condition, (2) MHLD damage condition. (a) no noise removal, (b) noise is removed by moving average technique (c) noise is removed by Gaussian kernel....................104
Figure 3-8. 10% colour noise, (1) noise is removed by Gaussian kernel, (2) no noise removal. (a) SLLD damage condition, (b) SHLD damage condition (c) MLLD damage condition, (d) MHLD damage condition. 106
Figure 3-9. Damage localisation results for MHLD damage condition obtained by GSM, (a) 5% Gaussian noise, (b) 10% Gaussian noise. 106
Figure 3-10. Experimental set up, illustration of the clamped-clamped beam. 107
Figure 3-11. (a) Measurements are taken at 12 evenly spaced grid points, (b) Inflicted damage in the beam using jig saw, *d/h=0.25*. 108
Figure 3-12. 4 sets of measurements, (a) arrangement (A), (b) arrangement (B), (c) arrangement (C), arrangement (D). 109
Figure 3-13. Comparison between measured FRFs in undamaged and damaged beam....................110
Figure 3-14. Damage localisation results using 12 accelerometers arrangement (A), (a) SSD condition using 394 spectral lines, (b) MSD condition using 401 spectral lines. 111
Figure 3-15. Damage localisation results using 45 accelerometers using noise suppression approach, (a) SSD condition, (b) MSD condition. 112
Figure 3-16. Damage localisation results using 45 accelerometers without any noise suppression approach, (a) SSD condition, (b) MSD condition. 113
Figure 4-1. White Gaussian source, (a) realisation of random process, (b) spectral moment of different orders. 121
Figure 4-2. Schematic diagram of the case studies, (a) fixed-free beam (C-F), (b) two-fixed-end beam (C-C). 128
Figure 4-3. Band limited Gaussian excitation and sampled displacement of the free end of the C-F beam.129
Figure 4-4. PSD of the response at ¼ beam span in the C-F beam, black line corresponds to the healthy state and grey line is related to the damaged state, (a) Damage case D1, (b) Damage case D2. 131

Figure 4-5. PSD of the response at ¼ beam span in the C-C beam, black line corresponds to the healthy state and grey line is related to the damaged state, (a) Damage case D3, (b) Damage case D4. 131
Figure 4-6. Damage localisation results for the C-F beam in noise-free condition (a) Damage case D1, (b) Damage case D2...134
Figure 4-7. Damage localisation results for the C-C beam in noise-free condition (a) Damage case D3, (b) Damage case D4...134
Figure 4-8. Damage localisation results for the C-F beam in noisy condition (2% white Gaussian noise), (a) Damage case D1, (b) Damage case D2. 135
Figure 4-9. Damage localisation results for the C-C beam in noisy condition (2% white Gaussian noise), (a) Damage case D3, (b) Damage case D4. 135
Figure 4-10. Damage localisation results for the C-F beam in noise free condition without extending the shape signals, (a) Damage case D1, (b) Damage case D2. 135
Figure 4-11. Damage localisation results for the C-F beam in noisy condition (2% white Gaussian noise) by using 25 sensors, (a) Damage case D1, (b) Damage case D2..136
Figure 5-1. Illustration of mapping from state space to symbol space. 144
Figure 5-2 Symbolic representation of a time series in a generating binary partitions; the obtained symbol sequence is, [01000000110100000111]. 144
Figure 5-3. Comparing the effect of threshold value on the symbol sequence, the symbol sequence is [01000000110100000111] while the threshold value is β and the symbol sequence is [01010000110110100111] while the threshold value is β_{Opt} 148
Figure 5-4. The impact of partitions' number on the (a) entropy and (b) the entropy excess 149
Figure 5-5. Space partitioning based on, (a) uniform entropy, (b) maximum entropy. 155
Figure 5-6. A simple 10-degree-of-freedom system subjected to random excitation at free end. 159
Figure 5-7. Stiffness deterioration in the system. 160
Figure 5-8. Random excitation with normal distribution. 160
Figure 5-9. Anomaly measure versus location and stage. 163
Figure 5-10. Anomaly measure versus location. 163
Figure 5-11. Illustration of the flexural beam with different boundary conditions, (a) fixed-free beam (C-F), (b) two-fixed-end beam (C-C)...164
Figure 5-12. Deterioration history, (a) Elastic Modulus of the damaged element, (b) The change in the Elastic Modulus compared to the nominal state (%). 165
Figure 5-13. Gaussian excitation. 165
Figure 5-14. The impact of deterioration in element 20 on anomaly measure at sensor located between elements 1 and 2. 167

Figure 5-15. Damage localisation results for the C-F beam, (a) single state damage in element 3, (b) single state damage in element 11, (c) single state damage in element 18, (d) multiple state damage in elements 3 and 11 (e) multiple state damage in elements 3 and 18, (f) multiple state damage in elements 11 and 18. 168
Figure 5-16. Damage localisation results for the C-C beam, (a) single state damage in element 11, (b) single state damage in element 17, (c) multiple state damage in elements 11 and 17, (e) multiple state damage in elements 3 and 17. 169
Figure 5-17. The impact of deterioration on the first natural frequency in the C-F beam. 169
Figure 5-18. Damage localisation results for the C-F beam using 10 sensors, (a) single state damage in element 3, (b) single state damage in element 11, (c) single state damage in element 18, (d) multiple state damage in elements 3 and 11 (e) multiple state damage in elements 3 and 18, (f) multiple state damage in elements 11 and 18. 172
Figure 5-19. A 2-D planar truss bridge. 173
Figure 5-20. Damage localisation results for single state damage at different locations, (a) damage in element 24, (b) damage in element 7, (c) damage in element 8, (d) damage in element 11, (e) damage in element 16, (f) damage in element 22. 176
Figure 5-21. Damage localisation results for multiple state damage at different locations, (a) damage in elements 7 and 8 (b) damage in elements 11 and 16, (c) damage in elements 13 and 19, (d) damage in elements 14 and 22. 176
Figure 5-22. Depiction of a three-bay space truss with 16 nodal points and 44 elements. 177
Figure 5-23. Random excitation applied at all nodal coordinates. 178
Figure 5-24. Deterioration history in the damaged members. 179
Figure 5-25. The history of anomaly measure, number of partitions=500, (a) element 2, (b) element 8, (c) element 27, (d) element 41. 182
Figure 5-26. Single state damage identification results in presence of 2% White Gaussian Noise, number of partitions=500 (a) damage in element 6, (b) damage in element 10, (c) damage in element 25, (d) damage in element 31, (e) damage in element 32, (f) damage in element 40. 184
Figure 5-27. Multiple state damage identification results in presence of 2% White Gaussian Noise, number of partitions=500 (a) damage in elements 29 and 36, (b) damage in elements 10 and 40, (c) damage in elements 12 and 22, (d) damage in elements 25 and 31, (e) damage in elements 4 and 44, (f) damage in elements 9 and 24. 184
Figure 5-28. Damage identification results in presence of 2% White Gaussian Noise, number of partitions=5 (a) damage in element 10, (b) damage in element 25, (c) damage in element 31, (d) damage in elements 10 and 40, (e) damage in elements 4 and 44, (f) damage in elements 9 and 24. 185
Figure 5-29. Experimental set up, (a) illustration of the component of the Sydney Harbor Bridge, (b) clamping of the specimen, (c) test specimen with indicated shaker location, (d) cross-sectional geometry of the structure with accelerometer locations. 187

Figure 5-30. Progressive damage in the concrete, (a) Damage case 1, (b) Damage case 2, (c) Damage case 3 and (d) Damage case 4. 187
Figure 5-31. Time history of the excitation and the response at sensor location A1. 188
Figure 5-32. FRFs of the structure at sensor location A1 for different damage conditions. 189
Figure 5-33. The history of anomaly measure for different sensor locations obtained by 200 partitions (a) A2, (b) A6, (c) A8 and (d) A10. 190
Figure 5-34. Damage localisation results using (a) 10 partitions, (b) 50 partitions, (c) 200 partitions. 192
Figure 6-1. Force–deformation hysteresis loops, (a) single Jenkins model, (b) bilinear elastic-plastic model, (c) nonlinear elastic-plastic model. 196
Figure 6-2. Nonlinear stress- strain constitutive law. 199
Figure 6-3. Experimental set up, (a) schematic of the assembled structure in clamped-free condition, (b) excitation of the structure at free end, (c) the interface between two pipes and location of two accelerometers. 200
Figure 6-4. The details of the test set up. 201
Figure 6-5. Measured linear FRF at sensor location A_1. 201
Figure 6-6. Time history of the input excitation and output response, (a) single harmonic excitation at selected frequencies close to the first mode, (b) time history response of the structure at sensor location A_1. 203
Figure 6-7. Comparison between measured linear and nonlinear FRFs, (a) first bending mode, (b) second bending mode. 203
Figure 6-8. Finite element model, (a) joint interface using solid elements, (b) pipes using shell elements. 205
Figure 6-9. Free-free vibration test on pipe with length 1080 mm. 205
Figure 6-10. The convergence history of design parameter. 209
Figure 6-11. Measured and updated linear FRFs around the (a) first mode, (b) second mode. 210
Figure 6-12. The flowchart of the identification procedure using DOT. 212
Figure 6-13. Convergence history of design parameters and objective. 213
Figure 6-14. Comparison between FRFs obtained by FEM and experiment, (a) first mode, (b) second mode. 214

LIST OF TABLES

Table 2-1 Fundamental frequency of the beam in undamaged and damaged conditions 79
Table 3-1. The first three natural frequencies of the undamaged and damaged beam 110
Table 4-1.Variation in the first four natural frequencies due to damage occurrence 128
Table 5-1. Introduced damage cases for the flexural beam 168
Table 5-2. Introduced damage cases for the truss structure..174
Table 5-3. The connecting nodes of the truss members 177
Table 5-4. Assumed damage scenarios considering gradual deterioration in single or multiple states 179
Table 5-5. Description of the tested cases 186
Table 5-6.The change in the first three modes in different damage conditions...189
Table 6-1. First four measured natural frequencies (Hz) of the longer pipe in separated freely-supported condition...206
Table 6-2. Comparison of the responses between the condensed system and the original one 208
Table 6-3. Comparison between the measured and predicted natural frequencies before and after updating (Hz) 209
Table 6-4. Identification of parameters associated with nonlinear portion of the constitutive law 213