PREFACE

Structural Health Monitoring (SHM) refers to the process of implementing nondestructive autonomous in situ damage detection in engineering structures to evaluate the condition of existing structures to ensure the safety of users. Among the well-established methodologies, the elastic guided Lamb wave-based SHM has gained a significant attention in the past few years because of the following properties: it is capable to inspect a large area of the structure in a short time, it is sensitive to small damage and discontinuities, it is able to identify both surface and internal damages, it consumes less energy, there is no need of transducers movement, it is quick and repeatable, and it is cost-effective. While the advances in Lamb wave technologies have established the feasibility of guided Lamb wave based SHM, there remain several challenges for applications such as adaptive mesh generation, error estimation, denoising and signal analysis, etc.

Numerical simulation of wave propagation is essential to understand the physical phenomenon of the wide variety of problems. Therefore, scientists and engineers have used numerical methods, such as, FDM, FEM, and BEM, etc. The computational accuracy and stability demand large set of grid points. Due to this limitation of the conventional methods for solving wave equations, the wavelet-based numerical method is proposed in the thesis. This hybrid numerical technique is able to combine the superiority of wavelet with conventional numerical methods. The proposed method is more efficient, accurate and stable than the conventional numerical methods. The purpose of this thesis is to provide an improved framework for simulation of linear and nonlinear elastic wave propagation and damage identification techniques feasible in the context of structural health monitoring. A wavelet-based adaptive multi-scale technique efficiently compresses the resultant large stiffness matrix from finite element (FE) discretization. To further reduce computational cost, non-standard wavelet operator is employed. The proposed masking eliminates the requirement of a very large number of nodes necessary for the simulation of wave propagation. The simulation of multiple harmonics requires a very high mesh density. Therefore, the method is also useful in the situations where higher harmonics are ignored due to very high computational cost. In this work, the results of wavelet-based dynamic adaptive grid selection technique are compared with the standard finite element method. Wave propagation in the healthy and damaged plate structures discussed in the thesis is very relevant for practical applications.

The adaptive numerical scheme and error estimation increase the usefulness and reliability of computations. The error estimation in computation provides the choice of error tolerance, confidence in the computed solution, and freedom from the tedious task of generating a very dense mesh. This thesis presents a method to estimate local as well as global errors by using wavelet-based error estimation technique which is motivated by hierarchical error estimation scheme. The functionals of wavelets coefficient are used as an *a posteriori* error indicator. The proposed method is an efficient technique which can be applied in some small region as well as the complete domain.

The presence of random noise, as well as narrowband coherent noise, makes the structural health monitoring a really challenging issue. To develop efficient structural health assessment methodology, a very good extraction of noise and analysis of the signals are essential. Filtration of time-frequency information of multimode Lamb waves from the noisy signal is investigated in this study using matched filtering technique (MFT) and wavelet denoising methods. Initially, we introduce the guided wave based MFT for handling noisy signal with the low signal to noise ratio (SNR) and subsequently develop the wavelet matched filter method (WMFM) which couples advantages of both the wavelet transform and matched filter method in order to enhance the utility of the filtration technique. The proposed WMFM technique significantly improves the accuracy of the

filtered signal and identifies relatively small damage in enormously noisy data. Correlation coefficient and RMSE are computed for both the discrete wavelet transform (DWT) as well as the continuous wavelet transform (CWT) for performance evaluation of the filters for various SNR. To establish the effectiveness, the proposed filtering method is tested for complex structures.

Keywords: Structural health monitoring, guided Lamb wave, finite element method, wavelet transform, wavelet finite element method, multi-scale simulation, *a posteriori* error estimator, multiresolution analysis, noise filtering techniques, Shannon's entropy.