ABSTRACT

There has been more than a century of history in modern civil engineering structures. These structures have undergone many effects in these times, altering their safety and health to an uncertain state that might be disastrous on some occasions. In this regard, Structural Health Monitoring (SHM) has emerged as an excellent choice for updating our information about these structures. However, the reference data from the construction time are mostly unavailable. This limits the use of data-based monitoring/detection of structural defects. Alternatively, model-based techniques such as model updating can be considered for applications of SHM and damage detection. Relying on model updating involves many uncertainties since modelling, in addition to collected data, encounters uncertainties. Bayesian model updating offers a solid approach to handling these uncertainties and provides plausibility measures for the best model amid a class of probable models representing the best fit to real data.

After twenty years of developing Bayesian model updating methods of civil and mechanical dynamical systems. Most methods solely use statistics such as Most Probable Values (MPVs) of modal parameters. This contradicts the nature of the Bayesian approach, which is strongly affected by higher moments information. In this thesis, modal data includes the MPVs and the variance/covariance matrix of modal parameters. Furthermore, in most cases in the literature, normal modes of vibration are used, and the damping parameters have been neglected. Damping existence usually alters the normal modal data to a complex form if distributed non-proportionally in the structure.

This study uses complex modal data, and a methodology is presented for Bayesian model updating using complex modal data without mode-matching or solution of the eigenvalue problem.

The procedure is based on model reduction, where the full system model is downsized to a smaller model corresponding to the measured Degrees of Freedom (DOFs). Establishing the model reduction-based method saves a lot of computational requirements. That is very important since the Bayesian approach is known to be computationally expensive.

The Bayesian approach faces the problem of finding the analytical solution for updating parameters. Usually, Markov Chain Monte Carlo (MCMC) algorithms are used to approximate the updating parameters' posterior Probability Density Function (PDF). This thesis presents a comprehensive MCMC solution, where a unique sampler called Metropolis-Within-Gibbs (MWG) is formulated to handle the high number of uncertain parameters. On top of that, an alternative method based on integrating system mode shapes is presented to account for the problems of locally identifiable cases.

One of the objectives of this work is to provide a comprehensive approach to be implemented with limited experimental tools for real experiments. A methodology that uses modal data from multiple setups is developed. The methodology requires the collection of partial mode shapes from multiple setups and does not need to form the global mode shape or scale the mode shape from a single setup.

Extensive validation of the proposed methods is done with various numerical problems with different numbers of DOFs and complexity. Also, different types of uncertainty in stiffness, mass, and damping characteristics are considered in these numerical examples. Furthermore, the approach is validated using two experimental models: a 3-DOF shear model and a laboratory model of the pedestrian bridge deck slab.