# Damage Identification of Large Scale Linear and Nonlinear Structural Systems using Finite Element Model Updating Techniques and Vibration Measurements

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## ABSTRACT

Vibration measurements have been increasingly used to detect changes in a mechanical system's behavior and to determine damage accumulation. The continuous tracking and processing of the vibration-induced response data for damage detection in structural systems, is known as structural health monitoring (SHM). SHM comprises on one-hand methods relying on raw signal processing, such as mean, spectral densities, root-mean-square evaluation; these present shortcomings in terms of early damage detection and are further not suited for damage localization and root cause analysis. On the other hand, model-based methods for structural health monitoring incorporate an analytical or numerical model of the mechanical or structural system, typically of the Finite Element (FE) type, that can integrate and reproduce ultimate limit states and failure modes. Use of a finite element model in combination with operational vibration measurements and state of the art FE model updating techniques, allows for prediction of the existence, location, time and extent of the damage [1]. This method provides much more comprehensive information about the condition of the monitored system than the analysis of raw data. In most cases, the indication of detected damage and its location is sufficient for further investigation and visual or non-destructive inspection.

Finite element model updating has nowadays become an integrated part of the structural modelling and simulation process. The underlying procedure aims at establishing a testing campaign, during which a number of structural vibration modes are identified and used as a set of target indicators, to which the FE model is fitted by adjusting a number of critical parameters, such as material properties, boundary conditions etc. Yet, the assessment of the testing procedure usually implements a non-parametric identification method, which suffers from well-known inconsistencies related to the uncertainty of the involved spectral-estimates, and it is not until quite recently, that more sophisticated, model-based identification methods are integrated into the process. However, their potentials and merits are thus far not clearly understood.

This study considers the above problem through an actual case study of a geometrically complex suspension system of a semi-trailer vehicle (Figures 1 and 2). More specifically, a computational framework is proposed for dynamic analysis and fatigue damage identification of large scale linear and nonlinear structural systems by integrating a reverse engineering strategy and applying a fatigue damage accumulation methodology. First, using an integrated reverse engineering strategy a discrete

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FE model of the suspension is developed. Focusing on the updating methodology, coupled with robust, accurate and efficient finite element analysis software, the linear and non-linear components of a whole structure assembly were updated in order to develop a high-fidelity FE model. This is achieved through combining modal residuals, that include the lowest identified modal frequencies and mode shapes, with response residuals, that include shape and amplitude correlation coefficients considering measured and analytical frequency response functions and time-histories of accelerations. Single objective structural identification strategies without the need of sub-structuring methods, are used for estimating the parameters (material properties) of the finite element model, based on minimizing the deviations between the experimental and analytical dynamic characteristics [2]. The effect of model error, finite element model parameterization, number of measured modes and number of mode shape components on the optimal models along with and their variability, are examined. In order to assess the fatigue damage and remaining lifetime, the full stress time histories of the suspension system were estimated, at critical locations, by imposing simulated ISO road profiles in the updated FE model. Fatigue is subsequently estimated using the Palmgren-Miner damage rule, S-N curves, and rainflow cycle counting.

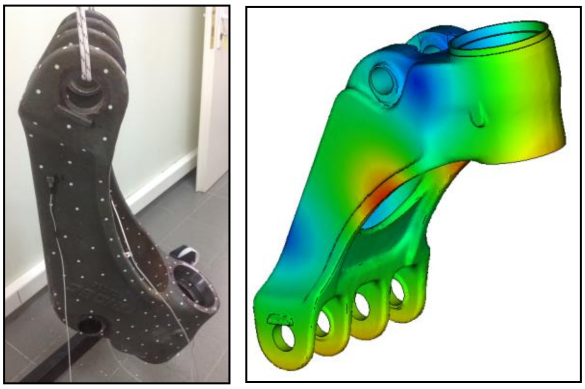

Figure 1: Experimental Modal Analysis Procedure, with Elastic Eigenmode.

Figure 2: Finite Element Model of suspension system of a semi-trailer vehicle; real system.

## References

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