A new approach for structural health monitoring: damage detection on large structures through a swarm of moving sensors

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Abstract. The present paper takes place in the context of identification problems: the aim is to propose a new approach for the detection of damages within large structures via the deployment of a set of moving sensors. The goal of the method is to optimally control the motion of the swarm driving the sensors in the optimal measurement regions, in order to perceive the field as clean as possible and to enhance the identification of any possible irregularity along the structure. The optimal control of the sensors motion and the consequent damage identification are achieved through a two-step strategy. The first one is based on: i) models for the dynamics of the structure, for the dynamics of the sensors; ii) LQR control logic to define the optimal trajectory of the swarm. The second step includes the identification of the damage module: the process of data analysis is investigated through a revision of the technique based on Empirical Mode Decomposition, combined with the Hilbert-Huang Transform.

Introduction

The methodology for the damage identification has been previously proposed and published by the authors [1]. The strategy showed that in the case of a fixed measurement station there is a dependence between the response of the method and the position of the crack with respect to the one of the sensors. This statement allows to reasonably think that there are different optimal measurement positions able to enhance the identification process that could be reached through the use of moving sensors exploring the system. Aim of the paper is to investigate different scenarios for both fixed and moving sensors in order to highlight the differences in the estimation response. Crack location is estimated by the analysis of the instantaneous frequencies, that present a sharp peak in correspondence of the damaged section.

Results and discussions

Simulations have been carried out considering a moving load crossing a beam with a crack modelled as a torsional spring between the two sections of the structure. The presence of the damage causes a discontinuity on the frequency response of the excited beam. Plots in Fig.1 show the results of the methodology for two different cases of study. In the figure are reported the instantaneous functions vs the moving load position, extrapolated from the processing, through EMD, of the acceleration signals measured from one sensor in different positions. The blue line represents the response in the case of a fixed sensor positioned at a longitudinal coordinate $x_s = 0.7L$, while the red line represents the response in the case of a controlled moving sensor crossing the damage ($x_{crack} = 0.4L = 8$ m) whose trajectory covers the spatial coordinates from $x_{s0} = 0.5L$ to a target point $x_t = 0.3L$. In this case the applied Hilbert Transform to the processed signal shows a peak at the instant the load crosses the damage position.

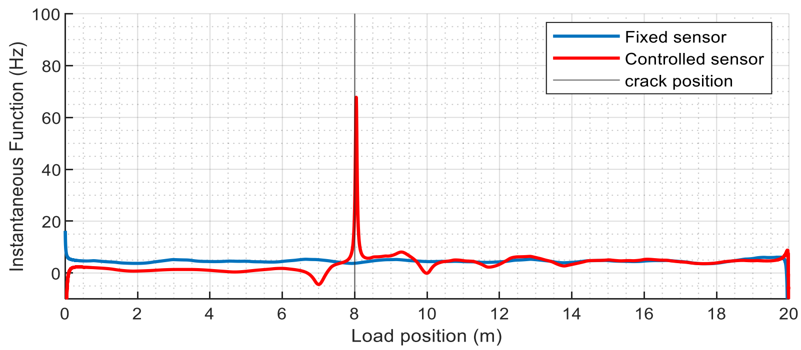

Figure 1: Comparison of the first Instantaneous Function in the case of a fixed sensor (blue line) and in the case of controlled moving sensor (red line).

Preliminary results show the potential of the strategy. The possibility of heading the measurement stations to more optimal and sensitive positions leads to an enhancement of the crack identification. The strategy is still under investigation. Further analysis will concern the influence of the sensors velocity and the influence of noise corrupting the acquired data, leading to the development of an estimator based on Extended Kalman Filter in order to reconstruct the elastic shape of the observed structure.

References

[1] N. Roveri, A. Carcaterra - Damage detection in structures under traveling loads by Hilbert–Huang transform. Mechanical Systems and Signal Processing 28 (2012) 128–144.