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Benefits of Observer/Kalman filter identification in system realization with low amount of samples

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Abstract: Impulse responses are function that characterize linear systems uniquely. They can be used to predict the responses of a system once the applied excitation is known. With the input and output signals of vibration tests, the impulse responses of mechanical systems can be estimated using different methods. Once those functions have been correctly estimated, the modal parameters can be identified using time-domain methods, as for example, the eigensystem realization algorithm (ERA). Problems can arise when the acquired data consist in only a few noisy samples. This paper analyses the benefits of the Observer/Kalman filter identification (OKID) to estimate the impulse responses and how it interferes in the identification of modal parameters. Experimental data of a uniform beam is used to exemplify the benefits of OKID in the modal identification using the ERA.

Keywords: Impulse response estimation, System realization, Experimental modal analysis, Observer/Kalman filter identification

1. Introduction

Impulse responses are functions that characterize linear systems since they relate input (excitation) signals with the output signals (responses). For linear time-invariant systems, the output signals can be seen as a sum of convolutions between the inputs and the impulse response functions (IRF). Using modal analysis, it is possible to decompose the IRF in terms of modal parameters (natural frequencies, damping factors and mode shapes). Hence, an estimation of this function becomes the main source of information about a structure in time-domain modal identification methods.

A proper system identification only occurs when reliable data is used. Modal parameters can only be accurately identified (in time-domain methods) if the impulse responses have been correctly estimated. Good experimental procedures and dedicated data processing are two main concerns when estimating the impulse responses. For the latter, the quality of the estimation usually depends on the number of samples recorded and in the signal-to-noise ratio of the measurements. When only a few noisy samples are recorded, the estimation process becomes challenging. The goal of this paper is to analyse the influence of the impulse response estimation in the identification of modal parameters, especially for tests with a low number of noisy samples.

2. Methods

Two impulse response estimators are compared in this paper: the inverse Fourier transform of the H_1 estimator and the Observer/Kalman filter identification (OKID). The H_1 estimator is a popular frequency response function (FRF) estimator that can be used to estimate the impulse responses using the inverse Fourier transform. It is an indirect method since it requires first the estimation in the frequency domain [1]. Differently, the OKID is a direct time-domain method that uses an observer to deal with noise and computational costs. Under certain noise assumption, the added observer can be related to the Kalman filter gain. The OKID method was first introduced in the literature by Phan et al. [2]. To evaluate the influence of the impulse response estimation in the identification of modal parameters, the eigensystem realization algorithm (ERA) is used here. This time-domain identification method is part of a larger group, known as realization algorithms, which are based on the minimum realization theory. The formal application of this theory in modal identification was first introduced by Juang and Pappa [3].

3. Results and Conclusions

A simple Experimental Modal Analysis (EMA) of a free-free uniform beam was conducted to demonstrate the quality of the IRF estimation. Since it is easier to visualize this function in the frequency domain, Fig. 1 shows the respective transformed estimations (FRF). When only a few noisy samples were used and only one data block was used in the H_1 estimator. Therefore, the noise was not averaged out and it is still present in the estimation. This led to a poor identification since a few modes were not identified. With the same number of samples, the estimation using the OKID led to a much better and smooth estimation. All modal parameters were correctly identified. By incising the number of samples and using more data blocks in the H_1 estimation, the noise was partially removed, and the identification was improved. Nevertheless, the estimation with OKID is still superior.

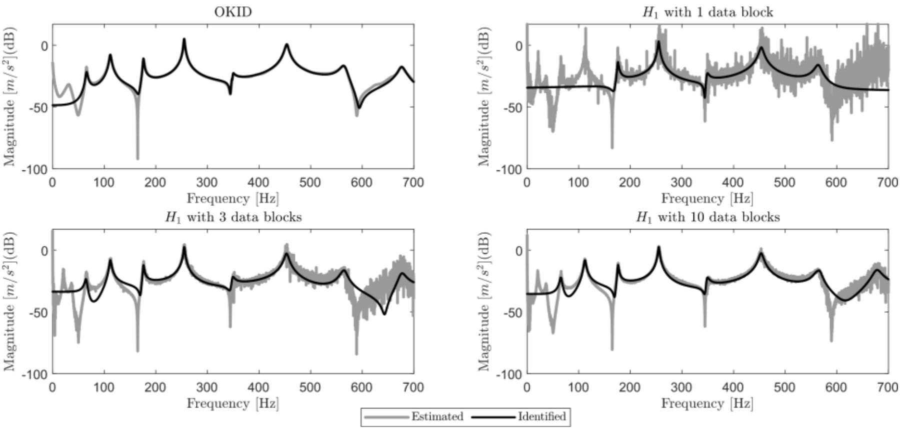

Fig. 1. FRF estimated using OKID and H_1 method. Modal synthesis after identification with ERA.

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