Uncertainty Minimization Technique for Joint Input-State Estimation Using Dummy Measurements

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Abstract

Joint input-state estimation algorithm is a Kalman filtering based technique that can be used for the identification of forces applied to a structure together with the unmeasured response quantities of interest. However, when applying this technique, displacement or strain measurements have to be used in order to guarantee the stability conditions. This paper presents a joint input-state estimation algorithm that uses dummy displacement or strain measurements to yield stable results. The quantification of the estimation uncertainty originating from the errors of using dummy measurements is elaborated in this paper. As joint input-state estimation is an on-line algorithm, this paper also provides an updating method to minimize the estimation uncertainty during the real-time estimation. This uncertainty minimization technique that uses dummy measurements in joint input-state estimation is verified using numerical simulations.

Keywords: kalman filtering; joint input-state estimation; uncertainty quantification; uncertainty minimization; on-line estimation.

1 Introduction

The problems of estimating the dynamic forces applied to a structure and the true states of the system are very important in structural dynamics. Several Kalman filtering based techniques have been proposed in the literature to jointly estimate the input forces and the corresponding states [1, 2, 3, 4]. The classical Kalman filter assumes the input forces either known or broadband, which may easily lead to bias errors in the results. While estimating the unknown forces and states together can yield unbiased estimates. However, if only acceleration measurements are used for jointly estimating the forces and states, the results will be unstable, where a drift can be seen in the estimated result [2, 3]. In order to guarantee the stability condition, displacement or strain measurements have to be used together with acceleration measurements in the estimation [5].

Displacement measurements can be measured with GPS or visual positioning systems, but unfortunately the accuracy of the measurements is usually too poor to give any practically useful results. High-quality strain measurements can be obtained with standard Fiber-optic Bragg Grating (FBG) strain sensors. However, the placement of strain-gauges is an arduous process and the interrogator instruments for FBG sensors are still very expensive. Without directly measuring the actual displacement or strain response, Naets [6] proposed to use dummy measurements to satisfy the stability condition.

In this contribution the method using dummy displacement or strain measurements for stable force identification is further investigated by

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