Examination of Modal Expansion and Kalman Filtering Techniques for Vibration Estimation

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ABSTRACT

State estimation is a well-established discipline within the field of modern control theory. In the context of vibration analysis, where application areas include damage prognosis and structural control with full state feedback, the topic has, however, emerged during the last couple of decades under the term *virtual sensing*. Here, the scope is to estimate physical quantities at both measured and unmeasured locations based on vibration signals captured in a limited set of sensors. The by far most applied approach is modal expansion, in which an augmented basis consisting of measured and analytical mode shapes is used to solve an inverse problem resulting in vibration estimates in all the unmeasured degrees of freedom in the model of the structure in question [1, 2]. It follows directly that the inverse problem to be solved is underdetermined if the number of included modes exceeds the number of deployed sensors; a scenario that can easily occur in practice. With this in mind, the scope of this paper is to examine and compare other state estimation/virtual sensing techniques adopted from modern control theory, namely, direct Kalman filtering [3] and a modified Kalman filter where the true value of the input is replaced by an optimal estimate [4]. The performance of these two schemes and the modal expansion technique is examined in an experimental setup with a cantilevered beam, which is subjected to different input types and installed with a limited set of accelerometers. Based on the experimental findings, some observations and particular recommendations on the use of the different schemes are provided.

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