Dynamic Stress Response Estimation in Structures using a Model Based Observer

Estimation of the stress and strain tensors at unmeasurable points in a solid or structure is a common problem encountered in many fields of science and engineering. Applications range from the fatigue monitoring on structural systems, estimation of the force through a joint in the human body, to estimating heart kinematics. In fatigue analysis, for example, the estimated stress time histories can be used as inputs to damage functions and consequently be used to estimate the failure risk due to oscillatory loads. If global system responses such as accelerations at a number of locations are measured, the objective is then to reconstruct unmeasured quantities of interest (QoI) from the available measurements and a model of the system.

This project presents the results from a series of experiments designed as a validation study of a recently proposed model based state estimator for inverse problems in structural dynamics. The estimator uses a finite element model of the structure and measurements of acceleration at discrete points to estimate stress time histories at arbitrary locations in the structure. The initial conditions and excitations are unknown and assumed to be realizations of random vectors and random processes with known covariance and power spectral density. The results obtained with the proposed estimator are compared to the actual measured stress at the location of interest and with estimates obtained using other well-established estimation methods, such as Luenberger observers and the Kalman filter. The main finding is that for all experiments conducted and under suboptimal conditions with respect to the assumptions, the proposed model based estimator yielded estimates more accurate or comparable to all other existing methods considered with the advantage of reduced computational cost.