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EFFICIENT EXPERIMENTAL VALIDATION OF STOCHASTIC SENSITIVITY ANALYSES OF SMART SYSTEMS

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Summary: A new method for the efficient experimental validation of stochastic sensitivity analyses is proposed and tested on a smart system for vibration reduction. Stochastic analyses are needed to assess the reliability and robustness of smart systems. Conventional reliability methods cannot taken into account parameter interactions in the system behavior which arise from the structural conformity integration of actuators and sensors. In order to account for such interactions, statistical variation of the system parameters need to be considered in the numerical simulation. Variance-based sensitivity analyses would be an example for such a numerical simulation. However, a quantitative experimental validation of the numerical results is difficult due to the random-based selection of simulation points in the stochastic analysis. The interactions need to be confirmed also in the experimental study with only a few measuring points. The model-based experimental design allows an adjustment of the study on the system under investigation and thus offers the possibility of efficient validation of the simulation results.
An exemplary system of structural dynamics is used to test the new method. The location of the eigenfrequencies of a smart beam as a function of geometrical, topological, and technological parameters is a complex non-linear system behavior and shows a variety of interactions. The case of active suppression of disturbing vibrations through active piezoelectric elements is considered as an application scenario. The observed target variable is the level of vibration reduction under uncertain system parameters. Based on an analytic model of the smart beam a variance-based sensitivity analysis is calculated to determine the parameters influencing the level of vibration reduction. Ensuing from these numerical results, a model-based experimental design is established and the experiments are conducted. In contrast to a conventional full factorial experimental design the model-based approach reduced the experimental effort by about 40%, without great loss of information. However, only main effects and interaction effects can be confirmed, which were found already in the numerical simulation, unknown interactions cannot be detected.