

SENSOR PLACEMENT OPTIMIZATION CONSIDERING MODEL UNCERTAINTY AND SENSOR CLUSTERING IN VARIABLE-STIFFNESS COMPOSITE STRUCTURES

Haichao An

Beijing Institute of Technology

Keywords: Optimal sensor placement, model uncertainty, sensor clustering, variable-stiffness composite, multi-fidelity surrogate model

Abstract

In variable-stiffness composite structures, fibers are placed in a curvilinear manner within a single layer to enable continuous tailoring of spatial stiffness. For damage detection in such structures, optimal sensor network design is essential for obtaining adequate and reliable information. While a dense distribution of sensors can provide sufficient data, it often introduces redundancy—particularly when sensors are of high reliability and quality. Therefore, clustered dense sensor configurations should be avoided. Additionally, model uncertainties arising from the manufacturing process must be considered in sensor network design. This work presents an optimization framework for determining sensor configurations that accounts for both model uncertainty and sensor clustering. Since any point on the structure could serve as a candidate sensor location—resulting in a large design space—a modal kinetic-energy-based index is proposed to reduce the design space. The first design objective, formulated using the modal assurance criterion, addresses model uncertainty. A second objective is introduced to quantify sensor clustering. The non-dominated sorting genetic algorithm II is employed to solve this multi-objective optimization problem, and Monte Carlo simulation (MCS) is used for uncertainty analysis within the first objective. To reduce computational cost, the actual performance evaluations in MCS are replaced with a multi-fidelity surrogate model corrected using an exponential function. Using the vibration data acquired from the optimized sensors, an optimization-based delamination detection process is applied to validate the resulting sensor layout. Case studies are presented to demonstrate the effectiveness and applicability of the proposed framework.