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UNCERTAINTY QUANTIFICATION OF SYNTHETIC JET GENERATOR USING MULTI-FIDELITY ELECTRO-MECHANICAL COUPLED MODELS

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Synthetic jet actuators [1] have been explored over the past decades as a promising technology for active flow controls in aerospace industries including applications in delay of flow separations on lifting surfaces. The synthetic jet actuator works on the principle of generating jet flows from an orifice connected to a gas chamber whose volume is varied by an oscillating diaphragm. In most of the designs, the diaphragm is a unimorph piezoelectric actuator undergoing oscillations with applied voltage input. Efficiency of the actuator depends on a large number of factors including the chamber and orifice sizes, dimensions of piezoelectric unimorphs as well as its material properties. With a great number of models developed over the past decades, modeling and simulations have become an effective tool in design and optimization of synthetic jet actuators. In this work we propose a multi-fidelity model for analysis and design of synthetic jet generator. A high fidelity finite element model (FEM) of electromechanical coupling was developed for simulations of piezoelectric generator responses. This is coupled with a incompressible Navier-Stokes flow solver for fluid structure interaction simulations of synthetic jets. While it provides highly accurate predictions, running the FSI model during optimization is prohibitive due to its computational cost. A lower fidelity lumped element model (LEM) is also developed to provide fast prediction of generators responses. Lumped parameters for LEM are obtained from a reduced order model of the FEM. With multiple fidelity models, uncertainty quantification of material properties is carried out to understand its effect on responses of piezoelectric generator. Results from different fidelity models are compared with experimental data showing effectiveness of the simplified model. Uncertainties in material properties of the generator are also accessed using a stochastic approach and an epistemic nondeterministic approach in order to quantify plausibility of response levels of the actuator. The coupled LEM model is subsequently used for optimization of the generator's shape.

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