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UQ Analysis and Robust Optimization of a Transonic Airfoil for Open Rotor Design

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In the framework of CFD-based aerodynamic design and optimization, uncertainties associated with the geometrical shape (due to manufacturing tolerance, wear and tear, etc.) or aerodynamic conditions are often evaluated using non-intrusive stochastic methods. These methods are subject to the curse of dimensionality, as the number of simulations needed increases exponentially with the number of uncertain parameters. Thus, the selection of the most efficient Uncertainty Quantification (UQ) techniques is crucial for the usability of robust optimization in industrial applications. In this work, we propose to assess efficient UQ methods on a 2D test case representative of an open rotor blade design, the NACA16-103 airfoil. Both its geometry and some external aerodynamic conditions are considered as uncertain, which is modeled by introducing twelve uncertain parameters. An accurate surrogate model is derived for this purpose based on a kriging approach. Generalized Polynomial Chaos (gPC) is considered using colocation techniques, namely Least Square Approximation (LSA), Least Square Approximation with Gradient Enhancement (LSAGE) [1], Least Angle Regression (LARS) [2] and Basis Pursuit Denoise (BPDN) [3]. A combination of compressed sensing (BPDN) enhanced with gradient information is also proposed. Finally the airfoil robust optimization is investigated taking as objective and constraints the statistical moments of the aerodynamic coefficients, e. g. drag and lift. A focus is placed on the assessment of the computational cost saving enabled by LSA enhanced techniques when engaged in the robust optimization process, as well as on the comparison of the obtained robust airfoil shapes.

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