An efficient non-intrusive reduced basis model for high dimensional stochastic problems in CFD

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Abstract

The major challenge industrial applications of uncertainty quantification (UQ) are facing, is the curse of dimensionality as a result of a large number of uncertainties. In this work, an efficient non-intrusive model reduction scheme is presented for UQ using proper orthogonal decomposition and a non-intrusive polynomial chaos approach based on regression. The main idea is to extract the optimal orthogonal basis via cheap calculations on a coarse mesh and then use this basis for the fine scale analysis. To validate the developed non-intrusive, reduced-order model, it is applied to two CFD type applications: (1) flow over a 2D RAE2822 airfoil and (2) the NASA Rotor 37, a transonic axial flow compressor. For the RAE2822, the surface of the airfoil is assumed to be stochastic and is defined as a random field with a given covariance and modeled using Karhunen-Loève expansion. For the NASA Rotor 37, the geometry of the rotor blade is parameterized into 2D sections of airfoils. A total of 21 uncertain parameters is considered containing both operational and geometrical uncertainties. The statistical results are compared with those of the standard polynomial chaos method. The results show that the developed model produces statistical results with good accuracy. It is found that the memory requirements and the computational cost of the reduced-order model is 5 - 10 times lower than that of the standard polynomial chaos.

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