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► **To cite this version:**

A Resmini, J Peter, D Lucor. High Dimensional stochastic investigation of 2D RANS flow about an helicopter airfoil. International Workshop on Numerical Prediction of Detached Flows, Oct 2014, Madrid, Spain. ⟨hal-01077350⟩

HAL Id: hal-01077350

<https://hal.science/hal-01077350v1>

Submitted on 24 Oct 2014

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HIGH DIMENSIONAL STOCHASTIC INVESTIGATION OF 2D RANS FLOW ABOUT AN HELICOPTER AIRFOIL

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Key words: CFD, Uncertainty Quantification, Detached Flow, RANS, Stochastic Collocation, Geometrical uncertainties, Operational uncertainties

Abstract. The use of Computational Fluid Dynamics (CFD) in the aeronautical research community is now well established. Due to the high costs that wind-tunnel tests require, the validation and verification of CFD simulations are of primary importance. Notwithstanding, several factors impact the solution quality. Physical modelling and numerical discretization are only two key examples on which most of the CFD researchers have been focusing on. Experiments and real flight conditions constantly show alterations of the observed quantities from nominal values, while, traditionally, CFD computations are performed for a given fixed condition. Since the last decade, more attention has been paid to the *impact* of input data lack of knowledge on simulations. Uncertainty Quantification (UQ) [1] deals with this aspect and, specifically, it quantifies the effect of data incertitude on the computed solution.

The *first* step in this UQ study is the identification of *realistic* uncertainties [2] both in wind-tunnel and real flight conditions. An extensive research has been performed where typical values of incertitudes have been quantified. Within the latter, the retain ones are the Ma , incidence and several surface imperfections. Depending on the available experimental data, the probability distribution of these uncertainties has been inferred.

The *second* step is the choice of the appropriate stochastic approximation. A *non-intrusive* stochastic collocation method [3] with sparse grids [4] built on Clenshaw-Curtis nodes [5] has been preferred. In this fashion, the ONERA finite-volume compressible *elsA*

flow solver has been used without modifications. The statistics of the solution in terms of lift, drag and pressure coefficients have been computed.

The present study addresses the prediction of 2D subsonic turbulent flow about NACA0015 airfoil in the presence of operational and geometrical uncertainties. The computations are carried out by means of RANS simulations at $Re \approx 2 \cdot 10^6$.

The results at a pre-stall condition, angle of attack equals to 10° and stochastic dimension equals to five, show that the joint uncertainties influence on the observed solution is *not* negligible in term

of lift and drag counts. Figure 1 shows the C_p distribution at the leading edge location. These observations with fully attached flow may be useful for robust airfoil design process.

Ongoing computations of higher stochastic dimension with adaptive sparse grids will better capture the uncertainties effect at detached condition.

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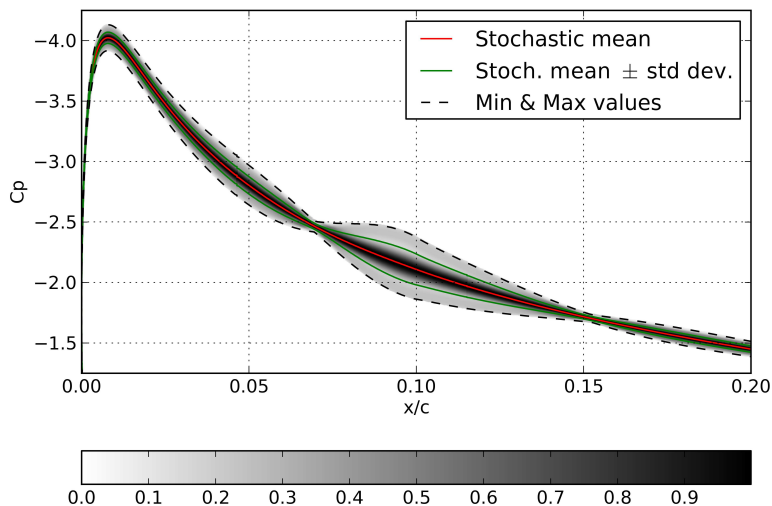


Figure 1: Stochastic pressure coefficient C_p profiles at the suction side of NACA0015 airfoil at $0 \leq x/c \leq 0.2$, A.o.A. = 10° . Gray-contour of non-uniform solution's PDFs at each x/c locations.