Comparison of Polynomial Chaos Expansion and Polynomial Chaos Kriging for Uncertainty Quantification of NACA66(MOD) Hydrofoil

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ABSTRACT

The Uncertainty Quantification (UQ) analysis has been gaining more and more interest over the time. In the realm of Computational Fluid Dynamics (CFD), the Uncertainty Quantification has exploited to assess the uncertainties related to specific model coefficients. In the context of Reynolds Averaged Navier Stokes (RANS) simulations, the sensitivity of the outcomes of the model to the uncertainty of the coefficients of the standard $k - \varepsilon$ turbulence model has been investigated for different cases. Among others Margheri et al. 2014 applied an UQ analysis for a turbulent channel flow while a similar study was applied by Zhang et al. 2020 for a subcooled boiling flow in a vertical pipe and by Liu et al. (2024) for a turbulent flow around a high-speed train. The present work treats the Forward Uncertainty Propagation (FUP) and the Global Sensitivity Analysis (GSA) of the lift and drag coefficients for the NACA66(MOD) hydrofoil at an angle of attack of 4 degrees for a fully wetted flow. The FUP has been conducted by applying and comparing the Polynomial Chaos Expansion model (PCE, Marelli, Lüthen et al. (2024)) against the Polynomial Chaos based-Kriging model (PCK, Schöbi et al. (2022)). The GSA is based on the Sobol decomposition of the outcomes of the CFD model (Marelli, Lamas et al. 2024). The study has been caried out with two different sets of uncertain coefficients, encompassing 42 and 252 samples, respectively. The lift and drag coefficients have been calculated by the commercial CFD solver Simcenter STAR CCM+ for each collocation point. Analyzing the response surfaces for different polynomial orders, the PCK metamodel seems to achieve a convergence trend of the prediction error for the drag coefficient by involving only 42 samplings while both surrogate models fail to converge for the two set of collocation points for the lift coefficient.

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