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Title

Multifidelity aerodynamic analyses of a hybrid laminar flow control and variable camber coupled wing

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Abstract

Within the German LuFo VI-1 project CATeW (Coupled Aerodynamic Technologies for Aircraft Wings), the potential for aerodynamic drag reduction by combined application of hybrid laminar flow control (HLFC) and variable camber (VC) technologies to the wing of a transonic transport aircraft is investigated. The project is organized in a bilateral manner, where analyses are conducted on two fidelity levels. The levels consist of high-fidelity (HiFi) aerodynamic analyses by means of computational fluid dynamics (CFD) simulations performed at the Chair of Aerodynamics and Fluid Mechanics (AER) of the Technical University of Munich, while the low-fidelity (LowFi) complement is being formed by the overall aircraft design (OAD) toolchain MICADO of RWTH Aachen University's Institute of Aerospace Systems (ILR). A detailed overview of the project is presented in Ref. [1].
A dedicated goal of the project is introducing HiFi aerodynamic results into the LowFi toolchain, thus enhancing the aerodynamic analyses performed via MICADO on OAD level by means of CFD results. This is achieved via formulation of surrogate (SG) and reduced order models (ROMs) based on the HiFi analyses and efficiently coupling the latter to the aerodynamic module of MICADO.
Within this contribution, coupling strategies between HiFi results and the LowFi aerodynamic toolchain via SG/ROM implementations, corresponding results of the enhanced toolchain, and standalone SG/ROM will be presented. The differentiation between SG and ROM results from the structure of the aerodynamic module of MICADO, offering different coupling points for the foreseen integration, as indicated in Fig. 1.

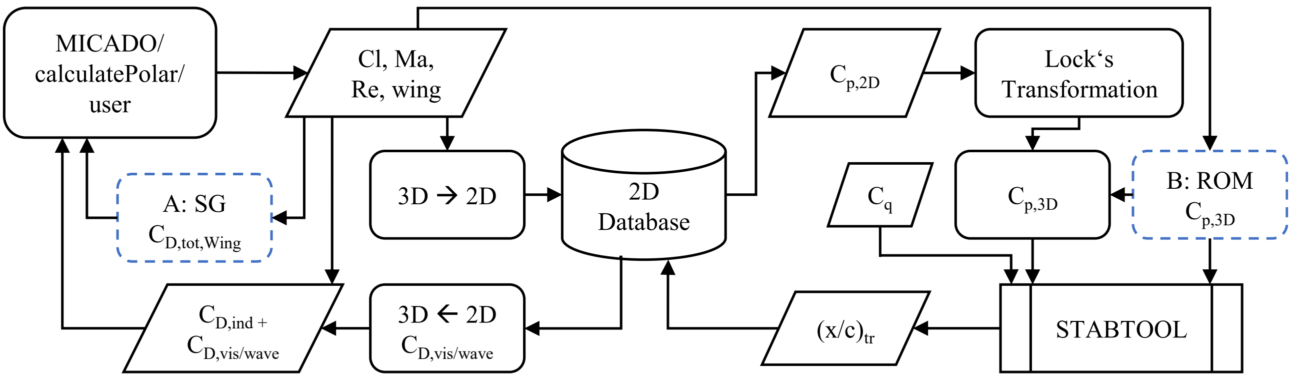

Figure 1: Overview of MICADO's aerodynamic module with indication of SG and ROM integration points.

Both the SG and ROM are required to predict aerodynamic quantities based upon parametric input. The input parameter space $\mathcal{P}$ is extracted from the cruise flight envelope of the reference aircraft, spanning the intervals:

$$\mathcal{P} = C_L \times \delta_{ADHF} \times H = [0.4; 0.6] \times [-2°; 4°] \times [33000ft; 39000ft],$$

where C_L denotes the lift coefficient of the wing, δ_{ADHF} the deflection angle of an adaptive dropped hinge flap (ADHF), which is used to incorporate VC capabilities to the reference wing, and H the flight altitude.

Based upon the integration points depicted in figure 1, the SG and the ROM possess different levels of abstraction for prediction of aerodynamic quantities. Within the contribution, coupling of a SG model based on Gaussian Process Regression (GPR) [2] for prediction of integral aerodynamic force coefficients, and model order reduction techniques based on proper orthogonal decomposition (POD) for prediction of aerodynamic surface quantities [3] are envisaged. Isolated analyses of both methods show good quantitative agreement of the predictive capabilities provided by the models, assessed with respect to a dedicated validation dataset. Considering the GPR SG, results for the wing of the reference configuration are submitted for publication in Ref. [4]; A predicted surface pressure coefficient distribution based upon POD for dimensionality reduction coupled to a radial basis function (RBF) interpolation for the corresponding POD coefficients (POD + I) at the design lift coefficient of $C_L = 0.5$, the initial cruise altitude of $ICA = 35000ft$ and a suction coefficient of $C_q = -12 \cdot 10^{-4}$ is additionally depicted in Fig. 2.

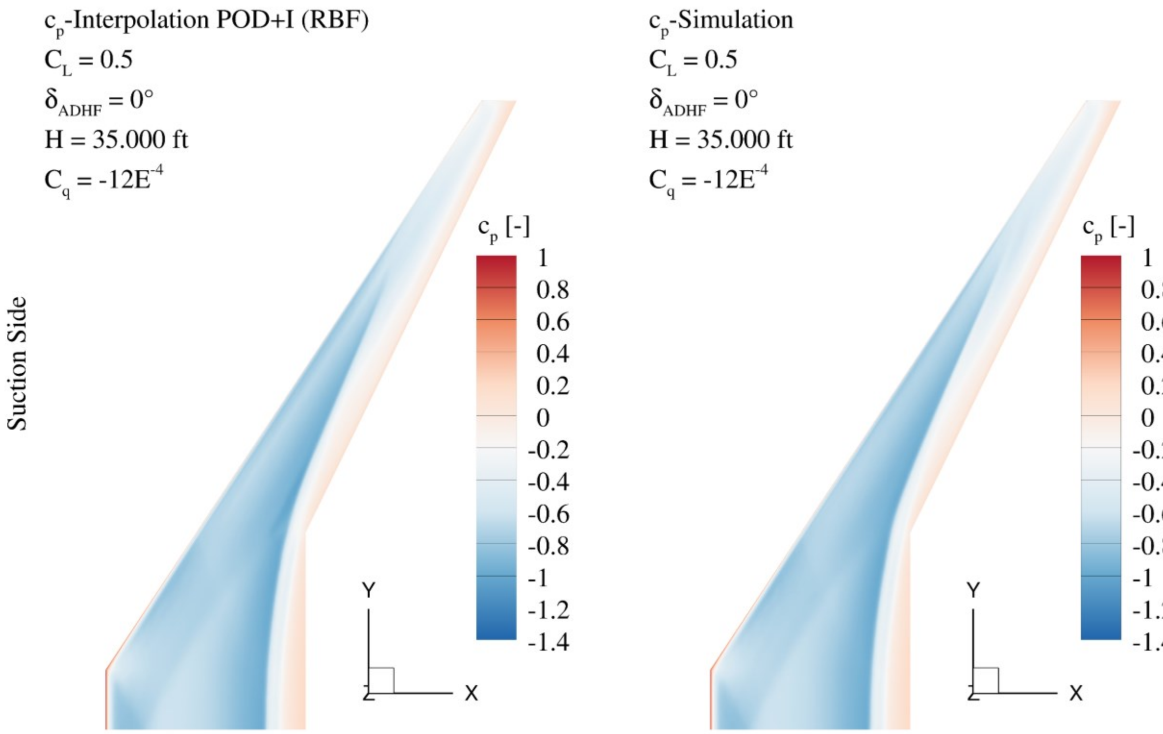

Figure 2: ROM (POD + I) prediction of pressure coefficient distribution (left), alongside simulated pressure coefficient distribution for the same parameter combination (right).

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