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A Mixed Fidelity Conceptual Design Process for Boundary Layer Ingestion Concepts

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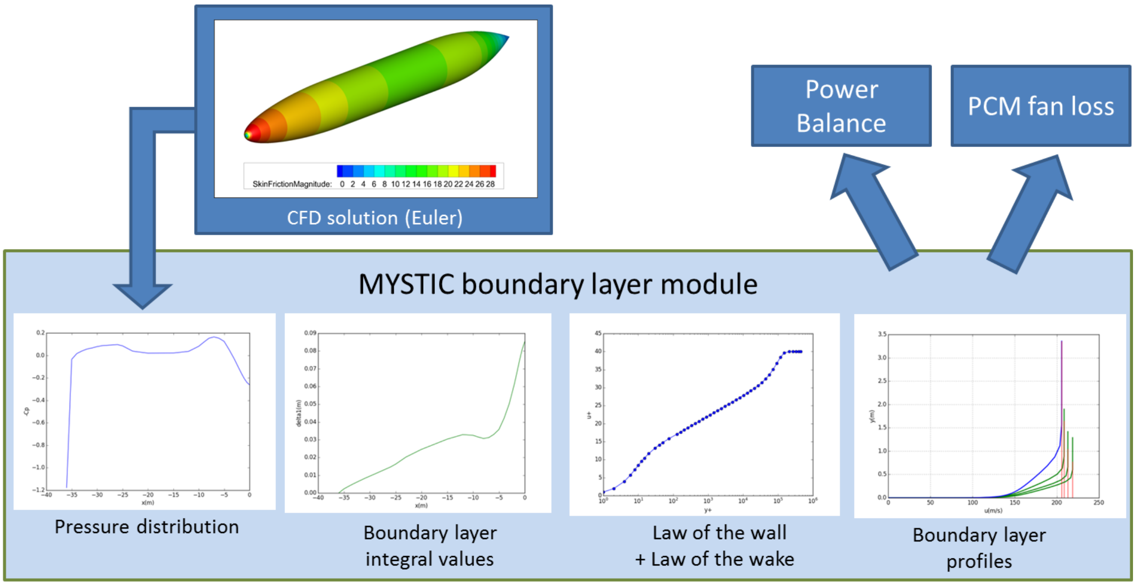
Boundary Layer Ingestion is one amongst promising concepts that would help improving aircraft aeropropulsive performance. Several studies ([1] to[12]) have already highlighted the benefit of that technology, either at OAD (Overall Aircraft Design) level with low fidelity models ([1], [5], [9], [10]) or in CFD (Computational Fluid Dynamics) studies with high-fidelity tools on particular cases ([2], [3], [7], [8], [11], [12]). However, it remains difficult to bring together OAD and high-fidelity tools due to the time of response of complex disciplinary tools. Within the European Clean Sky 2 AIRFRAME ITD platform ONERA has thus developed and coded a mixed fidelity approach inside its in-house OAD platform. The purpose is to mix various levels of fidelity from disciplinary tools (CFD, FEM, CAA), with the conventional and robust OAD methods. This paper focuses on the integration of rapid CFD tools inside the OAD process, in order to assess BLI benefits.

The purpose ONERA’s OAD platform, named MYSTIC [16], is to provide a software environment in which main aircraft disciplines can contribute, and able to capture the interaction effects between them and the corresponding snowball effects in the aircraft figures of merit such as fuel burn. Each major discipline can be integrated through a dedicated expert tool, to improve the accuracy of the aircraft performance prediction at OAD level. Depending on their level of fidelity to the physics, tools are classified as Level 0 (values from charts, abacus, semi-empirical formulae), Level 1 (basic physical equations are solved), and Level 2 (advanced physical equations are solved, using expert software such as CFD tools or FEM for example). The time of response must remain acceptable with respect to the OAD process.

As far as BLI is concerned, its integration within MYSTIC relies on those three fidelity levels. Level 0 is modelled by using a BLI effect proportional to the quantity of ingested drag, and is based on [13]. Level 1 is using a model of boundary layer growth using a simple integral method. A power law provides then the boundary layer profiles, which are finally sent to a Power Balance method [14]. Level 2 is of much higher fidelity: the geometry of the aircraft shape is generated by MYSTIC, then meshed and computed using a CFD Euler code. The pressure field on the fuselage is then recovered, and a boundary layer code, accounting for adverse pressure gradients, provides a boundary layer shape. That result is then used to assess the BLI performance more accurately with the Power Balance method [14]. It is also used to estimate the flow field in the fan plane, which is sent to a Parallel Compressor Method ([15]) in order to estimate the fan efficiency losses.



Those various tools have been validated against reference and experimental cases when available, or high-fidelity RANS data else. The paper intends to present the tools, their validation process, and the overall results at OAD level for different families of aircraft (such as medium range or business jet) when using the different levels of fidelity that are available.

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