PROPOSITION DE STAGE – MASTER 2 DET
Dynamique des fluides, Energétique et transferts
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Titre : Generating swirl inlet distortion for low fan-pressure propulsors

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Context and motivation

As the bypass ratio (BPR) is increased for improved fuel burn and reduced noise, the fan diameter grows, leading to shorter nacelles with reduced distortion-free operating ranges, and the fan pressure ratio (FPR) decreases, leading to less distortion-tolerant fan designs. Swirl distortion is often divided into three overall categories: bulk swirl, twin swirl and localized swirl in the form of ingested vortices. Twin swirl being mostly present in S-duct inlets and partially embedded inlets is of growing interest for new disruptive airframe configurations such as blended-wing body concepts. This project aims at designing means of generating swirl distortion for a turbofan test bed, through numerical simulation and shape optimization.

Early experimental studies on the impact of swirl distortion on turbofan performance report the use of either a symmetric delta wing under incidence to generate a symmetric pair of counter-rotating vortices [1] , or a non-symmetric half delta wing to generate one large vortex and simulate bulk swirl [2] . Work on wishbone and doublet vortex generators [3] show that these devices generate a vortex pair rotating in the opposite direction compared to a delta wing. Recent work on swirl distortion vanes [4] introduce a different method, particularly suited to generate non-symmetric vortex pairs.

The aim is to propose a method to design devices to recreate different swirl flow distortion conditions at the inlet of a turbofan in a ground test bed, using a combination of vortex generators. To this end, an optimization framework is currently being developed using an in-house CST-curve based geometry parameterization method, and available surrogate-based methods. In parallel, an experimental setup is in preparation in a turbofan test bed.

Proposed work

We will begin by studying the flow in a variety of S-duct configurations (using RANS simulations) to provide practical target flows and define relevant distortion metrics. In parallel, we will study the flow structures generated by a variety of vortex generator types placed inside a cylindrical duct, with the ambition to create low-cost design models. We will define and explore the design space, and design distortion generators for target flows of increasing complexity, symmetric and non-symmetric, and establish the limits of the approach. We will design a distortion generator for the experimental setup, and address key practical questions such as the influence of the vicinity of a fan downstream (using body-force RANS simulations), and the possibility to combine vortex generators with turbulence screens to recreate realistic flows including swirl distortion and total pressure distortion effects. If time and progress allow, the designed distortion generator will be manufactured and tested in the turbofan test bed.

References

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[2] N. R. Schmid *et al.*, Steady performance measurements of a turbofan engine with inlet distortions containing co- and counterrotating swirl from an intake diffuser for hypersonic flight, *Journal of Turbomachinery*, 2001.
[3] S. Farokhi, Propulsion system design with smart vortex generators, *Aircraft Design*, 1998.
[4] T. Guimarães *et al.*, StreamVane turbofan inlet swirl distortion generator: mean flow and turbulence structure, *Journal of Propulsion and Power*, 2018.
[5] T. Guimarães *et al.*, Complex flow generation and development in a full-scale turbofan inlet, *Journal of Engineering for Gas Turbines and Power*, 2018.