PROPOSITION DE STAGE – MASTER 2 DET
Dynamique des fluides, Energétique et transferts
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Titre : Validation of a swirl inlet distortion generator concept for low fan pressure-ratio turbofans

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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. Twin swirl distortion, present in partially embedded and S-duct inlets, is of growing interest for new disruptive airframe configurations such as blended-wing body concepts. This project aims at designing a device capable of generating the swirl distortion patterns of an S-duct inlet, in a turbofan ground test bed.

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 and turbulence screens. In previous work, we developed a RANS-based optimization framework using an in-house CST-curve based geometry parameterization of S-ducts and vortex generators, and available surrogate-based methods. In parallel, an experimental setup is in preparation to fit a turbofan test bed with different turbulence screens, as well as prototype vortex generators. Experiments are underway to characterize the stagnation pressure and turbulence profiles generated by the turbulence grids using five-hole probes and 2D hot-wire anemometry. A prototype vortex-generator (VG) assembly is being commissioned in order to study experimentally the interactions between the turbulence screens and the vortex generator.

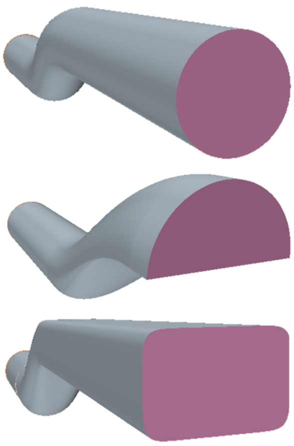
Fig. 1. S-duct configurations under study.

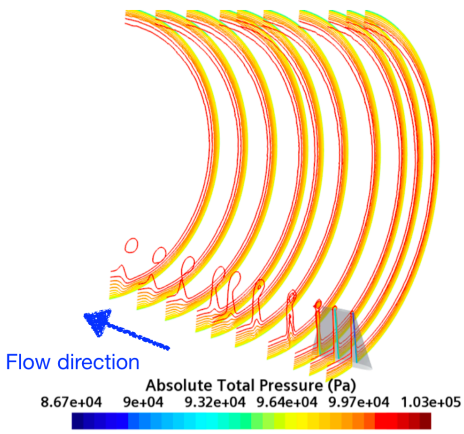

Fig. 2. Numerical study of the flow generated by a tapered wing under incidence in a cylindrical duct


Fig. 3. Turbofan experimental setup

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 a variety of vortex generator types placed inside a cylindrical duct, with the ambition to define relevant distortion metrics, considering stagnation pressure, swirl, and turbulence. We will conduct experiments on a prototype distortion generator, in the turbofan test bed, to validate numerical simulations and address key practical questions such as the influence of the vicinity of the fan downstream (using body-force RANS simulations), how to practically associate vortex generators and turbulence grids (which one upstream, which distance between VG and grid and to the fan, etc.), and the importance of unsteady flow features.

We will then define and explore the design space of both S-ducts and distortion generators using surrogate-based efficient global optimization methods, with the aim to find matching pairs. We will explore the use of different objective functions and discuss eventual trade-offs. If time and progress allow, we will explore different types of distortion generators, and attempt to extend the study to flows of increasing complexity, by exploring different shapes of S-duct, in order to assess the limits of the proposed method.

References

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