Research position / Starting as soon as possible / 12 months

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Generating swirl inlet distortion for low fan-pressure propulsors

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Context

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, motivating research on 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 recreating swirl distortion on a turbofan test bed, using vortex generators and turbulence screens, designed through numerical simulation and shape optimization.

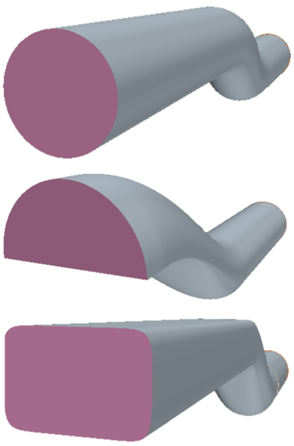

Fig. 1. S-duct configurations under study.

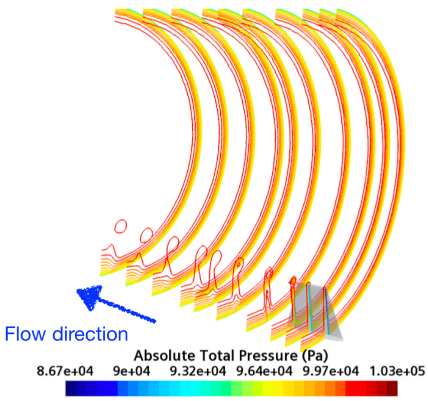

Fig. 2. Numerical study of the flow generated by a tapered wing under incidence in a cylindrical duct

Fig. 3. Turbofan experimental setup

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.

We aim 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

[1] W. Pazur et al., Turbo Expo: Power for Land, Sea, and Air, 1990.

[2] N. R. Schmid et al., Journal of Turbomachinery, 2001.

[3] S. Farokhi, Propulsion system design with smart vortex generators, Aircraft Design, 1998.

[4] T. Guimarães et al., Journal of Propulsion and Power, 2018.

currently being developed using an in-house CST-curve based geometry parameterization method, and available surrogate-based, gradient-free optimization methods. In parallel, an experimental setup is in preparation in a turbofan test bed.

Proposed work

The experiment currently features a set of turbulence screens that have been designed to generate different stagnation pressure profiles. A prototype vortex generator has been designed, and an update of the experimental setup has been commissioned to be able to place the vortex generator at different positions in the turbofan intake, in different combinations with the turbulence grids. The aim is to provide an experimental database to validate the concept.

The successful candidate will join the ongoing experimental campaign to characterize the turbulence screens by traversing the flow using five-hole probes and hot-wire anemometry. This data will be used to validate the grid design process, and study the fan performance under boundary layer ingestion. The next step will be to design a series of experiments to determine how to combine vortex generators with turbulence screens to recreate realistic flows featuring both swirl and total pressure distortion effects, typical of S-duct intakes. In particular, we will investigate experimentally how a vortex generator affects the total pressure and turbulence intensity profiles generated by a turbulence screen placed downstream, and, in turn, how a turbulence screen would affect a vortex generator that would be placed downstream.

RANS numerical simulations will be conducted in parallel to gain understanding on the driving flow structures. We will tackle questions such as the influence of the distance to the fan downstream, the importance of unsteady flows, and the influence of incident turbulence levels.

Finally, the experimental results will be used to study the impact of the resulting distortion on the turbofan performance. We will develop 0D performance model using PROOSIS, based on the parallel compressor theory to describe the fan performance under distortion, and validate against the experiments.

Requirements

We are looking for an enthusiastic engineer with an MSc degree in engineering in Fluid Mechanics, Energetics or a closely related discipline, and experience in computational and experimental fluid dynamics. Experience in scientific programming for post-processing of experimental data will be highly regarded.

Excellent English, communication and reporting skills are required. Comfort with working both independently and in a team, as well as a pro-active, problem-solving and result-oriented work attitude is highly regarded. The candidate is expected to contribute to the dissemination of research results and publication writing.

Information and Application

The position is open for a 12-month fixed-term period.

For more information about this position, please contact Dr. Nicolás García Rosa (nicolas.garcia_rosa@isae-supaero.fr).

Applicants should submit their letter of application along with a detailed curriculum vitae and all other information that might be relevant to Dr. Nicolás García Rosa (nicolas.garcia-rosa@isae-supaero.fr).