Post-doc proposal / Starting as soon as possible / 12 months, with possible extension

Ref. 2023SDUCT-postdoc

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.

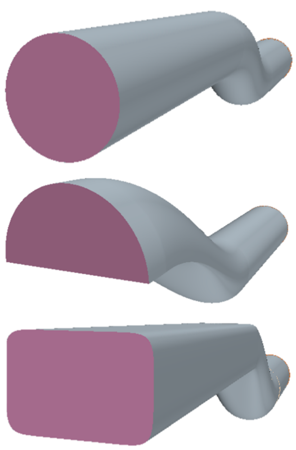

Fig. 1. S-duct configurations under study.

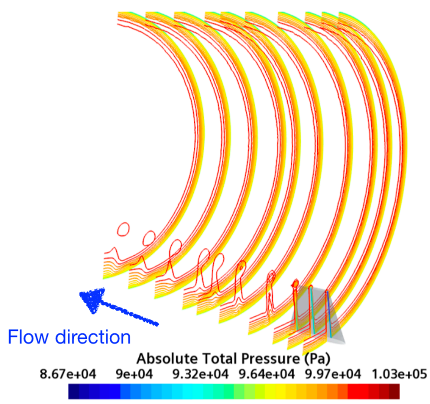

Fig. 2. Numerical study of the flow generated by a tapered wing under incidence in a cylindrical duct

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.

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

[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

We will begin by studying the flow in a variety of S-duct configurations (using RANS or URANS simulations) to provide practical target flows, define relevant distortion metrics, and gain understanding of the mechanisms involved in the generation of swirl distortion. 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 a design model, using a combination of potential flow models and CFD-based surrogate models. In both numerical studies, we will address key questions such as the influence of the vicinity of a fan downstream (using body-force RANS simulations), the influence of inflow turbulence conditions, as well as the importance of considering unsteady flows. Special attention will be given to defining relevant metrics to capture the vortical structures at fan inlet, serve as target in the vortex generator design procedure, and measure the agreement with the target flow.

A prototype will be designed to perform experiments in the turbofan test bed, including five-hole-probe and hot-wire measurements. Experiments will be used to validate the vortex-generator design procedure, and determine how to combine vortex generators with turbulence screens to recreate realistic flows including swirl distortion and total pressure distortion effects, typical of boundary layer ingestion configurations. In particular, we will study 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.

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.

Requirements

We are looking for an enthusiastic researcher with a PhD degree in Fluid Mechanics, Energetics or a closely related discipline and a strong background in computational fluid dynamics, modelling and post-processing techniques. Experience in CFD of turbomachinery, optimization or scientific programming in Python will be highly appreciated.

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 publish and participate in an international conference, as well as in the regular internal project status reports.

Information and Application

The position is open for a 12-month fixed-term period, with a possible extension after the first 12 months.

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, a list of publications, title and abstract of PhD dissertation, contact information of at least one academic reference and all other information that might be relevant to Dr. Nicolás García Rosa (nicolas.garcia-rosa@isae-supaero.fr).