



DynFluid - Ecole Nationale Supérieure d'Arts et Métiers

Post-doctorate position for CleanSky project PERSEUS:

High-fidelity simulation of the internal flow in a pulsed jet actuator

1 Context and objectives

The take-off and landing are critical flight phases where the pitch of the airplane and the angle of attack with respect to the air flow may lead to detrimental effects such as the onset stall and an increase of drag for mild lift increase. Although the stalling process is now well documented, the physics of turbulent boundary separation, and in particular its control using active methods is still a very active area of research. While progress in flow control, based on laboratory experiments shows promising potential, the upscaling phase targeting full scale aircraft remains a challenge posed by the overall efficiency of the embedded system into the aircraft [5]. So far, embedded active flow control devices leading to a net gain in the energy balance on a full-scale aircraft remains an open issue. To tackle this issue, the investigation of possible solution to improve the effectiveness of flow-control based on net-mass-flux Pulsed Jet Actuators (PJAs) to reattach the boundary layer has been defined as one of the objectives of the CleanSky2 JU program (JTI-CS2-2019-CFP10-AIR-02-77 - *Increasing the efficiency of pulsed jet actuators for flow separation control*).

In this context, the PERSEUS (Pulsed jEt actuatoRs for SEparation control of tUrbulent flowS) project, funded by European Union CleanSky2 program, has started in September 2020 for 30 months. This project will combine wind tunnel experiments with numerical simulations and a sensitivity analysis to improve the control authority of pulsed jet actuators (PJAs) to separated turbulent flows over a 2.5D airfoil equipped with a flap. The target of this approach is to determine the minimum net-mass-flux required by PJAs to compensate for the momentum deficit in the boundary layer. The two main objectives are 1) to design a new generation of PJAs, 2) to develop a new methodology to optimize the PJA design (size, aspect ratio) as well as its operating parameters (location, amplitude and frequency). The project is built on the complementary partners' experiences in fluidic oscillators PJAs design, manufacturing, and ground testing (ICA/INSA Toulouse), high-fidelity numerical simulations of compressible flows (DynFluid/ENSAM), fluid flow optimization for active control of separated flows (DynFluid/ENSAM and Prisme/Univ. Orléans) and wind-tunnel model design and testing (Prisme/Univ. Orléans and ICA/INSA Toulouse).

The objective of the present post-doctoral research project (12 months at DynFluid/ENSAM) is to contribute to optimization and characterization of PJAs, by using high-fidelity numerical simulations. Compared to steady blowing methods, the active flow control based on periodic fluidic excitations is much more efficient. We are interested in actuators without moving parts that rely purely on unsteady fluid dynamics created by particular

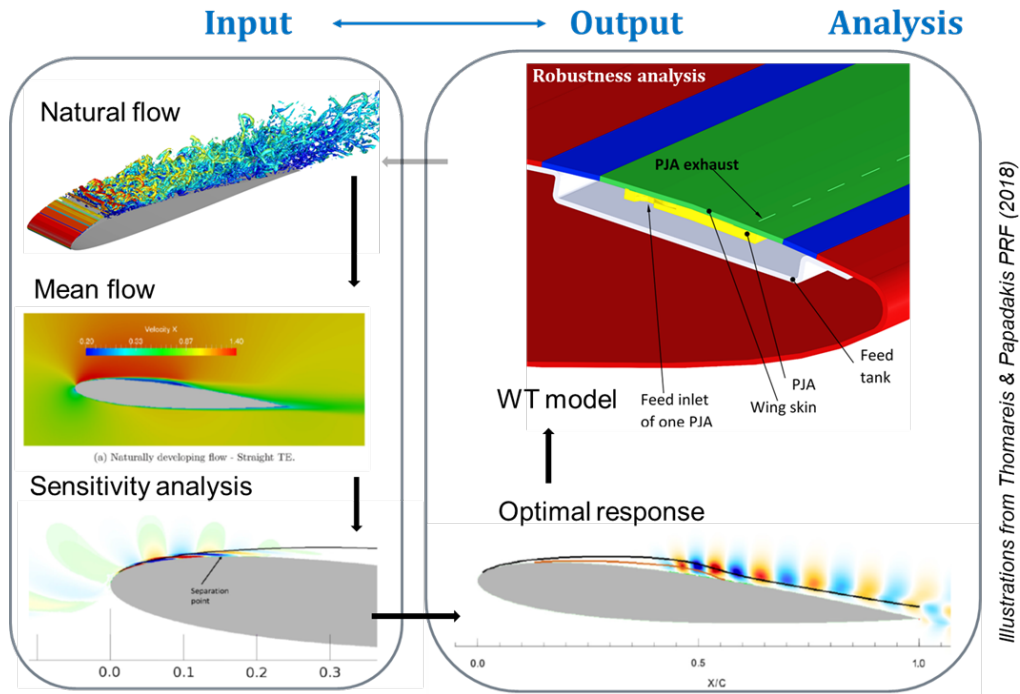


Figure 1: Schematic of the overall strategy of the PERSEUS project.

geometries and recirculation loops, such as fluidic oscillators [1, 2, 3, 4, 5]. They can be considered as a great advantage for active flow control in terms of reliability and robustness [3]. Since the oscillations are totally self-induced and self-sustained and only dependent on the internal flow dynamics, fluidic oscillators can emit periodic jets in a wide operating frequency and velocity ranges when supplied with a pressurized fluid.

2 Work plan

The present work would explore and analyze new PJA fluidic oscillator designs and will help improving their performances. For that purpose, numerical simulations will be carried out. On one side, the INSA team will develop low-fidelity numerical models of the fluidic oscillators using the open source CFD solver OpenFOAM and/or FLUENT software, based on their previous experience on similar PJA (Fig.2a from Wang's thesis [4]). This preliminary approach will permit to define the main geometrical characteristics of the oscillators allowing to reach the desired performances in terms of oscillation frequency and blowing flow rate. High-fidelity compressible large-eddy simulations will then be performed at ENSAM to get further insights into the flow dynamics and performances of the fluidic actuator for the pre-selected configuration. High-fidelity simulations of compressible flows in fluidic oscillators remain scarce. To our knowledge, the only work exploring this issue was recently published by Kim *et al.* [6] (Fig.2b). DynFluid's compressible flow solver MUSICA2 based on high-order numerical algorithms [7] will be used to simulate the PJA internal flow. The computational domain will include the fluid region from the PJA inlet to the exit tubes (see Fig.2). Wall-resolved LES is planned on structured multi-block curvilinear grids. One of the objectives of the high-fidelity simulations is to provide a detailed analysis of the link between the inlet flux and the exit mass flow rate and velocity considering fluid compressibility. In particular, the shape and amplitude of the velocity profiles of the jets at the exit of the actuators will be compared to URANS simulations and experimental data. Spectral and modal decomposition, such as SPOD (Spectral Proper Orthogonal Decomposition) can be used to analyse the compressible flow dynamics in the fluidic oscillator.

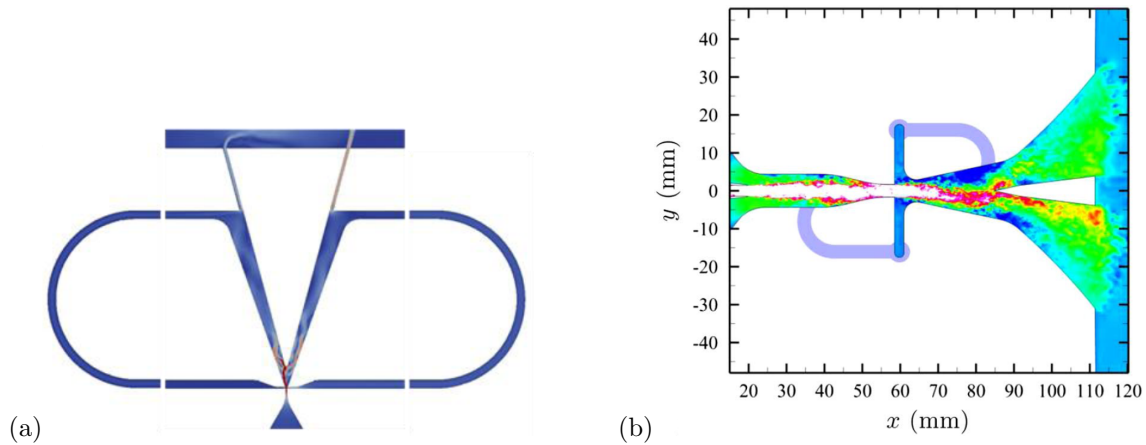


Figure 2: (a) OpenFoam simulation of a micro-fluidic oscillator for flow separation control [3, 4]. (b) Large-eddy simulation of an oscillatory blowing fluidic actuator (instantaneous contours of streamwise velocity) [6].

Duration: 12 months (starting: September 2021)

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