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Design and evaluation of pulsed jet actuators (PJAs) network for active flow control on NACA-4412 profile

Guillermo López Quesada

*Lucien Baldas, Stéphane Orioux, Ahmad Batikh, Nicolas Mazellier
GDR - Contrôle de Décollements*

09/11/2021

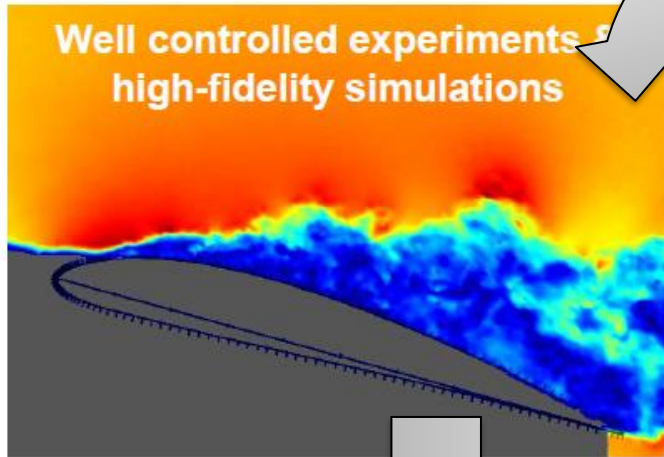
- Introduction
- Working principle of the fluidic oscillator
- Validation of numerical tools
- Design of PJAs for the NACA-4412
- Definition of the PJAs assembly
- Manufacturing of the PJAs assembly
- Analysis approach
- Results:
 - First prototype
 - Round splitter
- Conclusions and perspectives

Pulsed jET actuatoRs for SEparation control of tURbulent flowS

- CleanSky 2 - RIA
 - JTI-CS2-2019-CFP10-AIR-02-77
 - Increasing the efficiency of pulsed jet actuators for flow separation control
- Consortium
 - University of Orleans (PRISME)
 - INSA Toulouse (ICA)
 - ENSAM Paris (Dynfluid)



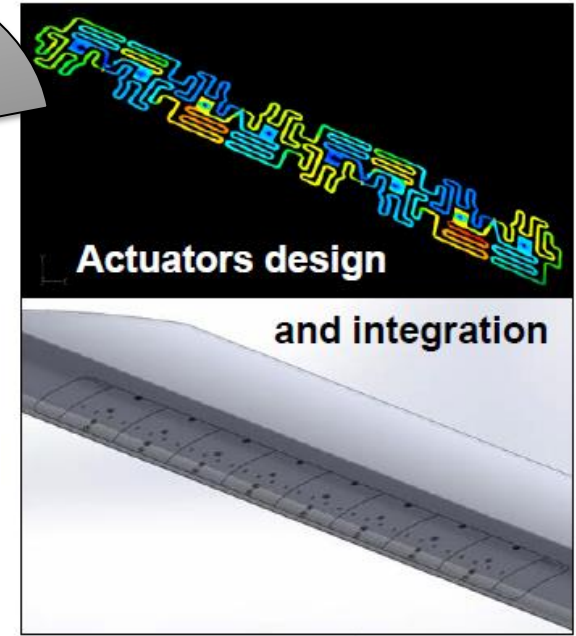
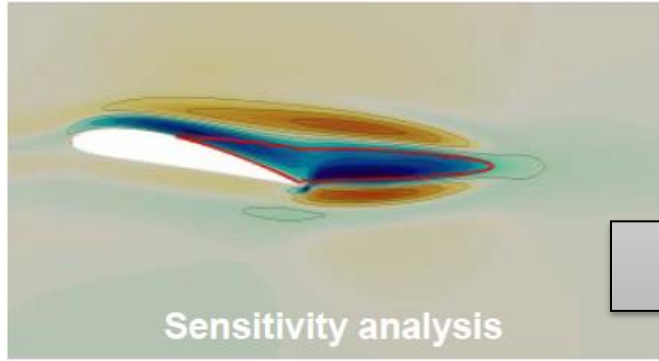
Introduction: PERSEUS strategy



Design and optimization of PJAs for lift configurations

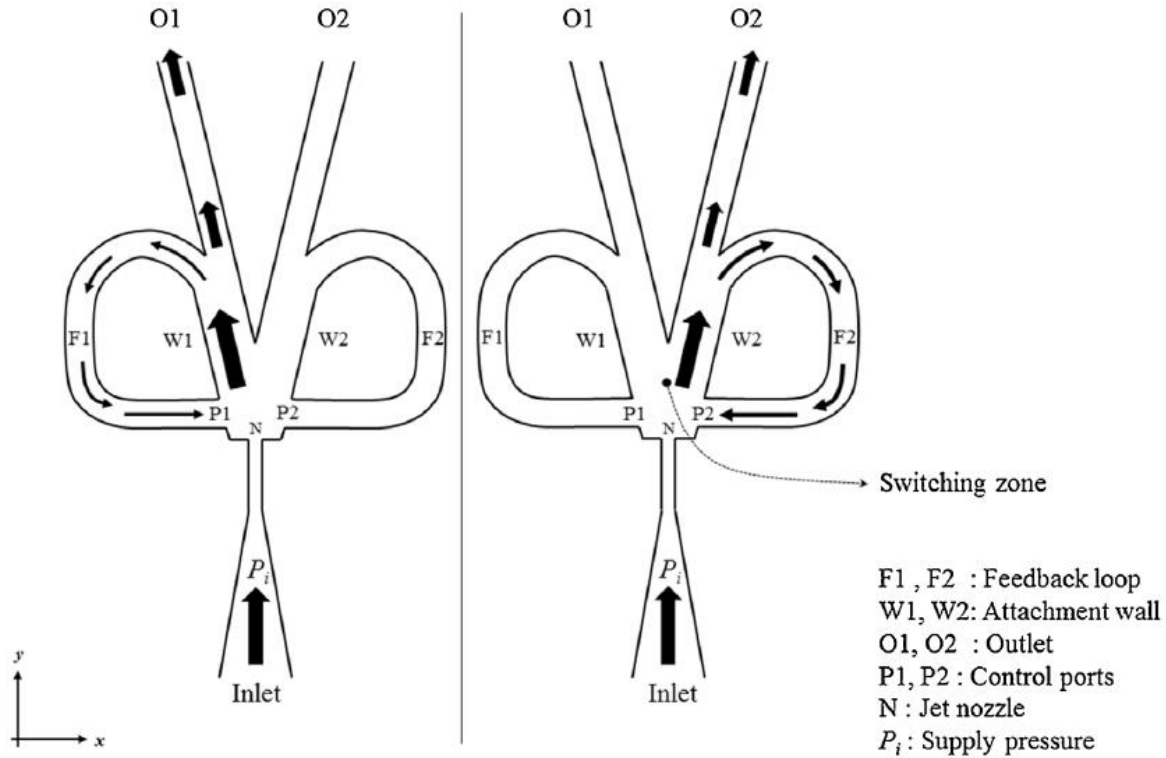
Reduced net mass-flux

Increase gain of Active Flow Control



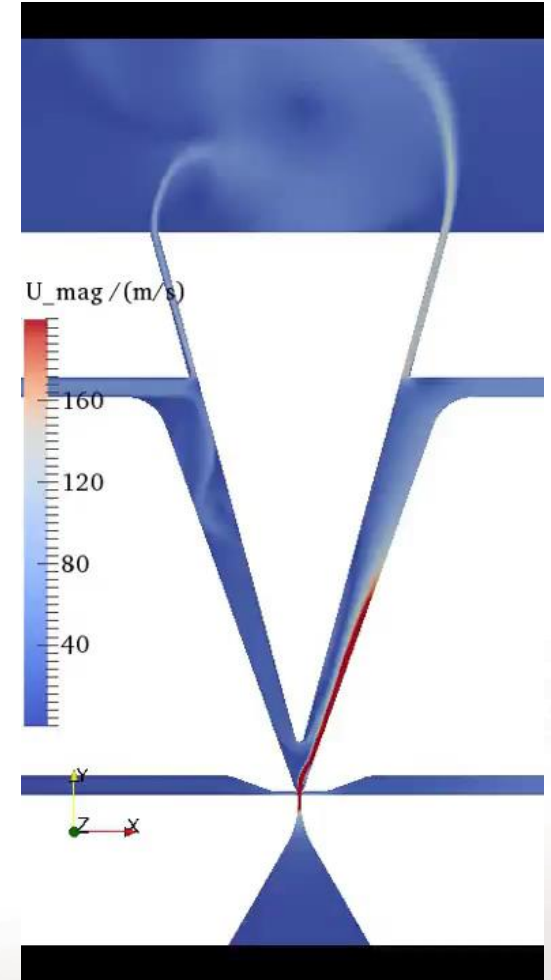
Working principle of fluidic oscillators

Jet oscillation mainly caused by the pressure wave propagation in the two feedback loops alternatively



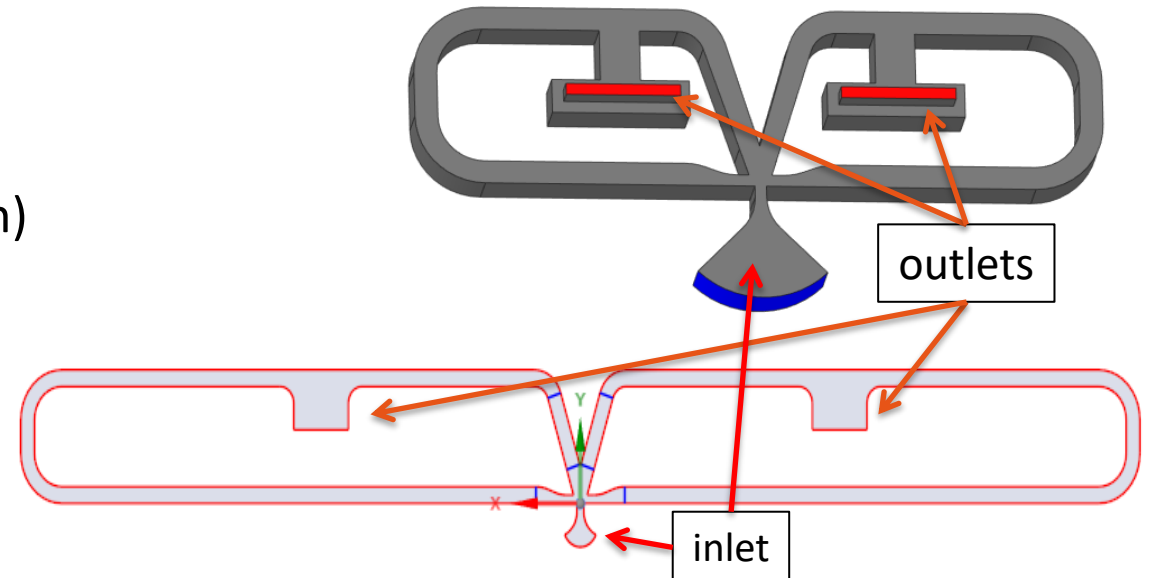
Pressure

Velocity



(Wang 2019)

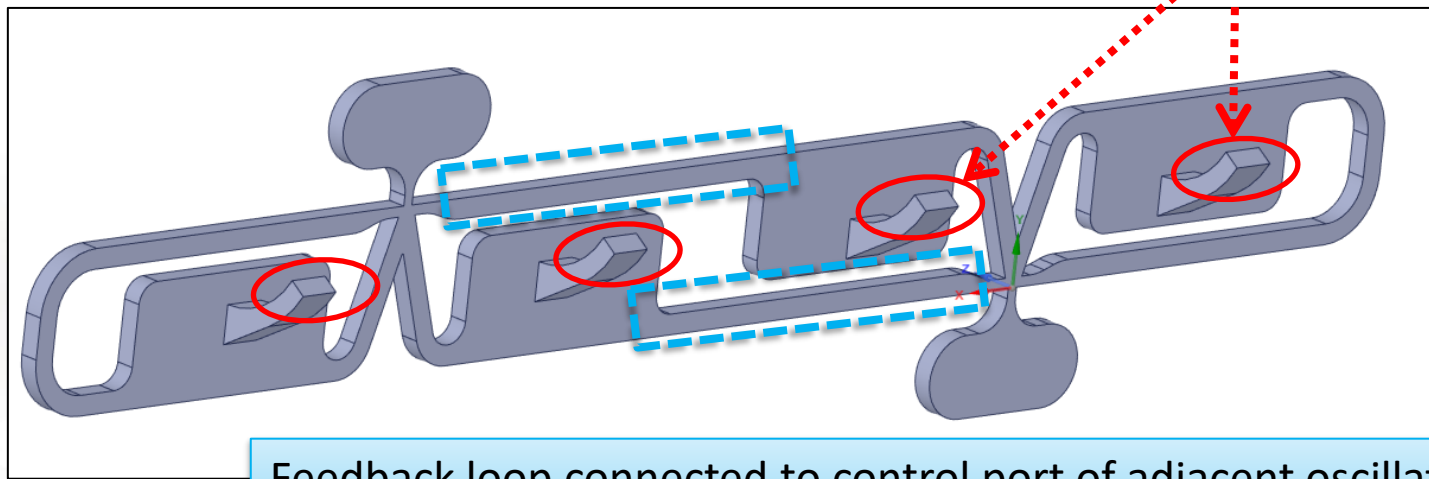
- CFD simulation with ANSYS FLUENT
 - K-epsilon turbulent model
- Sensitivity analysis 3D and 2D (18 different cases run)
 - Mesh quality (20k, 40k, 80k cells) $\leq 5\%$
 - Time step size (1e-5s, 5e-6, 1e-6, 1e-7) $\leq 2\%$
 - Discretization schemes (1st order, 2nd order) \approx same



3D and 2D simulations performed
validated with hot wire anemometer

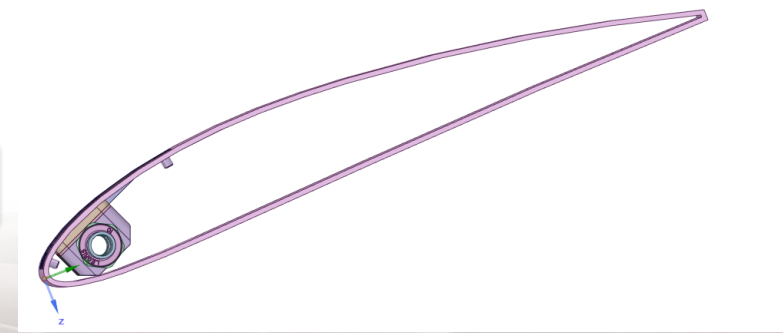
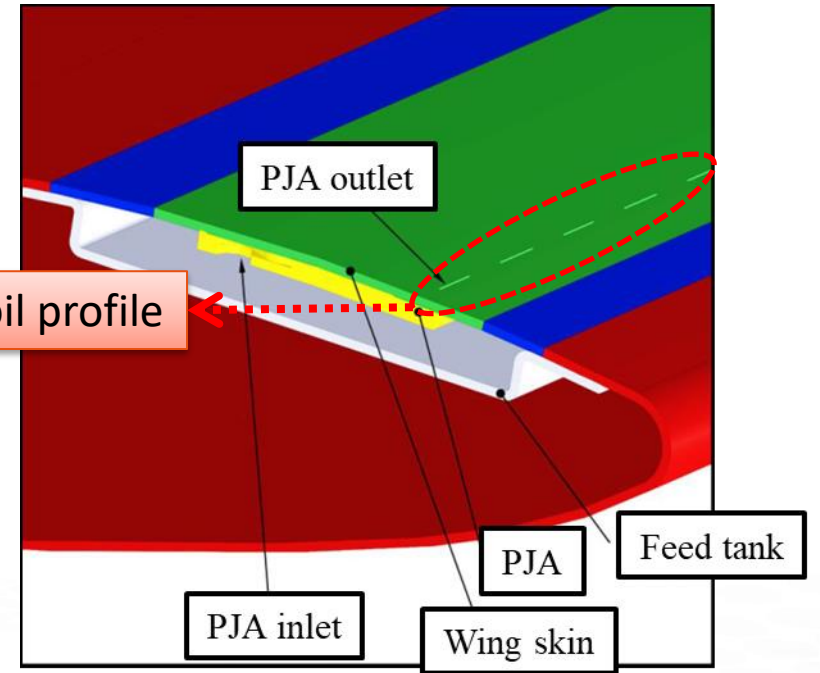
$F=1416$ Hz
 $V=20-120$ m/s at $P_i=3$ bar

- Adaptation of the PJAs for the implementation on the airfoil
 - Direction of the outlet
 - Synchronisation
 - Dimensional constraints (few centimeters)

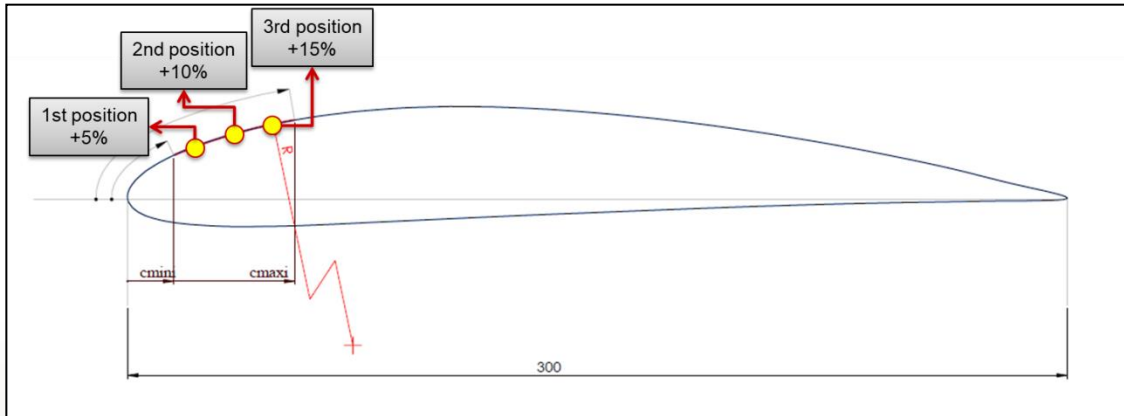


Feedback loop connected to control port of adjacent oscillator

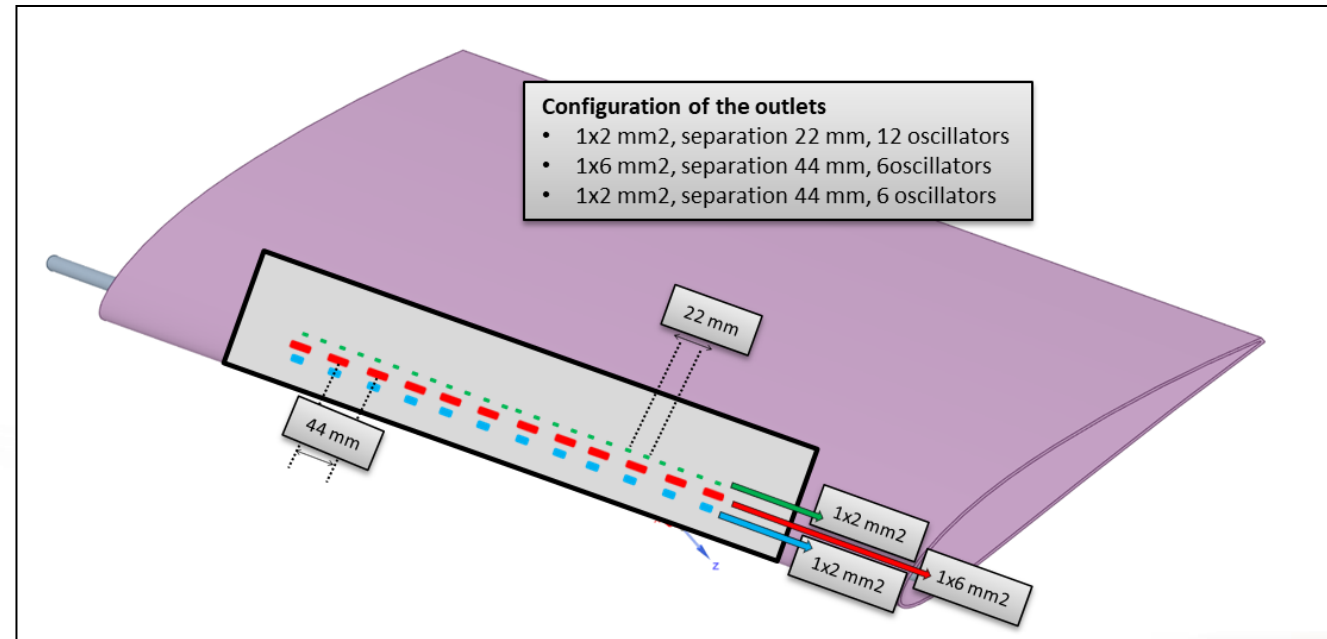
Outlets tangential to the airfoil profile



3 positions to be tested

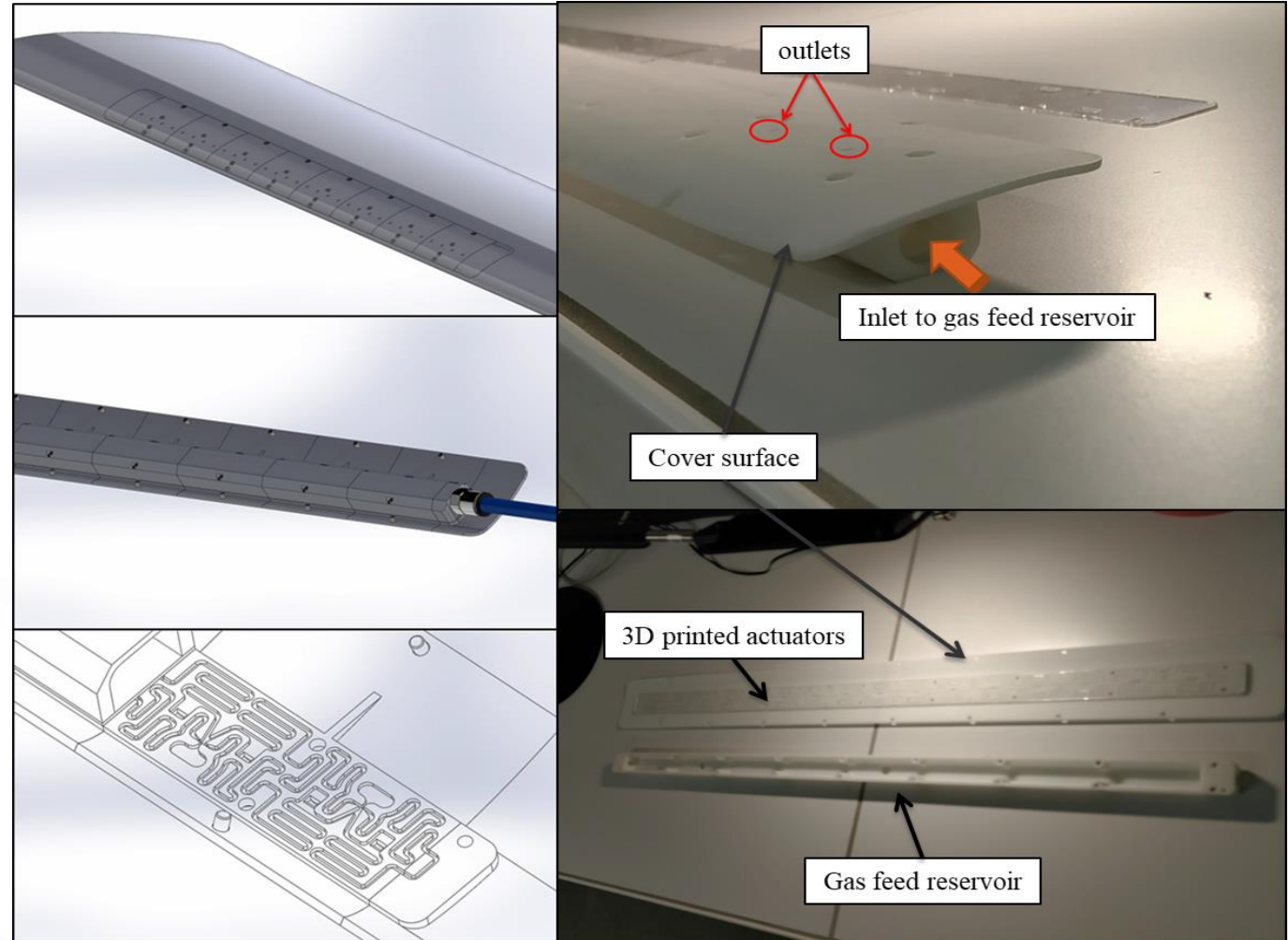


3 different aspect ratios-separations



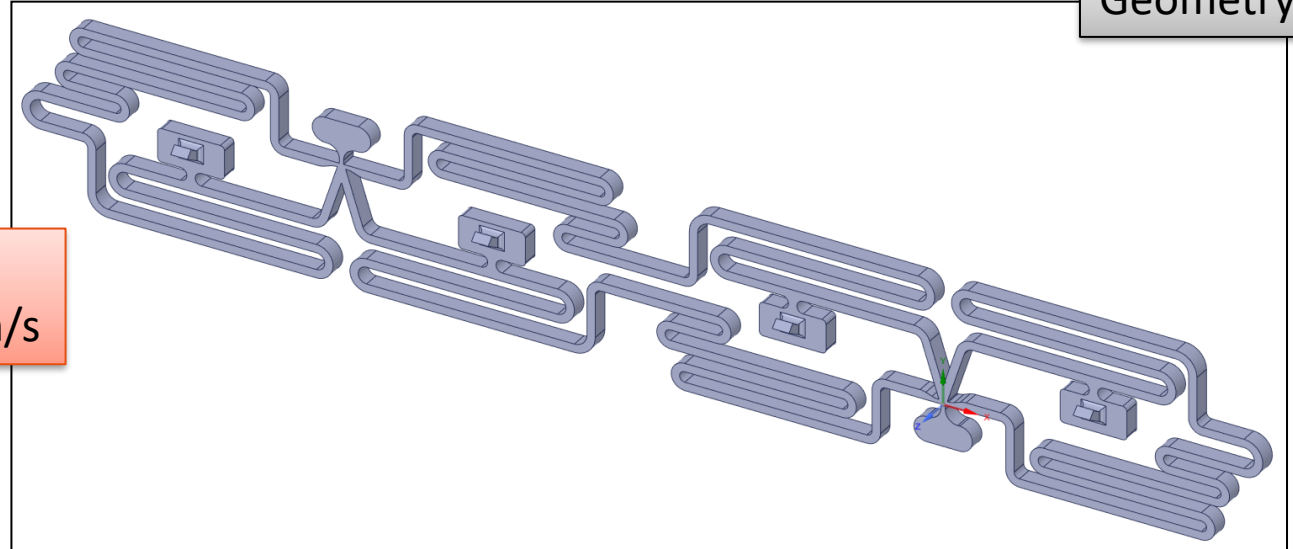
Manufacturing: 3D printing in one piece

- Minimum number of connections
- Profile smooth and perfectly adapted to the airfoil
- Outlet channels tangential to the profile
- Cost effective solution
- **A different actuator assembly for each configuration**



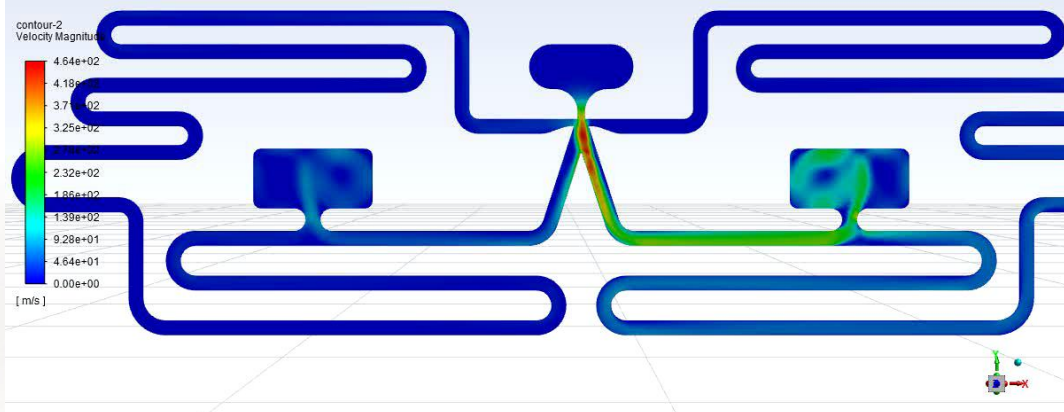
- First prototype:
 - Feedback loop length ≈ 190 mm
 - Feedback loop width ≈ 1 mm
 - Depth ≈ 2 mm

Geometry

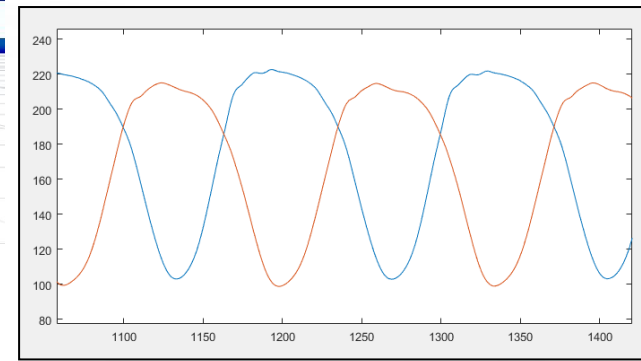


CFD Frequency ≈ 743 Hz
 Vel. Amplitude ≈ 100 -220 m/s

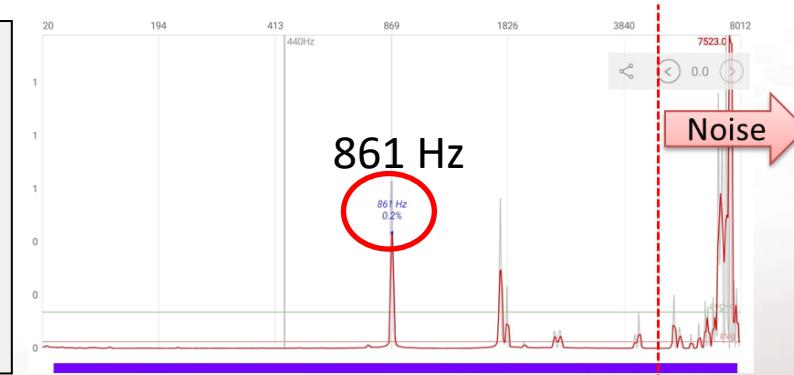
Velocity fields (CFD)



JET DOES NOT COMPLETELY SWITCH



Avg. Velocity outlets (CFD)

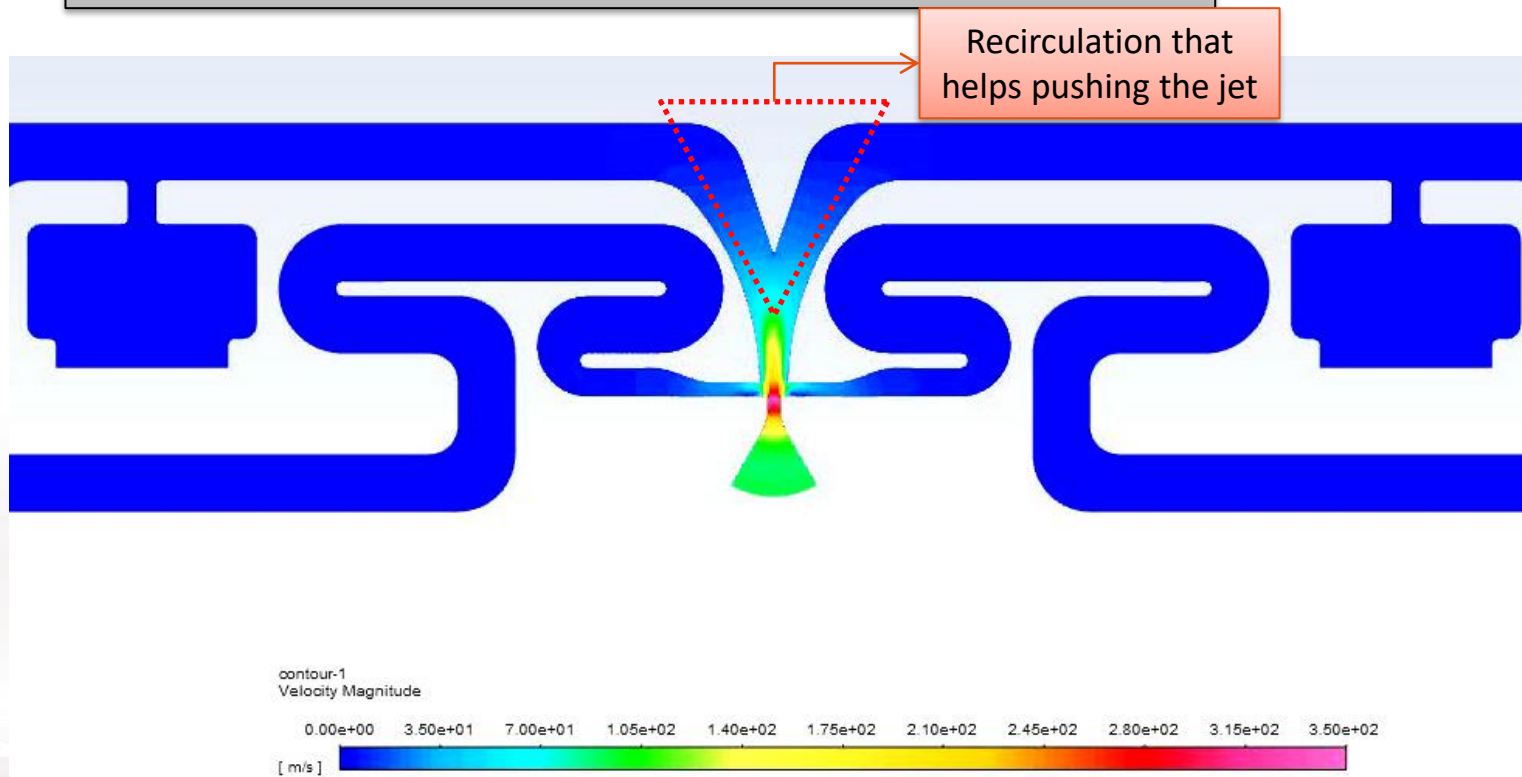


Measured frequency spectrum

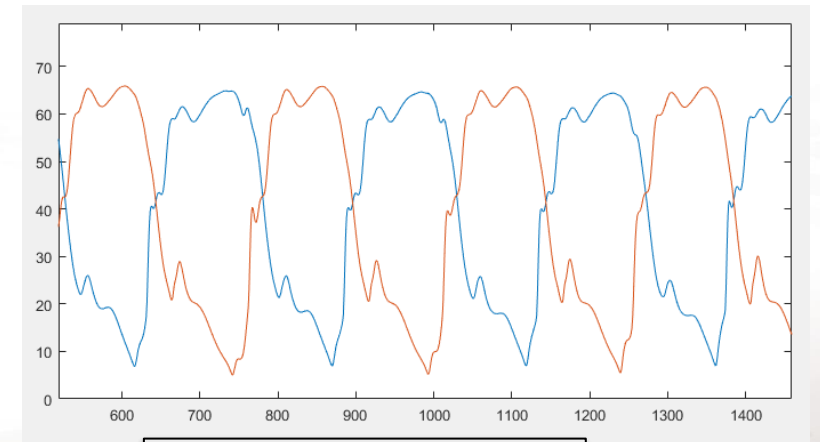
- Modifications of the feedback loop:
 - Increase of the width
- Modifications on splitter:
 - Width of the splitter
 - Radius of the splitter corner
 - Angle of the splitter walls

Results: round splitter

- Rounded walls to induce smooth attachment
- Increased distance from inlet to splitter
- Increased width of the channels



- Model with round splitter:
 - Feedback loop length ≈ 137 mm
 - Feedback loop width ≈ 2 mm
 - 2D



Avg. Velocity outlets (CFD)

- **Conclusions:**

- The design of a PJAs assembly has been proposed and adapted to the constraints of a NACA-4412 profile
- The numerical tools used for the design of the PJAs has been verified and a sensitivity analysis has been done
- A preliminary prototype was fabricated for its implementation in the wing
- A new design with round splitter walls has been proposed to improve the switching of the jet

- **Perspectives:**

- 3D validation of model
- Fabrication and characterization (hot wire anemometer) of the new prototypes with round splitter walls
- Implementation and testing of the PJAs in the airfoil
- PJAs with different phases and/or multi-frequency

