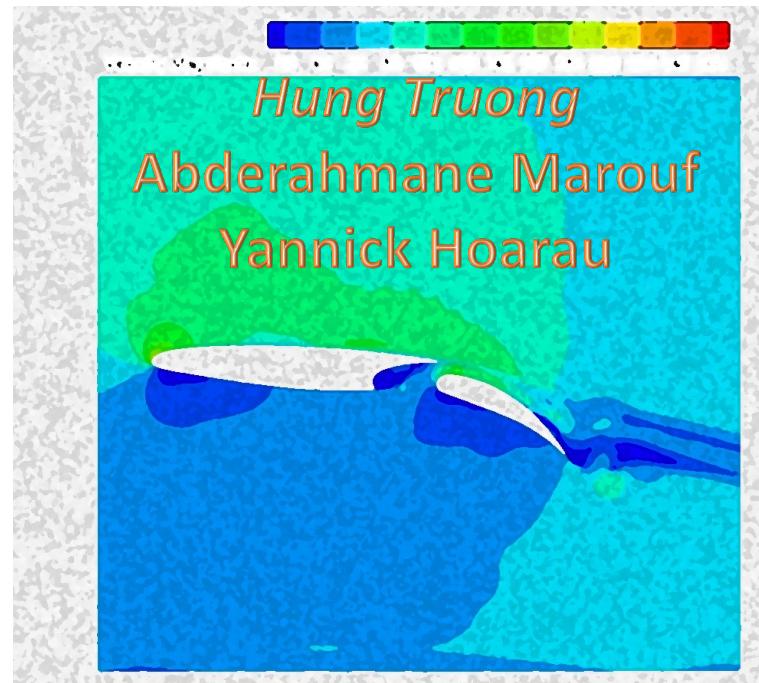




Unsteady CFD simulations for Active Flow Control on a High-lift Wing-Flap system



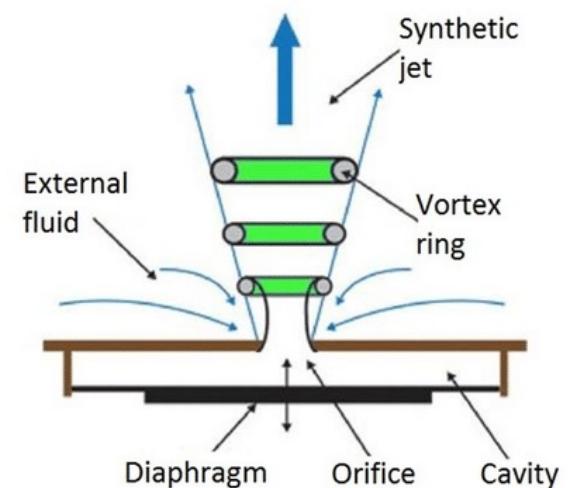
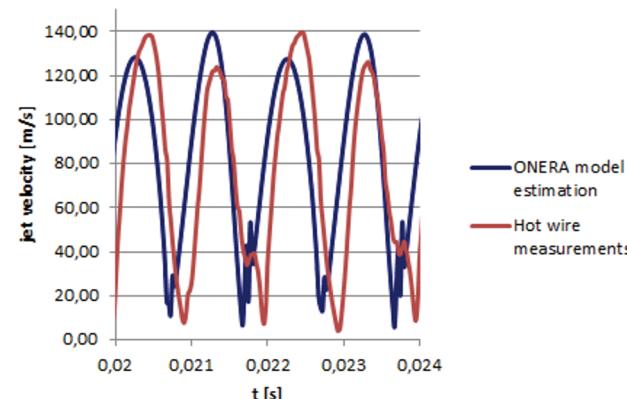
GDR 2502 Flow Separation control
Futuroscope, 09/11/2021

Introduction

Context



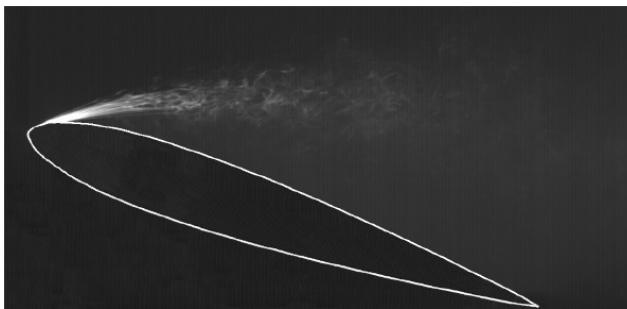
- Investigate the use of Active Flow Control using synthetic jets - Zero Net Mass Flux (ZNMF) devices
 - ✓ No air supply is required since the air is sucked from the main flow
 - ✗ Constrain of peak velocity
- Perform a multi objective optimization study to optimize the location and parameters of the ZNMF devices



https://www.researchgate.net/figure/Synthetic-jet-a-instantaneous-b-time-averaged_fig1_310437397

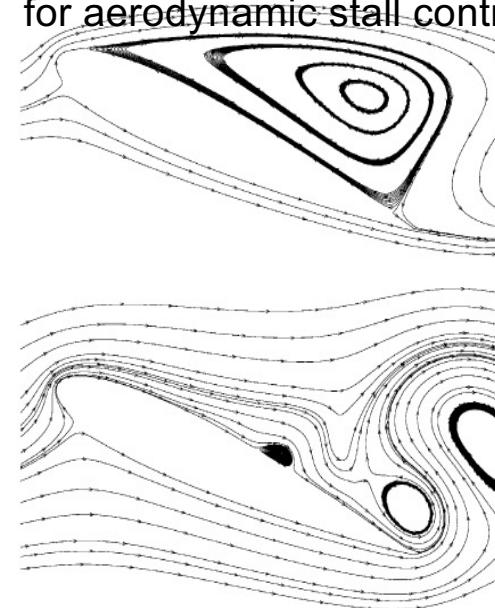
Previous studies

Experimental studies of AFC
over a NACA 0015 Airfoil
using a ZNMF Jet



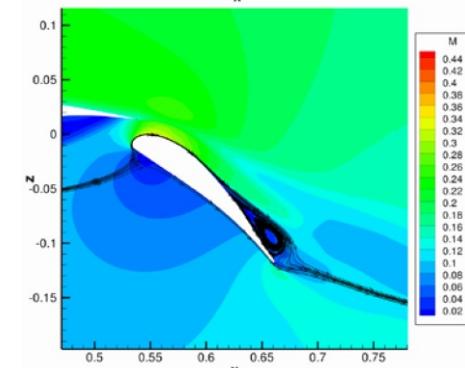
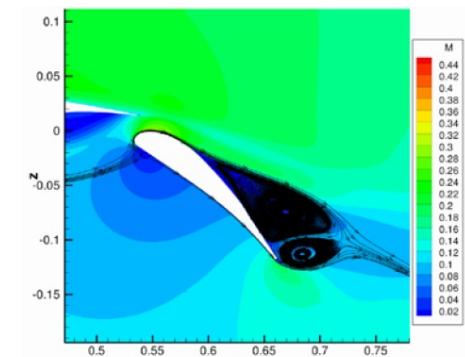
Tuck and Soria 2014

Optimization of a synthetic jet
actuator
on a NACA 0015 airfoil
for aerodynamic stall control



Duvigneau and Visonneau 2006

Numerical studies conducted for
pulsed blowing devices
on 2D high-lift configurations DLR-

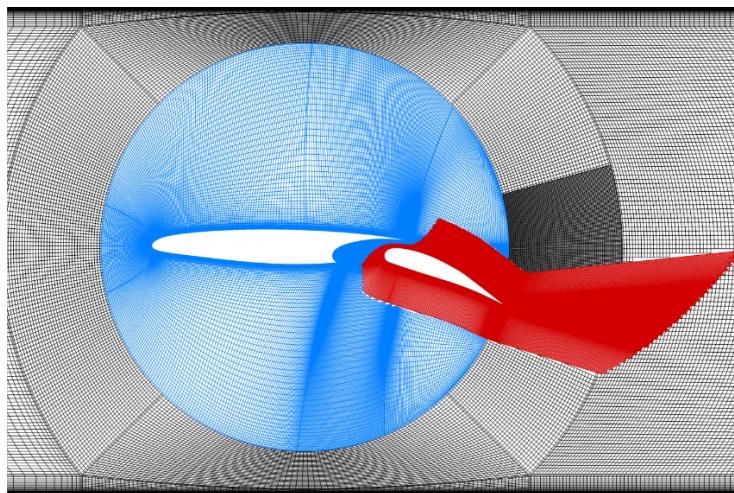


Ciobaca et al. 2012

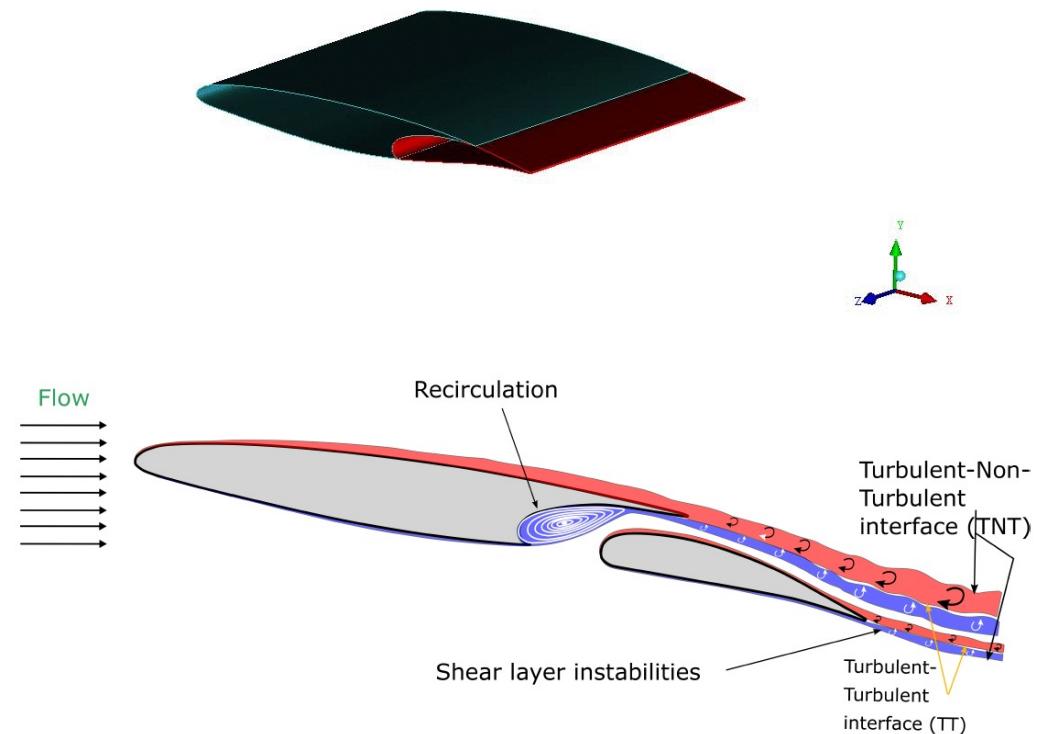
Numerical methods and ZNMF modeling

CFD Solver & Numerical Methods

- *NSMB solver: Navier Stokes Multi-Block code*

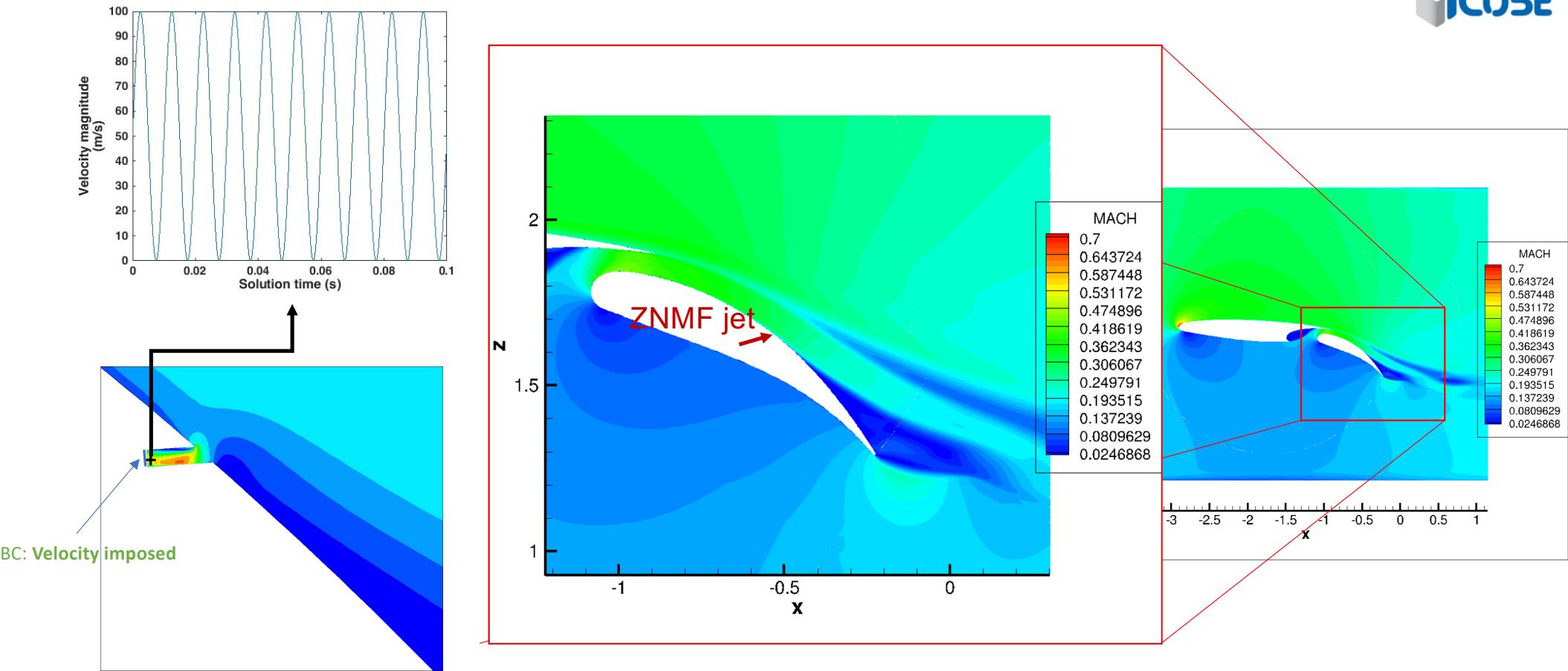


U_∞	68 m/s
Re	4.6×10^6
Ma	0.2
α°	$0^\circ - 8^\circ$
δ	$10^\circ - 40^\circ$



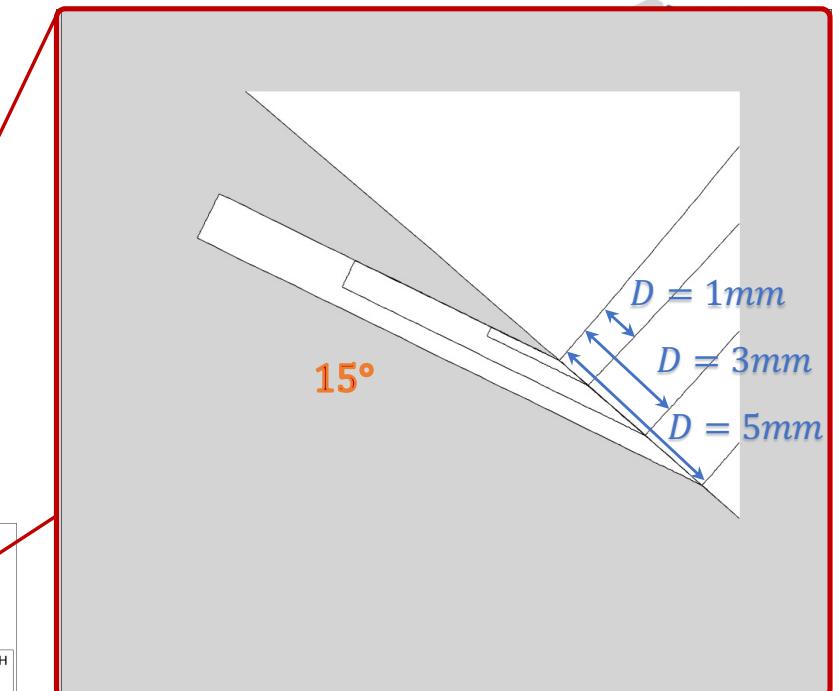
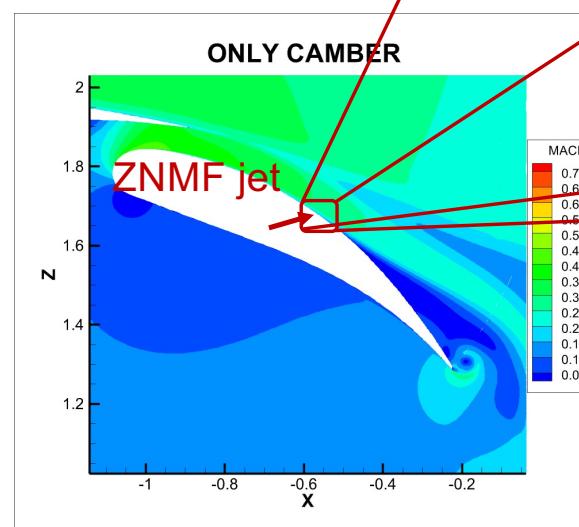
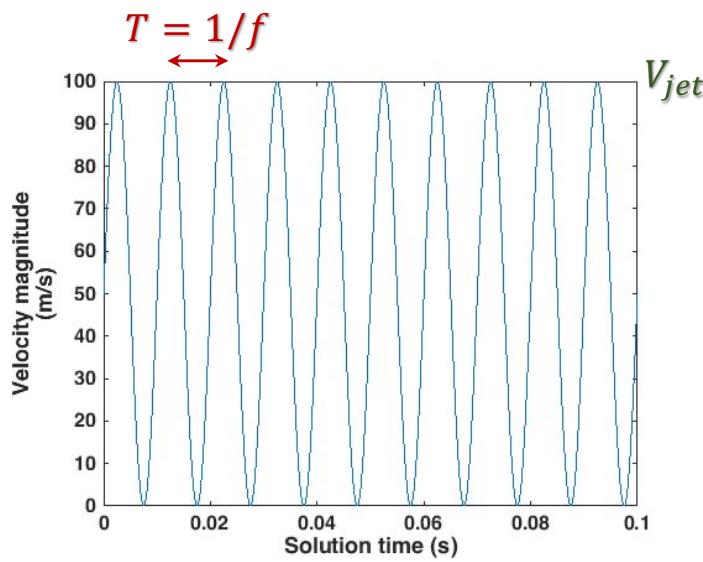
- *Turbulence model: Spalart Allmaras*

ZNMF actuators for flow separation control



Optimisation of the ZNMF jet parameters

- Jet frequency f
- Jet peak velocity V_{jet}
- Jet location
- Jet shape D/H
- Jet orientation



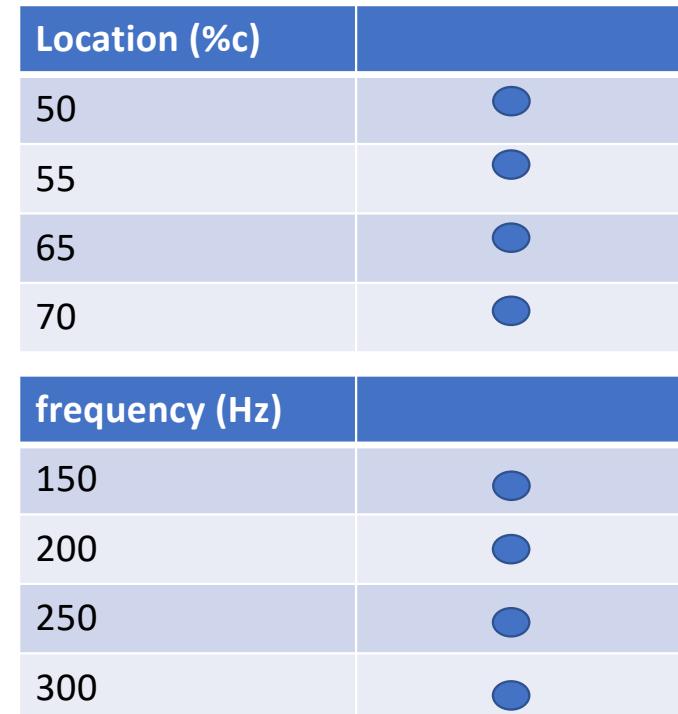
Results & Discussion

Optimisation of the ZNMF jet parameters

- Fixed jet dimensions 45°, 5mm

Velocity [m/s]	Frequency [Hz]				
	20	50	100	150	200
70	●	●	●	●	●
100	●	●	●	●	●
150	●	●	●	●	●
200	●	●	●	●	●

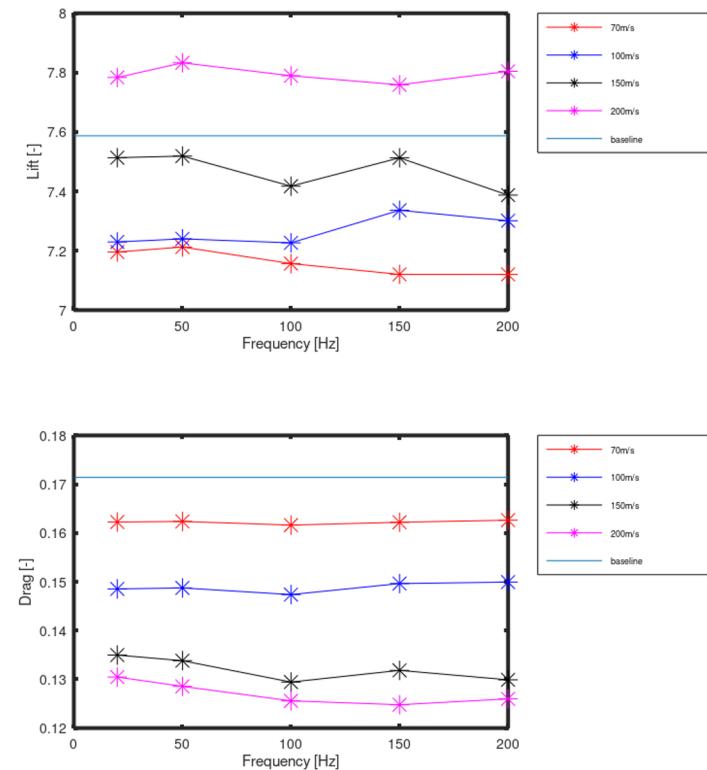
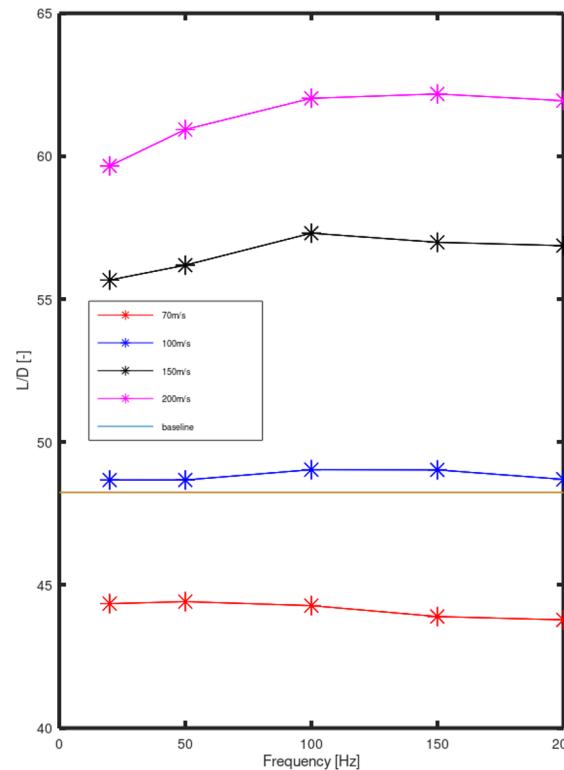
- Fixed jet dimensions 45°, 1mm



Optimisation of the ZNMF jet parameters

- Fixed jet dimensions 45°, 5mm

Cases	C_l	C_d	Lift-to-Drag
70m/s			
20Hz	-5.2%	-5.7%	-7.6 %
50Hz	-4.9%	-5.6%	-7.4 %
100Hz	-5.7%	-6.03%	-7.74 %
150Hz	-6.19%	-5.7%	-8.5%
200Hz	6.187%	-5.45%	-8.9%
100m/s			
20Hz	-4.75%	-13.7%	1.4%
50 Hz	-4.61%	-13.65%	1.41%
100Hz	-4.79%	-14.32%	2.16%
150Hz	-3.4%	-13%	2.15%
200Hz	-3.8%	-12.83%	1.46%
150m/s			
20Hz	-1%	-21.53%	15.9%
50Hz	-0.93%	-22.2%	17.1%
100Hz	-2.27%	-24.7%	19.39%
150Hz	-1.01%	-23.35%	18.73%
200Hz	-2.67%	-24.48%	18.49 %
200m/s			
20Hz	2.55%	-24.15%	24.95%
50Hz	3.2%	-25.26%	26.95%
100Hz	2.63%	-26.9%	29.2%
150Hz	2.23%	-27.45%	29.54%
200Hz	2.85%	-26.7%	29.05%



Optimisation of the ZNMF jet parameters

Different locations

- Fixed jet dimensions 45°, 1mm

Jet velocity=200m/s

frequency (Hz)	C_l	C_d	Lift-to-Drag
150	-0.61%	-21.02%	15.69 %
200	-1.21 %	-21.68%	15.9 %
250	-0.87%	-21.57%	16.19 %
300	-0.64%	-21.46%	16.23%

Separation point

Location (%c)	C_l	C_d	Lift-to-Drag
50	-1.96%	-15.63%	6.83 %
55	-1.33 %	-18.31%	11.04 %
65	-0.46%	-19.22%	13.2 %
70	-0.02%	-23.17%	19.56%

Optimisation of the ZNMF jet parameters

Shape optimisation

NEW CASES :

| 1 | 60 | 1.0 | 15 | 0.2584000164180948 | V=Q/D=***176,7244375/**0,2584000164180948= 683,918 m/s

RUN | 4 | 60 | 3.0 | 15 | 0.7809431719217895 | V=Q/D= **176,7244375**/0,7809431719217895 = 226,296

RUN | 7 | 60 | 5.0 | 15 | 1.30165528528316 | V=Q/D= **176,7244375**/1,30165528528316= 135,769

RUN | 2 | 60 | 1.0 | 30 | 0.4997186801380233 | V=Q/D= **176,7244375**/0,4997186801380233 = 353,64785

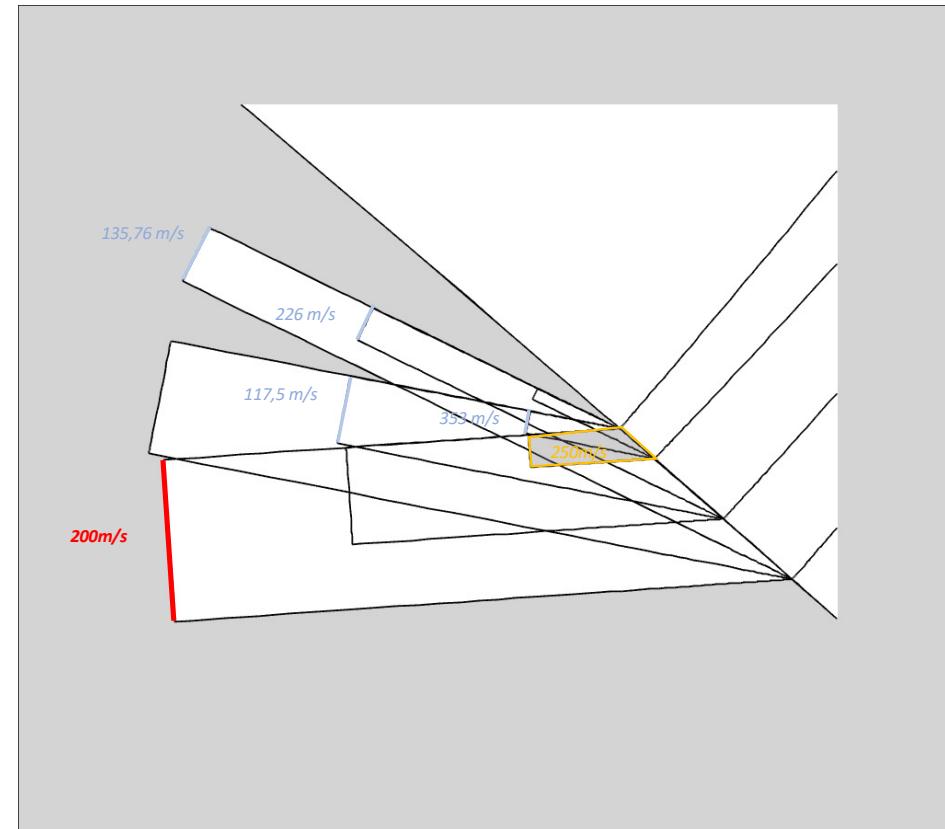
RUN | 5 | 60 | 3.0 | 30 | 1.504052613272536 | V=Q/D= **176,7244375**/1,504052613272536 = 117,49884

| 8 | 60 | 5.0 | 30 | 2.506799708017016 | V=Q/D= **176,7244375**/2,506799708017016=70,498

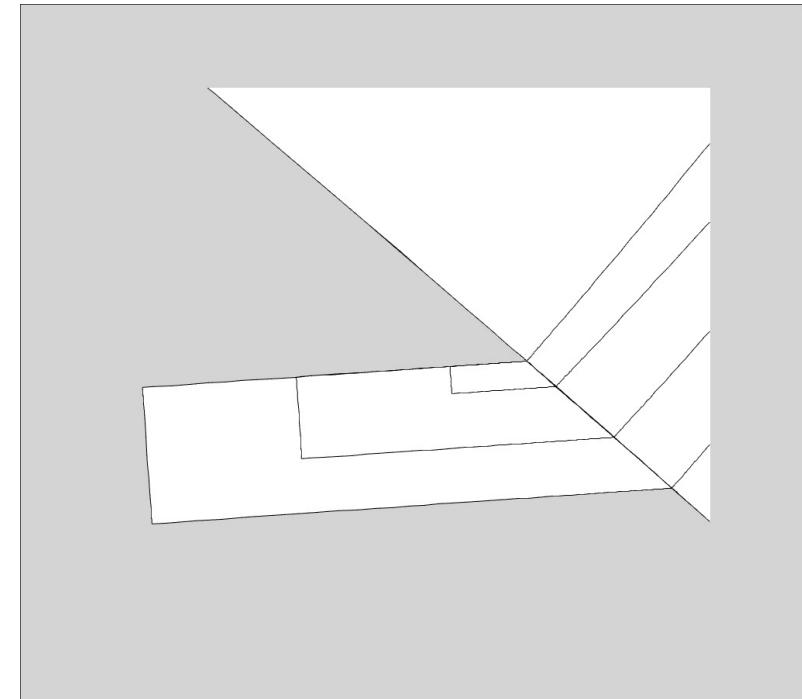
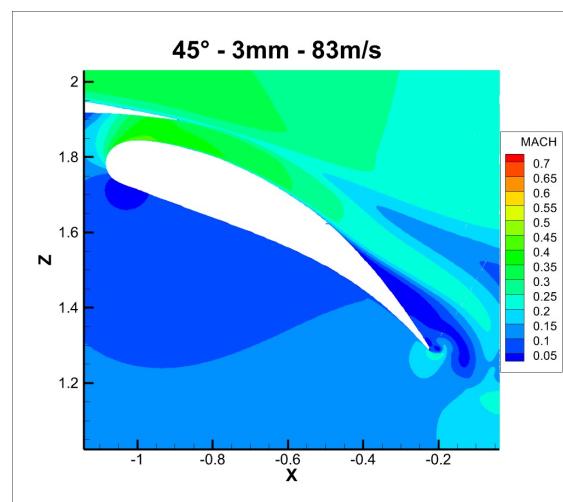
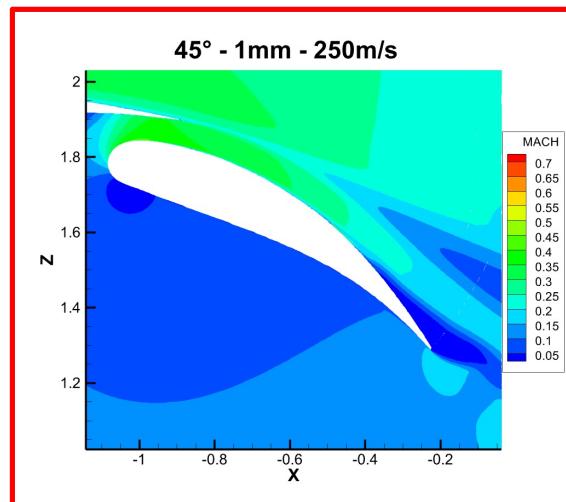
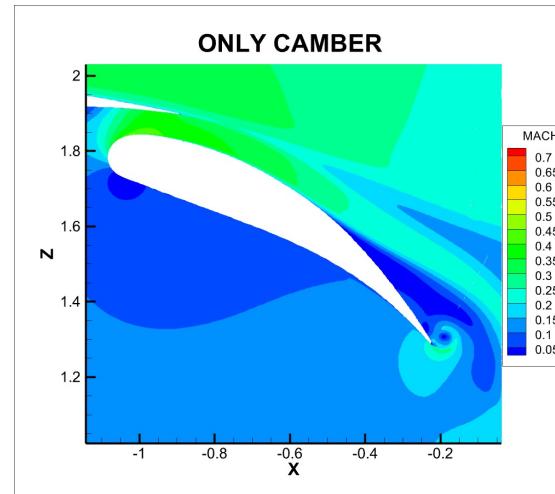
| 3 | 60 | 1.0 | 45 | **0.7068977552277825** | Q=VxD =**250** x 0,7068977552277825 = **176,724 m²/s**
(REFERENCE)

| 6 | 60 | 3.0 | 45 | 2.124637415255685 | V=Q/D= **176,7244375** /2,124637415255685= 83,1786337899601

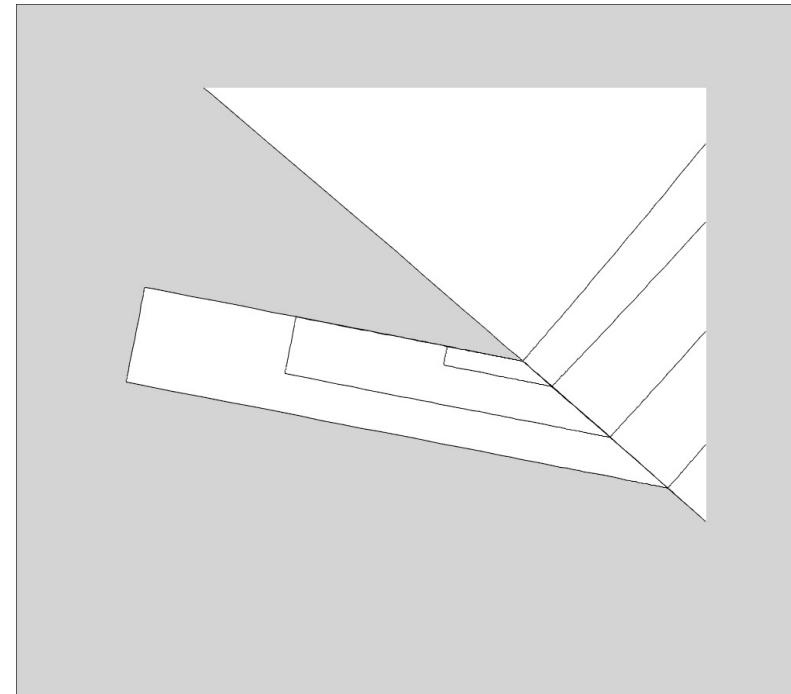
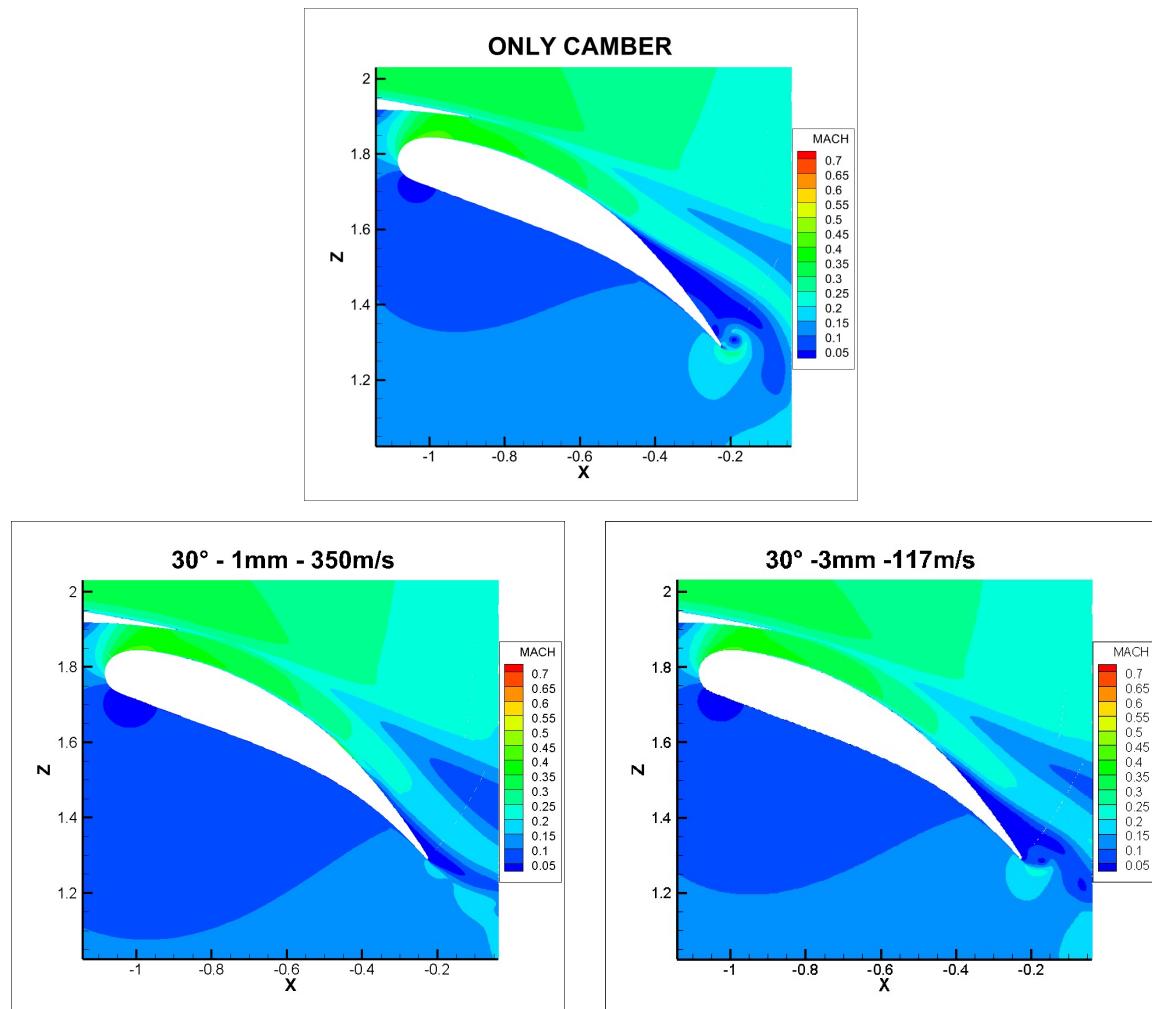
| 9 | 60 | 5.0 | 45 | 3.541139370040709 | V=Q/D= **176,7244375** /3,541139370040709= 49,9060



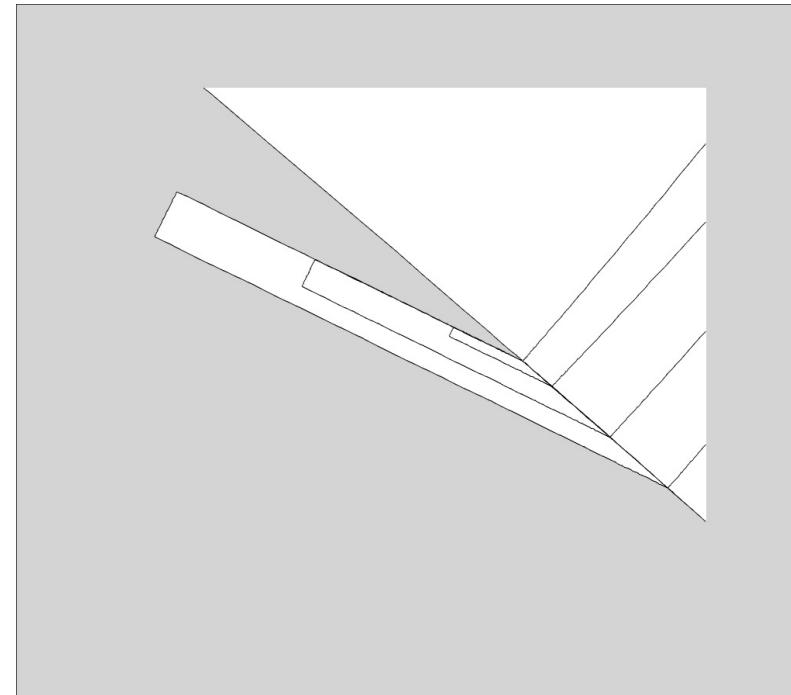
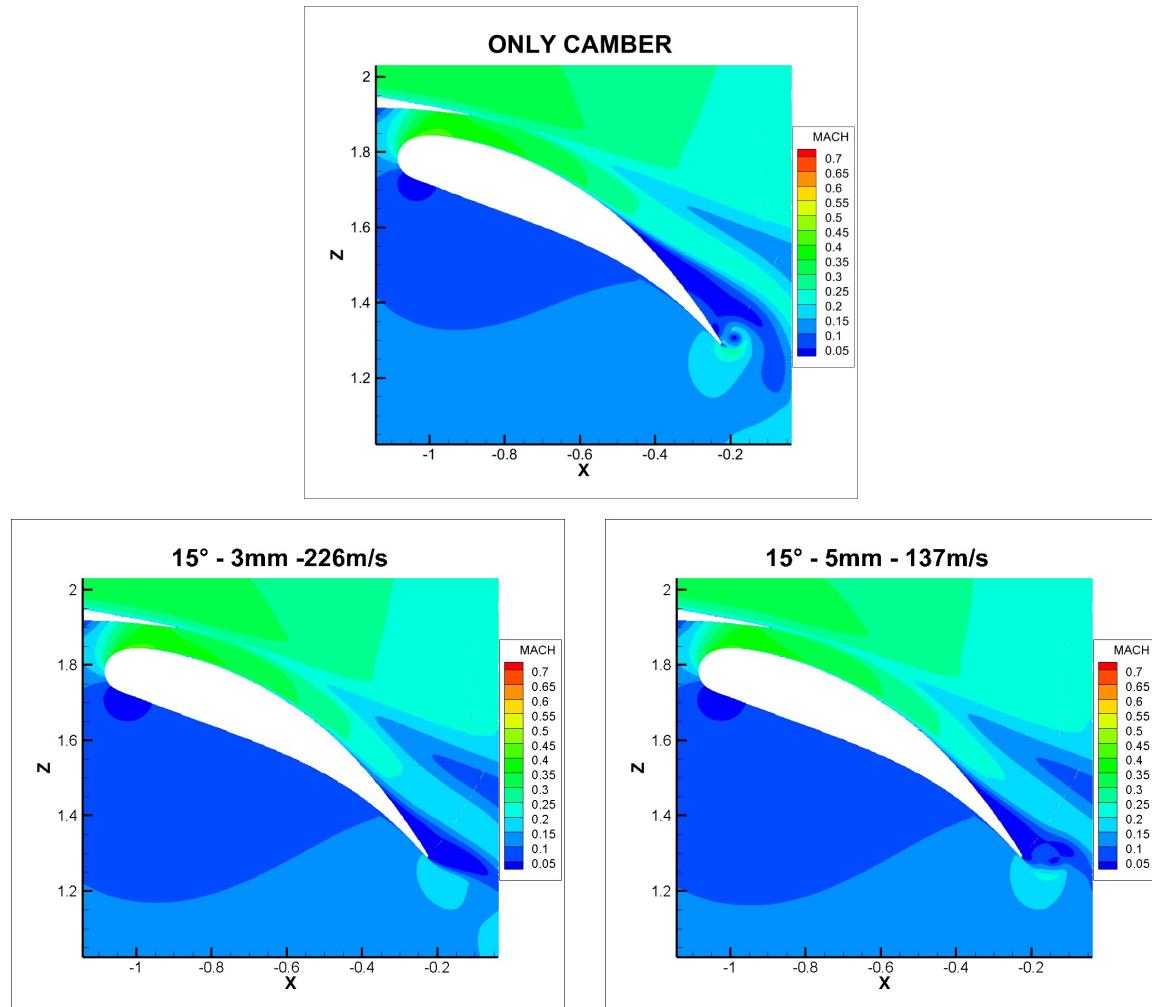
Optimisation of the ZNMF jet parameters



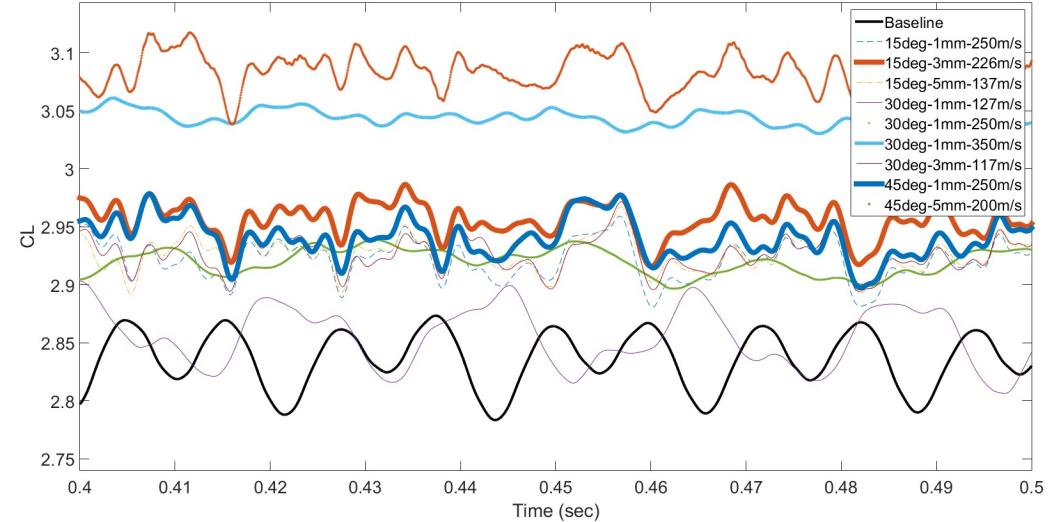
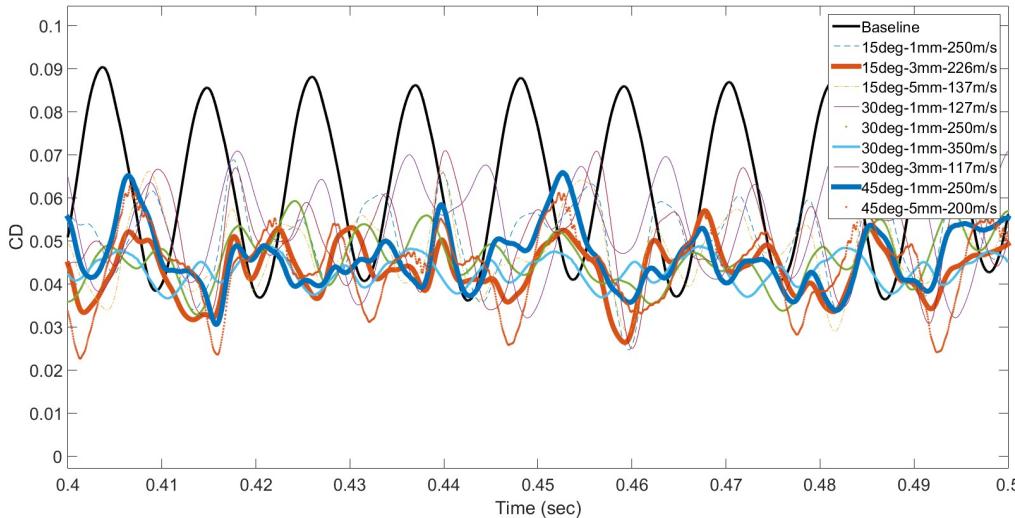
Optimisation of the ZNMF jet parameters



Optimisation of the ZNMF jet parameters



Optimal parameters of the ZNMF jet



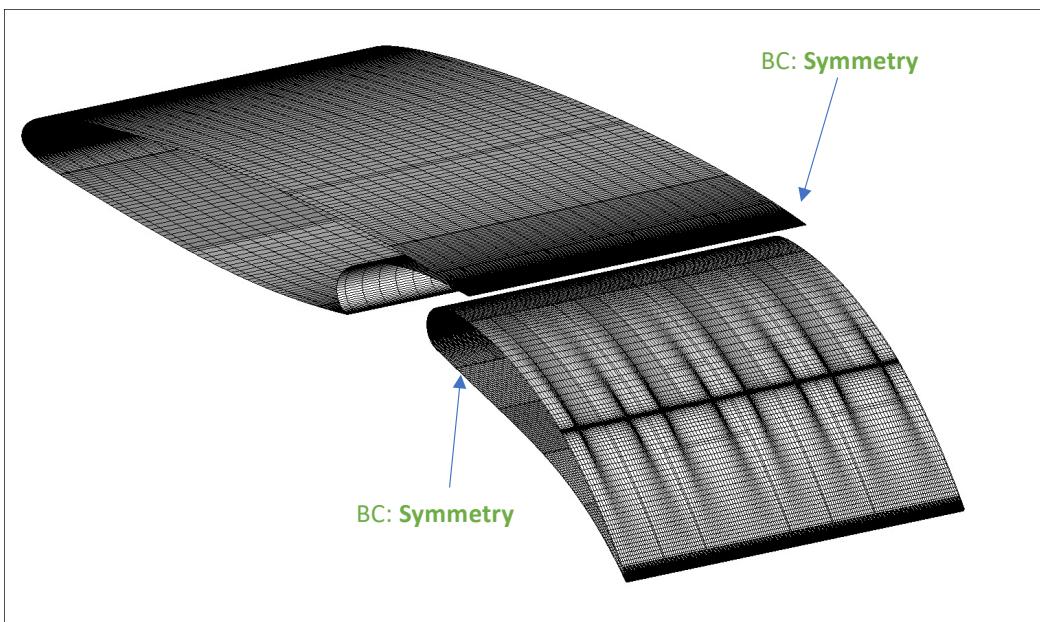
- The optimal parameters that give the best performance:
 - $45^\circ - 5mm - 200m/s$ -> higher mass flux than the reference
 - $30^\circ - 1mm - 350m/s$ -> high peak velocity
- The “realistic” parameters that give the best performance:
 - $45^\circ - 1mm - 250m/s$
 - $15^\circ - 3mm - 226m/s$

Conclusion & Perspectives

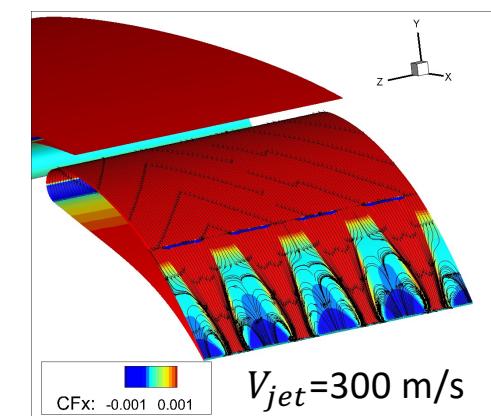
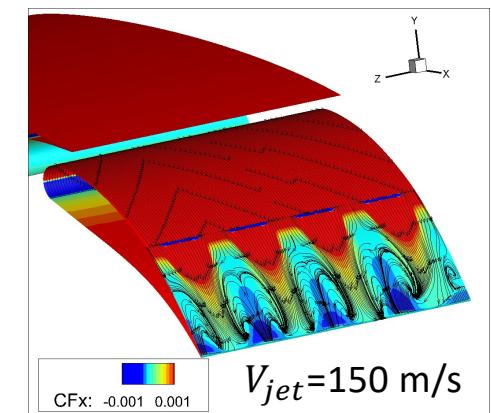
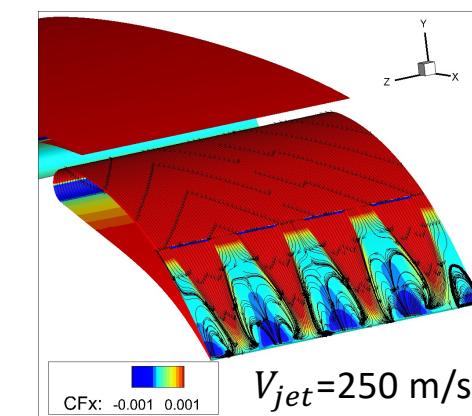
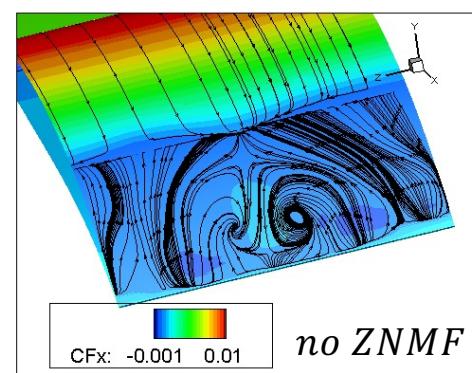
Conclusions

- The aerodynamic forces are independent of the frequency of the actuation when this last is $> 100\text{Hz}$
- An increase of the velocity of the jet, improves better the aero efficiency
- The jet location in 2D should be near the separation point to effectively reattach the flow.
- Based on existing ZNMF actuators, a shape optimization of the ZNMF actuator is investigated using a fixed mass-flux.
- 2D analysis provided: best frequency, velocity, jet shape D/H , angle and location of the ZNMF to improve the performances.

Perspectives for 3D simulations

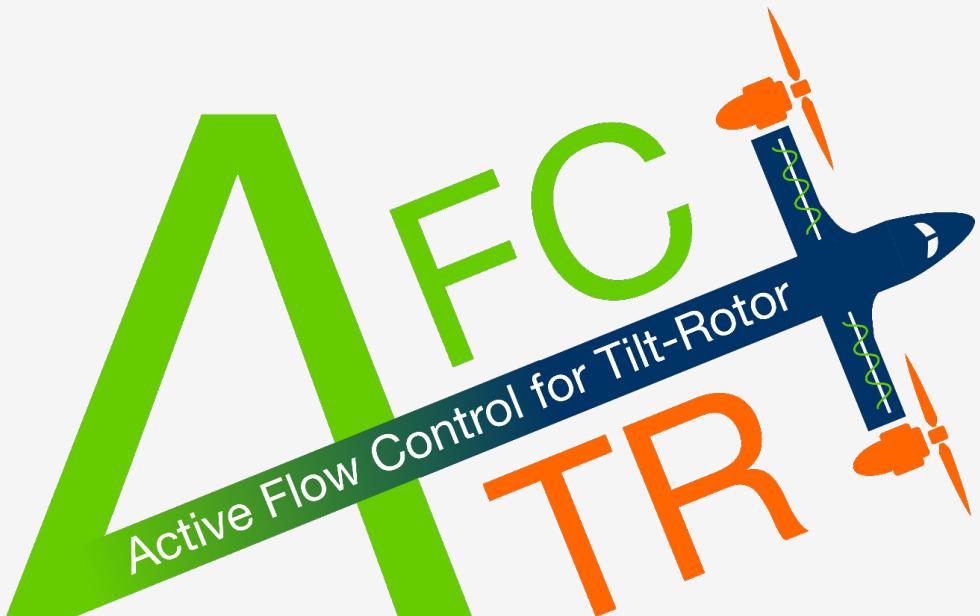


4 ZNMF (1mm x 150mm x 45deg)





Thank You !



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