Micro devices for enhanced performance of airfoil sections (NTUA, POLIMI)

Update from ongoing experiments

May 28, 2025
TWEET-IE M30 Plenary meeting and Technical Workshop

Introduction

Flatback (FB) airfoils: Thick airfoils with a blunt trailing edge (TE)

- Used near the root region of modern WT blades

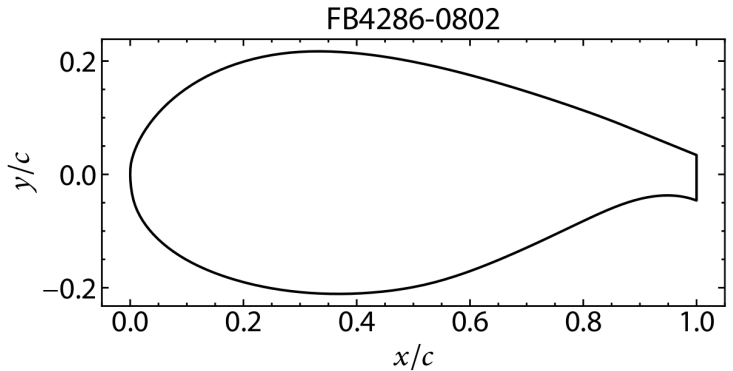
Introduction

Flatback (FB) airfoils: Thick airfoils with a blunt trailing edge (TE)

- Used near the root region of modern WT blades
  - Higher lift than airfoils of similar thickness but thin TE
  - Increased flapwise stiffness
  - Drag increase
  - Blunt trailing edge $\rightarrow$ Vortex shedding $\rightarrow$ Unsteady loading
  - Sparse literature about experimental studies (<6) at moderate Re (Re$>$1M) numbers
  - Need of passive flow control devices (separation + drag reduction)

The airfoil model

- FB4286-0802 airfoil
- Max thickness: $42.86\%c$
- TE thickness: $8.02\%c$
- $AR = 2$
- Chord $= 0.5\mathrm{m}$
- 63 pressure taps



Setting up the Twin Wind Tunnel Test

	NTUA	POLIMI	Notes
Blockage	$\approx 11\%$	$\approx 1\%$	
Re ($\times 10^6$)	1.25	1.25	
BL Transition	Free & Fiixed	Free & Fixed	$h_{ZZ} = 0.125\mathrm{mm}$

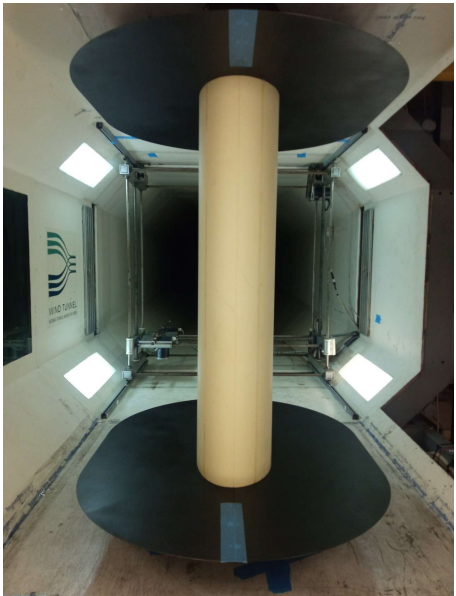
Setting up the Twin Wind Tunnel Test

	NTUA	POLIMI	Notes
Blockage	$\approx 11\%$	$\approx 1\%$	
Re ($\times 10^6$)	1.25	1.25	
BL Transition	Free & Fiixed	Free & Fixed	$h_{ZZ} = 0.125\text{mm}$
Surface Pressure	✔(32/63 taps)	✔(63/63 taps)	
Hot-wire	✔(single film)	✔(triple)	
Balance	✖	✔	
Tufts	✔	✔	
StereoPIV	✔	✖	

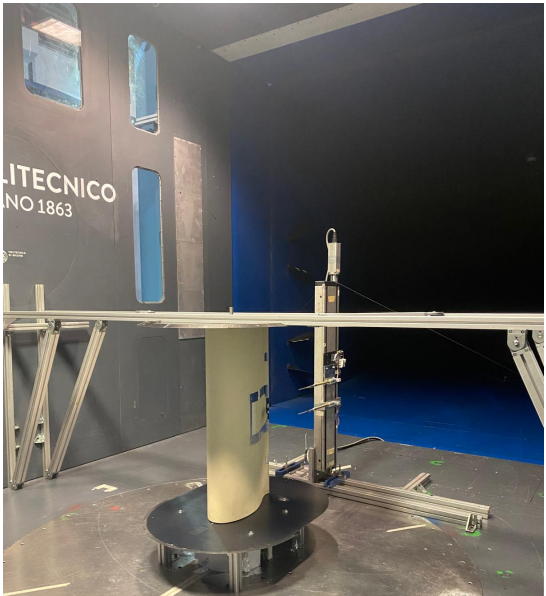
Setting up the Twin Wind Tunnel Test

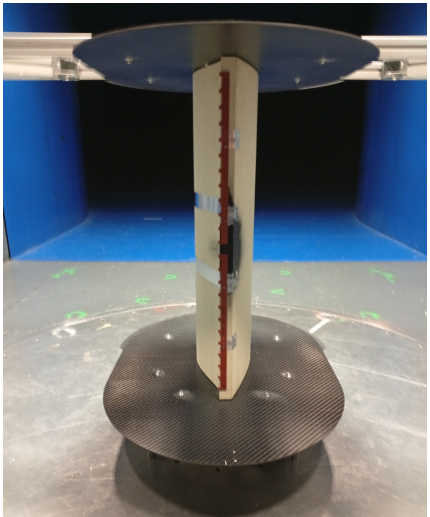
	NTUA	POLIMI	Notes
Blockage	$\approx 11\%$	$\approx 1\%$	
Re ($\times 10^6$)	1.25	1.25	
BL Transition	Free & Fiixed	Free & Fixed	$h_{ZZ} = 0.125\text{mm}$
Surface Pressure	✔(32/63 taps)	✔(63/63 taps)	
Hot-wire	✔(single film)	✔(triple)	
Balance	✖	✔	
Tufts	✔	✔	
StereoPIV	✔	✖	
Vortex Generators	✔	✔	Separation Control
Vortex Generators near Trailing Edge	✔	✔	Drag Reduction
Tabs near Trailing Edge	✔	✔	Drag Reduction
Gurney Flaps	✔	✔	Lift Increase

NTUA Setup

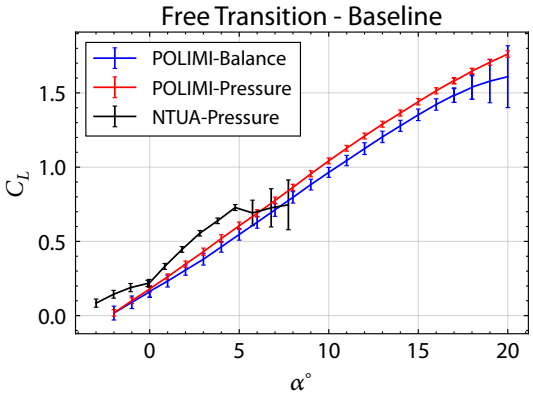


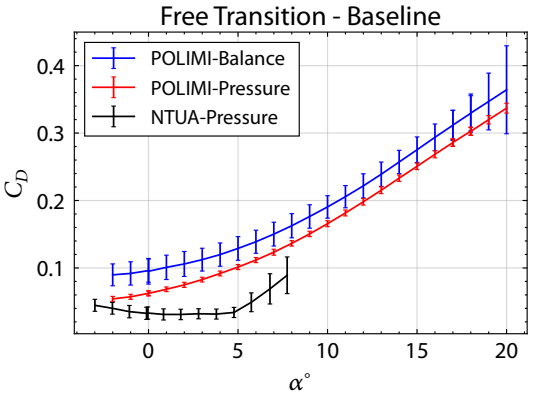
POLIMI Setup



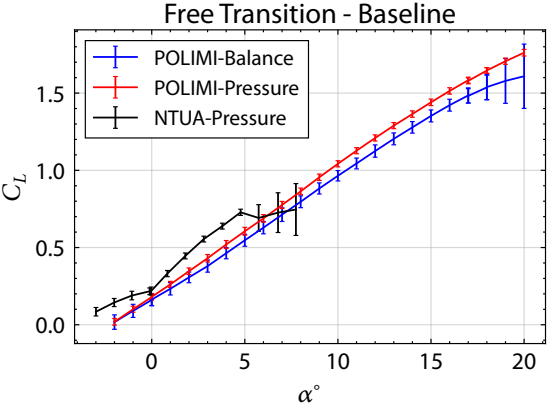


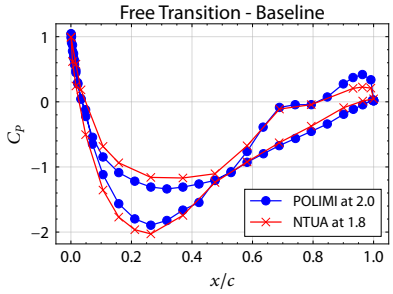
Baseline C_L & C_D

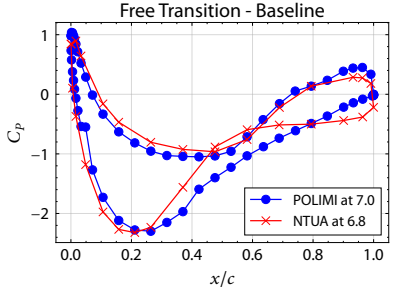




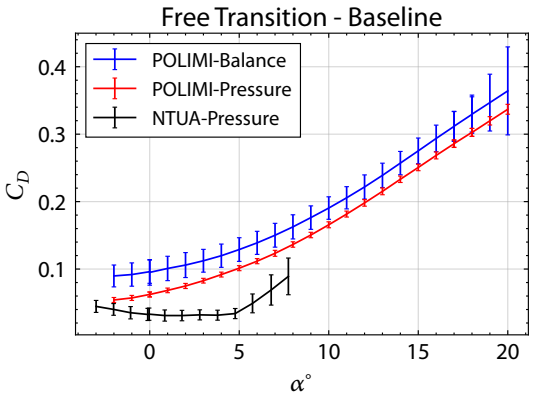
Baseline C_L & C_P

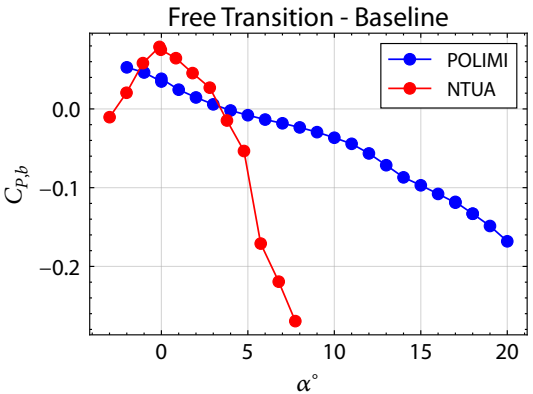






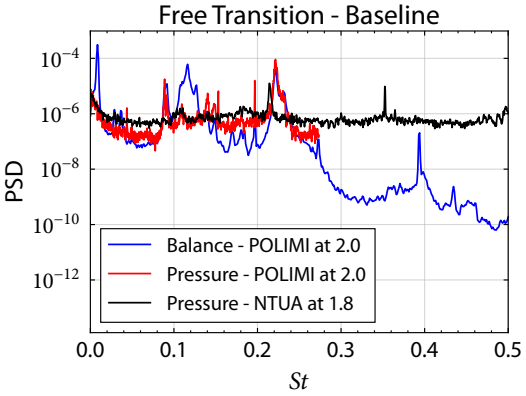
Baseline C_D & $C_{P,b}$



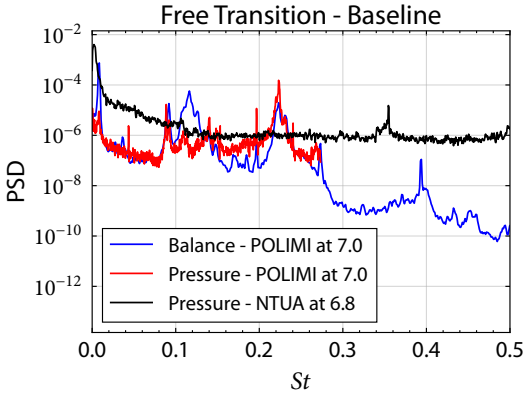


$x/c = 1$ & $y/c = 0.007$

Baseline Frequency domain

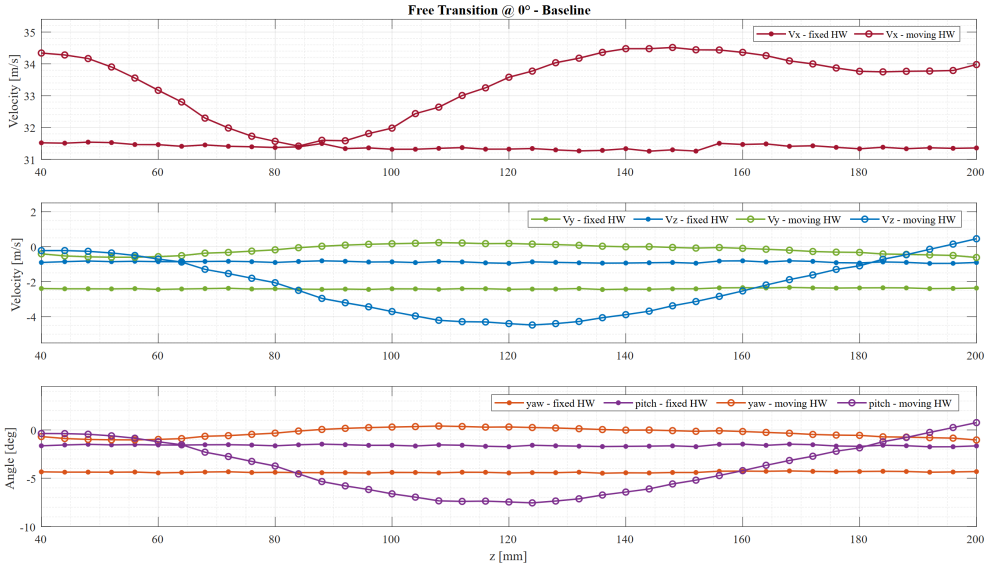


$\alpha \approx 2°$

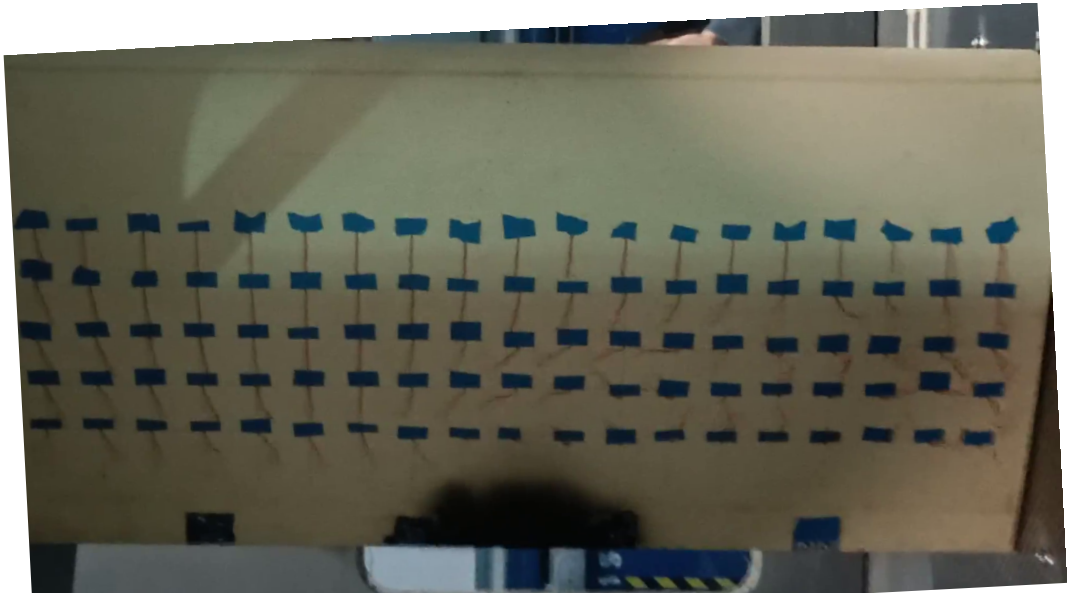


$\alpha \approx 7°$

Baseline Hot-wires POLIMI



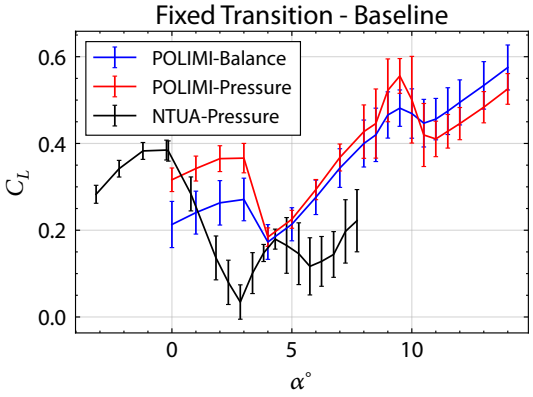
Fixed Baseline: An intro

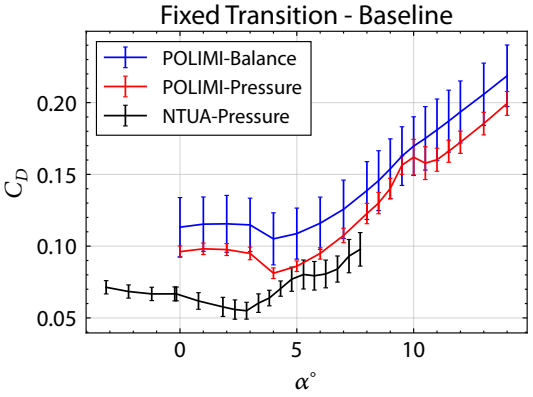


Fixed Baseline C_L & C_D

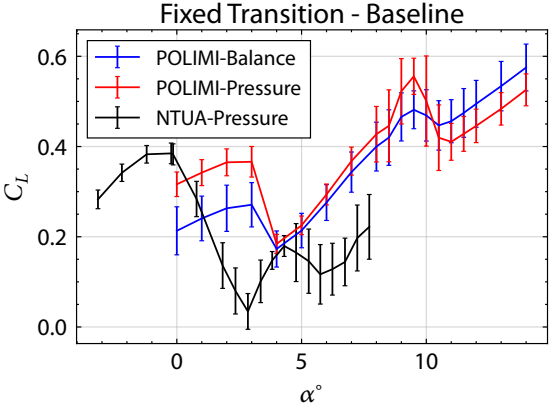
Fixed transition:

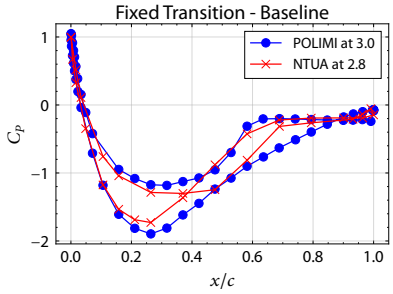
- Suction side 5%c
- Pressure side 10%c

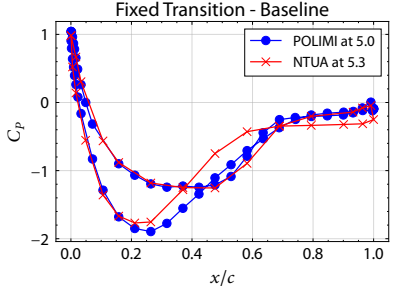




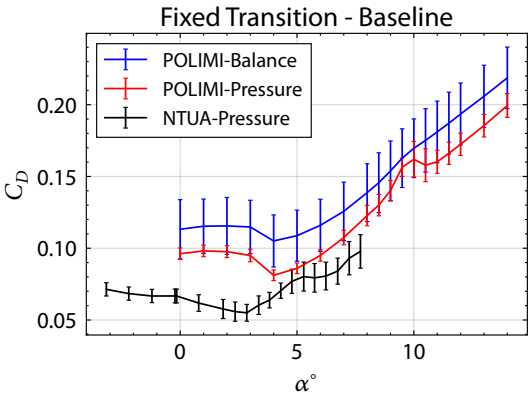
Fixed Baseline C_L & C_P

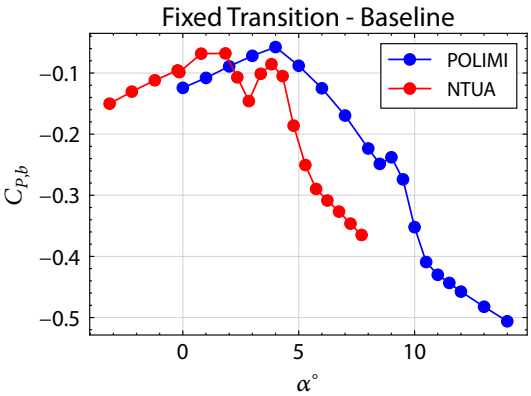






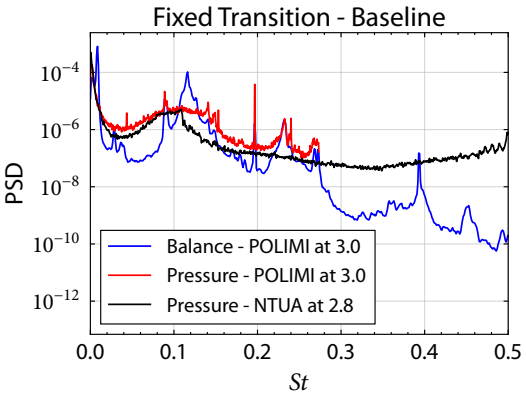
Fixed Baseline C_D & $C_{P,b}$



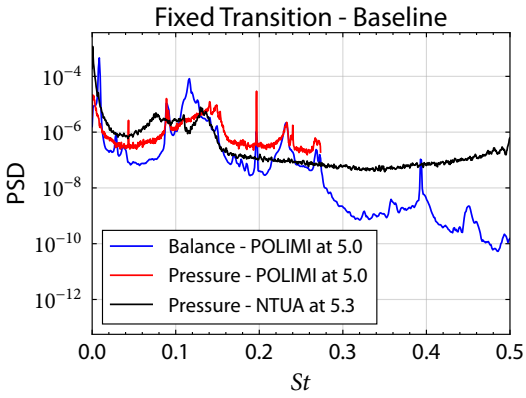


$x/c = 1$ & $y/c = 0.007$

Fixed Baseline Frequency domain

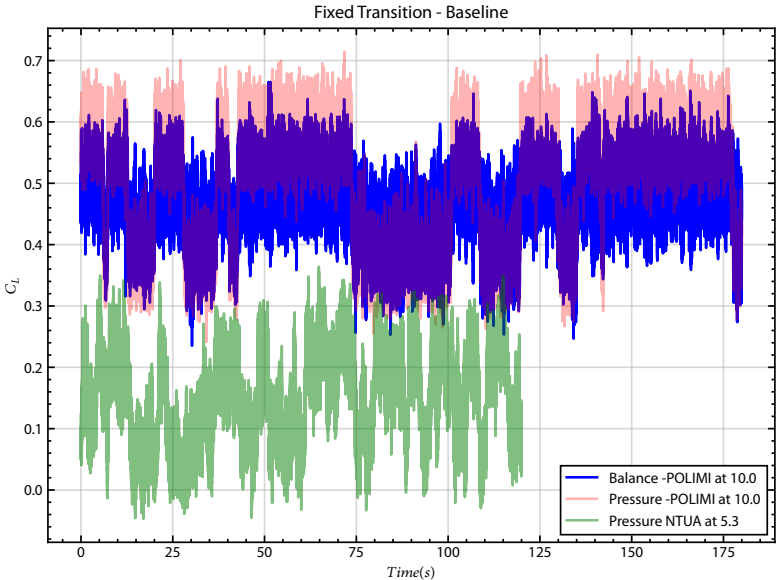


$\alpha \approx 3°$

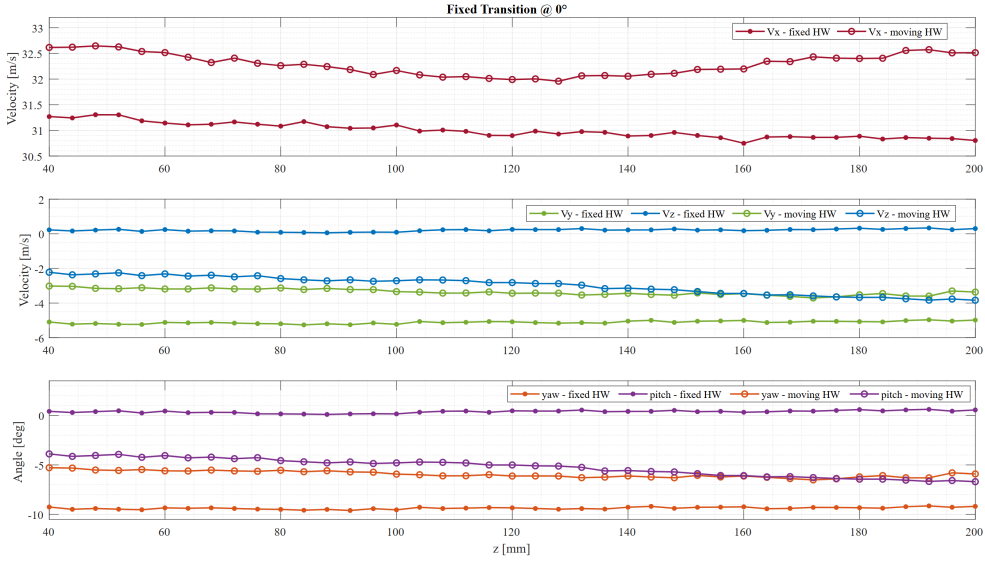


$\alpha \approx 5°$

Fixed Baseline Bifurcating Behavior

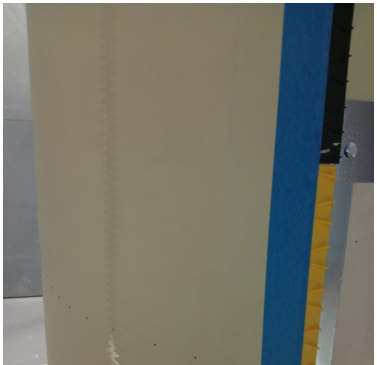


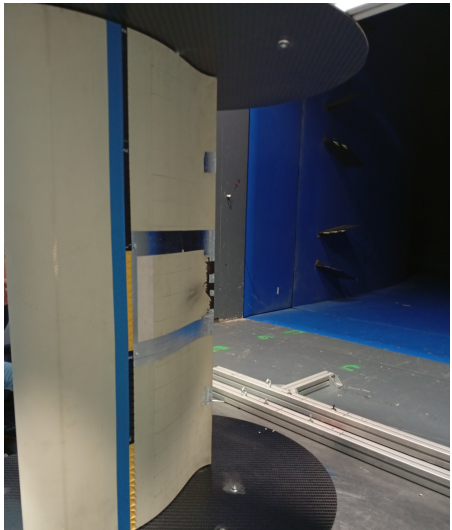
Fixed Baseline Hot-wires POLIMI



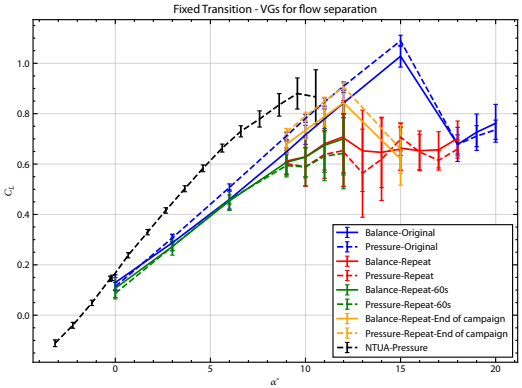
Fixed & VGs for flow separation

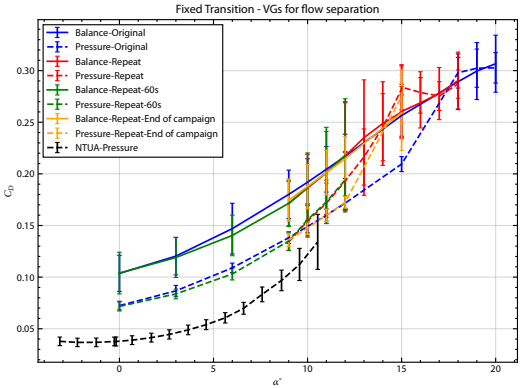
- Fixed transition:
  - Suction side 5%c
  - Pressure side 10%c
- VGs placed at
  - Suction side 30%c
  - Pressure side 35%c



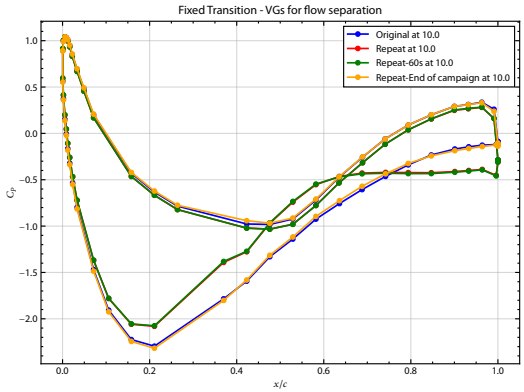


Fixed & VGs for flow separation C_L & C_D

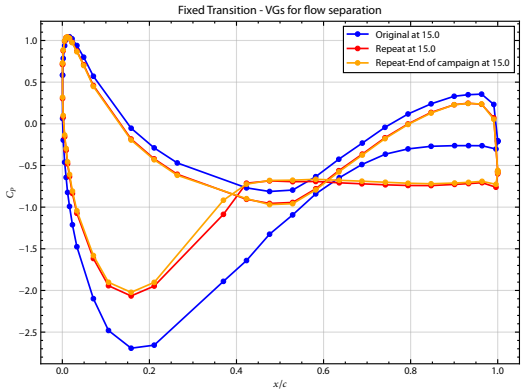




Fixed & VGs for flow separation C_P



$\alpha = 10°$



$\alpha = 15°$

Open Questions

- Differences in flow separation
  - Extent of separation
  - Onset of separation
  - 3D separated flow structures
  - $\alpha_{C_L,max}$
- Bifurcating behaviour for the fixed transition case
- Wake correlations (Hot-wires)
- Wake averaged flow structures (SPIV & Hot-wires)
- Flow control solutions

K. Kellaris, L. Calzoni, A. Croce & M. Manolesos, "Twin Wind Tunnel tests of a very thick flatback airfoil" *to be presented* at Wind Energy Science Conference 2025, June 2025, Nantes, France