Thick airfoils, Vortex Generators, Gurney Flaps and Flatback Solutions: How to get better performance out of the blade inner region?

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The project

Let’s be blunt and drop the mic!
An experimental study of very thick flatback airfoils.

Aims

1. To investigate the aerodynamic performance of a Flatback airfoil with and without flow control devices.

2. To investigate the unsteady wake characteristics and noise generation using microphones.

Supergen Offshore Renewable Energy

Vestas

Motivation

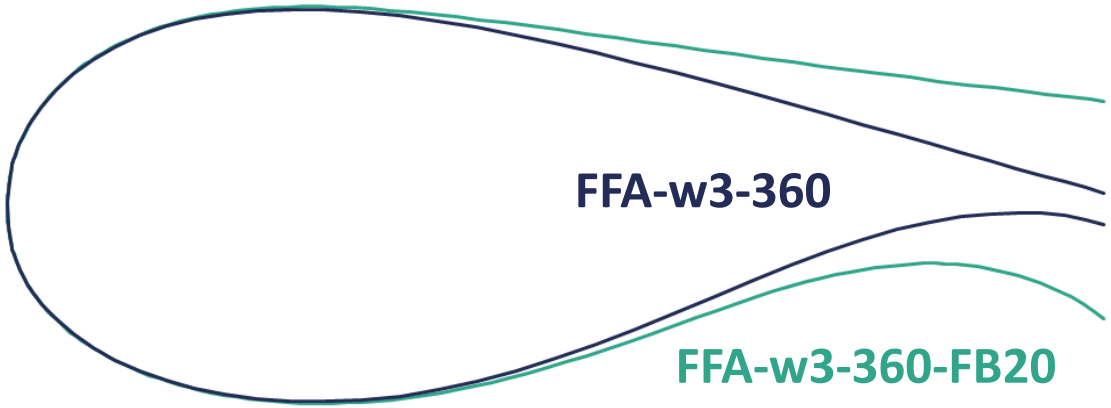
Project Background

- Can we get **increased performance** out of a Flatback Airfoil by means of passive flow control devices?
  - Vortex Generators (**VGs**)
  - Gurney Flap (**GF**)

Introduction

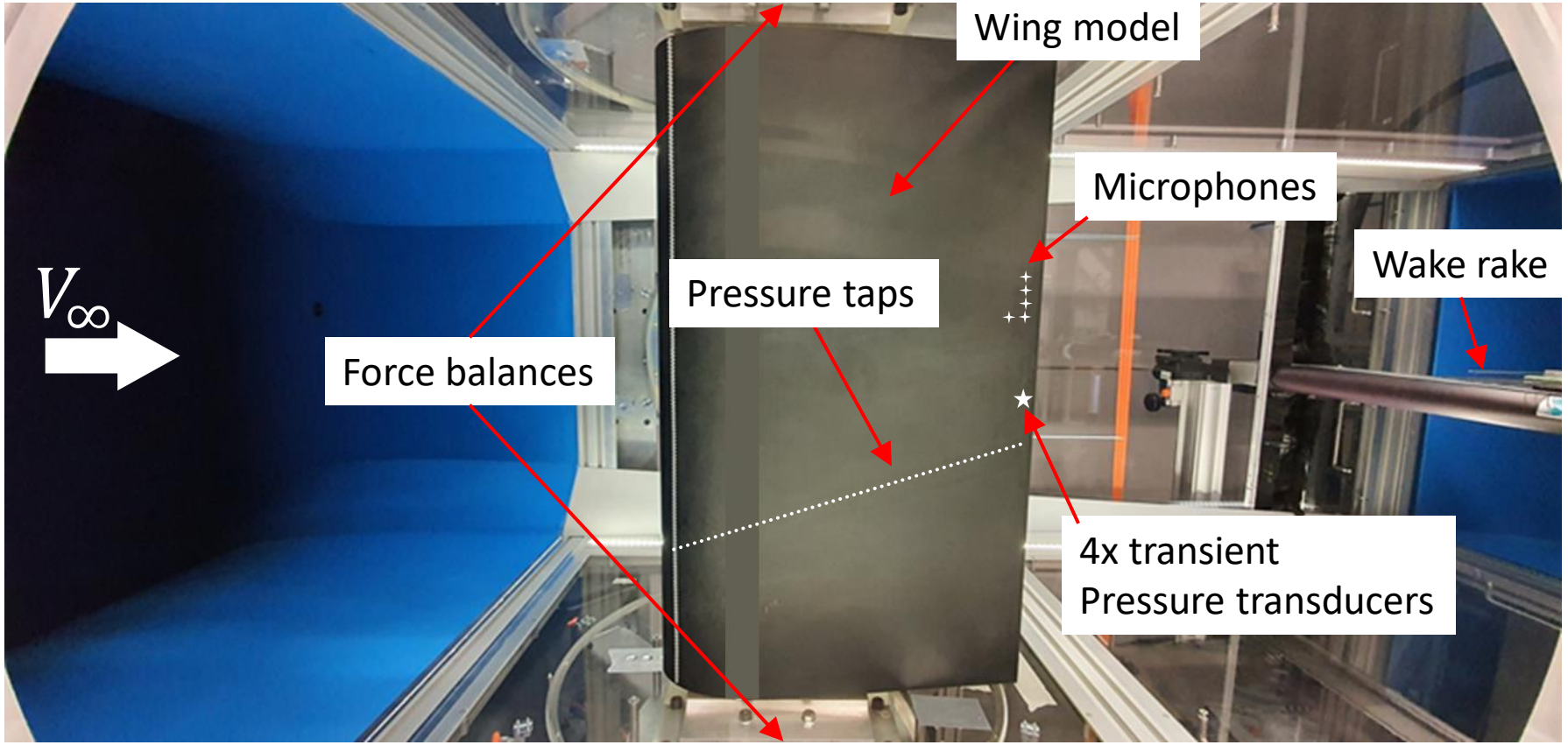
Airfoil Profiles and flow conditions

Profiles	**FFA-W3-360 / FFA-W3-360-FB20**
Chord	600 mm
AR	1.67
Thickness	36%
Transition	Free + Fixed (ZZ tape, 0.26mm thickness, 10%c PS and 5%c SS)
Chord Re Number	**1.8M**
Flow Control	VGs - Triangular type with 6mm height Gurney Flap with 5%c height
Strouhal Number definition	$St = \frac{f h_{TE}}{V_\infty}$, $St_{GF} = \frac{f(h_{TE}+h_{GF})}{V_\infty}$
Power Spectral Density (PSD)	PWELCH (MATLAB)



Introduction

Experiment setup



Force Balances

2x AMTI MC12-1000 balances for 3D lift and drag measurements

Pressure taps

64 pressure taps around the airfoil for 2D lift measurements

Wake rake

60 total pressure probes and **3 static tubes** for wake rake drag measurements

Pressure transducers

4x HDOM100DE8P pressure transducers for surface pressure measurements

P1 on suction side
P2, P3 on TE
P4 on pressure side

Microphones

10x FG-23329-PO7 microphones for sound pressure measurements

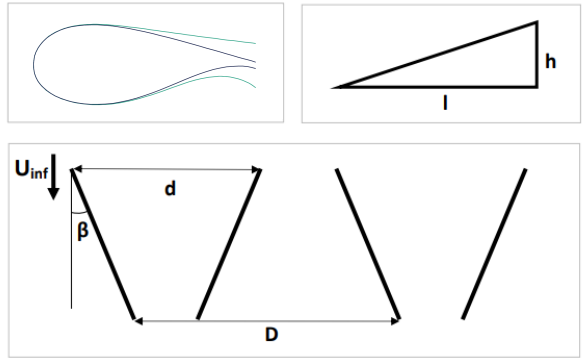
Introduction

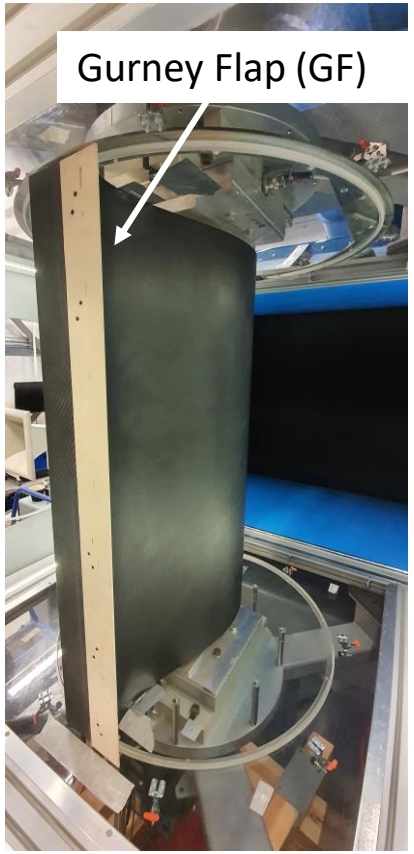
Cases discussed

- Free and Fixed transition
- FFA-w3-360 with and without VGs
  - VGs on suction side @30% c
- FB20 with and without VGs
  - VGs on pressure side @ 40% c
- FB20 with GF
  - GF with 5% c height

NOTE: No lift or drag values shown for confidentiality reasons

Vortex Generators (VGs)

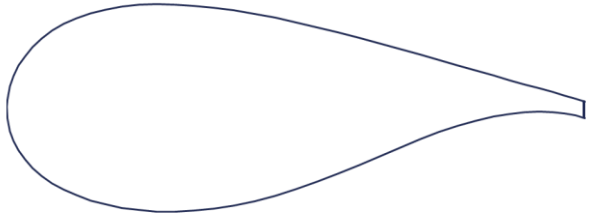


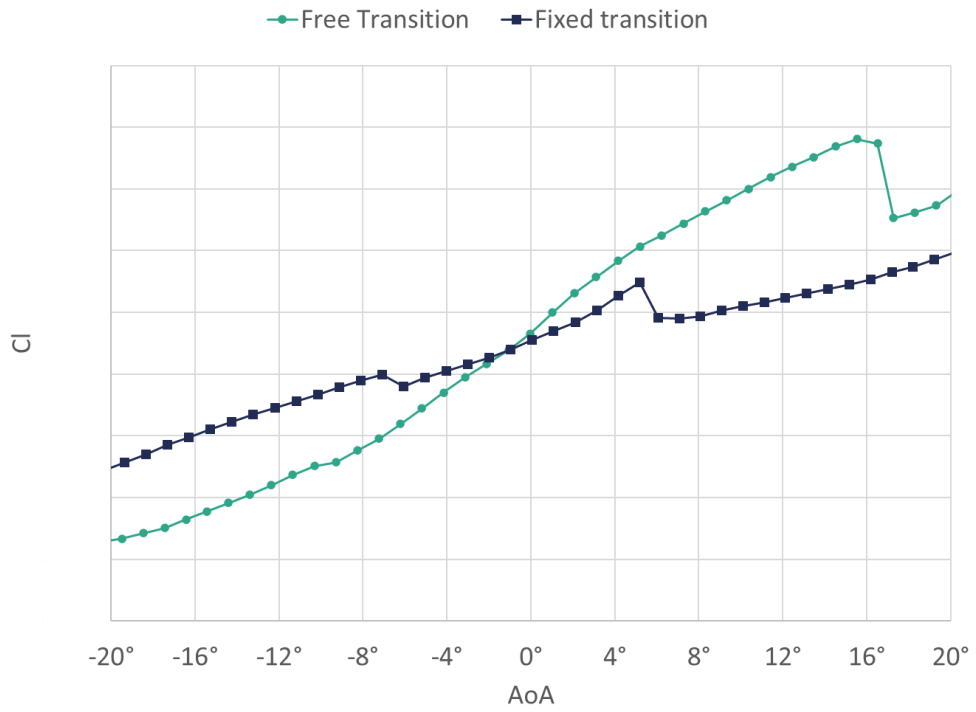


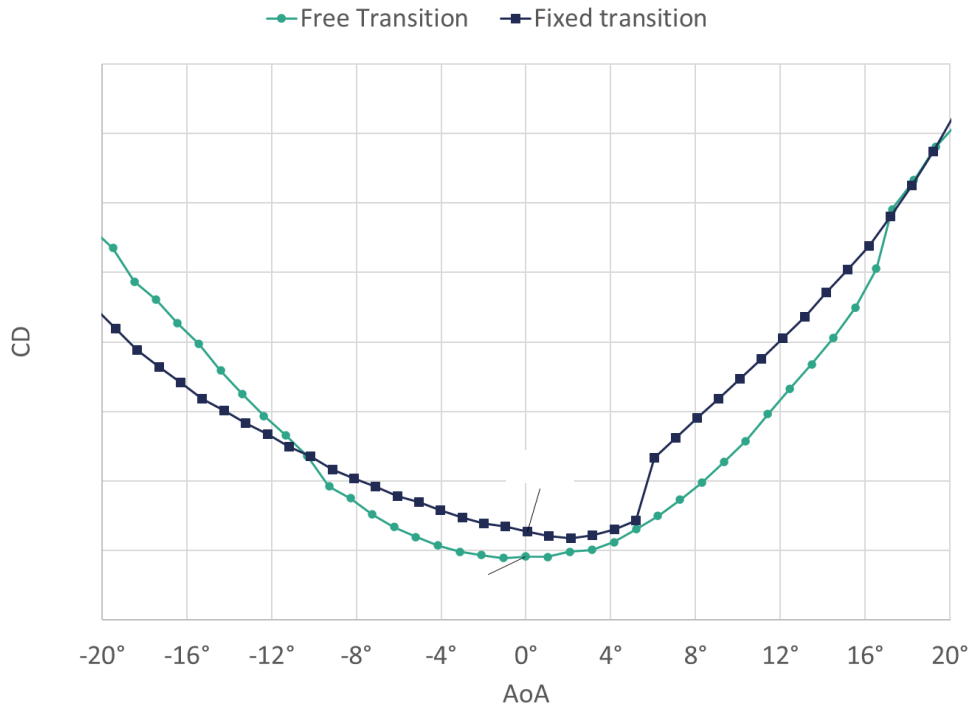
Results

FFA-W3-360 – Effect of ZZ tape

The FFA-w3-360 is very sensitive to tripping



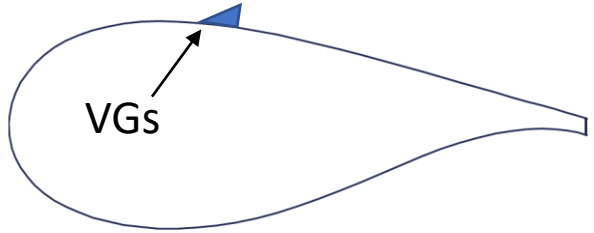


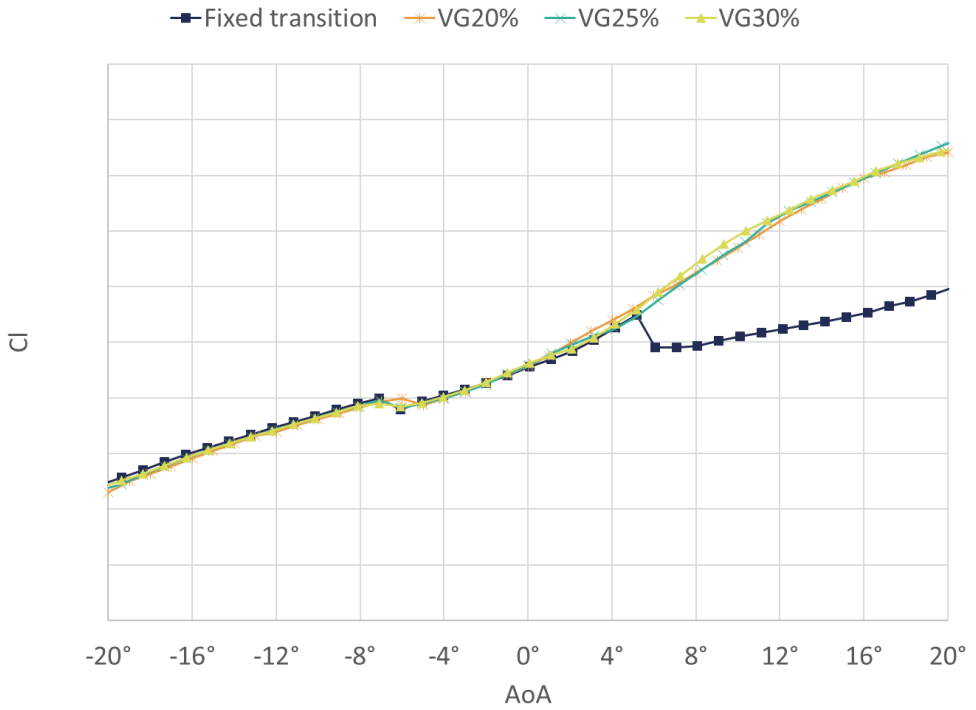


Results

FFA-W3-360 – Adding VGs on suction side

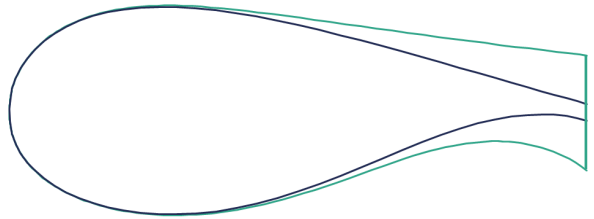
The VGs increase lift performance for both free and fixed transition cases



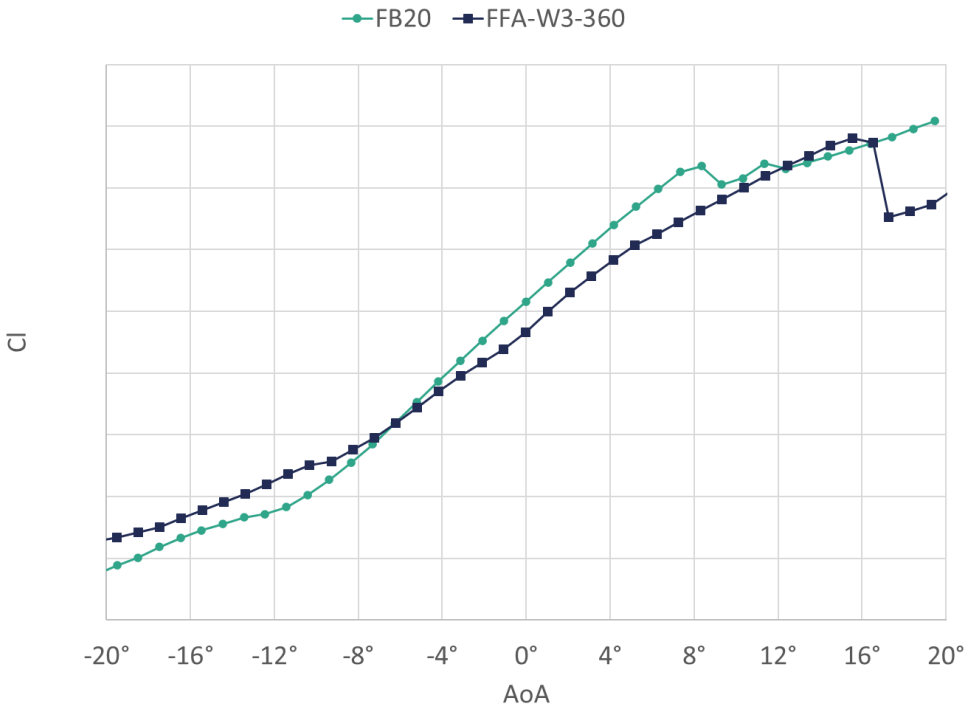


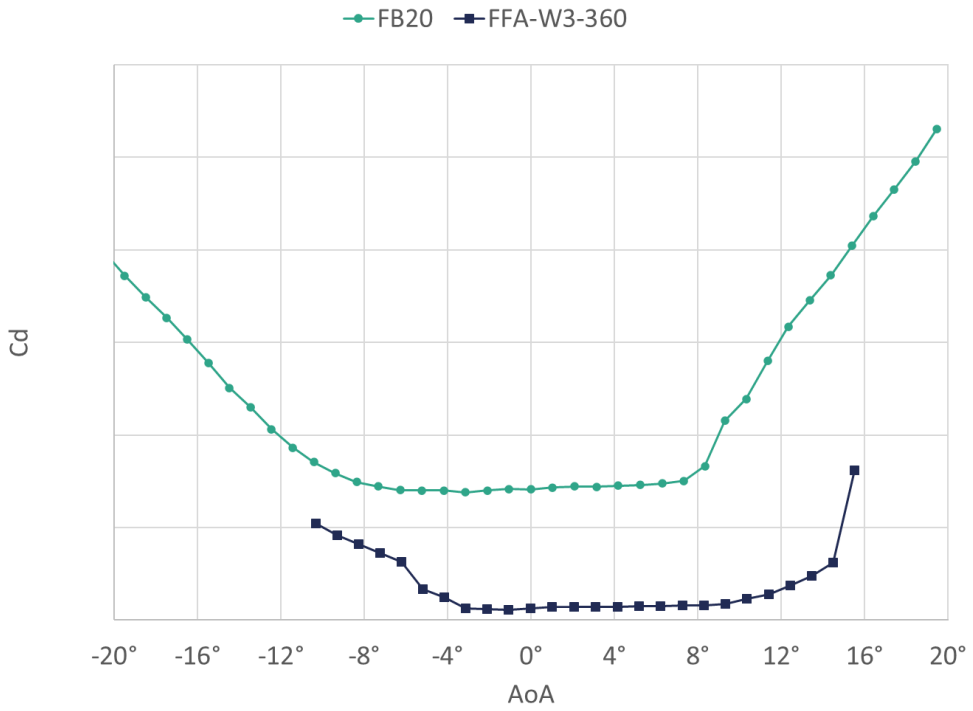
Results

FFA-W3-360 vs. FB20 – Free transition



Increase in lift accompanied by a significant increase in drag for the FB20 profile

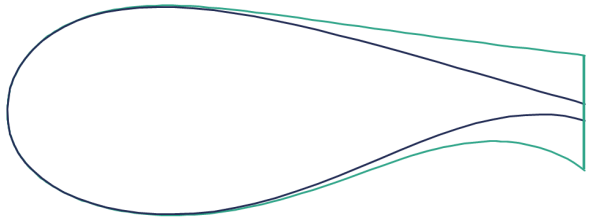


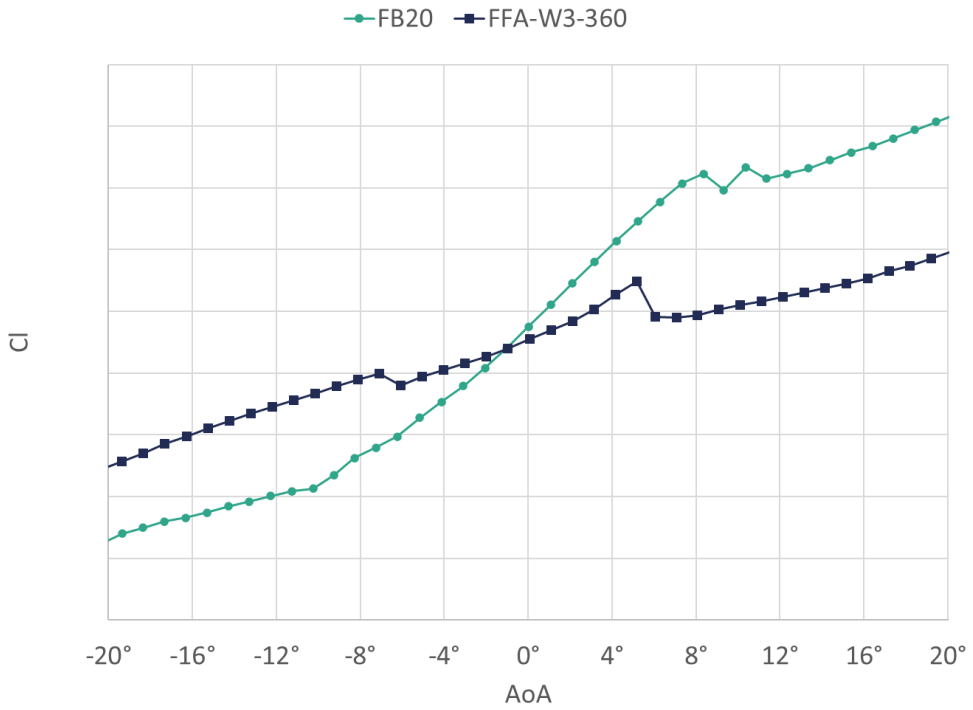


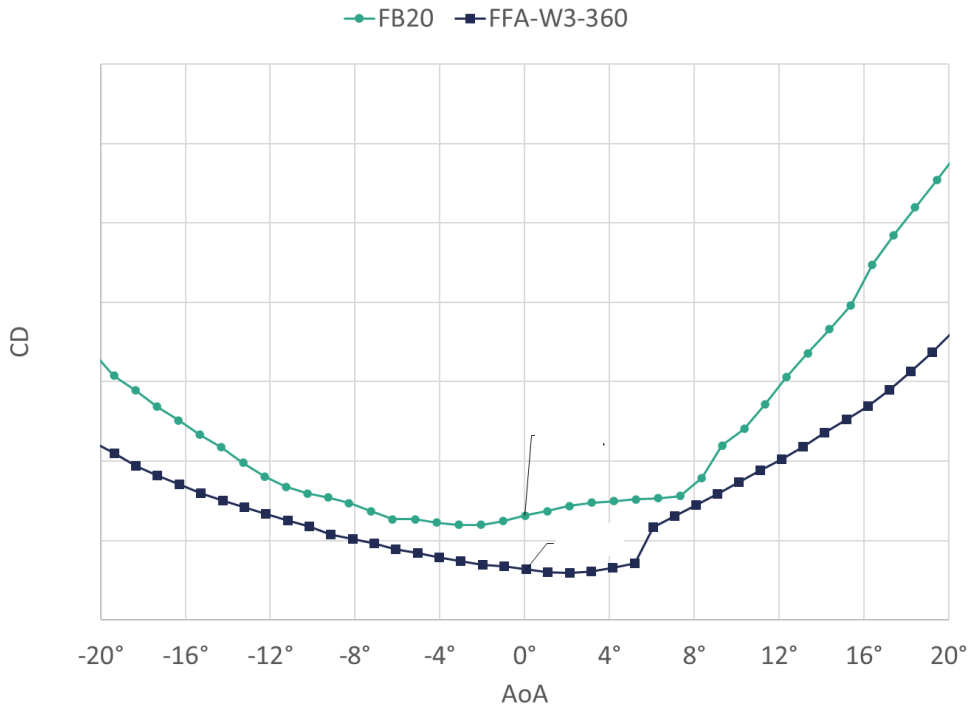
Results

FFA-W3-360 vs. FB20 – Fixed transition

The FB20 profile provides significant benefits for tripped flow.

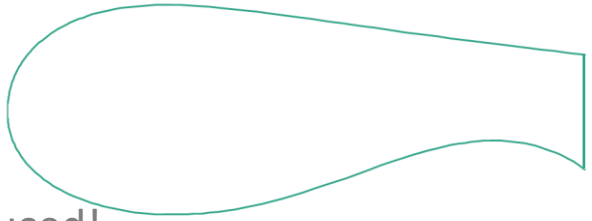




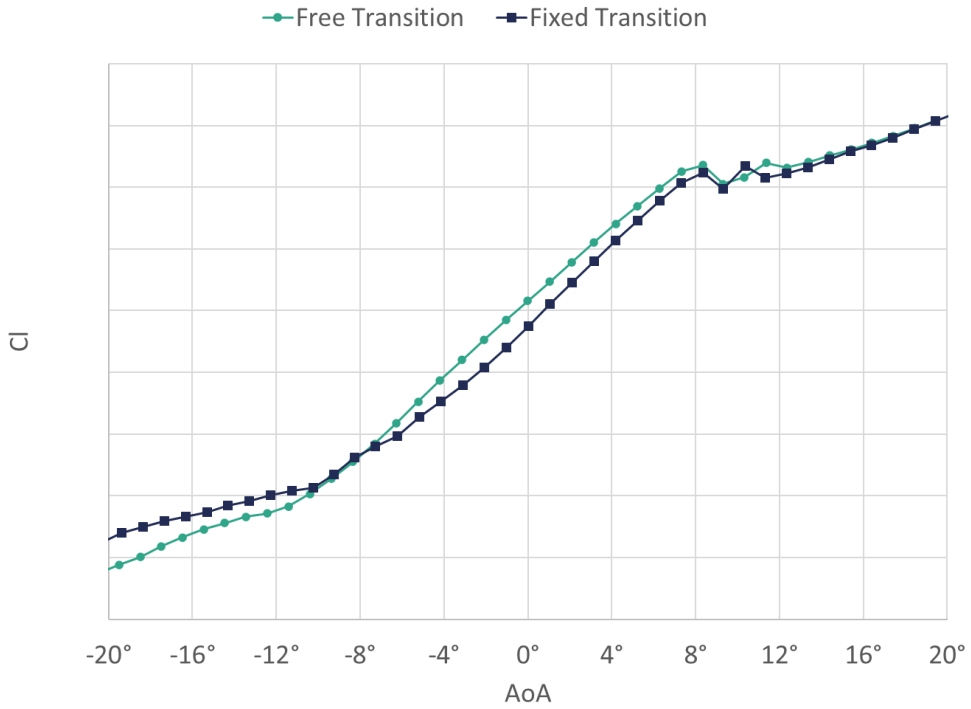


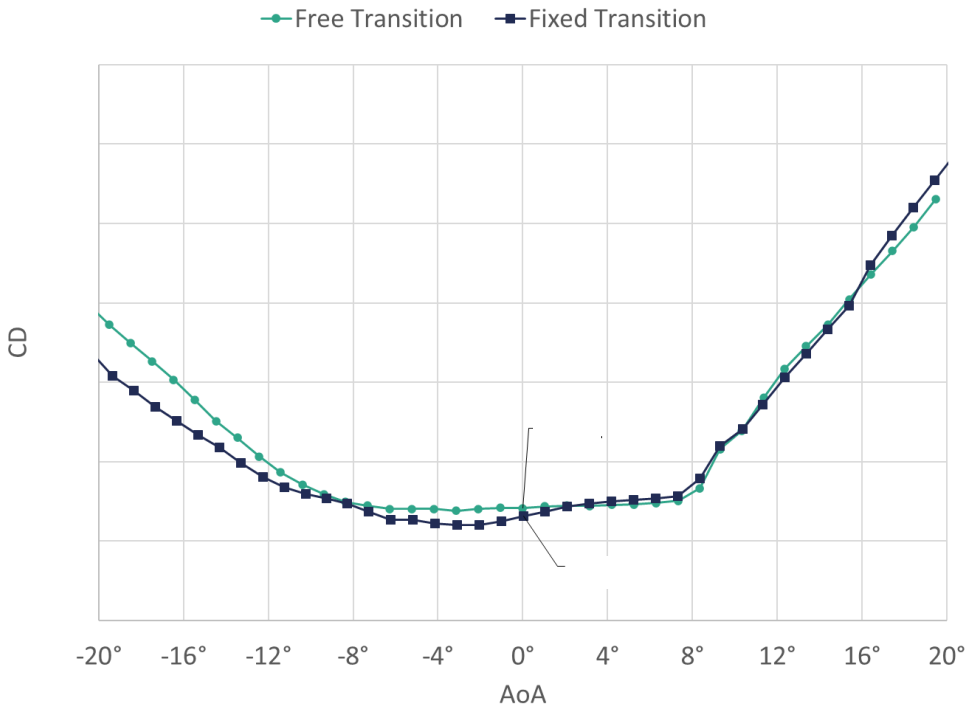
Results

FB20 – Effect of ZZ tape



The FB20 profile is less sensitive to tripping than the FFA-w3-360. Drag is actually reduced!

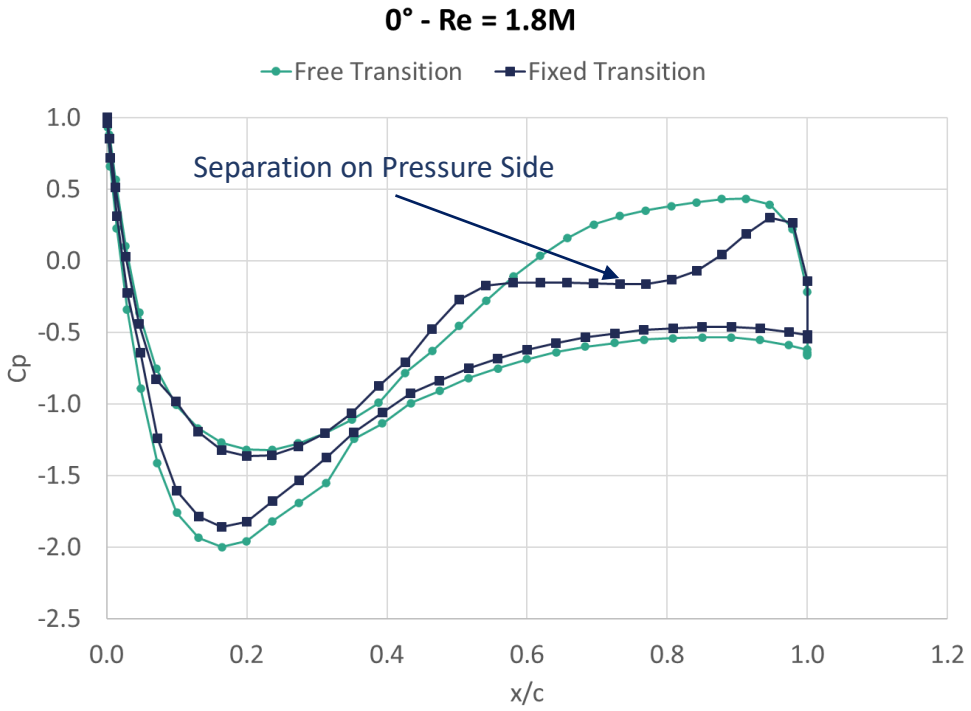


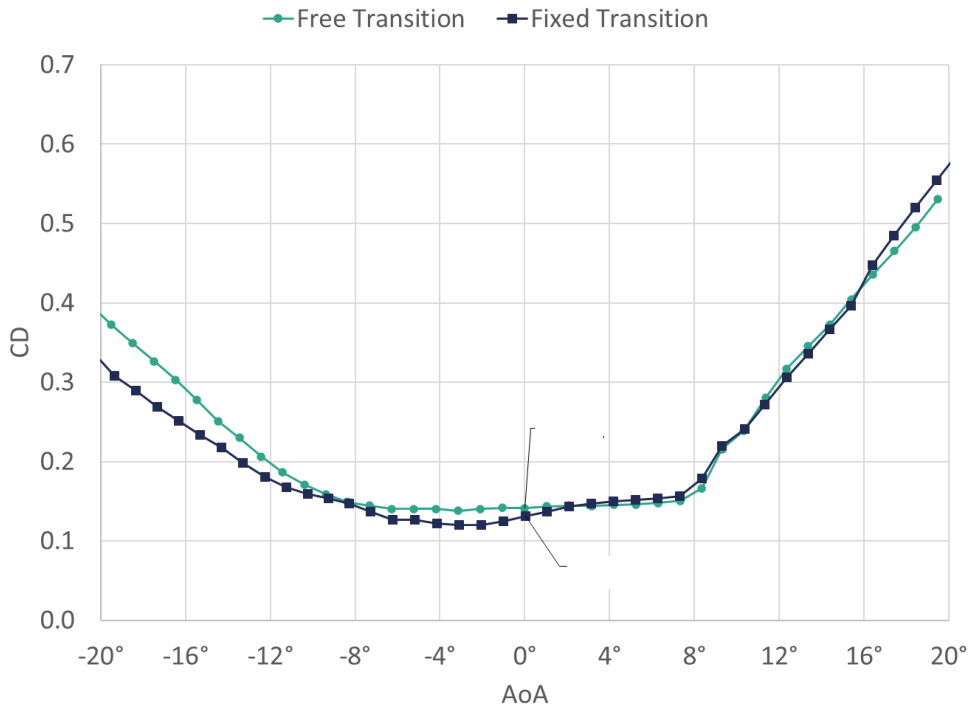


Results

FB20 – Effect of ZZ tape

Fixed transition leads to separated flow on pressure side, which affects vortex shedding and hence drag

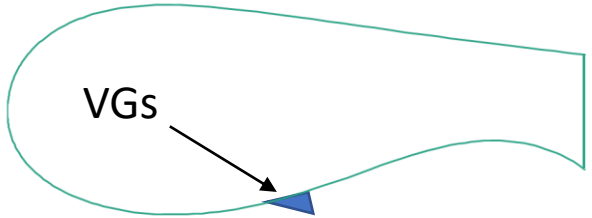


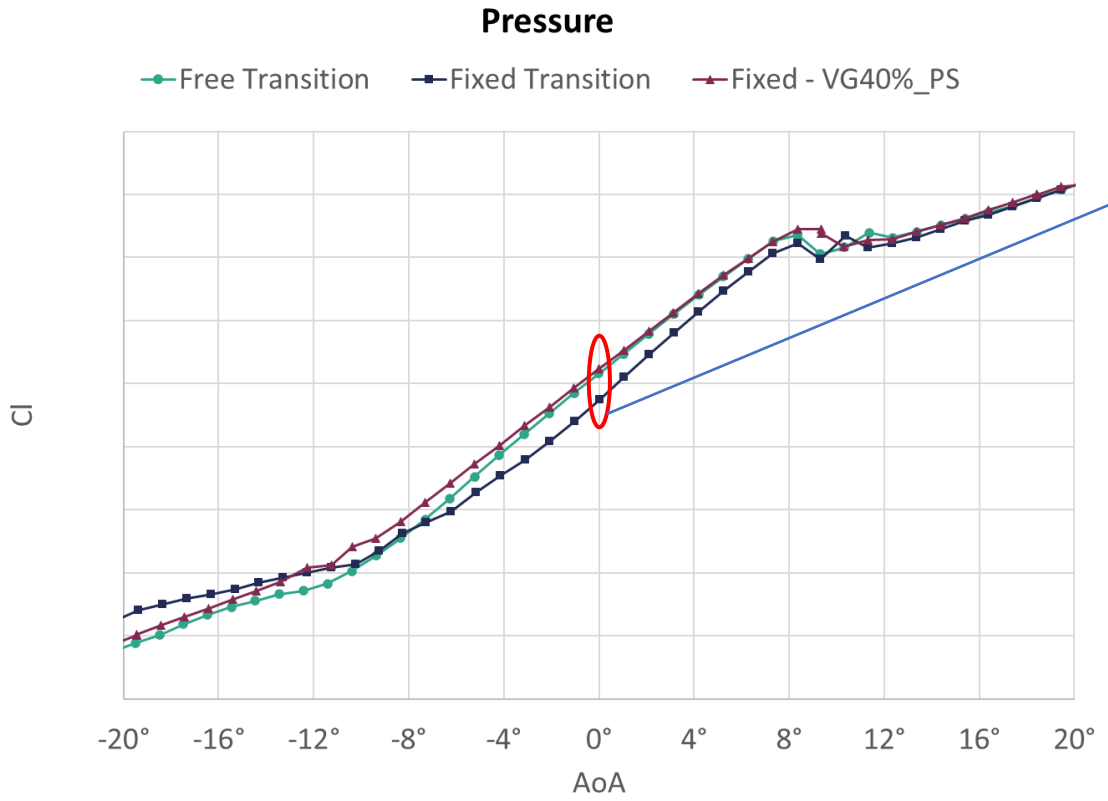


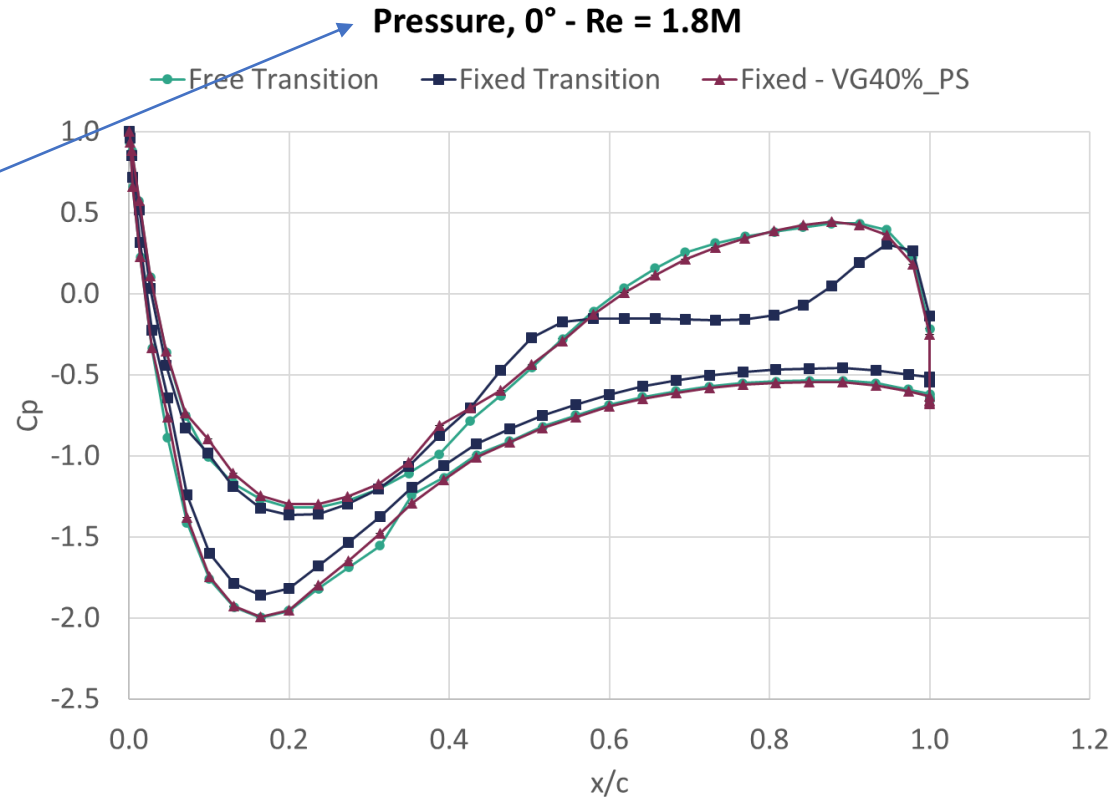
Results

FB20 – Adding VGs at 40% Pressure Side

Separation on PS eliminated, performance back to Free transition levels



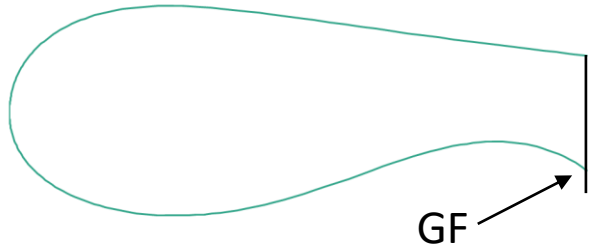


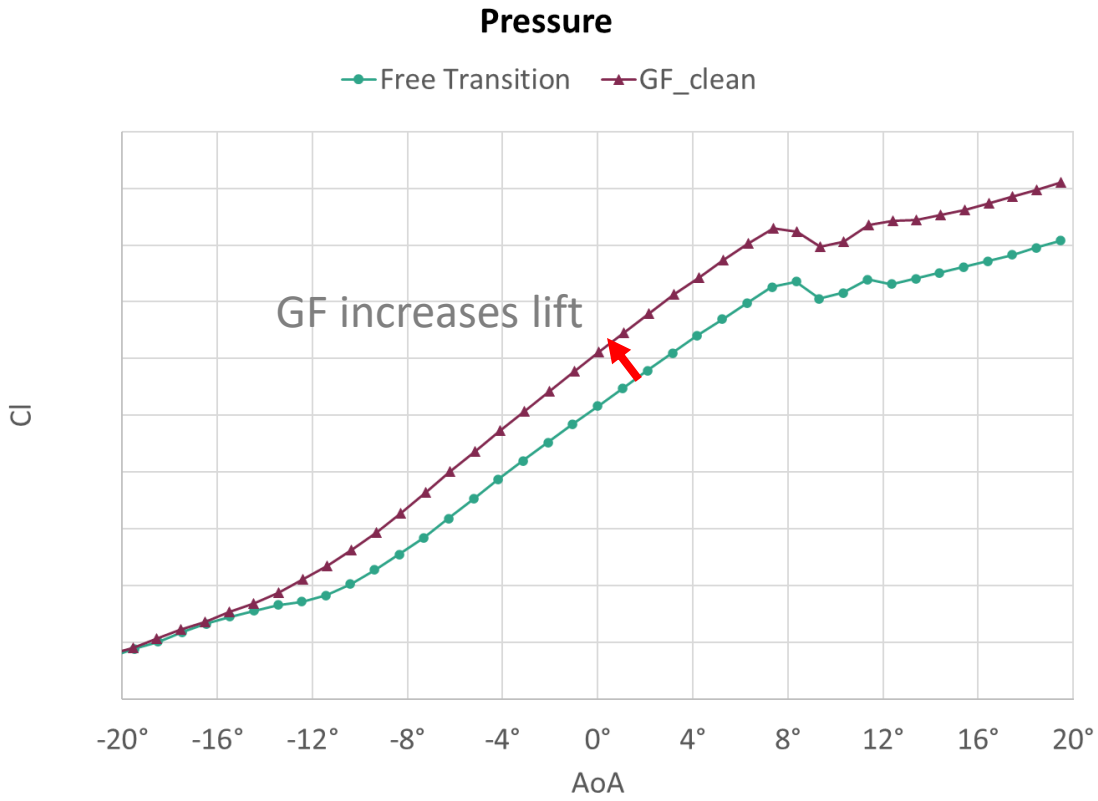


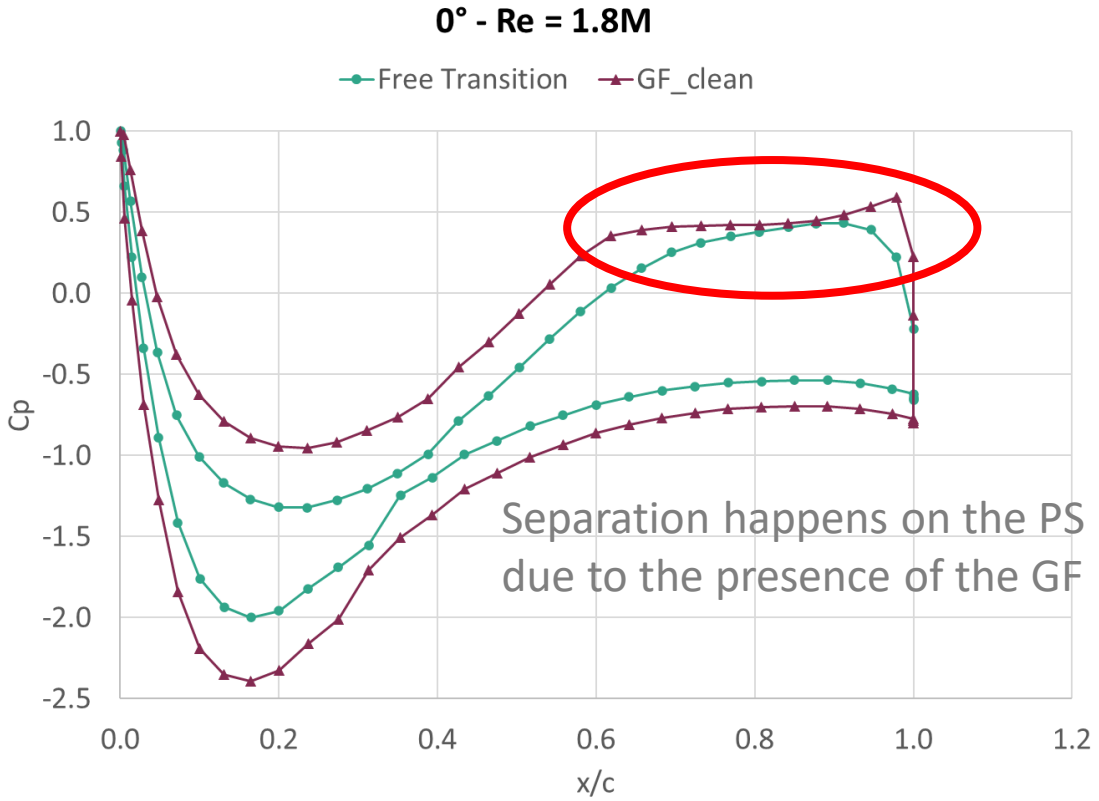
Results

FB20 – 5% Gurney Flap – Free transition

GF provides the highest lift for both free and fixed transition cases



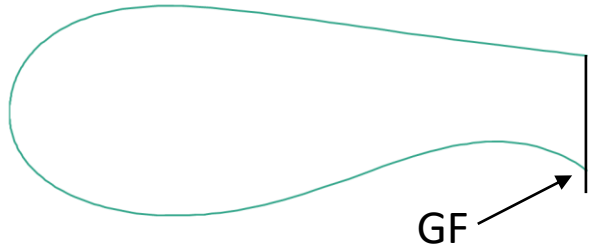


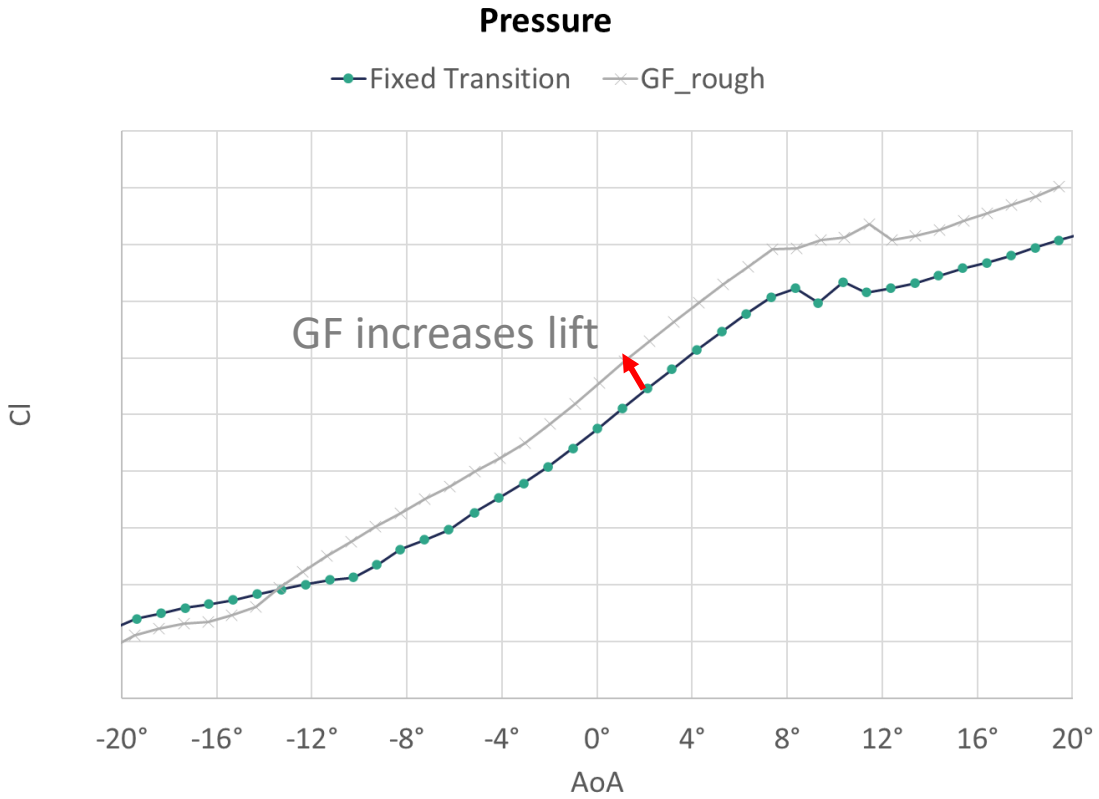


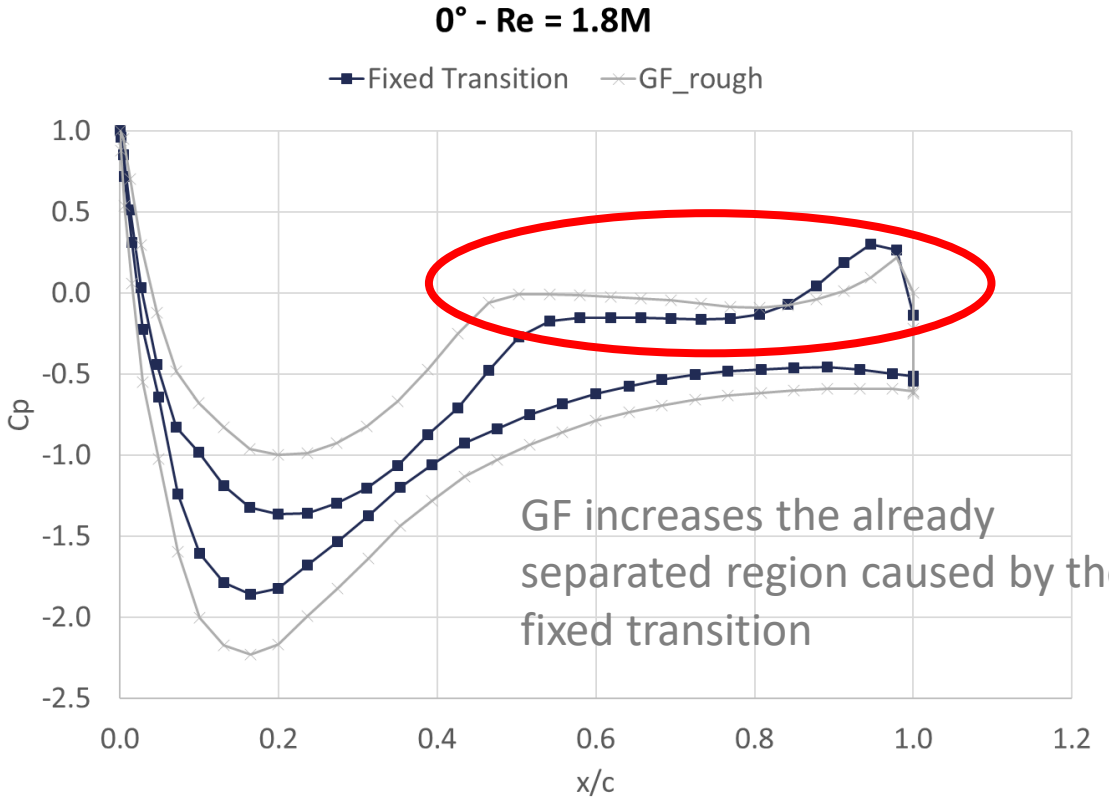
Results

FB20 – 5% Gurney Flap – Fixed transition

GF provides the highest lift for both free and fixed transition cases

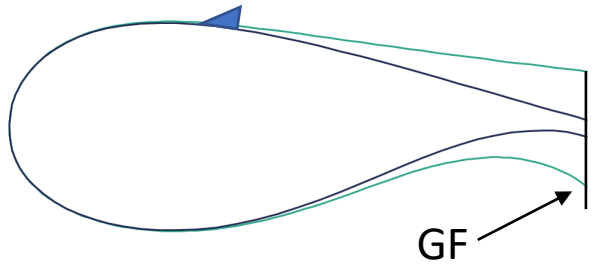


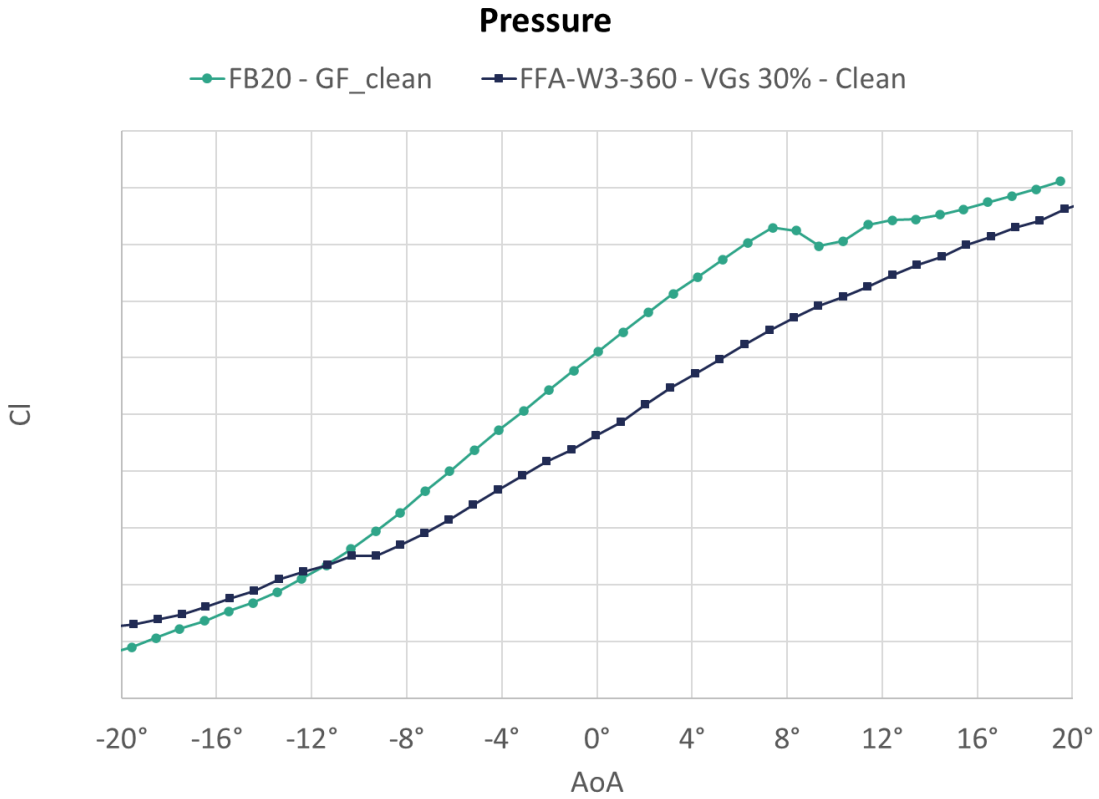


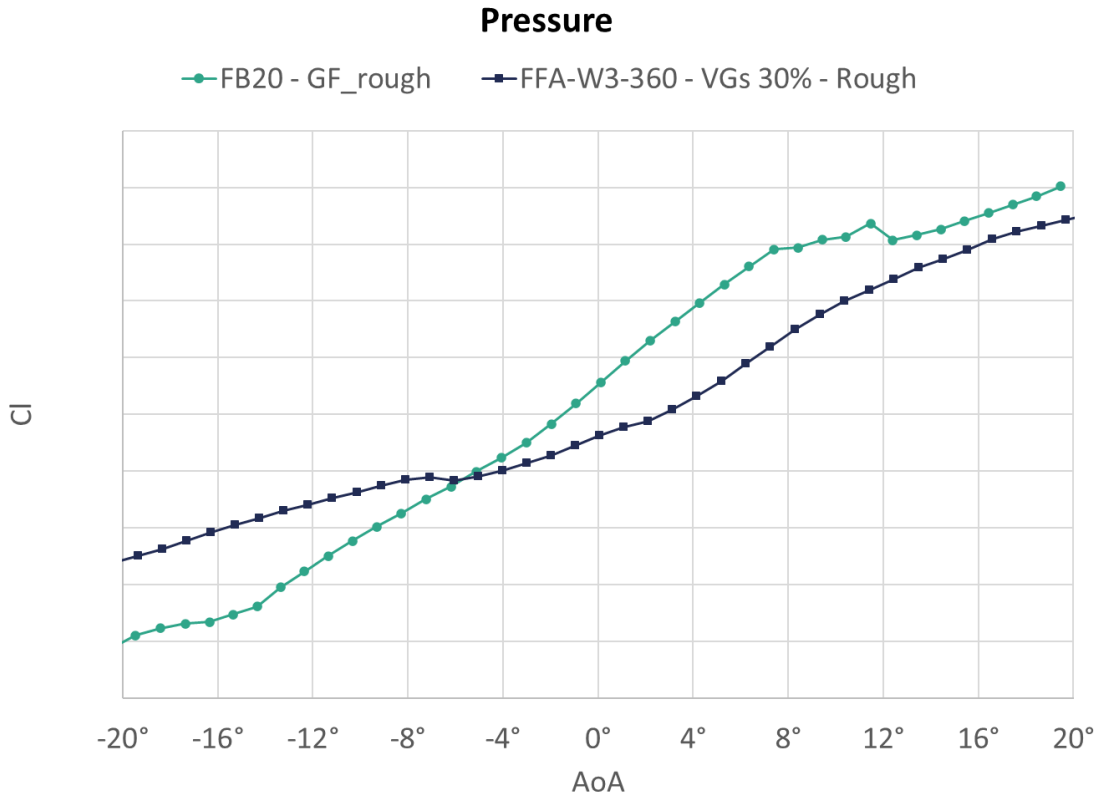


Results

Best performing combination?







Conclusions

- Large, slender blades require **very thick profiles** at the inboard part of the blade.
- **Flatback profiles** offer significant advantages which can be further enhanced by means of **VGs and GFs**.
- Stay tuned for **noise** and **wake** characteristics!

Acknowledgements

Let’s be blunt and drop the mic! An experimental study of very thick flatback airfoils

- Supergen ORE Hub Early Career Researcher Fund
- Vestas Technology
- Swansea University