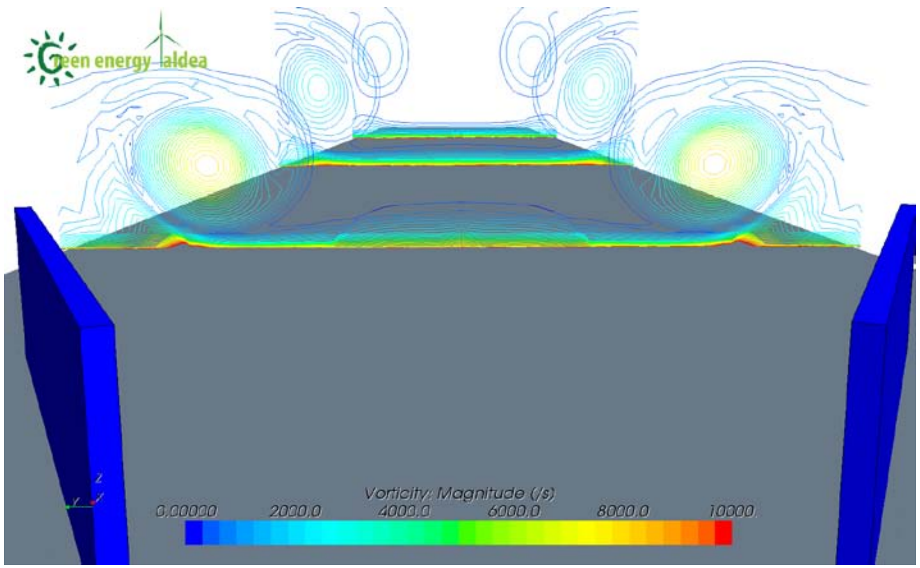
eman ta zabal zazu

Universidad del País Vasco — Euskal Herriko Unibertsitatea

Green energy aldea

Computational Simulations of a pair of Rectangular Vortex Generators on a flat plate.



G. Esteban ,

U. Fernández*,

A. Peña,

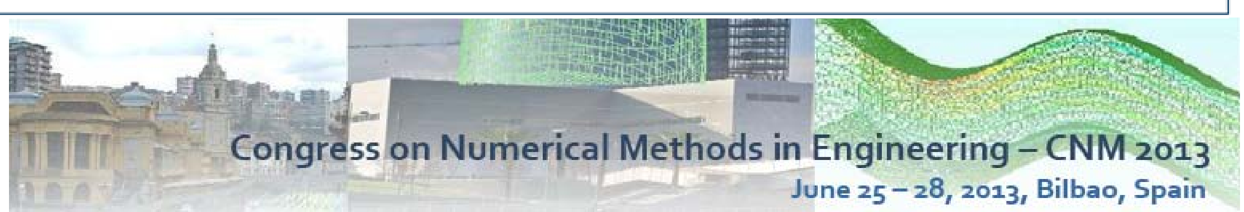
K. Olalde.

*Presenting author: unai.fernandez@ehu.es

UNIVERSITY LOCATION

THE BASQUE COUNTRY
Population: 2.129.339 inhab.
Area: 7.089 Km^2

VITORIA-GASTEIZ
Population: 236.525 inhab.



OUTLINE

1. INTRODUCTION
2. COMPUTATIONAL SET UP
3. RESULTS
4. CONCLUSIONS
5. FUTURE WORK

Introduction

Applied aerodynamics on aircraft wings

Source: Vortex generators on the wing of an airplane at the Air Force Museum of the German Federal Armed Forces in Berlin. Image credit: Wikimedia Commons
http://phys.org/news/2012-09-scientists-purpose-vortex.html#jCp

What is a VG? How does it work?

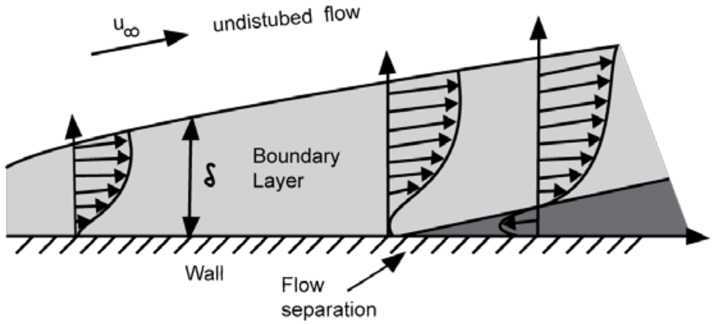


Figure 1: Evolution of boundary layer velocity profiles with adverse pressure gradient.

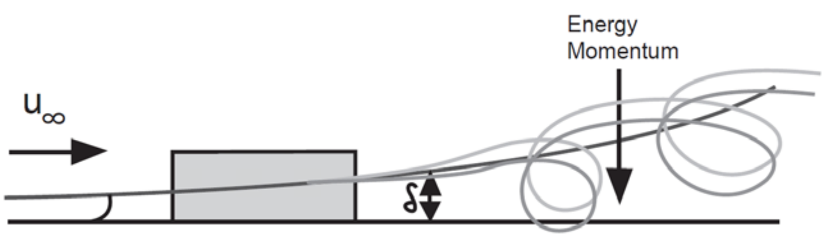


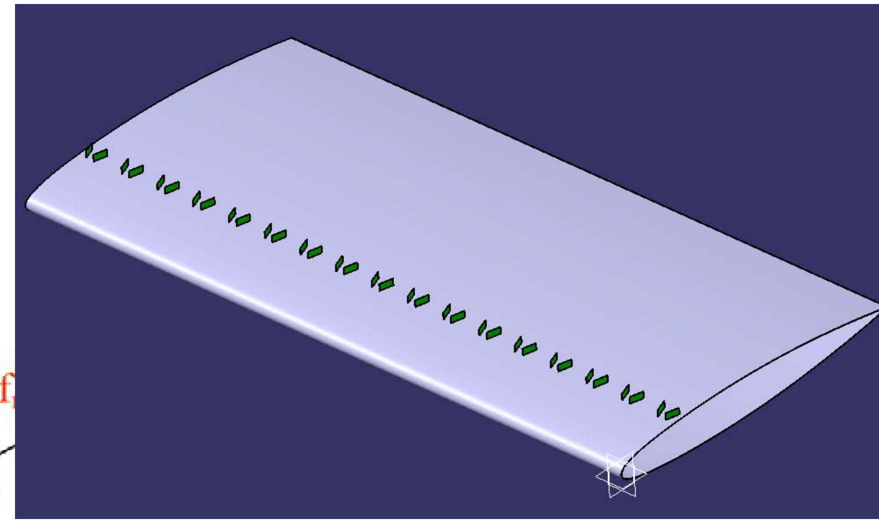
Figure 2: Boundary layer motion alteration by a rectangular VG.

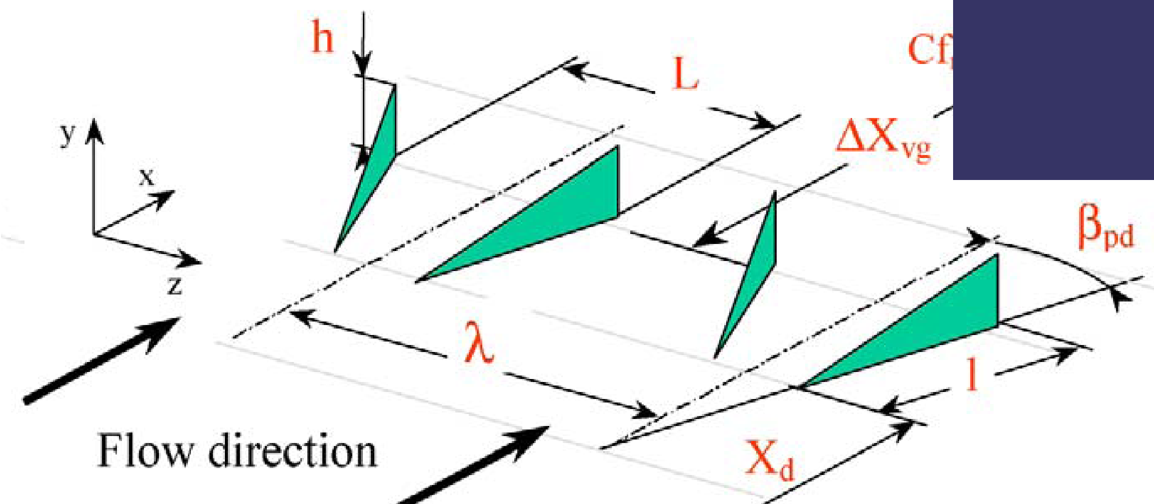
These passive devices are used for flow control:

- Modifying the boundary layer motion.
- Generation of longitudinal vortices.
- Overturn of the BL flow via large scale motions.
- Bringing high momentum fluid down into the near wall region of the boundary layer.
- In short: separation of the flow is delayed.

VGs on Airfoils

- GEOMETRY: triangular or rectangular vanes.
- Dimensioned : to the local boundary layer thickness.
- Lay-out: in cascades in groups of two.





Ref.: G. Godard , M. Stanislas 2005

Figure 3: Counter rotating passive device configuration.

VGs on Airfoils

- Main functionality:
  - to delay or prevent separation of the flow.

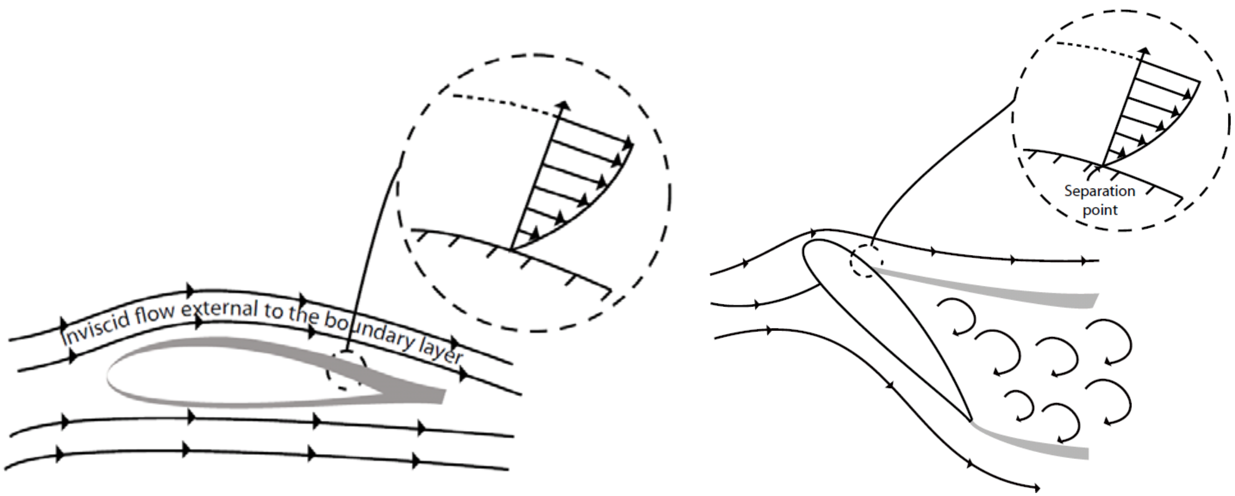


Figure 4: (a)Flow across an airfoil. (b) Separated flow over the top surface of an airfoil)

SOURCE: J.D. Anderson Jr., Brief History of the Early Development of Therotical an Exp. Fluid Dynamics Willey&Sons 2010

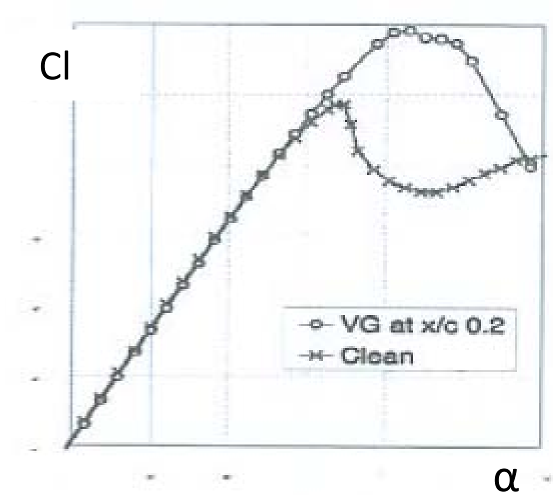


Figure 5:: effect of vortex generators on the performance of DU 97-W-300.

Ref.: van Rooij R. P. J. O. M. and Timmer W A "Roughness Sensitivity Considerations for Thick Rotor Blade Airfoils". AIAA-paper 2003-0350.

VGs on Wind Turbines

Increased wind turbine performance from implementing VGs on the blades has also been confirmed through various field tests.

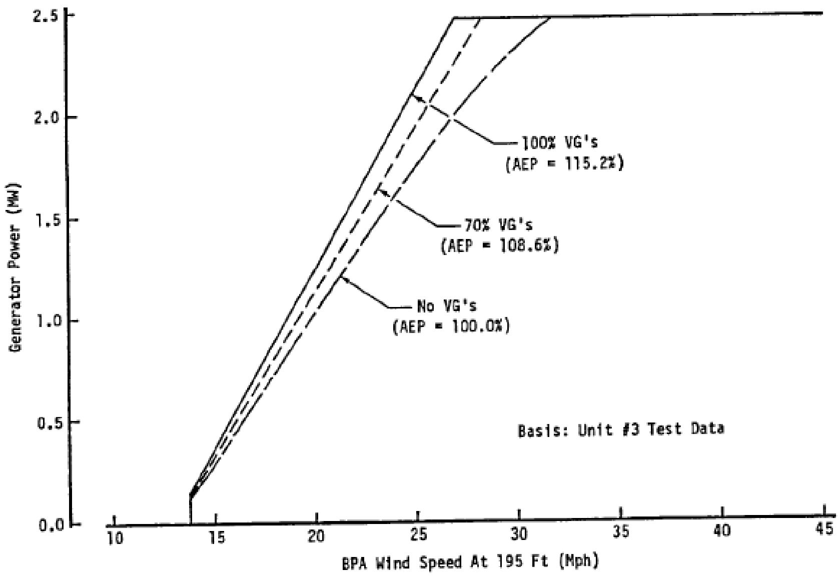


Figure 6 (a): Effects of VGs on a 2.5 MW wind turbine performance.

Ref.: Miller, G.E., "Comparitive Performance Tests on the Mod-2 2.5 MW Wind Turbine With and Without Vortex Generators," NASA TM N95-27978, Presented at the DOE/NASA Workshop on Horizontal Axis Wind Turbine Technology, May 8-10, 1984, Cleveland, OH.

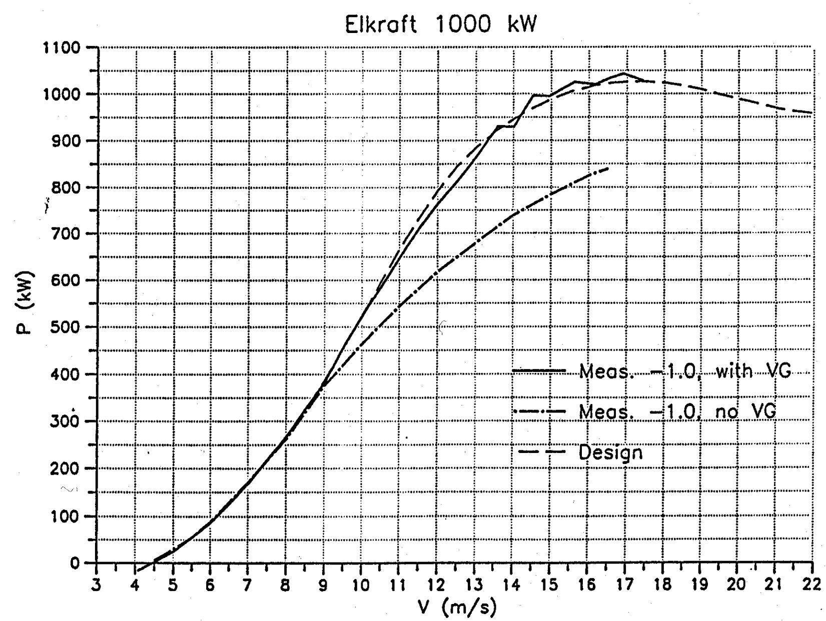
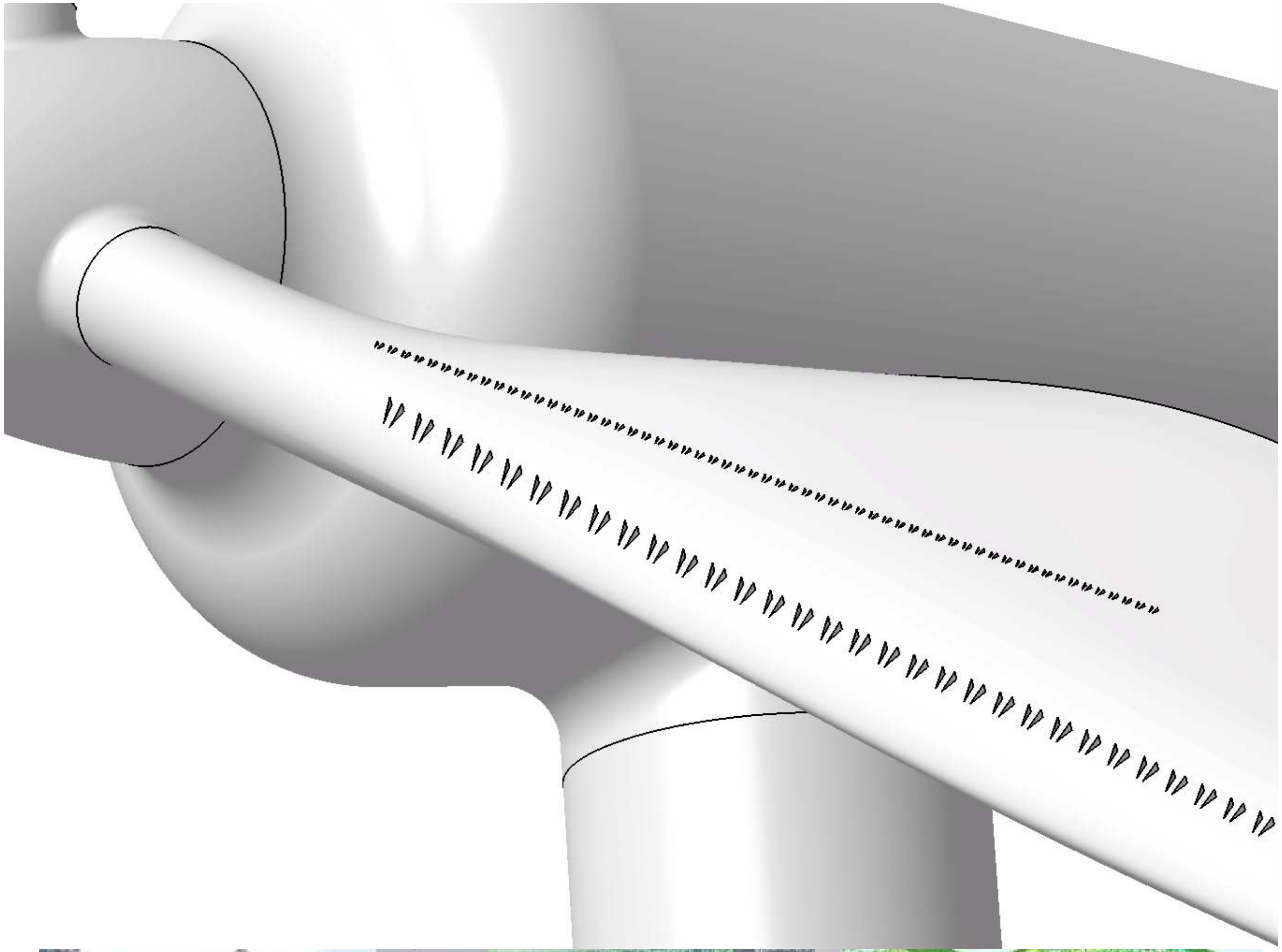


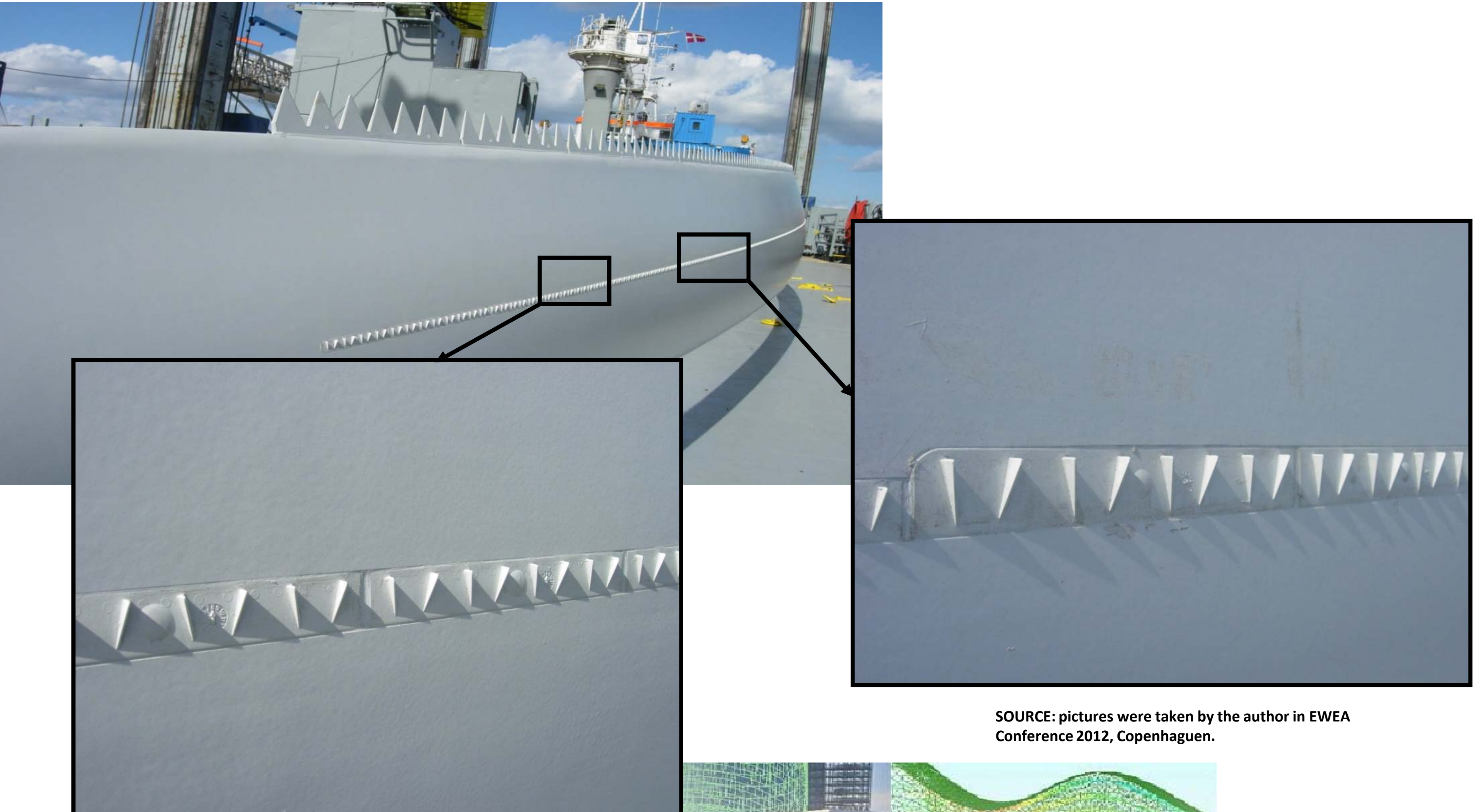
Figure 6 (b): Effects of VGs on a 1 MW wind turbine performance.

Ref.: S. Øye, The effect of Vortex Generators on the performance of the ELKRAFT 1000 kW Turbine, 9th IEA Symp. On Aerodynamics of Wind Turbines, 1995.

VGs on Wind Turbines



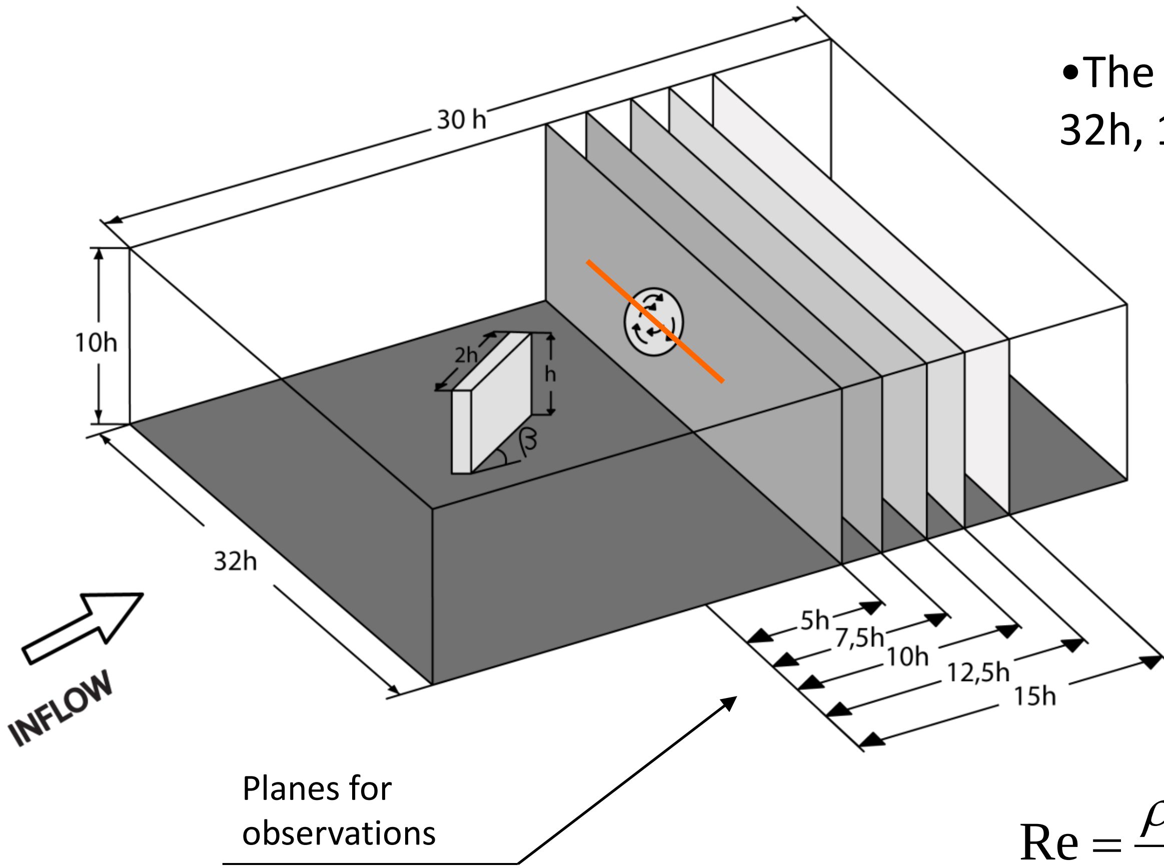
VGs on Wind Turbines

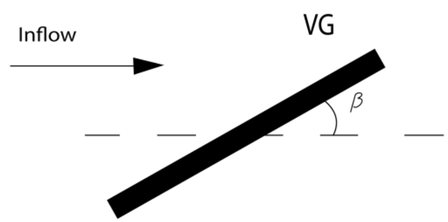


SOURCE: pictures were taken by the author in EWEA Conference 2012, Copenhaguen.

Computational Set Up

- The flow domain dimensions: 32h, 10h and 30h.





$$\mathrm{Re} = \frac{\rho U_{\infty} H}{\mu} = 20000$$

Figure 7: Computational domain and plane location where the measurements were conducted

Computational Set Up

- **Unsteady state** computations have been carried.

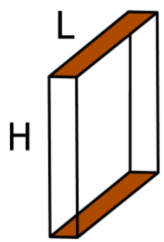
- CFD computations: EllipSys3D code. RANS equations.

- The convective terms are discretized utilising the third order Quadratic Upstream Interpolation for Convective Kinematics (QUICK).

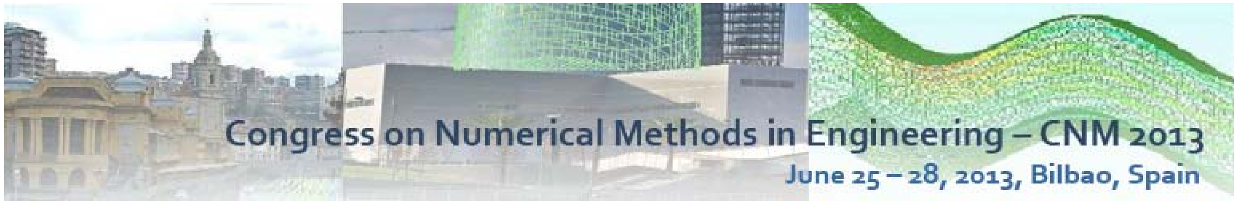
- ***k-ω SST*** (Shear Stress Transport)

$$\mathrm{Re} = \frac{\rho U_\infty H}{\mu} = 20000$$

H=0.01 m



L=2H



Mesh

- Block structured mesh ($2x10^6$ cells)
- Around the VG geometry: $7x10^5$ cells. Downstream the VG: $4x10^5$ cells.

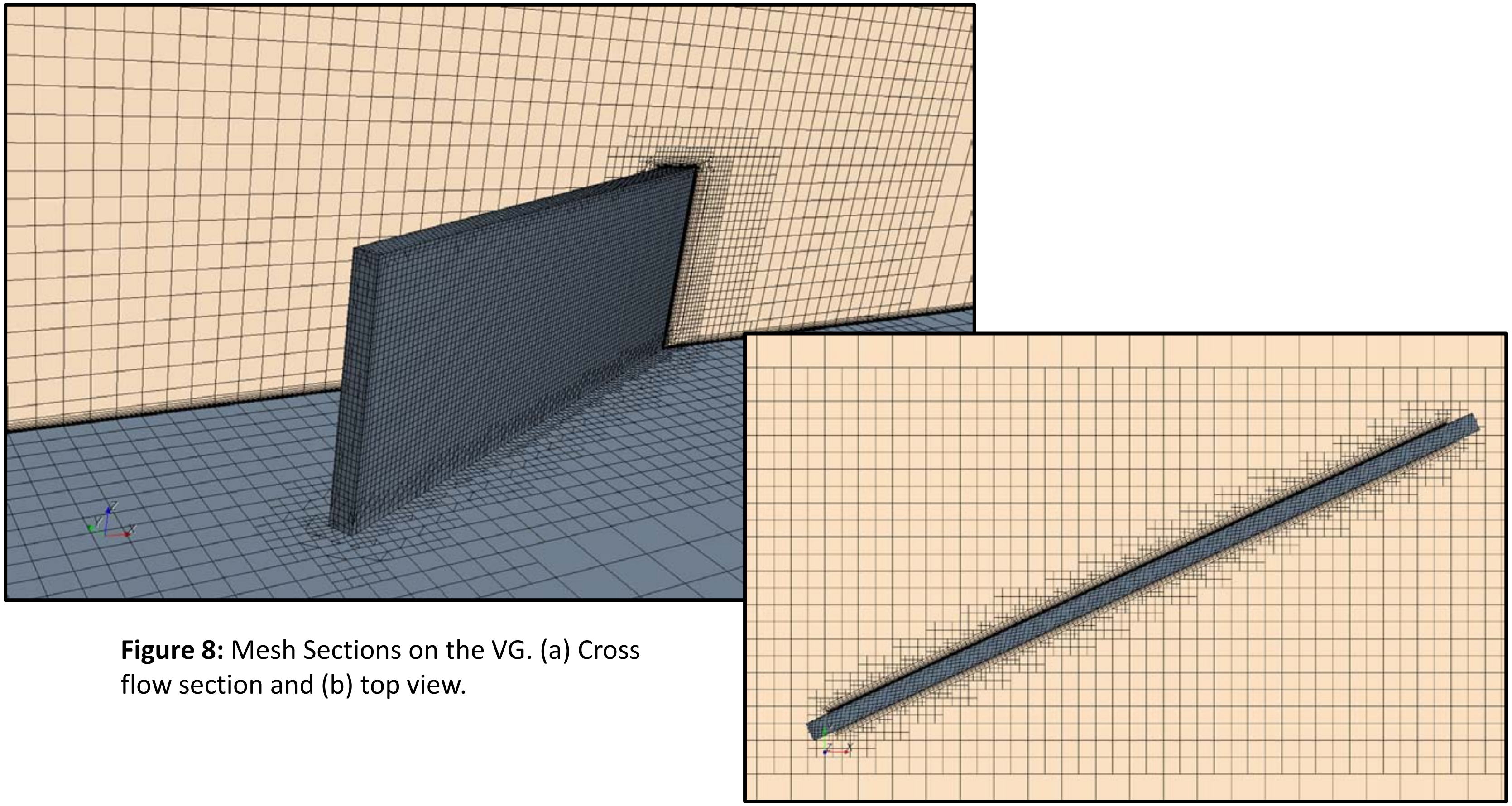
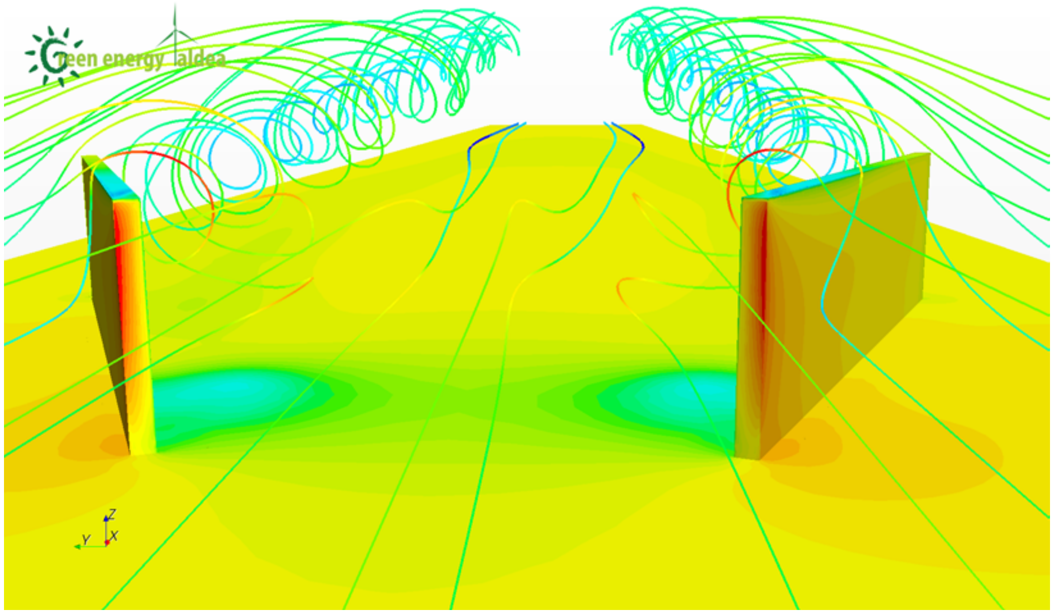


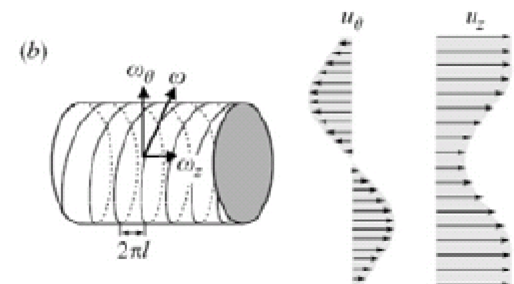
Figure 8: Mesh Sections on the VG. (a) Cross flow section and (b) top view.

Analytical model

- The axial, u_z, and rotational, u_Θ, velocities are linearly related:



$$u_z = u_0 - r\,u_\theta / l$$

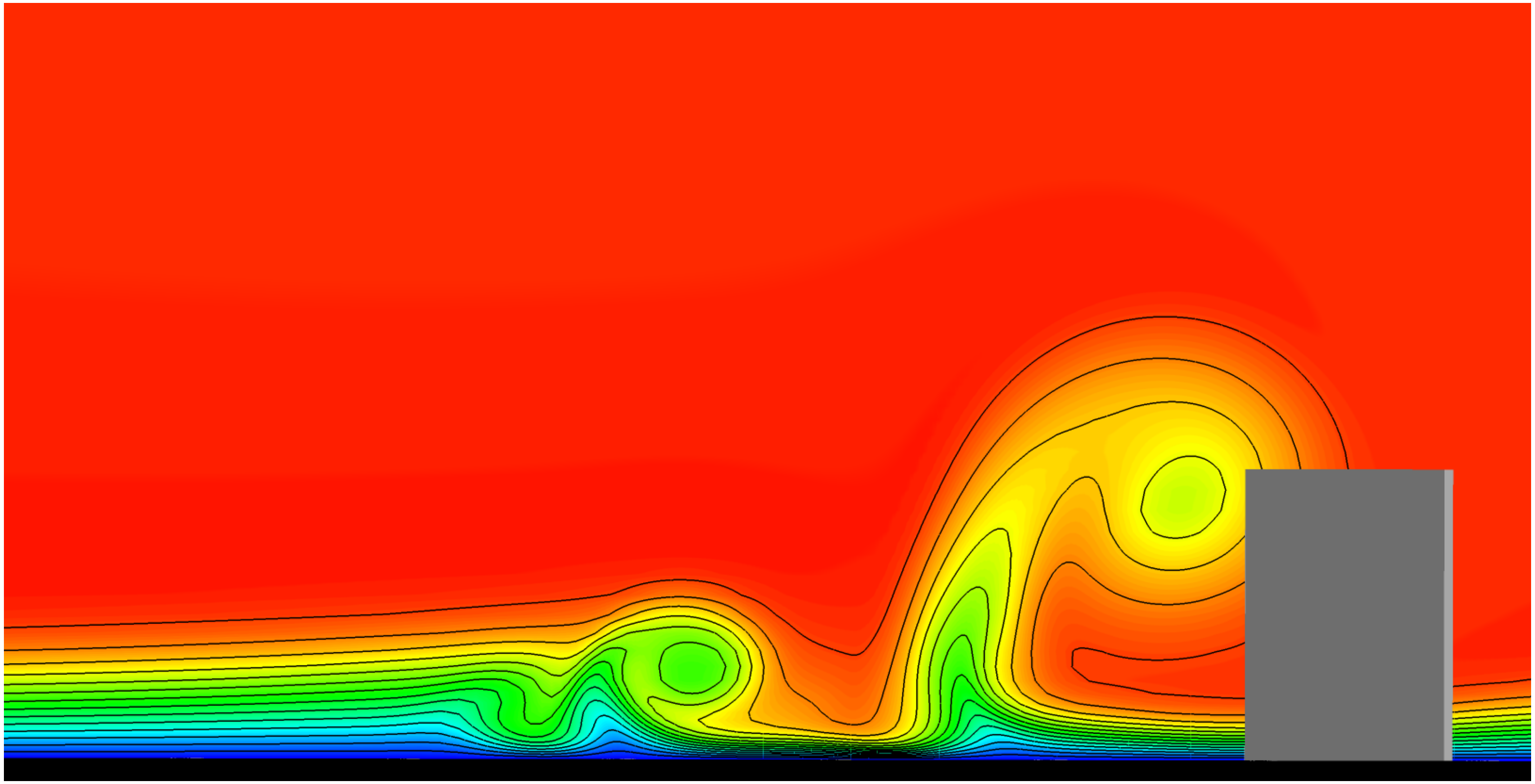


Together with the Batchelor vortex model

$$u_\theta(r,\theta,z) = \frac{\Gamma(z)}{2\pi r}\left[1-\exp\left(-\frac{r^2}{\varepsilon^2(\theta,z)}\right)\right]; \quad u_z(r,\theta,z) = u_0(z) - \frac{\Gamma(z)}{2\pi l(\theta,z)}\left[1-\exp\left(-\frac{r^2}{\varepsilon^2(\theta,z)}\right)\right]$$

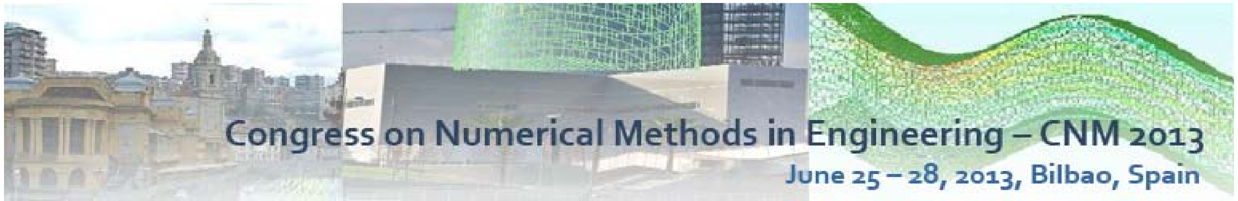
four parameters: $\varepsilon(\Theta,z)$, circulation $\Gamma(z)$, $u_0(z)$ and $l(\Theta,z)$,

Axial Velocity Fields

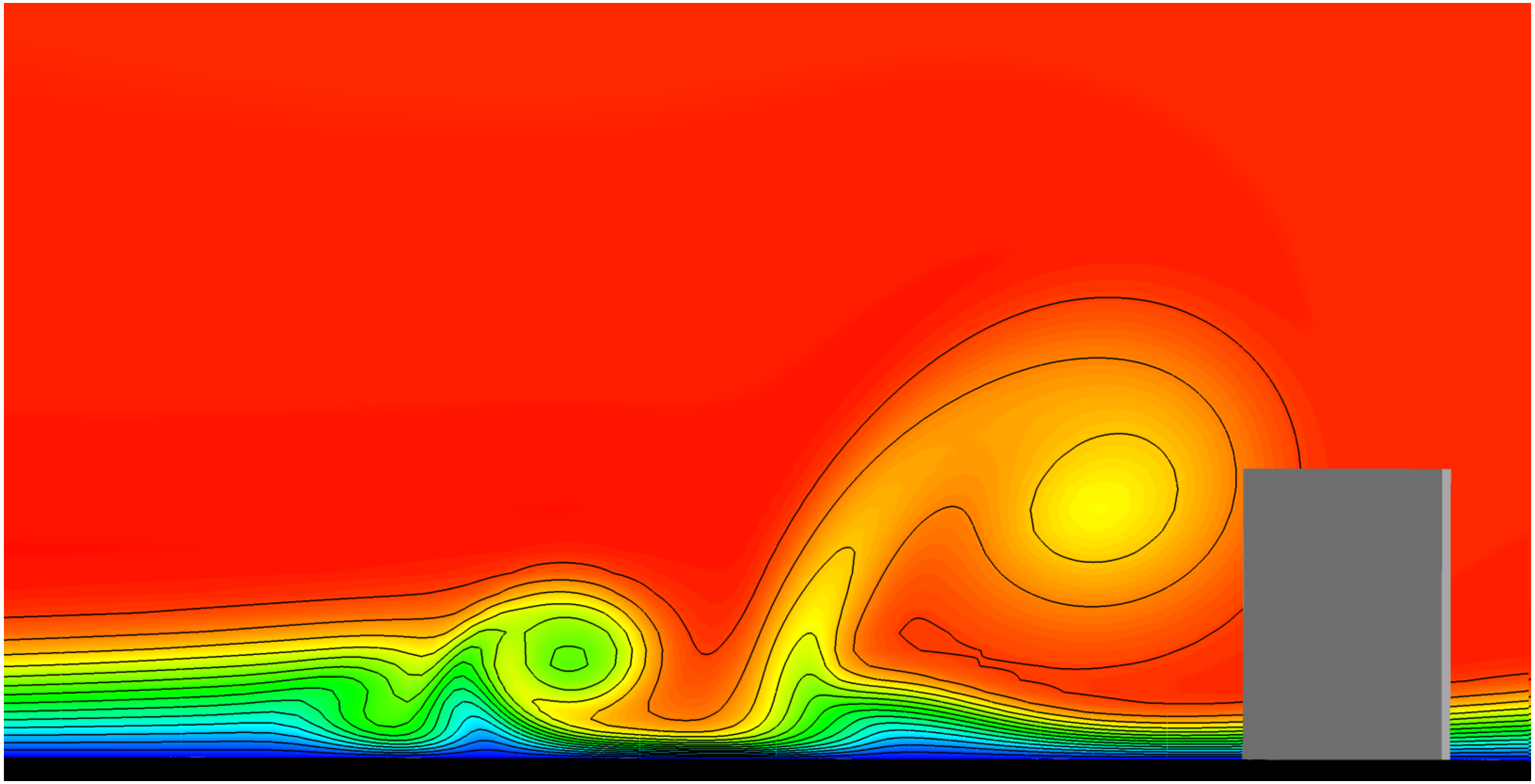


x/h = 5

Figure 9: Axial velocity fields at five plane positions: *z/h* = 5-15.



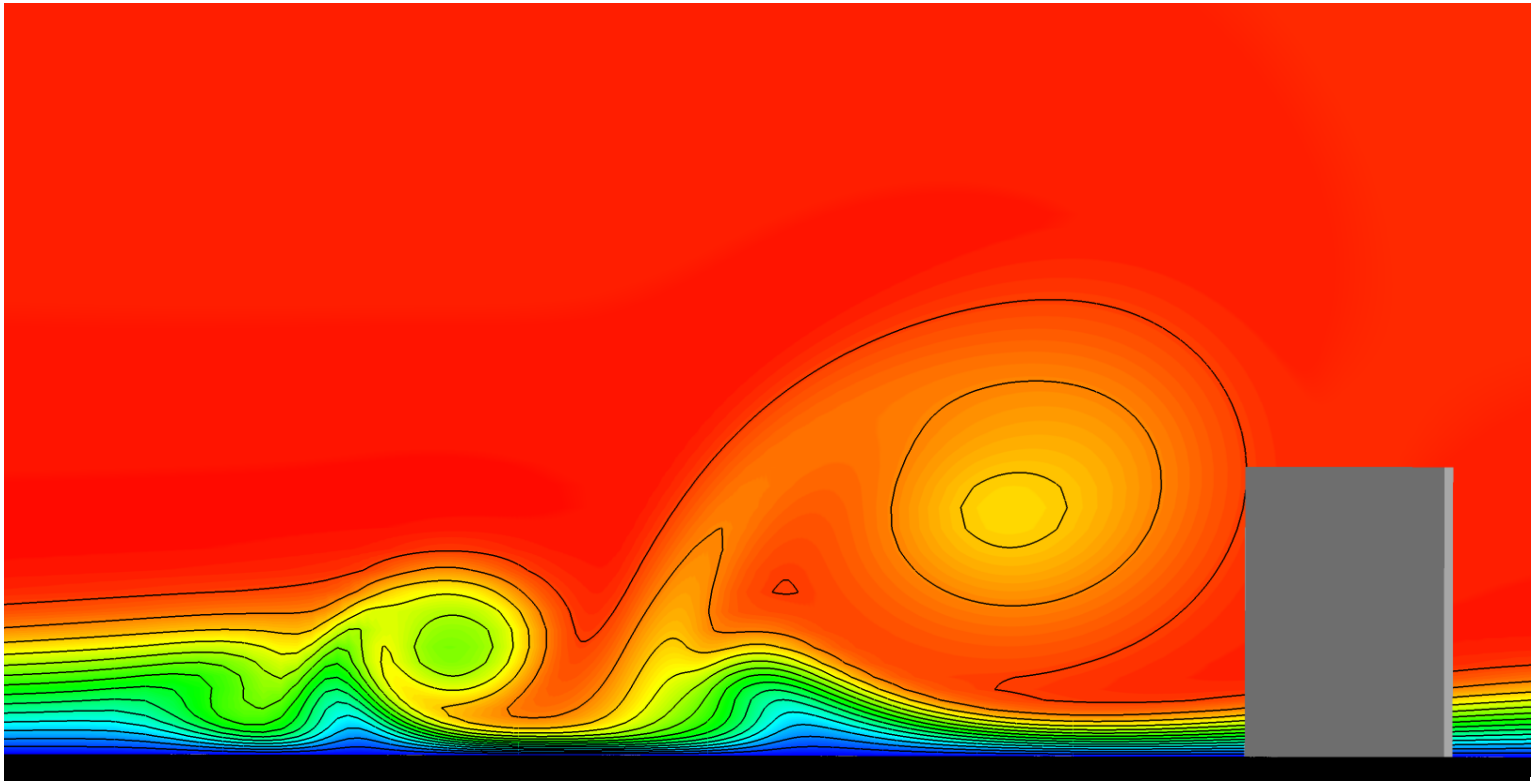
Axial Velocity Fields



z/h = 7.5

Figure 9: Axial velocity fields at five plane positions: z/h = 5-15.

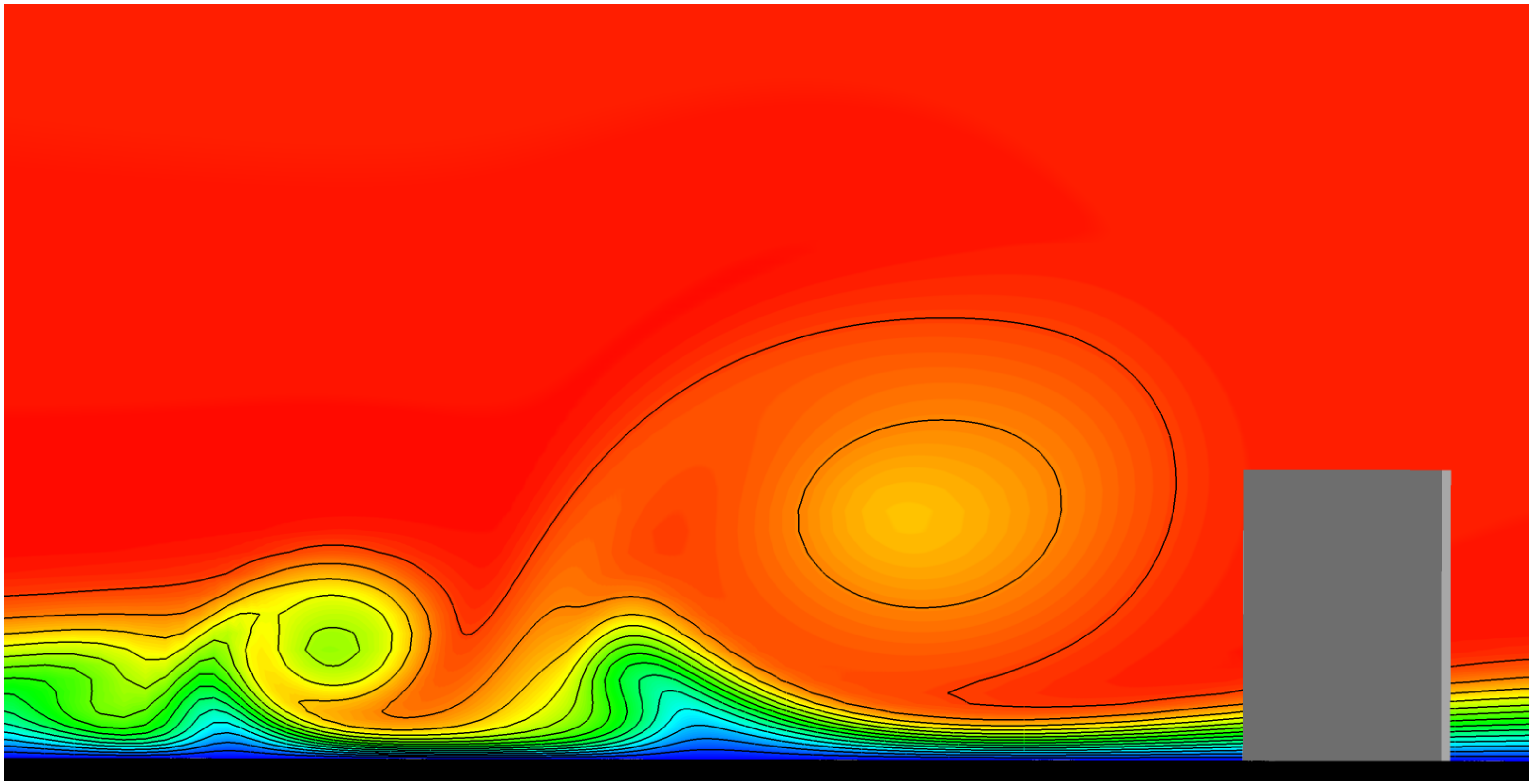
Axial Velocity Fields



$x/h = 10$

Figure 9: Axial velocity fields at five plane positions: z/h = 5-15.

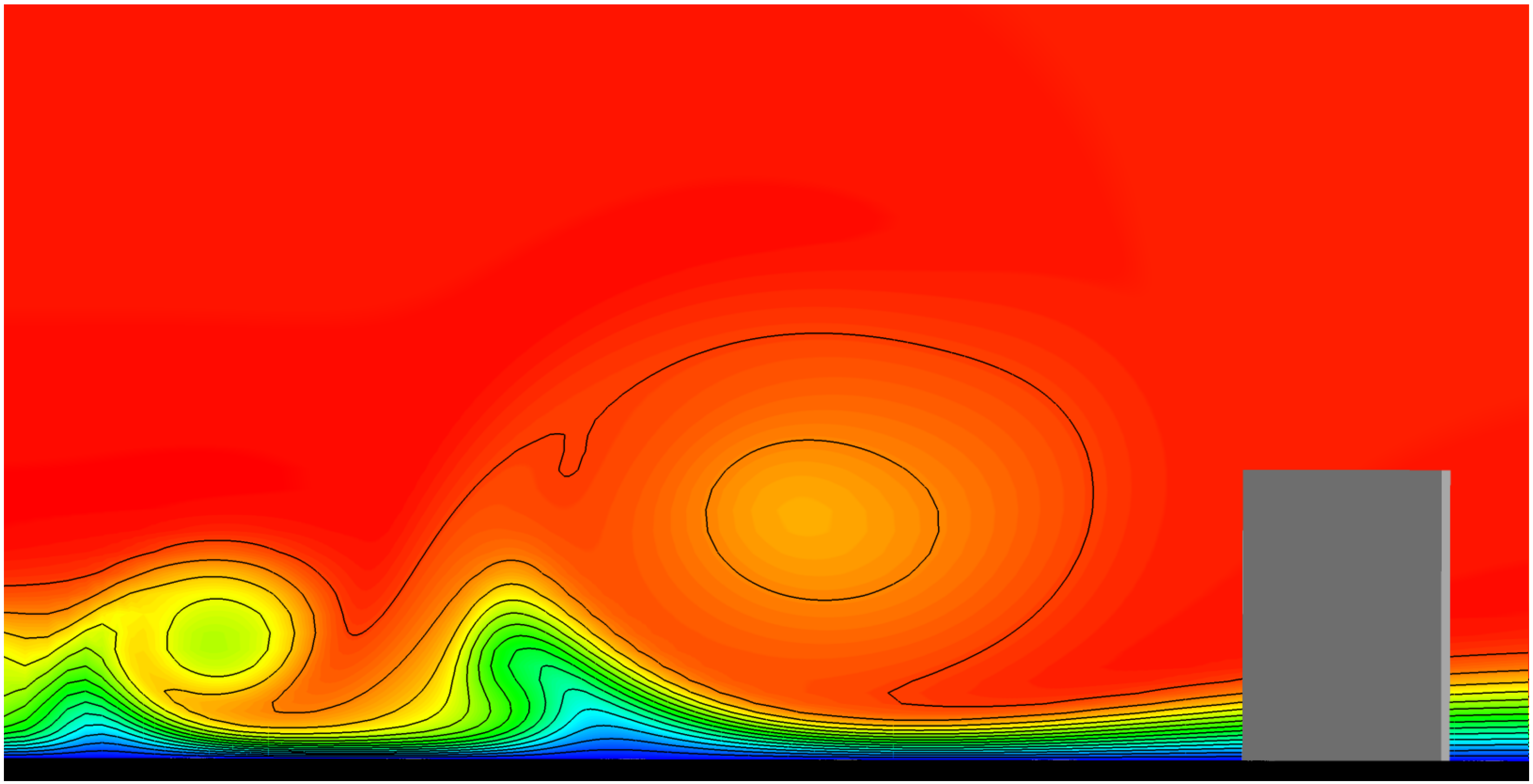
Axial Velocity Fields



x/h = 12.5

Figure 9: Axial velocity fields at five plane positions: *z/h* = 5-15.

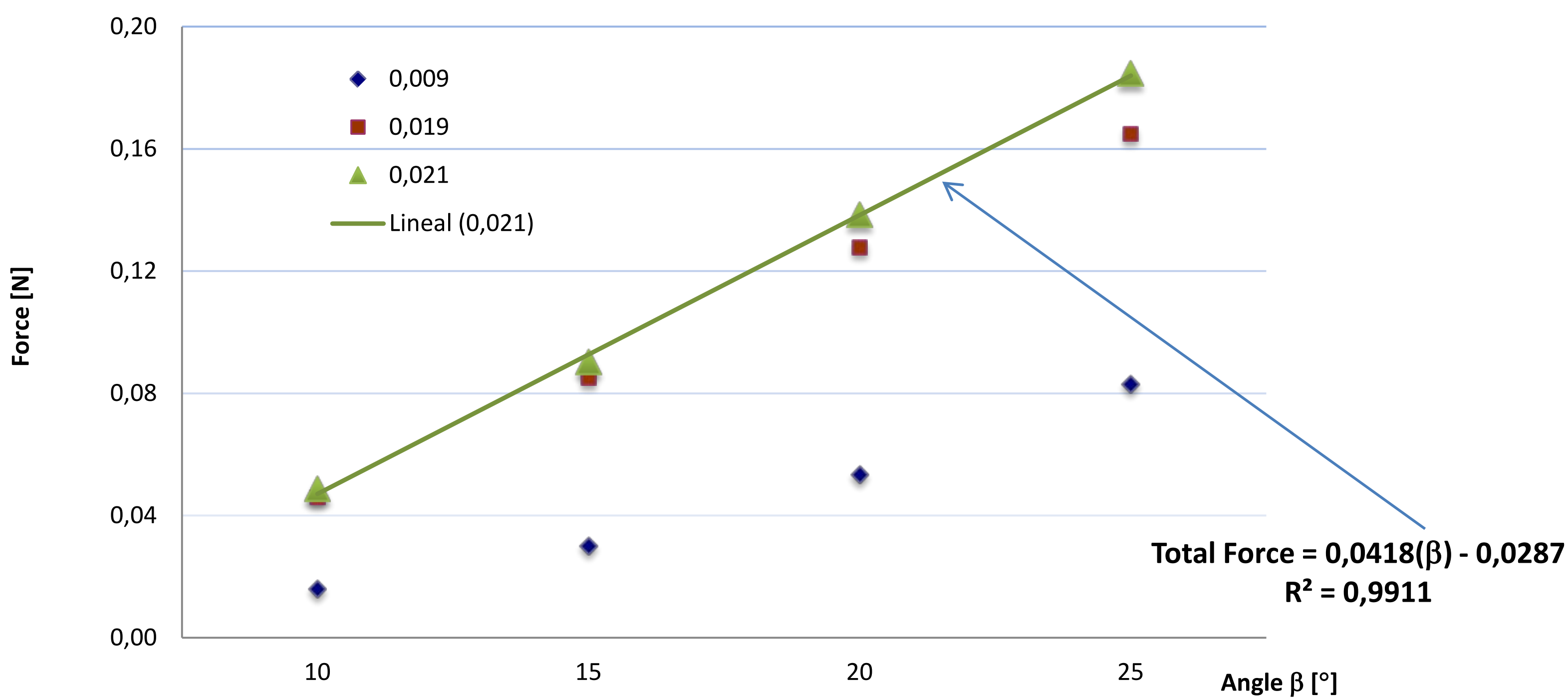
Axial Velocity Fields



x/h = 15

Figure 9: Axial velocity fields at five plane positions: z/h = 5-15.

FORCES PLOT



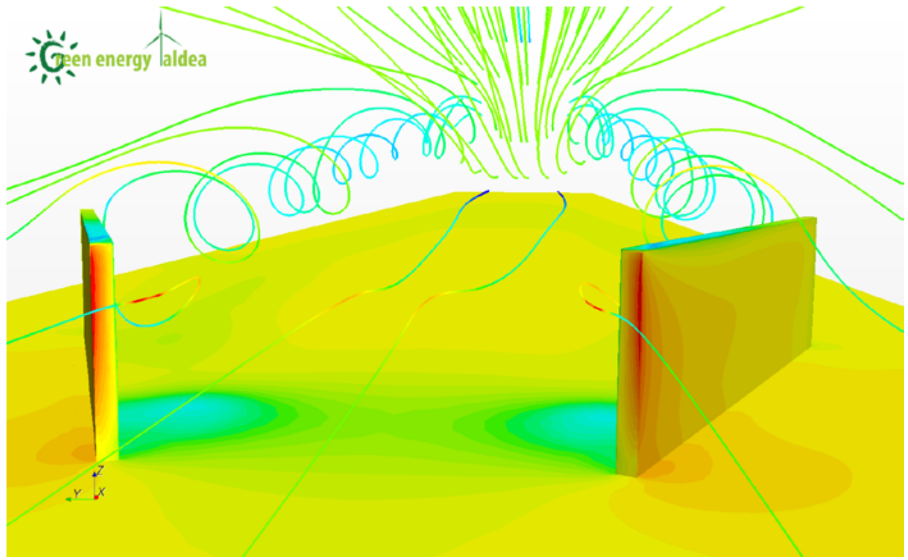
Angle [°]	Force x [N]	Force Y [N]	Total Force [N]
5	0,009	0,019	0,021
10	0,016	0,046	0,049
15	0,030	0,085	0,090
20	0,053	0,128	0,139
25	0,083	0,165	0,185

Conclusions

- The main vortex generated by the VG possesses helical symmetry and self-similar behavior for both the axial and azimuthal velocity profiles. It has been proven based on five plane positions z/h=5-15 downstream of the trailing edge of the VG and with β=20º of the vane to the incoming flow.
- From the point of view of self-similarity, computational simulations are able to reproduce the physics of the vortex generated by a rectangular VG with considerable reliability.

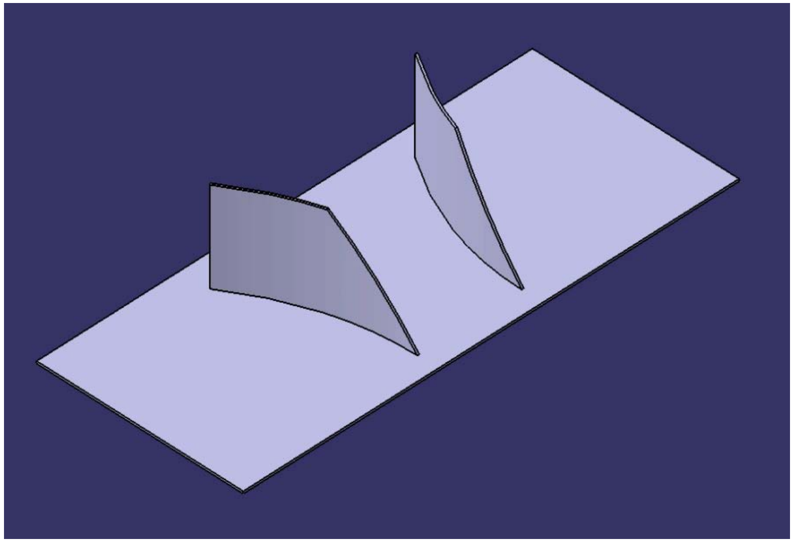
Future Work

- Additional work:
  - Comparison with wind tunnel experimental data.
  - Computations with Different VG geometries.



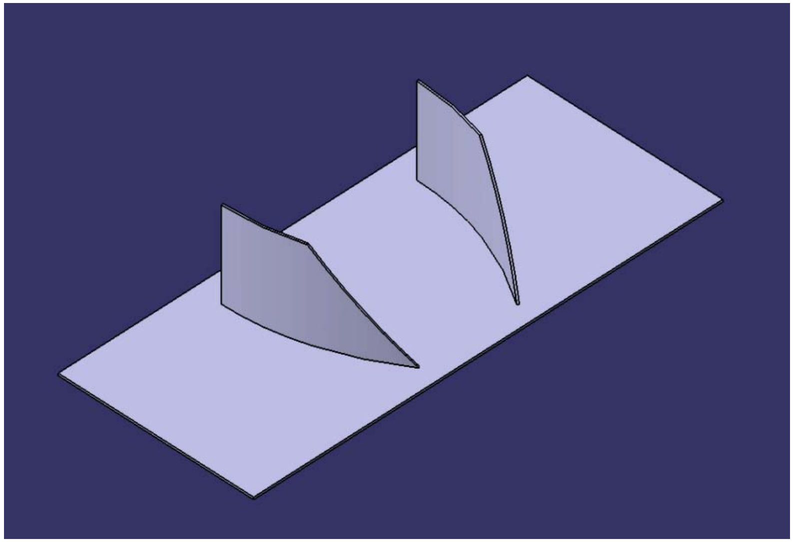
Future Work

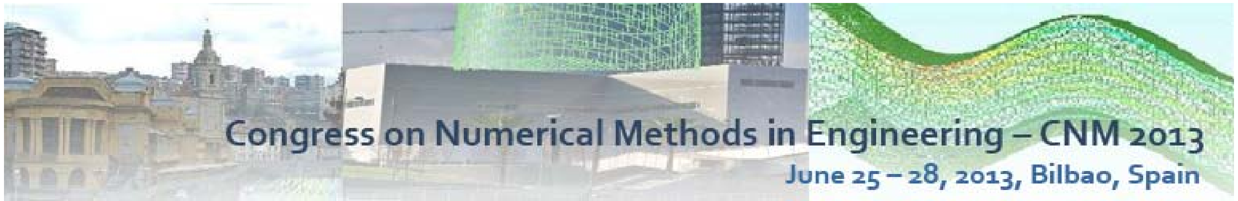
- Additional work:
  - Comparison with wind tunnel experimental data.
  - Computations with with Different VG geometries.



Future Work

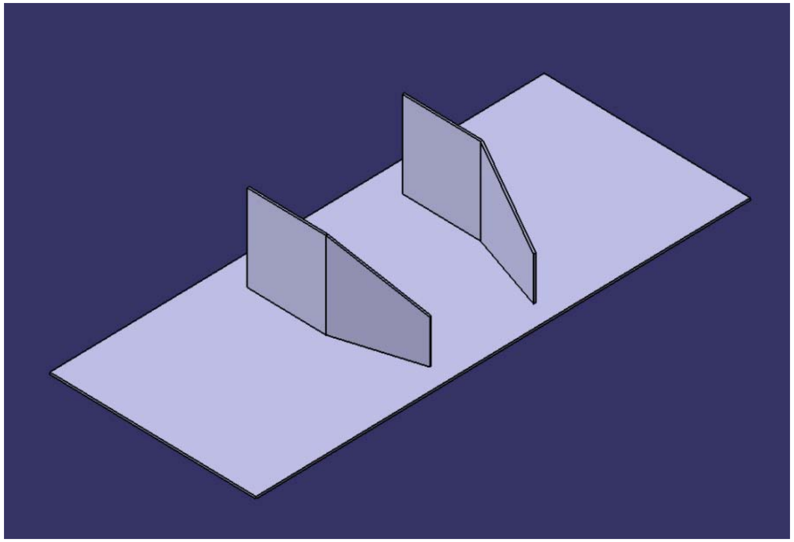
- Additional work:
  - Comparison with wind tunnel experimental data.
  - Computations with with Different VG geometries.





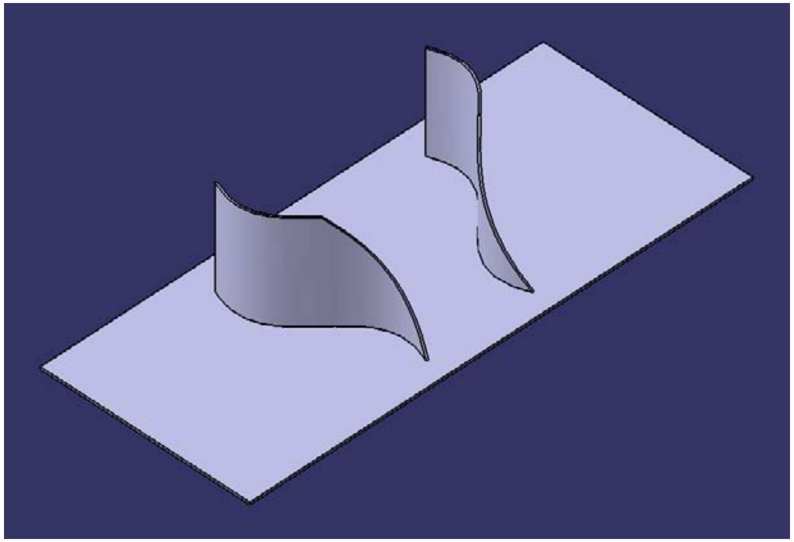
Future Work

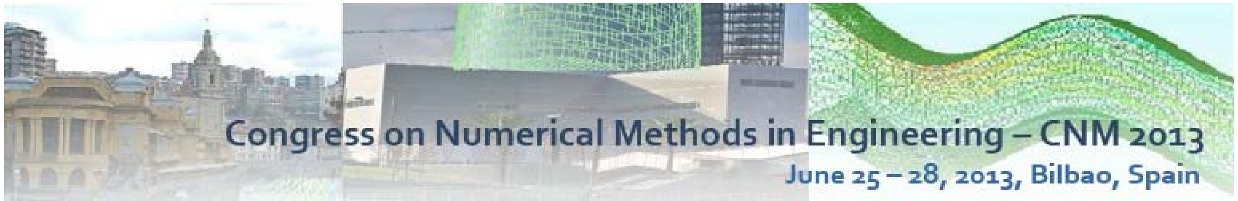
- Additional work:
  - Comparison with wind tunnel experimental data.
  - Computations with with Different VG geometries.



Future Work

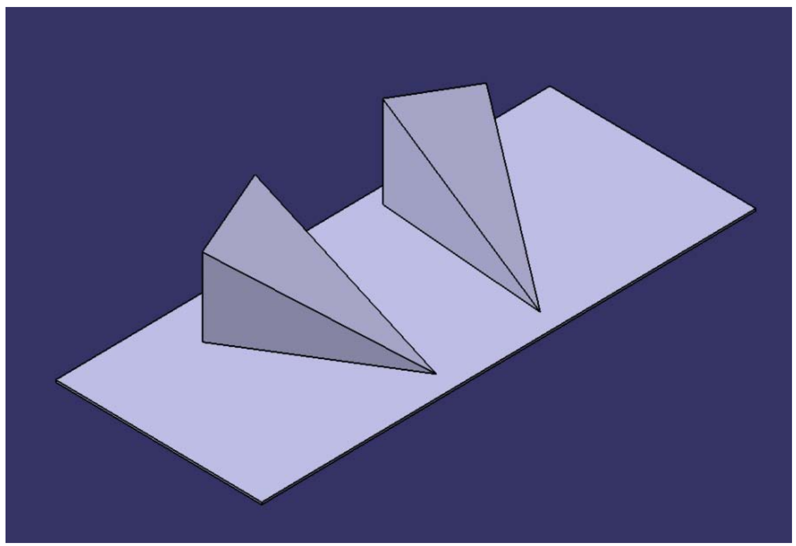
- Additional work:
  - Comparison with wind tunnel experimental data.
  - Computations with with Different VG geometries.





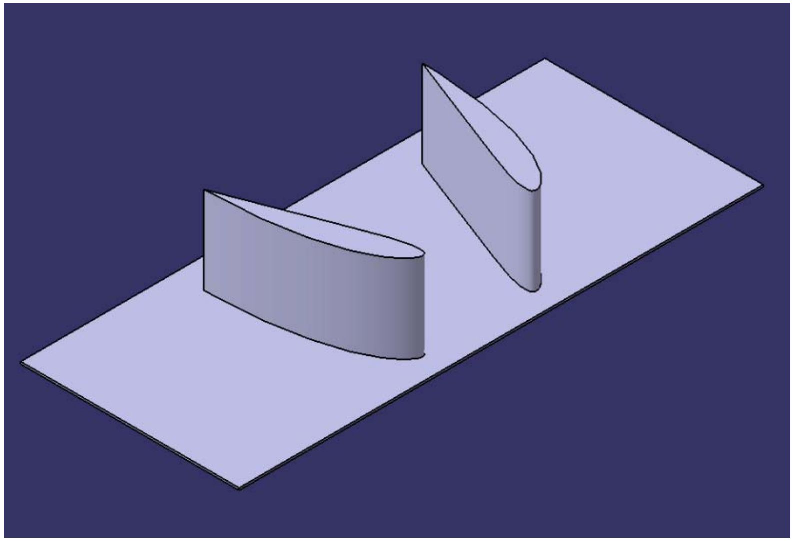
Future Work

- Additional work:
  - Comparison with wind tunnel experimental data.
  - Computations with with Different VG geometries.



Future Work

- Additional work:
  - Comparison with wind tunnel experimental data.
  - Computations with with Different VG geometries.



Thank you very much for your attention!

Eskerrik asko zuen arretagatik!

¡Muchas Gracias por vuestra atención!