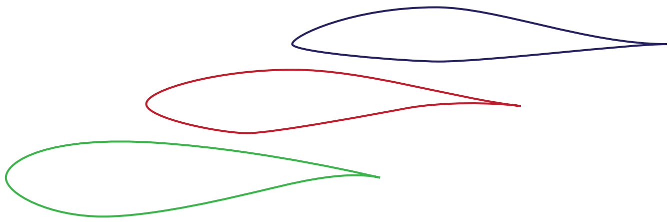
CENER | CENTRO NACIONAL DE ENERGÍAS RENOVABLES
NATIONAL RENEWABLE ENERGY CENTRE

WIND ENERGY DEPARTAMENT

AEROFOIL DESIGN

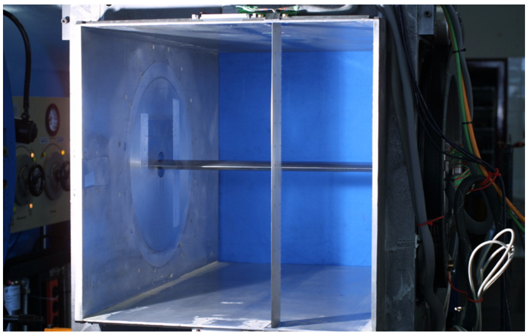
CENER AEROFOIL FAMILY

- Multi MegaWatt machines.
- High Lift for slender blades.
- Low sensitivity to roughness.
- Low noise.



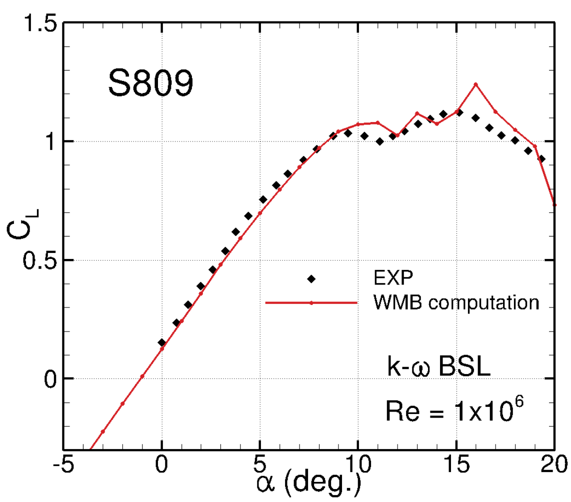
WIND TUNNEL TESTS AT HIGH REYNOLDS

- Test design and execution.
- Clean & Rough configurations.
- High Reynolds (3-6-9 million).
- Previous experience: 4 aerofoil families.

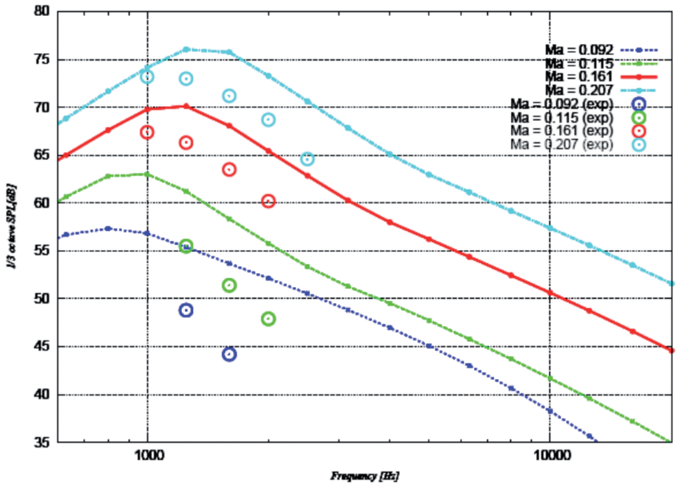


CENER NUMERICAL METHODS FOR AEROFOILS

- Aerofoil Design tool CAO
- Compressible CFD method: WMB



- Unsteady aerodynamic tool: DYSTOOL
- Aerodynamic Noise prediction: HASE 2D/3D



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The **aerofoils of CENER family**, that at this stage is composed by three thicknesses (18%, 21% and 24%), are designed for High Reynolds numbers (>3mill). The aerodynamic performance of the 3 aerofoils has been verified with CENER CFD method, WMB, and validated in the Wind Tunnel at DNW HDG Göttingen. These specific High Reynolds aerofoils have, as design criteria, the following characteristics:

- They are robust to the change in turbulence or gusts, due to their **high and plateau efficiency,** and **easy to control.**
- They were created to **permit slender blades** to be designed easily since they have a high Cl at high efficiency.
- They are **tolerant to roughness or manufacturing imperfections**, since they have been designed together as a family to built a blade. Therefore, they present reliable aerodynamic and geometry compatibility.
- Finally, the tip aerofoil (t/c = 18%) has been designed to commit **low levels of Noise**.

The **Wind Tunnel test** of the aerofoils enables realistic blade designs. CENER has specialised designing and performing wind tunnel tests **at high Reynolds numbers** (3-6-9 million) at clean and rough configurations, where the lift is measured through surface pressure taps transducers and drag from wake rake total and static probes. The full control of the aerofoil model, instrumentation and test procedures are key factors to obtain the most reliable data. Cross check of data among different wind tunnels have been performed in order to validate results and testing techniques.

The experience of CENER is backed up with the test of four different aerofoil families.

Developed activities at wind tunnel tests are:

- Wind tunnel selection
- Specification of the wind tunnel models
- Design of the test program
- Supervision of the test process
- Post processing experimental data
- Results assessment

CENER numerical methods for aerofoils, covers from aerofoil design, noise prediction, detailed CFD studies and unsteady aerodynamic prediction tool.

The aerofoil design tool, **CAO** (Cener Aerofoil Optimization), has coupled an in-house version of XFOIL panel method with DAKOTA optimization tool which allows to design thin to thick aerofoils targeting and weighting different parameters like high Cl, roughness insensitivity, aerodynamic geometry constrains, structural requirements, ...

HASE 2D/3D is an aeroacoustic tool from CENER designed for aerofoil noise prediction that has been extended for blades (an example of the comparison between experiments and simulations of the NACA0012 turbulent boundary layer trailing edge noise (TBLTE) at α=7.3º, on the front page bottom right figure).

WMB (Wind Multi-Block) is the **compressible CFD** method of CENER validated for wind turbine flows, developed, and developing, in collaboration with the University of Liverpool. Among others, it has shown strong capability for distributed roughness simulations and aerofoil predictions (an example of the comparison between experiments and simulations of the S809 aerofoil is shown in the front page bottom left figure). Further, it has been extensively used for the analysis of dynamic stall cases, transitional flows, wind tunnel test assessments and for studying non conventional geometries.

DYSTOOL is an **unsteady aerodynamic** tool based on Beddoes-Leishman model. It is able to characterize the dynamic stall phenomena using general or dedicated parameters optimized from experiments or/and CFD. The performance of the tool has been comprehensively validated with unsteady experimental data from the S809, LS(1)0417MOD and NACA0015 aerofoils (an example of S809 aerofoil computation shown in the front page bottom right figure). In addition to the 2D approach, DYSTOOL has been integrated into the aeroelastic code FAST, taking advantage of the DYSTOOL features for wind turbine modelling. This modified FAST version is available for wind turbine loads calculation.