airworks engineering

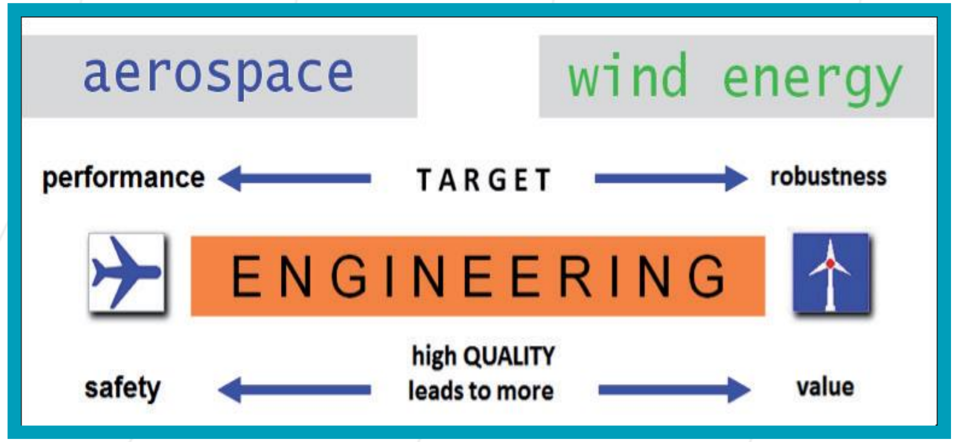
AIRWORKS

Wind Energy Capabilities

Rome // 02.12.2013

Aerospace Technologies for Turbine’s development

Since year 2010, AIRWORKS is developing technologies to support Wind Power turbine manufacturers in the segment of large rotor blades.



SERVICE RANGE

- **Contractor for complete rotor design**
- **Contractor for Research & Development projects**
- **Aerodynamic design of rotor blades**
- **Structural blade design**
- **Mould design**
- **Sizing and Certification of rotor blades according to GL (IEC 64100), DNV**
- **Design of systems & components (Nacelle, Tower, Hub)**
- **Turbine load calculations**
- **Performance optimization on existing turbines**
- **Implementation of composite materials**
- **Manufacturing support**

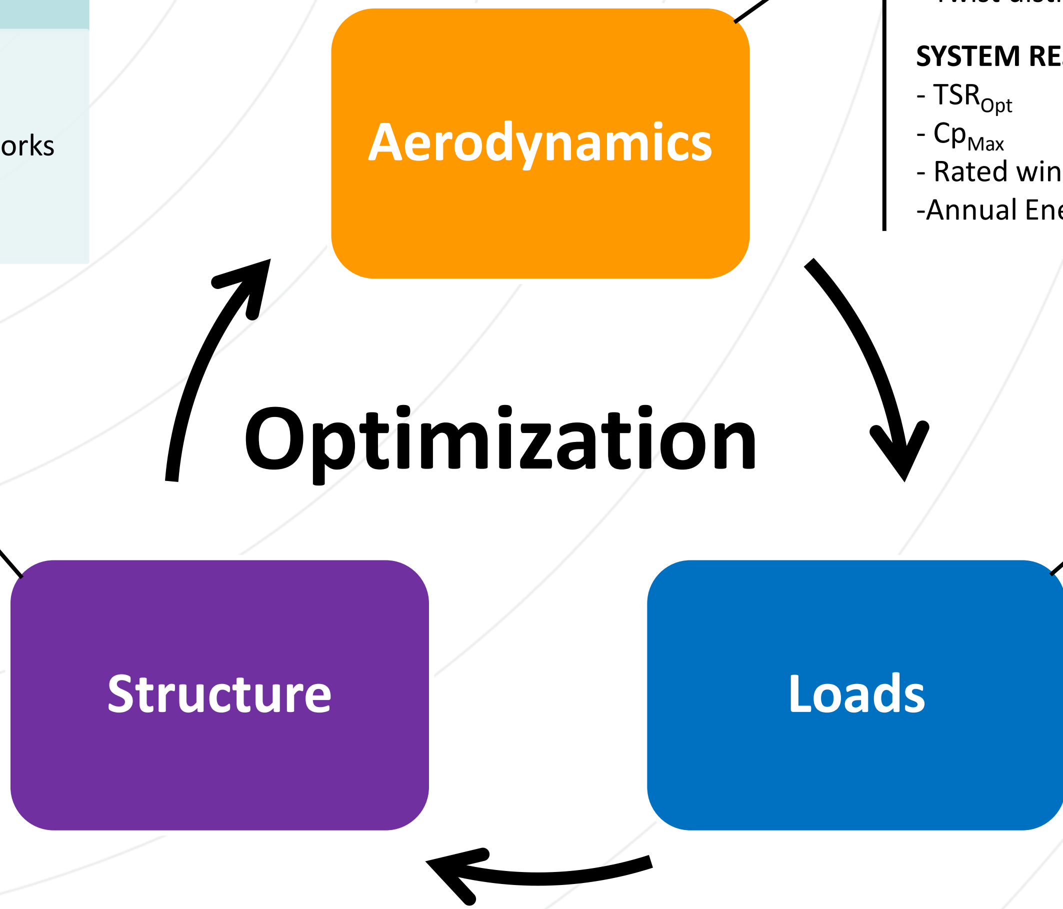
BENEFITS

- **Know-How and strategies protection**
- **Networking with main sector’s specialists (ex-ENERCON, MBB,..) and leading companies**
- **10 years experience in Lightweight Design for Space and Aeronautics**
- **CFRP structures optimization capability (already performed for the most advanced aerospatial projects)**

Pre-Design

Design Tools

- **Aerodynamics**: WARP®
- **Loads**: Focus 6
- **Math. simulation**: Hyperworks
- **Aeroelastic Optimization**: Proprietary Software



Aerodynamics

DESIGN VARIABLES
- Chord distribution
- Twist distribution

SYSTEM RESPONSES
- TSR_{Opt}
- Cp_{Max}
- Rated wind speed
- Annual Energy Yield

Structure

DESIGN VARIABLES
- Structural layout
- Mass & stiffness

SYSTEM RESPONSES
- Strain field
- Tip Deflection
- Eigenfrequency
- Blade Mass
- Fabrication cost

Loads

DESIGN VARIABLES
- Adjusted mass & stiffness

SYSTEM RESPONSES
- Extreme load envelope
- Equiv. fatigue loads

Detailed Design

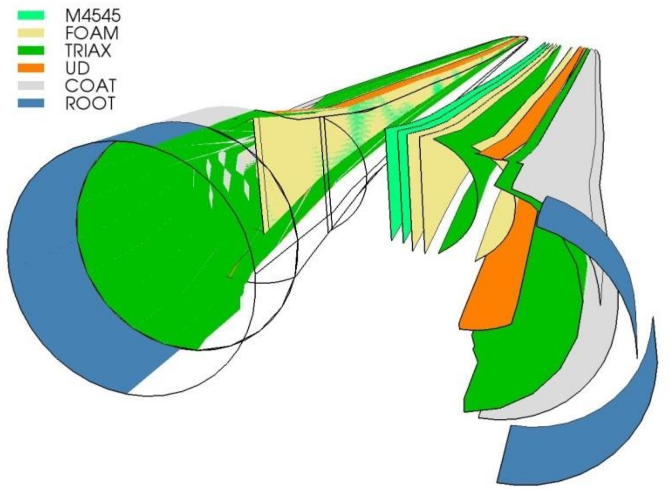
- Rotorblade loft
- Structural layout
- Loads
- Design objective
- Design constraints
- Design responses

Input

SIZING

Output

- Laminate plan
- Structural drawings
- Bill of materials
- Design reports
- Test plan

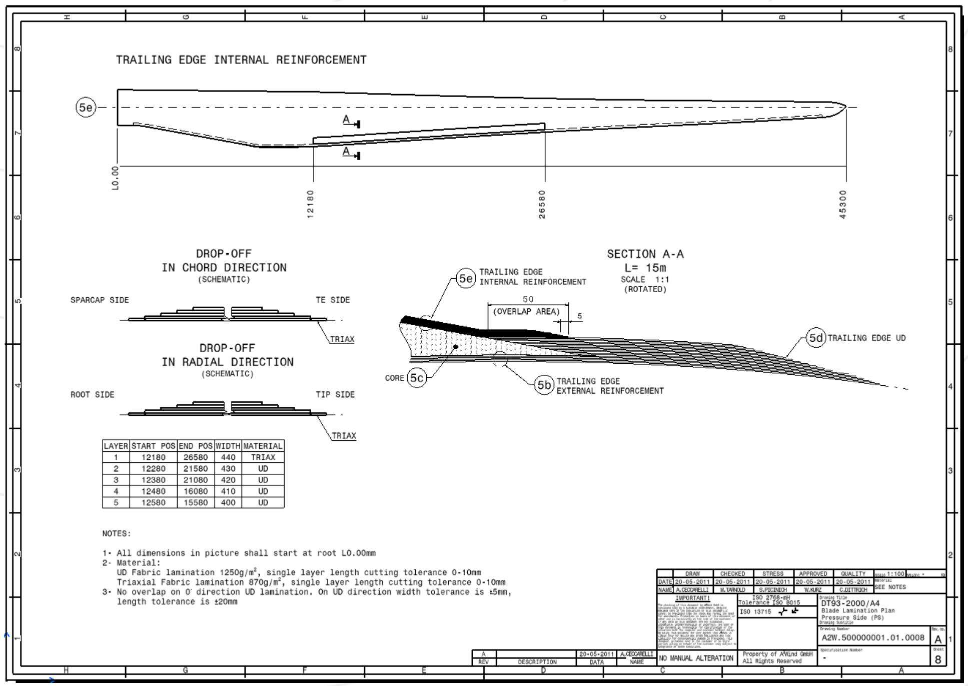


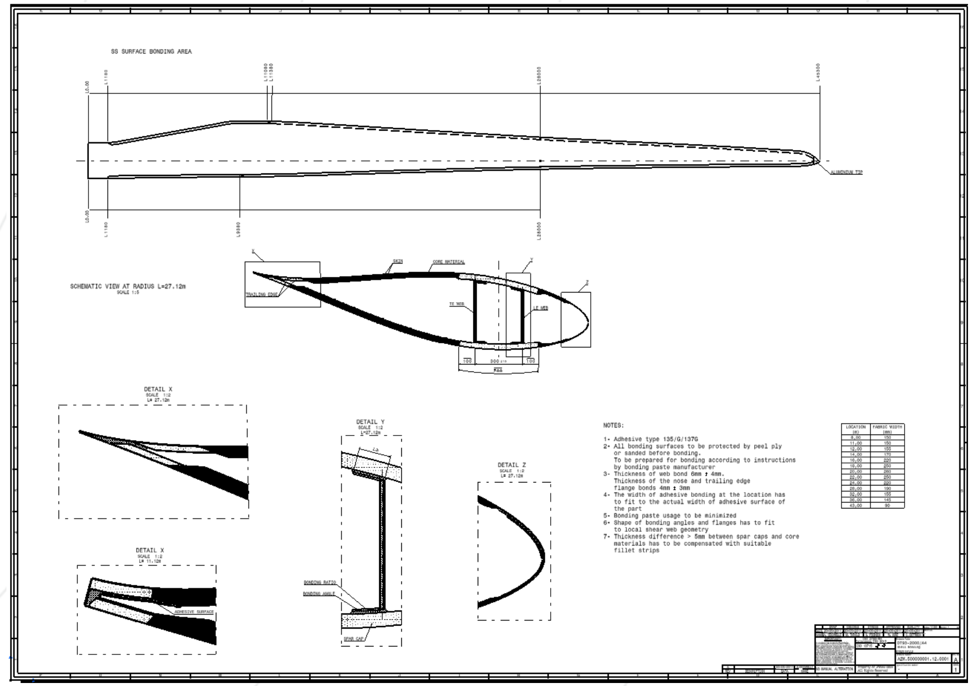
Blade Projects: From Scratch to Certification through Manufacturing (1/2)

DONGTAI (XEMC) 45.0m – 1.5MW Blade

In 2011, Air Works (via his subsidiary company A2Wind) developed a 45.3m – 2.0MW glass fiber blade from the scratch book to the manufacturing drawings.

Our team was involved in all the phases of the project (including GL certification and tests) and Air Works personnel was in charge in all the key roles.





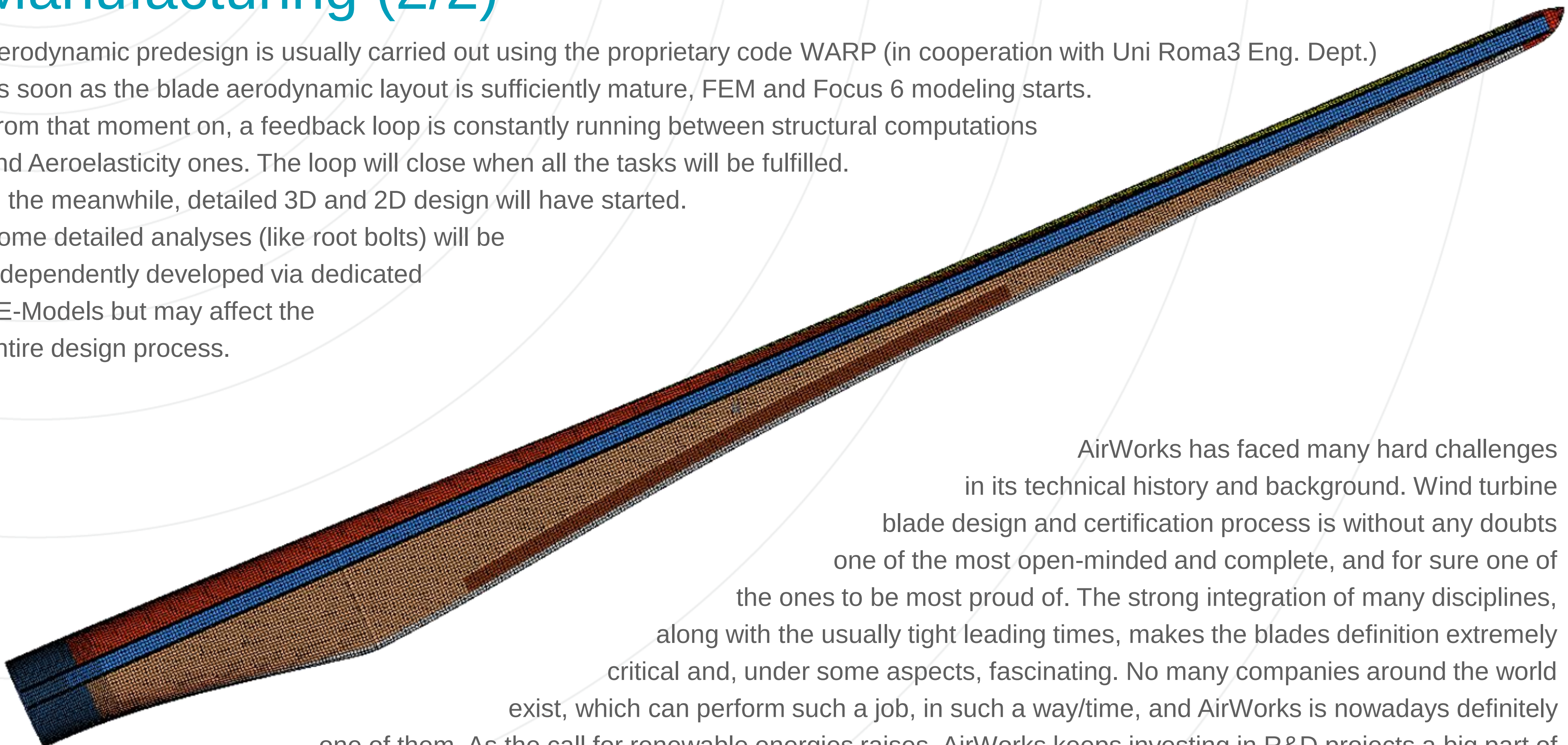
The entire sizing and design was carried out in < 5 months.

Client’s main tasks (weight, performances, stiffness, manufacturing process optimization) were completely fulfilled.

Static, fatigue and dynamic loads were obtained by an internally developed Visual Basic code and the commercial software Focus-6. CatiaV5 was used for 3D and 2D CAD.

Blade Projects: From Scratch to Certification through Manufacturing (2/2)

Aerodynamic predesign is usually carried out using the proprietary code WARP (in cooperation with Uni Roma3 Eng. Dept.)
As soon as the blade aerodynamic layout is sufficiently mature, FEM and Focus 6 modeling starts.
From that moment on, a feedback loop is constantly running between structural computations and Aeroelasticity ones. The loop will close when all the tasks will be fulfilled.
In the meanwhile, detailed 3D and 2D design will have started.
Some detailed analyses (like root bolts) will be independently developed via dedicated FE-Models but may affect the entire design process.



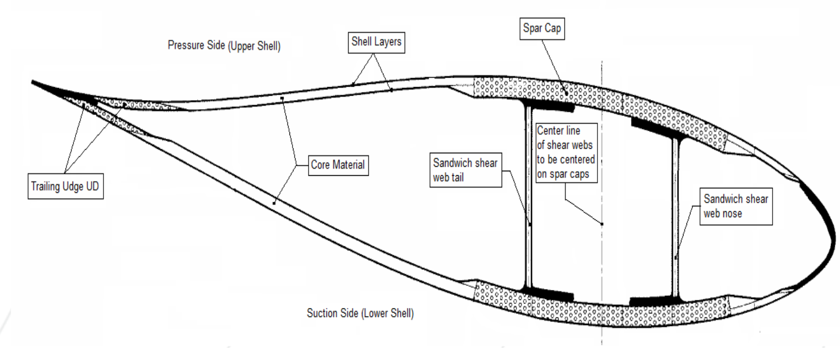
AirWorks has faced many hard challenges in its technical history and background. Wind turbine blade design and certification process is without any doubts one of the most open-minded and complete, and for sure one of the ones to be most proud of. The strong integration of many disciplines, along with the usually tight leading times, makes the blades definition extremely critical and, under some aspects, fascinating. No many companies around the world exist, which can perform such a job, in such a way/time, and AirWorks is nowadays definitely one of them. As the call for renewable energies raises, AirWorks keeps investing in R&D projects a big part of its income. Our attention is now focused on optimization processes, to cut delivery times and improve blades performances.

DONGTAI (XEMC) 45.3m – 2.0MW Blade

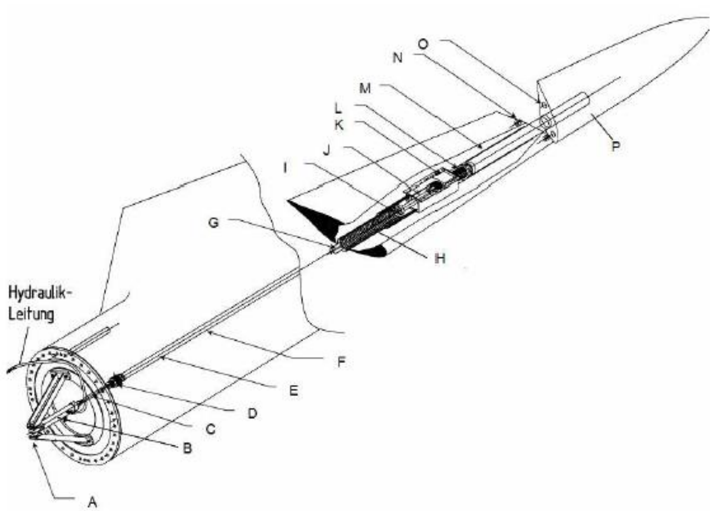
Blade Projects: Feasibility Study for a Stall Regulated Blade Family (1/2)

KM 14.2m –15.5m 750kW Blade Family

In 2011, Air Works (via his subsidiary company A2Wind) developed an aerodynamic and performances feasibility study for the Korean company KM for the design of Stall Regulated Wind Blade Family for 750 kW for length variable between 14.2m and 15.5m for wind class III with an aerodynamic tip brake system.



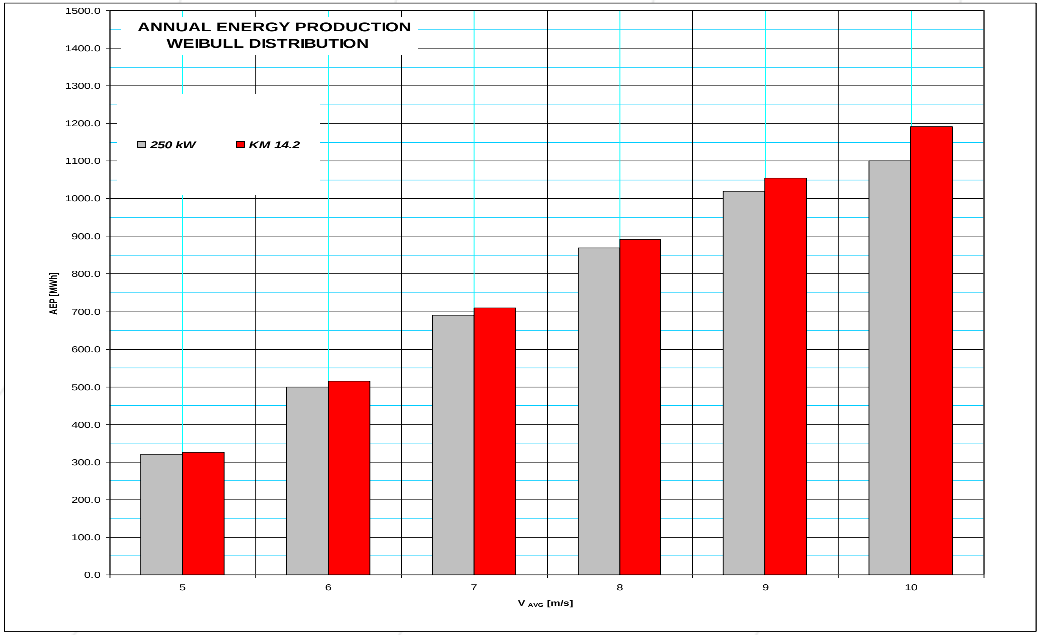
- The blade is built as a self-supporting structure comprising of two skin-halves mounted round the main spar.
- Two U-beams goes from the Root end to tip.
- Bushings with internal thread are embedded in the root section, and so forming the attachment to the hub. This root-to-hub-mounting-principle has been extensively
- Shells, spars and root section are made of fibre-glass reinforced polyester, where the main strength properties have been achieved by using continuous fibres (Unidirectional Rowings). The bushings are made of chrome alloy steel. All metal parts for the aerodynamic blade tip brake are made of stainless steel and carbon fiber/epoxy.
- The aerodynamic tip brake consists of the outer 2090 mm of the blade, mounted on a carbon/epoxy shaft.
- The profile chosen DU and NACA 63-XXX series has proven highly productive and shows little sensitivity to dirt. Also the stalling properties are fine.

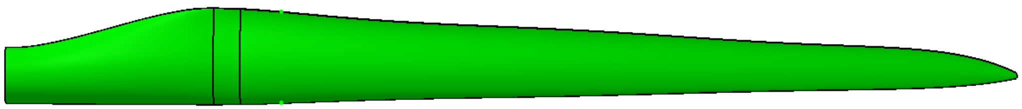


Blade Projects: Feasibility Study for a Stall Regulated Blade Family (2/2)

The aerodynamic performances have been computed by means of in house developed software WARP.

Aerodynamic performances and Annual Energy Production have been improved with respect to similar blade already available on the market achieving the target of weight , maximum Deflection , tip clearance and allowable maximum loads.

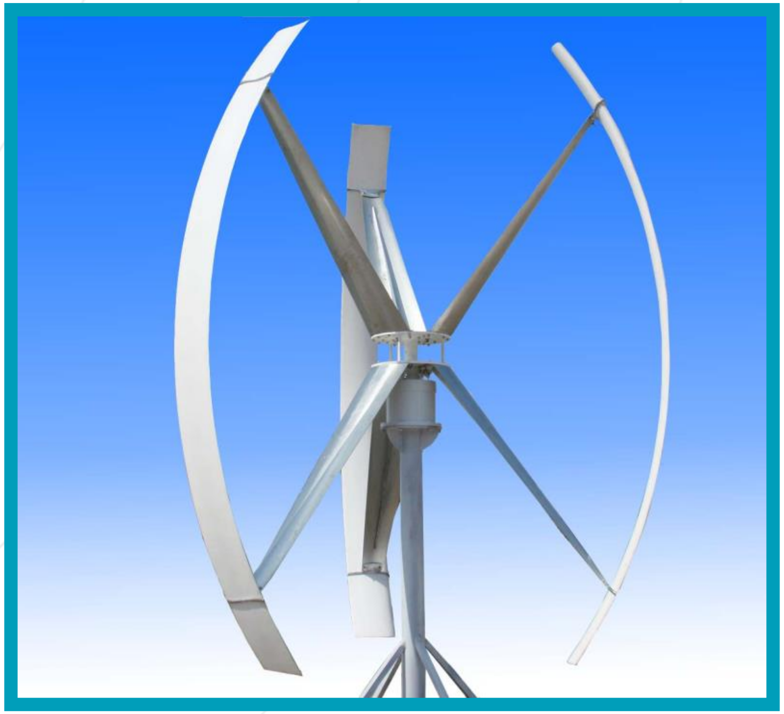




WARP®

Airworks developed their own in house aerodynamic code for the complete Wind Blade Aerodynamic Design and Performance Prediction (WARP). WARP ® originally created as Excel calculation sheet, and with incorporated VBA macro, is going to be converted into a standalone executable program developed with Python and a user friendly and graphical input /output interface.

WARP ®, originally created for performance analysis of Horizontal Axis Wind Turbine, now includes the design and simulation of Vertical Axis Wind Turbines (VAWT), by means of Double-Multiple Stream Tube Model developed by Ion Paraschivoiu.

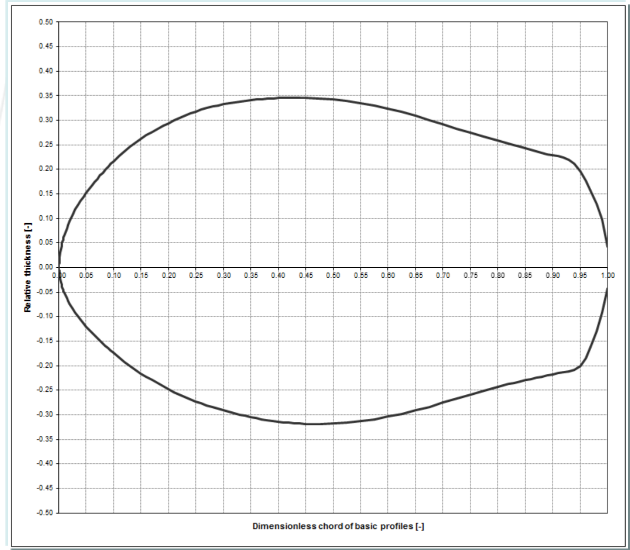


WARP®

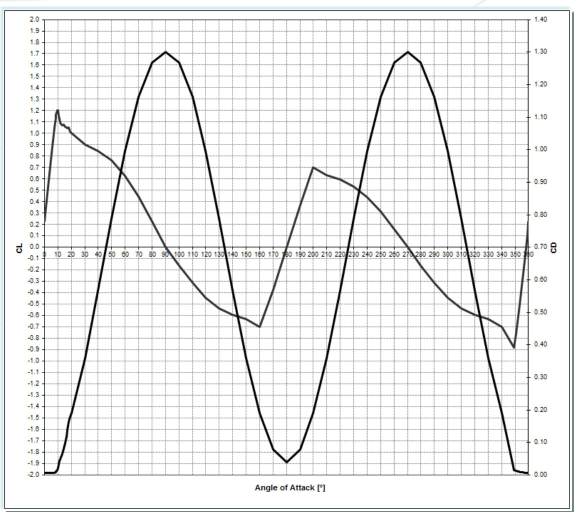
It will include the following main capabilities:

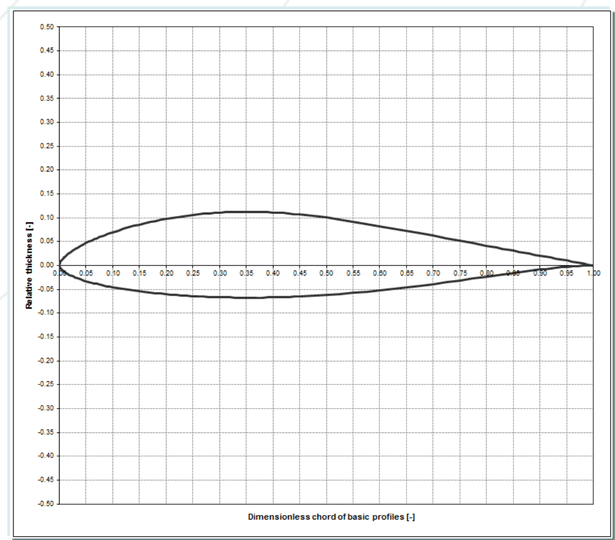
- *Extrapolation of airfoil polar data to 360° AoA,*
- *Blade design and optimization, including 3D visualization,*
- *Turbine definition (rotor blade, turbine control, generator type, losses),*
- *Computation of rotor performance over lambda (tip speed ratio) range,*
- *Computation of turbine performance over wind speed range,*
- *Annual yield computation with WEIBULL distribution,*
- *Manual selection of all simulation parameters,*
- *Data browsing and visualization as post processing,*
- *Export functionality for all created simulation data,*
- *Blade geometry export functionality (FOCUS and CATIA V5).*
- *Cp computation for Horizontal Axis Wind Turbine based on a proprietary aerodynamic code developed and tested in cooperation with Stuttgart University*
- *Cp computation for Vertical Axis Wind Turbine based on the Double Multiple Stream Tube Theory of Ion Paraschivoiu*

WARP® Airfoil Aerodynamic



- 2D Airfoil Aerodynamic Properties Calculation (Eppler Code)
  - Conformal-mapping method for the design of airfoils
  - Panel method for the analysis of the potential
  - Integral boundary-layer method.
  - Reynolds numbers from 30,000 to 50,000,000.
  - Compressibility correction to the velocity distributions
- 3D Centrifugal Pumping Effect Calculation Apply Selig Du correction per ASME paper, Reno, 1998, page 9. Also include Eggars CD adjustment from ASME, 2003
- Airfoil 3D properties extrapolation (Viterna-Method)





WARP® Blade Geometry Definition (HAWT)

POLY I	Sta(Rmin)	1	Sta(Rmax)	6
	6th deg Err:	1.000	☐	Check To Plot
	5th deg Err:	1.000	☑	Check To Plot
	4th deg Err:	0.999	☐	Check To Plot
	3th deg Err:	0.999	☐	Check To Plot
	2th deg Err:	0.996	☐	Check To Plot
POLY II	Sta(Rmin)	6	Sta(Rmax)	24
	6th deg Err:	1.000	☑	Check To Plot
	5th deg Err:	1.000	☐	Check To Plot
	4th deg Err:	0.999	☐	Check To Plot
	3th deg Err:	0.997	☐	Check To Plot
	2th deg Err:	0.995	☐	Check To Plot
POLY III	Sta(Rmin)	24	Sta(Rmax)	25
	6th deg Err:	1.000	☐	Check To Plot
	5th deg Err:	1.000	☐	Check To Plot
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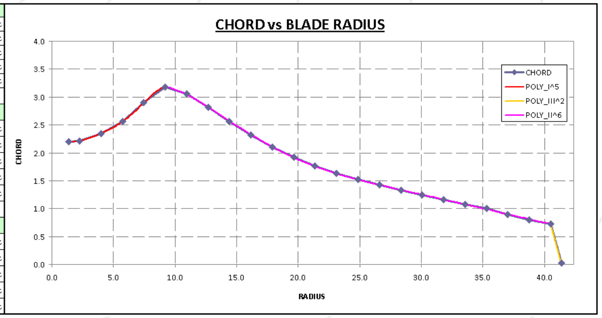
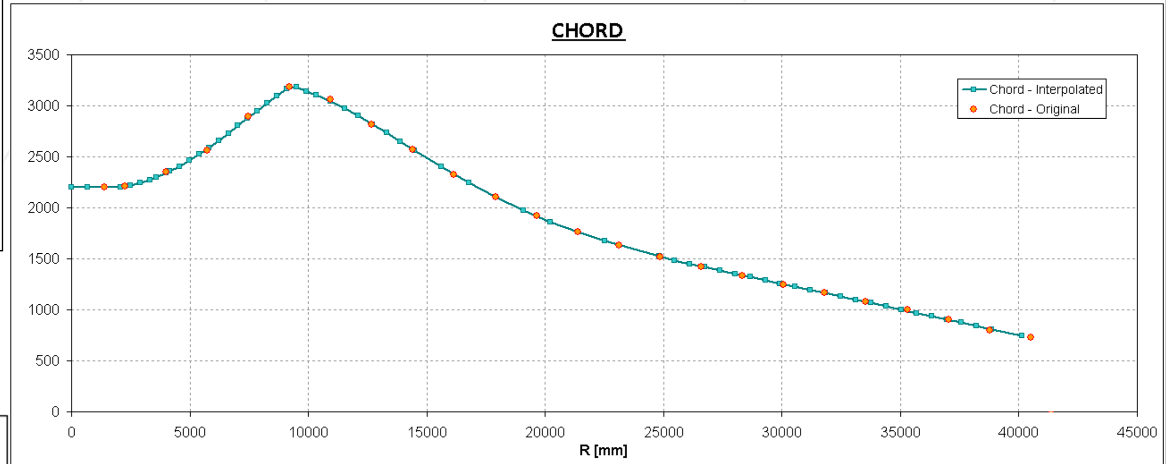
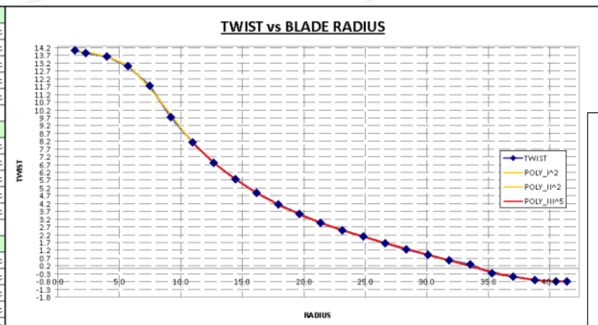
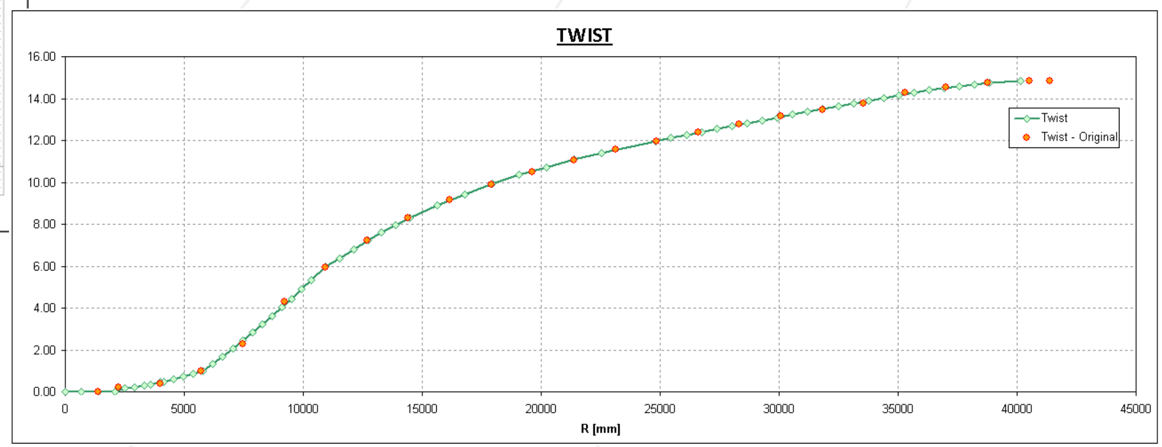
	3th deg Err:	1.000	☐	Check To Plot
	2th deg Err:	1.000	☑	Check To Plot



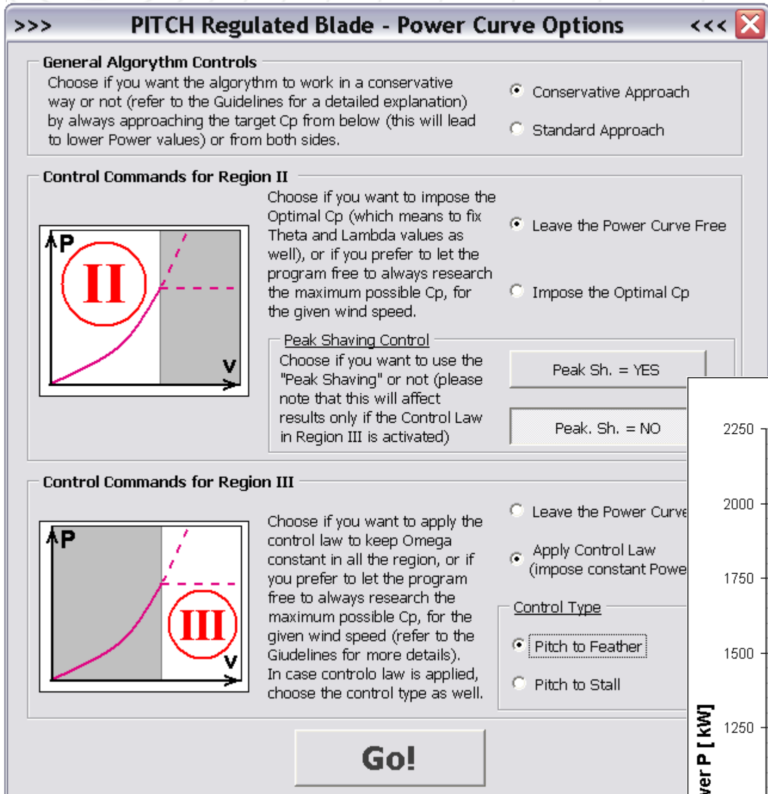


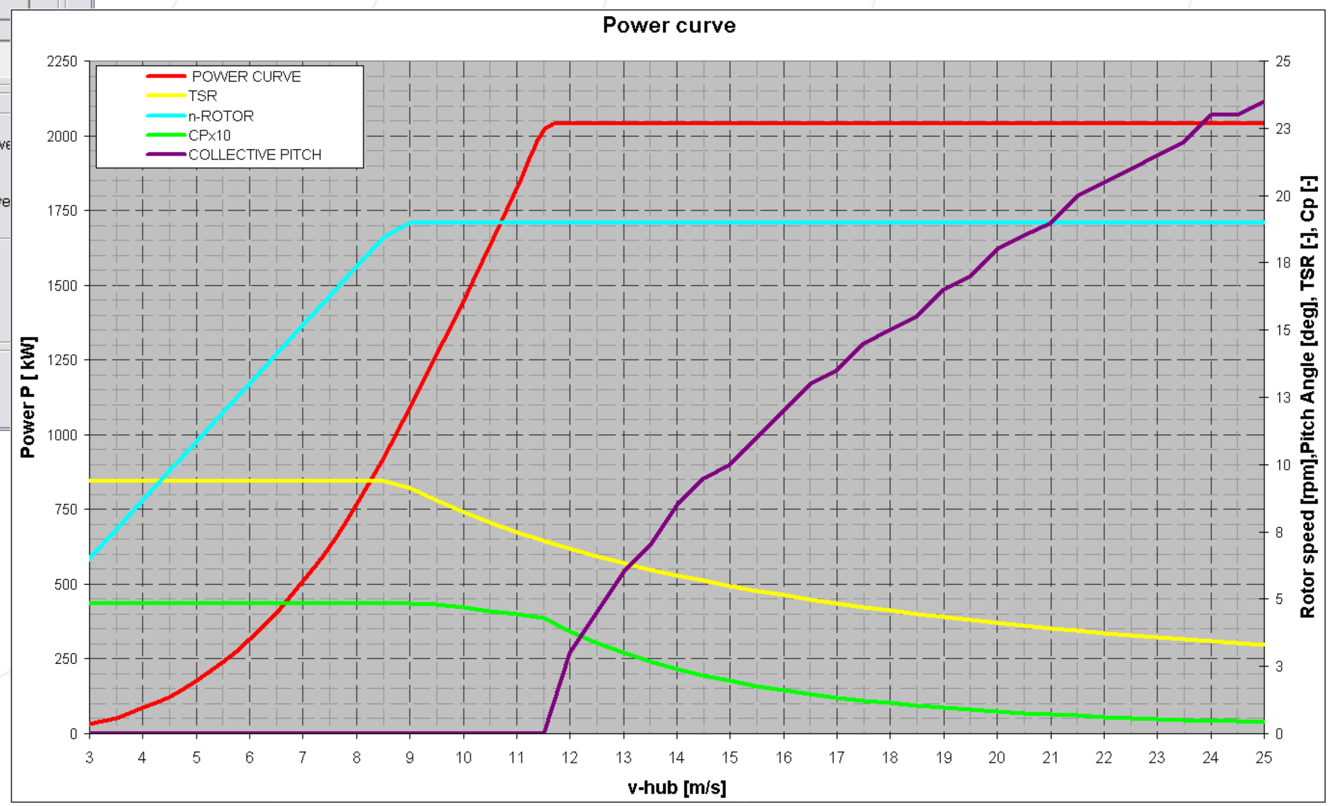
POLY I	Sta(Rmin)	1	Sta(Rmax)	4
	6th deg Err:	1.000	☐	Check To Plot
	5th deg Err:	1.000	☐	Check To Plot
	4th deg Err:	1.000	☐	Check To Plot
	3th deg Err:	1.000	☐	Check To Plot
	2th deg Err:	0.982	☑	Check To Plot
POLY II	Sta(Rmin)	4	Sta(Rmax)	7
	6th deg Err:	1.000	☐	Check To Plot
	5th deg Err:	1.000	☐	Check To Plot
	4th deg Err:	1.000	☐	Check To Plot
	3th deg Err:	1.000	☐	Check To Plot
	2th deg Err:	0.995	☑	Check To Plot
POLY III	Sta(Rmin)	7	Sta(Rmax)	25
	6th deg Err:	1.000	☐	Check To Plot
	5th deg Err:	1.000	☑	Check To Plot
	4th deg Err:	1.000	☐	Check To Plot
	3th deg Err:	0.998	☐	Check To Plot
	2th deg Err:	0.994	☐	Check To Plot



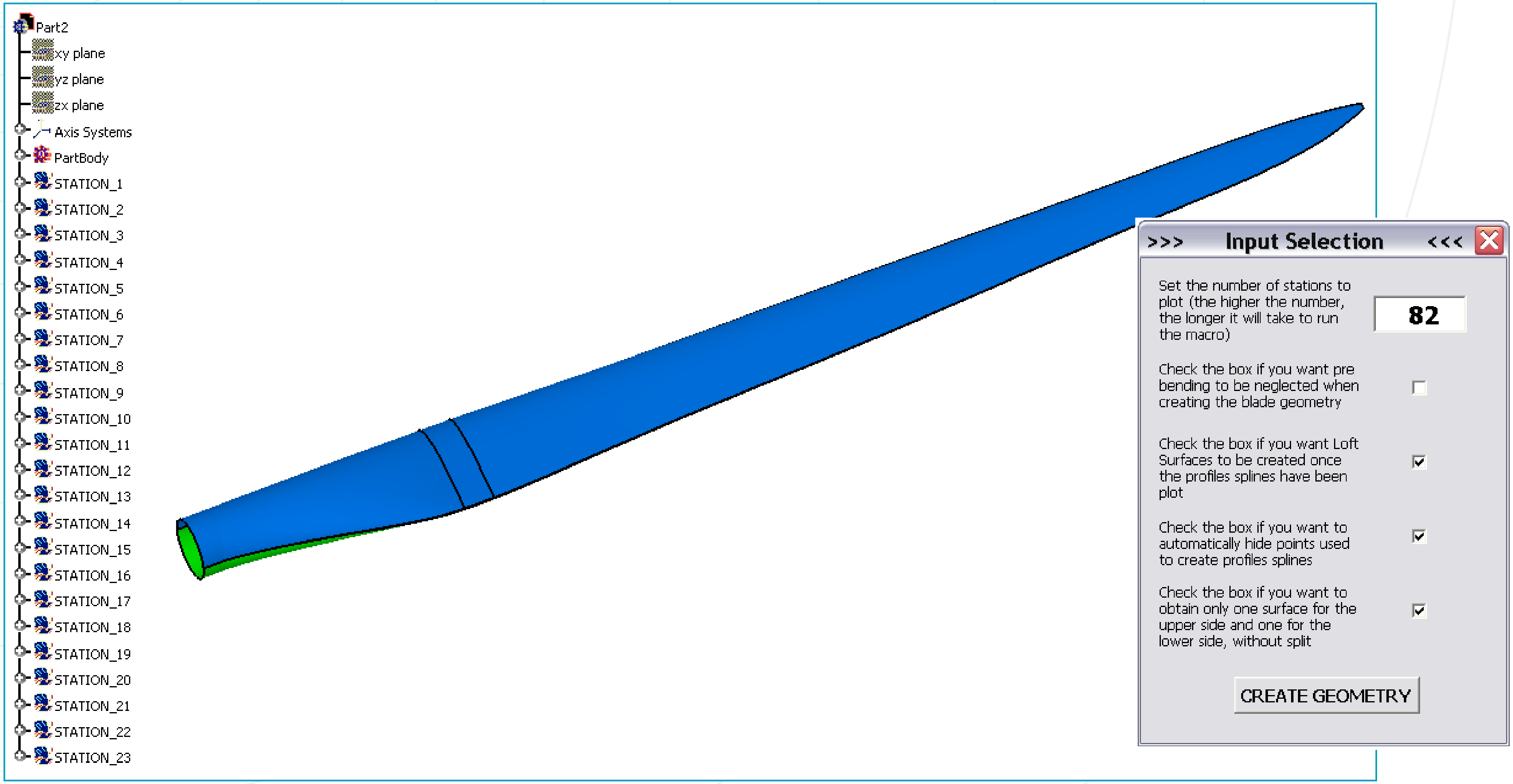


WARP®Power Curve Creation (HAWT)

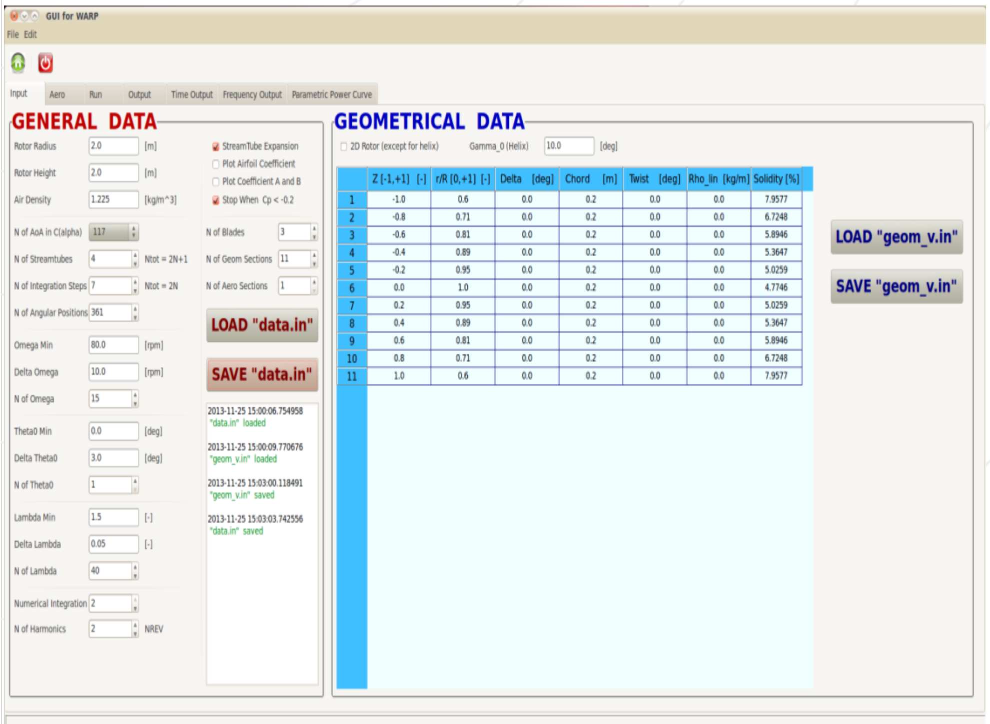


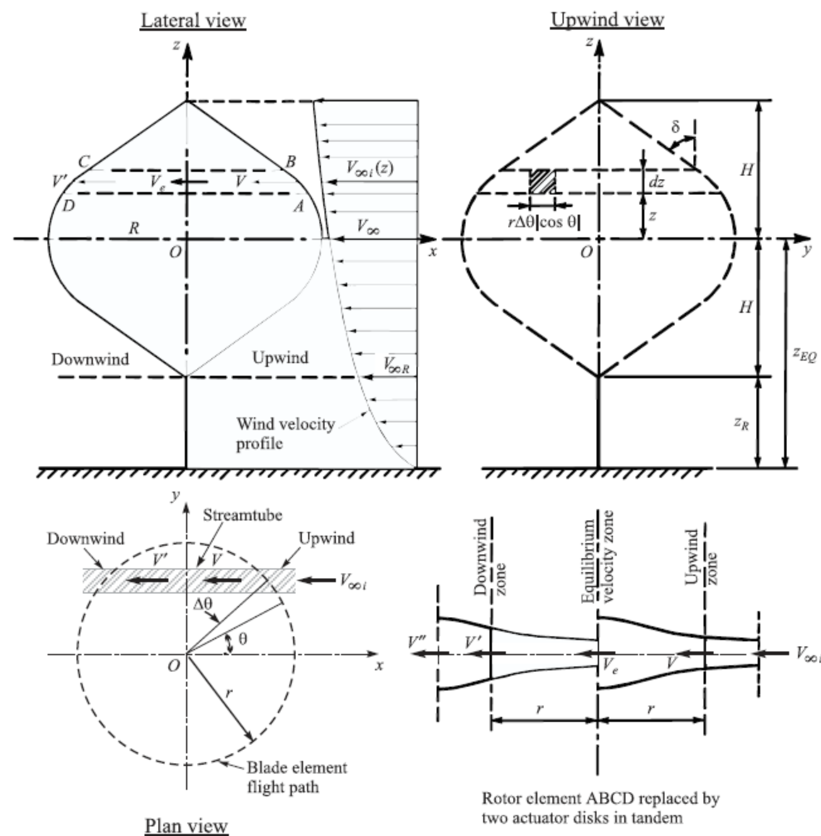


WARP® Blade 3D model Creation (HAWT)

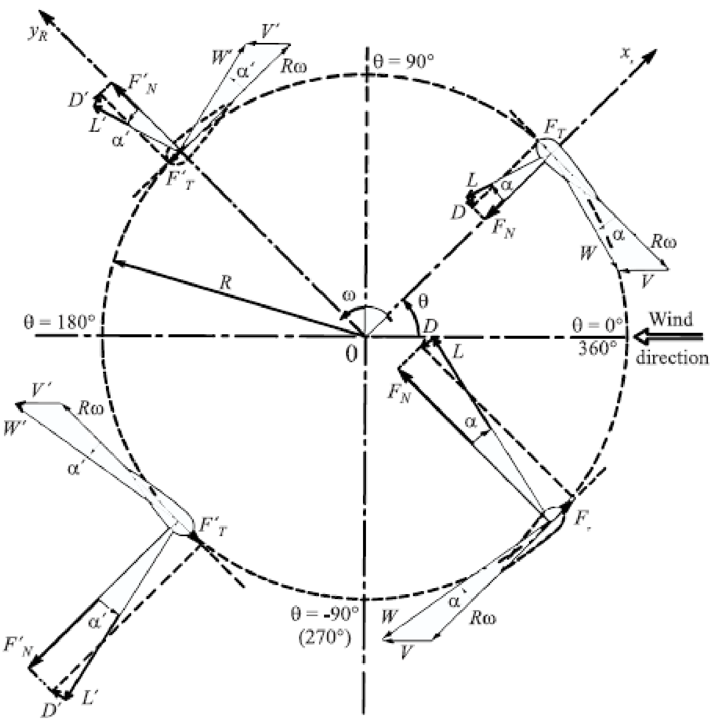


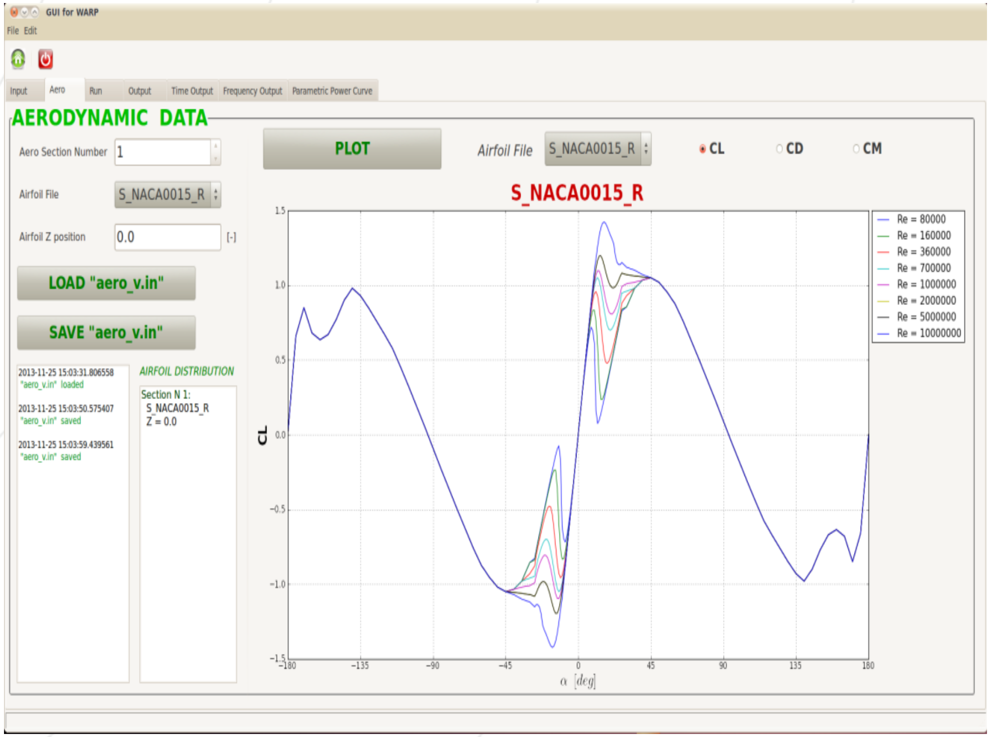
WARP® Aerodynamic and main parameter definition made extremely easy (VAWT)



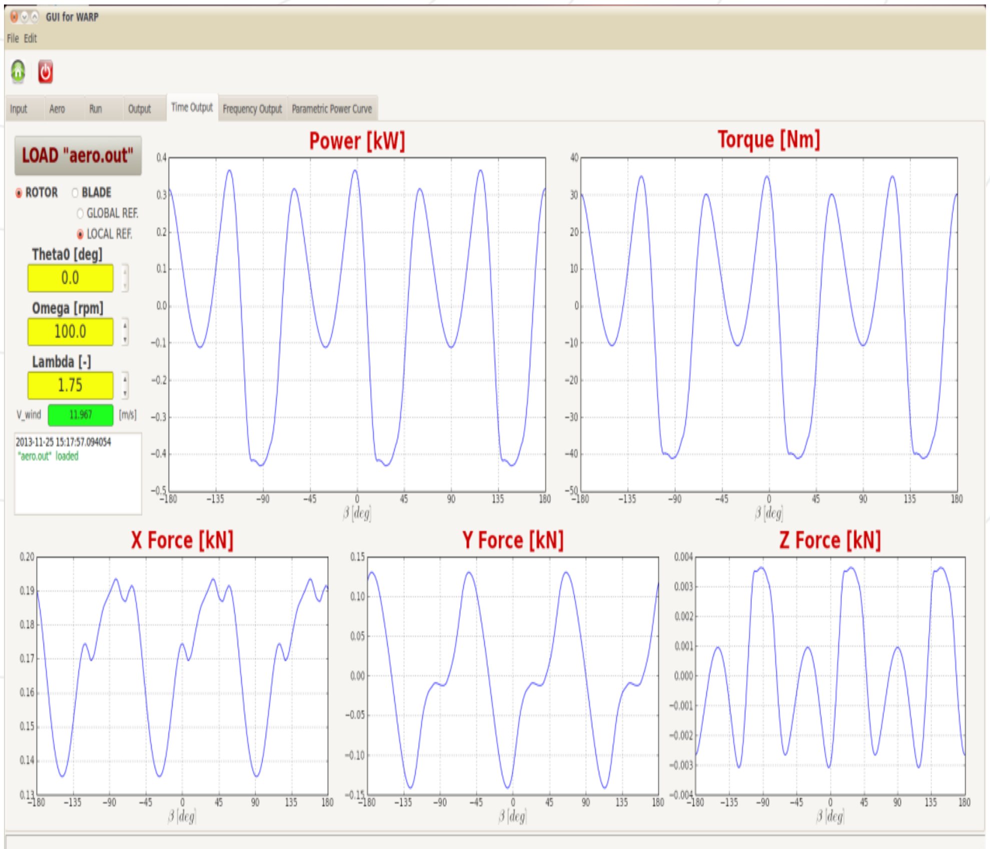


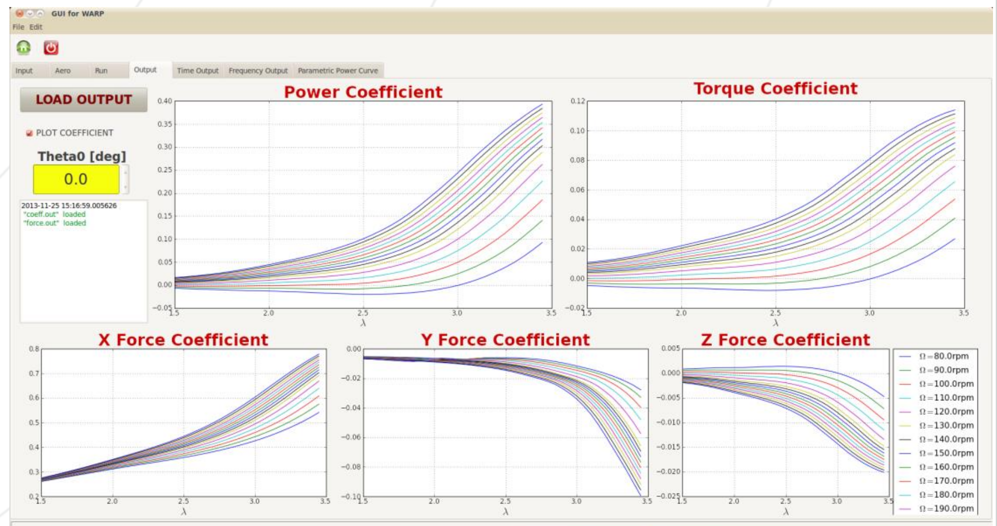
WARP® Aerodynamic and main parameter definition made extremely easy (VAWT)





WARP® Fast and interactive output (VAWT)





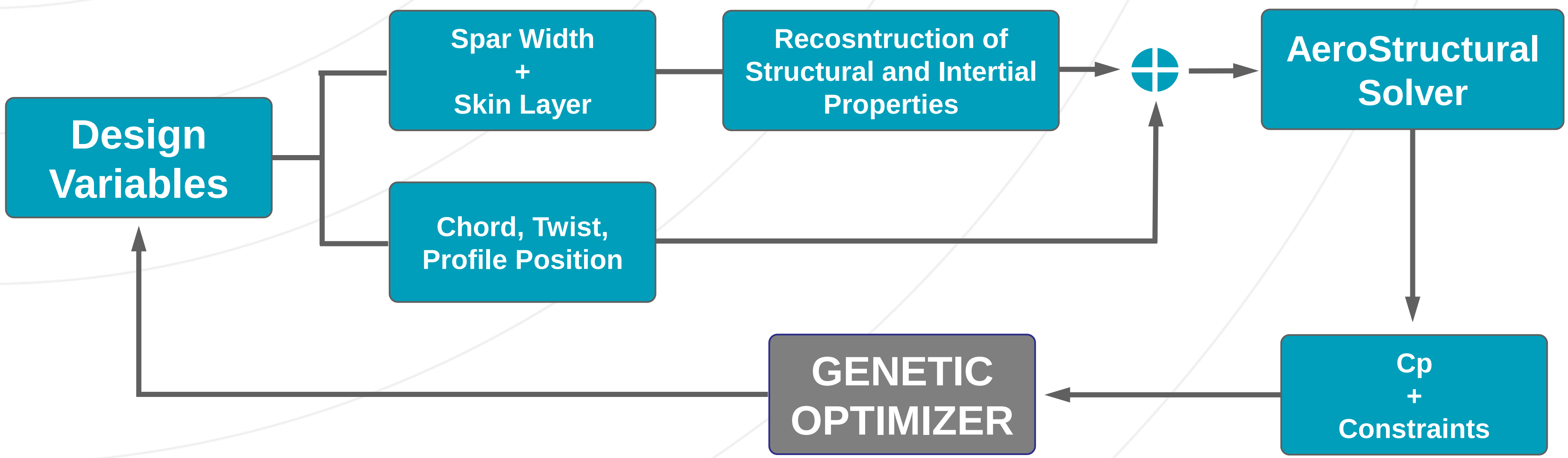
R&D Projects

Development of a code aimed at performance-optimization of Horizontal Axis Wind Turbines

(in cooperation with Rotorcraft Group of Engineering Department University Roma Tre, UR3)

Highlights:

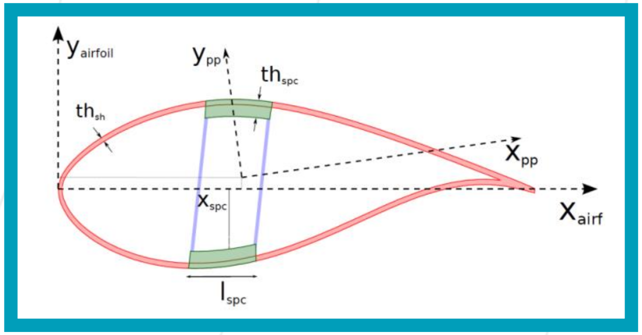
- fast, as accurate as possible both in the aerodynamics and in structural dynamics modelling, useful to dramatically speed up the preliminary-design phase of HAWT blades layout;
- takes into account elastic deformations not only due to torsion contribution to the angle of attack, but due to bending deflections as well, simultaneously allowing to consider not axial/steady conditions;
- a database relating the main sectional aeroelastic properties to a selection of meaningful internal parameters describing the actual blade section box, has been identified;
- a Genetic-Algorithm, Multi-Disciplinary-Optimization (MDO) process has been set by UR3, based on the aeroelastic tool developed, to identify a configuration able to enhance the obtainable maximum power coefficients, under suitable structural constraints.



R&D Projects – Future Development

- ❑ *AERODYNAMIC*

The aerodynamic model will be improved by introduction BEM (Boundary Element Method) aerodynamic model for induced velocity calculation , including Beddoes Leishman type dynamic stall model in state space, wind shear , gust , and wake inflow.

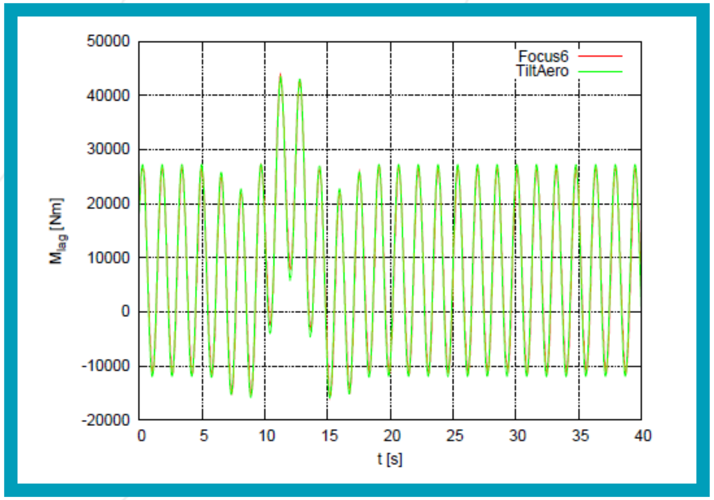


- ❑ *STRUCTURAL PROPERTIES*

The section properties database used in the previous version will be replaced by a dynamic sectional properties calculation and update process able to calculate and update the cross sectional elastic and inertial properties starting from the shape , material and main dimensions definition

- ❑ *STRUCTURE*

In the optimization process will be introduced the possibility of verifying the blade strength and the blade max deformation in order to verify step by step and lead the optimization process to the best solution as quick as possible



- ❑ *OPTIMIZATION*

The Optimization process will be improved by introducing new objective function as for example AEP , COE