Adjoint-based aerodynamic and aeroacoustic shape optimization of roof- and ground-mounted HAWTs in the built-environment

# zEPHYR Marie Skłodowska-Curie project: towards a more efficient exploitation of on-shore and urban wind energy resources

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## CONTEXT

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➢ Due to the dramatic increment of world consuming energy, the **global annual CO2 emission** is increased from **13.85 Billion t** in 1969 to **37 Billion t** in 2019. This is a big warning that we should be more environmentally friendly.

➢ Renewable energy would play significant role to reduce emission. **Wind power** is one of the most efficient forms of **green energy**.

➢ **Wind farms** should be located close to the **urban environment** and **smart cities** to reduce the distance from production to consumption.

➢ In view of the above, a great challenge is to design **aerodynamically** more efficient rotors and, at the same time, reduce the **noise emitted** by them. To this end, modern **Computational Fluid Dynamics** (**CFD**) and **Computational Aro-Acoustic** (**CAA**) analysis and optimization tools can be used, by also considering **uncertainties** regrading the flow data in an **urban environment.**

## PROBLEM DEFINITION

➢ New optimally shaped rotor blades of **HAWTs**, installed in an **urban environment**, must be designed, according to **aerodynamic** and **aero-acoustic** criteria.

➢ **Adjoint-based** tools built for appropriate objective functions should be derived and used in the optimization of **HAWTs**; by incorporating them into optimization loops, new **efficient shapes** can be designed.

➢ An indispensable part of the whole process is the exact modelling of the **atmospheric boundary layer**.

➢ Among other, methods for the shape optimization of HAWTs under **uncertainties** in an **urban environment** will be devised and used.

## METHODOLOGY

◆ **Mesoscale** analysis of **HAWT** rotors installed on buildings' roofs will be performed by accounting for the **atmospheric boundary layer** through the **Weather Research and Forecasting (WRF)** Model. Simulations will be performed on a multi-processor platform, in the **OpenFOAM** environment**.**

◆ Since **gradient-based** shape optimization methods will be used, the **continuous adjoint method** coupled with the **Multiple Reference Frame (MRF)** model, will be implemented using the in-house **OpenFOAM** toolbox, [1].

◆ **Flow data** for either simulation or optimization runs will be obtained by the Weather Research and Forecasting **(WRF)** Model simulating atmospheric boundary layers.

◆ **Noise emitted** by the wind turbine will be modelled using **hybrid** approaches**.**

◆ **Uncertainties** due to the incoming boundary layer will be accounted for by the **Stochastic Collocation Uncertainty Quantification** method.

## OBJECTIVES

◆ **Increasing** the **power output** of horizontal axis wind turbines (**HAWTs**), installed in the built environment.

◆ **Reduction** of the **emitted noise** of the blade.

## RESULTS

✔ Aerodynamic shape optimization of MEXICO wind turbine

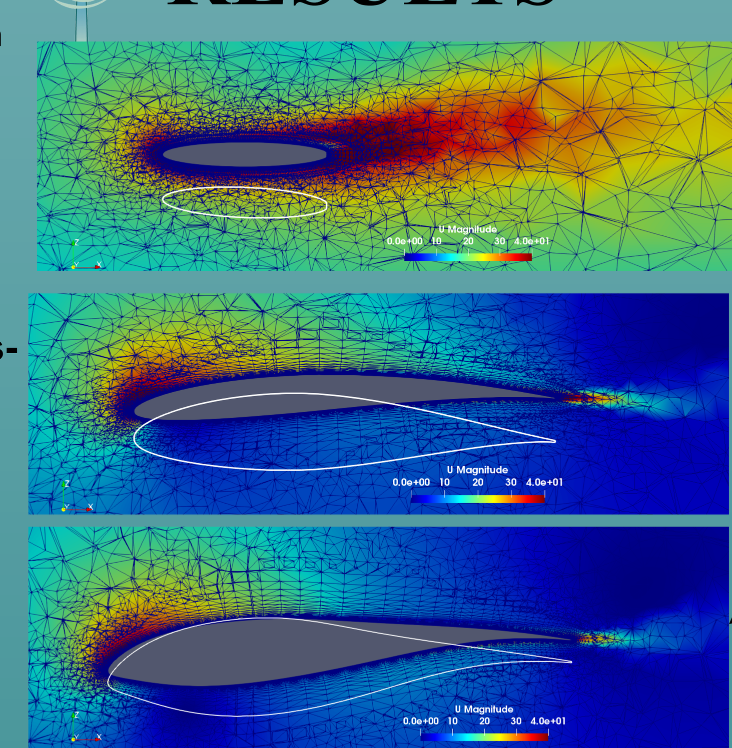



**Fig 1- Three different cross-section in 45%, 90% and 100% span.**

The white line is the initial blade

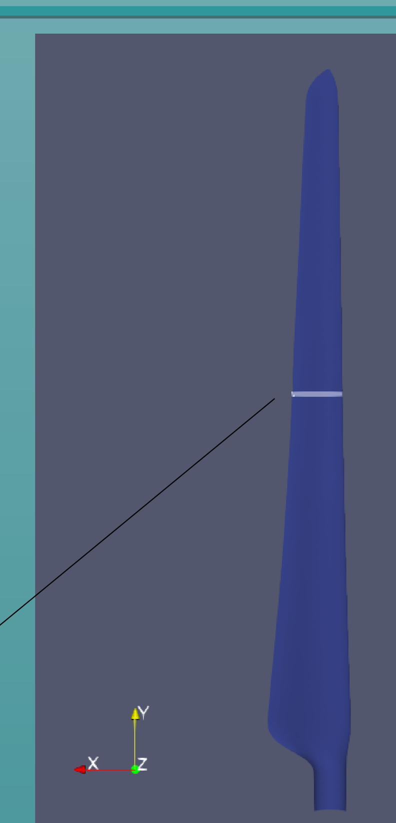
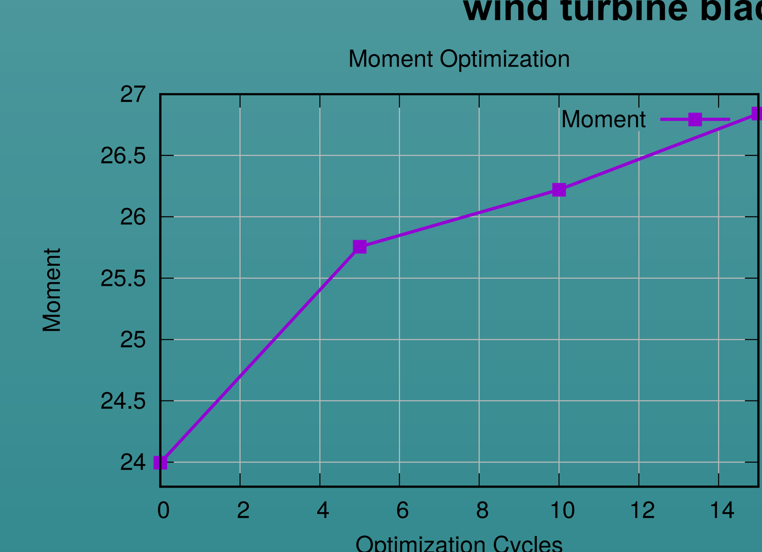


**Fig 2- MEXICO wind turbine blade**

**26.84** **Maximized moment**

**11.88%**

23.99 Initial moment




[1] Ioannis S. Kavvadias PhD Thesis NTUA.

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