Computational aeroacoustic methods for blade noise prediction

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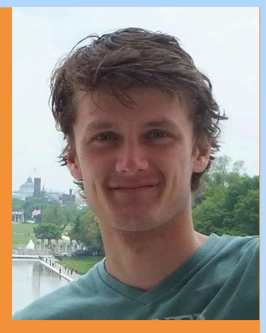


Situation

Siemens Wind Energy aims at an increase in market share for on-shore wind turbines. On-shore turbines cause these are three times less expensive to produce, it is closer to the end user and much easier to access. Possible disadvantages for on-shore wind turbines are the view and noise pollution for persons living nearby

Complication

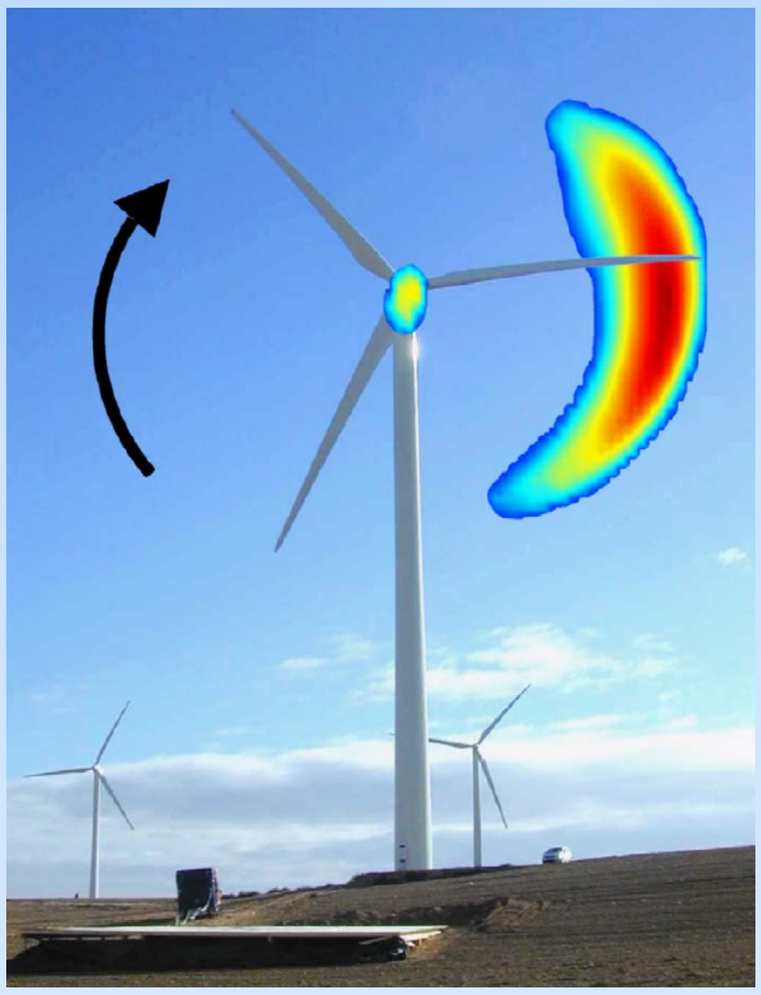
Governments apply noise regulations for maximum allowable noise levels for wind turbines. The primary noise source of a wind turbine is the turbulent trailing edge noise, originating from the rotation of the blade. Increasing the angular velocity primary leads to a larger energy production, but also causes higher noise levels. Therefore,, the power production of a turbine is currently limited, especially during night when noise regulations are stricter.

Question

How to reduce the noise of a wind turbine in order to achieve maximum performance?

Answer

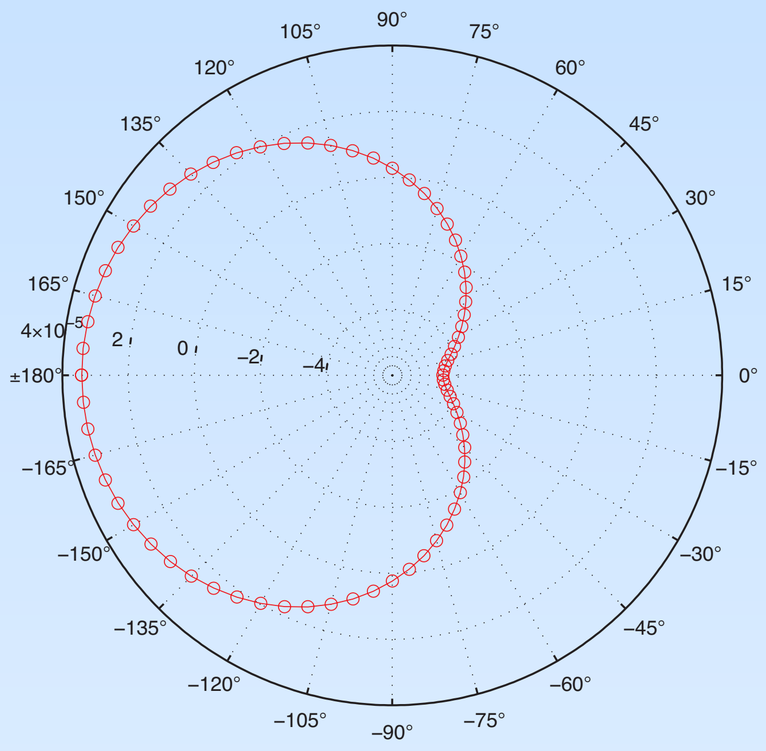
Applying noise-suppression add-ons at the trailing edge of the wind turbine blade to reduce the turbulent trailing edge noise.



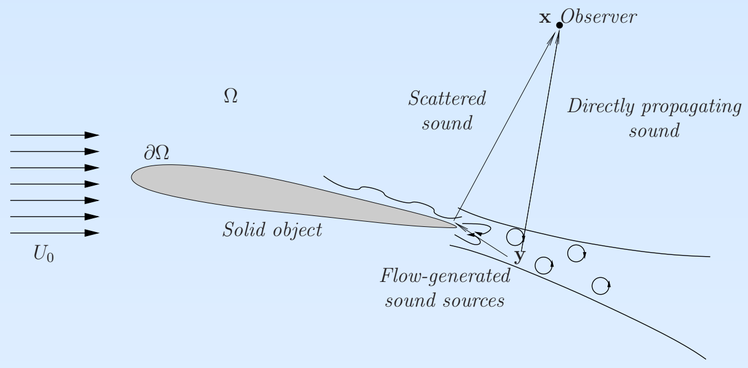
Location of noise sources on a wind turbine, [Oerlemans 2007]

Project plan

- Analysis of the turbulent boundary layer using an **infinite flat plate** model
- Study into trailing edge flow using different **beveled flat plate** models
- Comparison of the acoustic field from experimental PIV and numerical LES for the **beveled flat plate**
- Investigation into the three dimensional flow effects and noise reduction mechanisms for serrated trailing edges using a **thin flat plate** model
- A clean **DU96-180** wind turbine airfoil flow and acoustic analysis
- Experimental and numerical flow and acoustic comparison of a serrated **DU96-180** airfoil
- Relative comparison of serrated trailing edges behind a **DU96-180** airfoil and **Siemens Wind Power** airfoil



Acoustic directivity of beveled flat plate



Sound generation and propagation by flow over an airfoil

Fluid flow simulation methodology

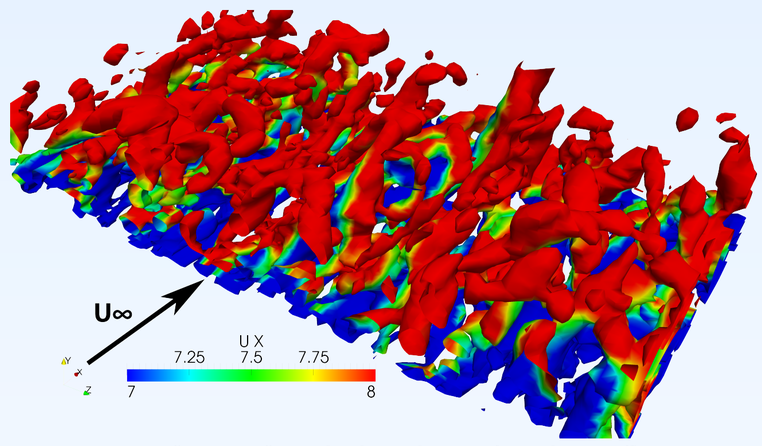
- **Navier Stokes (OpenFOAM)**
  Transient, incompressible Large Eddy Simulation
  No direct acoustic
- **Lattice Boltzmann (PowerFLOW)**
  Transienst, compressible Large Eddy Simulation
  Near field acoustic

Acoustic far field simulation methodology

- **Ffowcs Williams & Hawkings analogy (MATLAB)**
  Free-field Green function
  Dipole, pressure surface sources
- **Ffowcs Williams & Hall analogy (MATLAB)**
  Semi-infinite plane Green function
  Quadrupole, velocity volume sources
- **Boundary Element Method (LMS Virtual LAB)**
  Tailored Green function
  Quadrupole, velocity volume and dipole, pressure surface sources

1dB(A) noise reduction increases 20% of the annual energy production

"Develop a fast, reliable and accurate computational aeroacoustic method that can predict primary noise sources on a wind turbine blade with noise-suppression add-ons"



Q isosurfaces of turbulent boundary layer flow, colored by the streamwise velocity

Publications

- W.C.P. van der Velden, A.H. van Zuijlen, A.T. de Jong, H. Bijl (2014), "On the estimation of spanwise pressure coherence of a turbulent boundary layer over a flat plate", *WCCM XI, ECCM V, ECFD VI Barcelona*, 1598
- W.C.P. van der Velden, A.H. van Zuijlen, A.T. de Jong, H. Bijl (2014) "On the trailing edge noise of beveled flat plates", *2nd Symposium on OpenFOAM in Wind Energy, Boulder, E3S Web of Conferences*

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