

Scientific challenges in Aerodynamics

Science & The Energy Challenge on Offshore Wind

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Is it interesting?

- *“With over 250 years of wind turbine aerodynamics science, why are we not “done” yet?”*
- *“Why can’t we just compute Navier-Stokes?”*

Is it relevant?

- *“If the rotor would be for free, Offshore Wind Energy would still be too expensive”*
- *“It costs the same to build a rotor with bad or good aerodynamics... in a conservative approach”*

We have the equations,
but the range of scales is daunting!

	Length scale (m)	Velocity scale (m/s)	Time scale (s)
Airfoil Boundary Layer	0.001	100	0,00001
Airfoil	1	100	0,01
Rotor	100	10	10
Cluster	1000	10	100
Wind Farm	10,000	10	1000
Cluster of Wind Farms	100,000	10	10,000



Is the acceleration of CFD codes the main challenge?

Are our models suitable?

- What are our blind spots in Blade Element Momentum (BEM)?

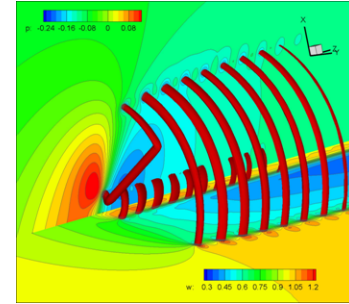
- What engineering rules used in BEM are still possible of validation and verification?
- What are the weak points in BEM?
- Is it still relevant and feasible to improve it?

- 3D unsteady aerodynamics

- What is the best approach?
- Should we in 5 - 10 years from now still use Theodorsen and Beddoes-Leishmann models?
- What is the best approach for unsteady fluid-structure-control interaction?

- Uncertainty

- What are the relevant levels of uncertainty of different aerodynamic phenomena?



Do we still have physical problems to solve in rotor analysis?

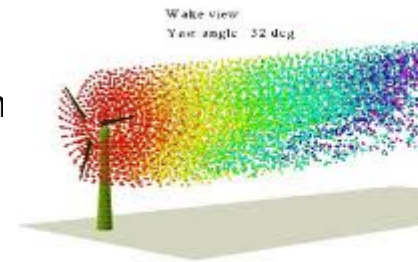
- What is their impact?
- Do we need dedicated models?

... let us take two examples

How does the wake-wake and the rotor-wake interaction depend on the near wake and blade flow?

- Wake stability

- What are the relevant scales? How to model the effect of the wake on the turbulence field?
- What instabilities are desired to improve the mixing process?
- Can we define regions inherently stable and inherently unstable, and if yes, h
- How to couple near wake models?

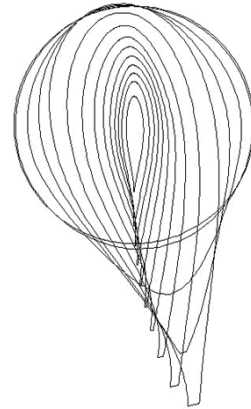


- Wake-wake and rotor-wake interaction

- What information of the vortical structures must be preserved to ensure the correct modelling of their interaction with the actuator?
- Can all the multiple interactions simply be treated as turbulence, or are there stochastic modes and scales that more dominant?

How to improve the science behind airfoil design?

- The airfoil is a 2-D concept, while our flow is 3D.
 - *Can we achieve the aerodynamic properties as accurate and proven as for 2D aerofoil design, including wind tunnel testing?*
- Transition and turbulence
 - *How to model and define the uncertainty of contamination in the aerodynamics of a blade, in particular its effect on transition and separation?*
- Flow separation
 - *What are the 3D effects that are relevant to capture separation correctly?*
 - *Would a non-stochastic approach be more effective?*
- Unsteady 3D boundary layers with flow control
 - *Usually defined by either detailed experimental and numerical simulation, or by empirical approaches and engineering methods. What is missing in the bridging between obtaining data and fostering insight?*



If the rotor is cost irrelevant, are we on the right path with incremental improvements?

Vertical Axis Wind Turbines



Kite Power





Thank you