Benchmark of ice noise modelling

Max Muckermann – Winterwind 2015 – 03.02.2015

Personal Introduction

Max Muckermann

- Final year student at
  E.ON Climate & Renewables GmbH, Technology and Innovation
- Studies of mechanical engineering at
  Bochum University of Applied Sciences
- Bachelor thesis:
  Benchmark of ice noise modelling

Outline

- Background
- Ice noise analysis
  - Ice noise simulation
  - Ice noise field measurements
- Conclusion & Next steps

Background

- Increased noise due to ice is a new topic to E.ON
- Icing occurs at E.ON sites, but no noise issues so far

So why is it important to E.ON and the wind industry ?

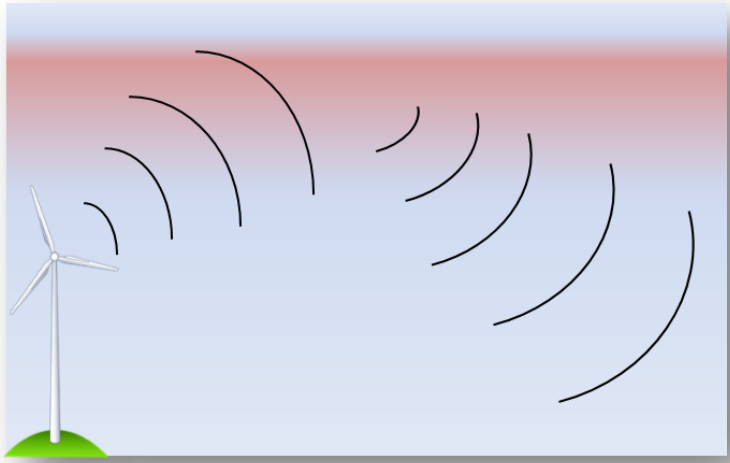
Noise of wind turbines is one of the main arguments against wind power

- Noise increases by ice accretion
- Ice-generated noise could exceed the noise regulations
- How to sort out the issue?

Noise regulations and development process

- Noise regulations: **40dB(A)** at residential areas, e.g. in Sweden
- The operator has to provide evidence of being within noise regulations
- Due to potential uncertainties in the development process or complaints
  - Measurements afterwards are required
- Ice noise could exceed noise regulations – investigations[1] in the past show:
  - Up to + 11 dB(A) over a clean blade could occur

 Ice noise is a potential uncertainty and could be a reason for complaints



Sound reflection by temperature inversion

1) Peter Arbinge, AF Consult – *icing wind turbine – the effect on noise emission* – Winterwind 2013

Can we not just melt the ice from the blades?

Ice detection systems

- Registers ice on the blade
- At some amount of ice, **safety risk** and **mechanical stresses** are too high

→ Turbine is stopped

De-icing systems

- Starts de-icing
- Ice melts

→ Turbine can be restarted

Active anti-icing systems

- Blade is heated during operation

→ Turbine continues production

Why can’t de-icing and anti-icing systems solve the problem?

- **De-icing** systems only melt the ice while cut-off

  - Ice noise can occur from start of icing till de-icing process

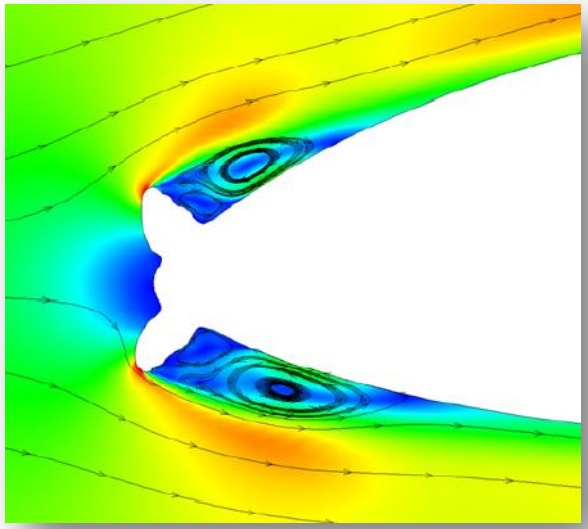
- **Active anti-icing** systems may only prevent severe ice accretion

  - Light icing could be still present

Nordex active anti-icing system

How to get to know about ice noise?

Simulation or Measurement



Richard Hann, Winterwind 2013

Peter Arbinge, Winterwind 2013

- As ice accretion at leading edge can be simulated, ice noise simulation is possible, too.

General approach for a 3D simulation

- Full 3D simulation is possibly too time consuming for practical purposes
- *Whole wind turbine – mesh with ~100 Mio cells*
- *Computation time with supercomputer in the order of months*
- Ice build-up codes may not provide sufficient resolution to reflect reality
  - Used to estimate power for de-icing
  - Ice has a complex structure

What can be done to save time?

- Simplifying the CFD calculation is limited
- Acoustic simulation requires a highly detailed flow simulation

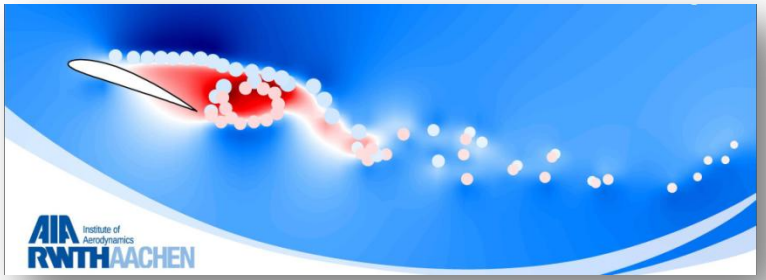
Modify the approach:

- At which local position along the blade, does the highest noise level occur?
- Compute again with local improvement
- Compare the results

An alternative method in CFD computation

AISE – An Integrated Simulation Environment

- Aerodynamic Institute of RWTH Aachen works on this method
- No finite volume method



Purpose:

- Reduce computation time – *factor 100 times less than finite volume method*
- Be accurate enough for fluid dynamical and aeroacoustical analysis of complex geometries

→ **Almost all noise sources can be resolved and several acoustic solvers be applied**

Pros and Cons about simulation

Pros

- Independent of icing events and weather conditions
- Icing events can be reproduced as needed
- Free of background noise

Cons

- High level of knowledge needed
- Very resource and time consuming
- Current academic models take too long to be of practical use for industry
- Needs to be validated

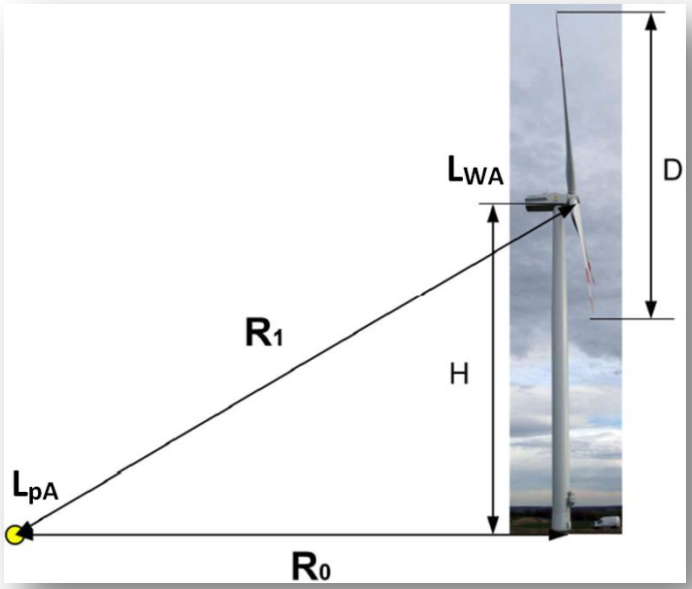
How field measurements work according to IEC-61400-11

Measurements:

- *Sound pressure level* [dB(A)] downwind at $R_0 = H + ½ D$
- *Wind speed* [m/s] to classify into wind bins from 6m/s to 10m/s
- *Power output* [kW] – compare with power curve
- Noise propagation software needs sound power level L_{WA}

$L_{pA} \rightarrow L_{WA}$

Microphone on acoustically hard plate



Position of microphone

Pros and Cons about field measurement

Pros

- Reflect best the reality
- No errors because of simplifications
- Do not need to be verified

Cons

- Errors in measurement
- Trees and bushes can invalidate the results
- Dependent of icing events and weather conditions
- Potentially long measurement campaigns needed to capture data
- Therefore also potentially costly and time consuming

How we can use the ice noise results

Situation:

- Software tools are used to predict noise propagation
- Manufacturer provide input data

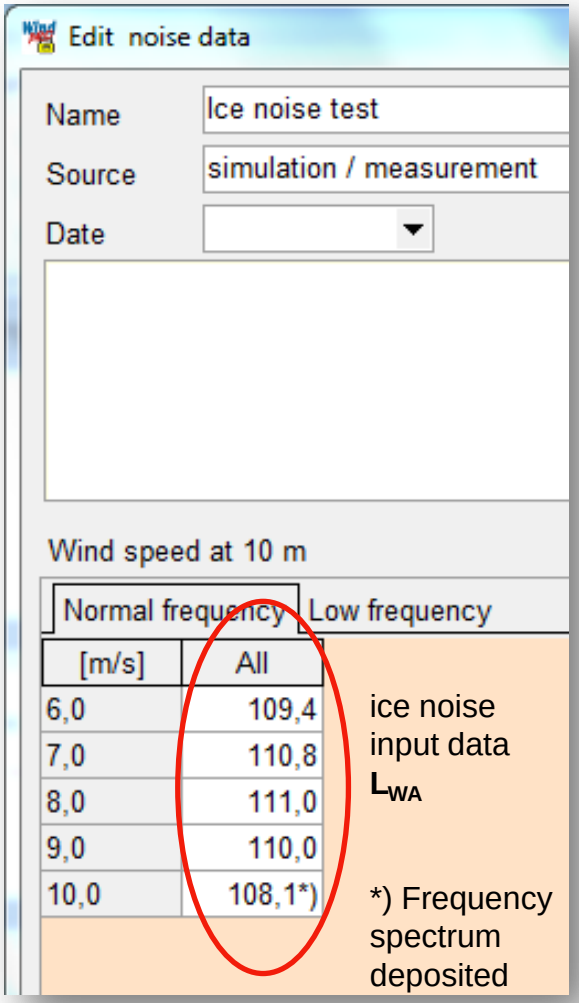
Challenge:

- Sound power level of ice noise is needed as new input data

Open questions:

- Is a frequency spectrum necessary?
- Anecdotal evidence: Ice noise is high frequency

⇨ We can answer this when we know about the properties of ice noise



Screenshot – WindPRO 2.9

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What we know now

Conclusion:

- Simulation should be preferred: independent and very accurate
- Industries requires a method that can provide results faster
- New developments in CFD (e.g. AISE method) could make the change
- In any case measurements are needed for verifying simulation models and will also help us better understand the real significance of ice noise.

Next steps

- I will explore in my further work…
- …If field measurements can provide data and insight
- …How complex a model really needs to be for practical purposes

Thank you for your attention!

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