Icing impact on trailing edge Noise in Wind Turbines
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- IEA Wind Task 19
- IEA Wind Task 39
Motivation

- Noise caused by aerodynamic effects
- Icing impacts aerodynamics
- Effects of icing on wind turbine noise not as well researched as icing impact on production
- Noise effects relevant for public acceptance
- Ice detection?
Approach

- Look at existing research on the topic
- Simulation study to look at the impact of changes in surface roughness on aerodynamic noise
- Corresponds to early stages of icing event
Cold climate wind and noise

- Overall ~25 relevant articles
- Two main themes were visible:
  - Aerodynamic noise at the blade
  - Changes in environmental sound propagation
    - Snow
- More of this kind of research has been done related to aviation, airfoils, helicopters etc.
Sound propagation

- Field measurements and modeling
- Snow can have a dampening effect
  - Depends on snow conditions (snow surface)
  - Snow on trees
- Atmospheric conditions
  - Turbulence
  - Vertical temperature and wind speed gradients
  - Wind maximum below hub height reduced sound levels at ground level

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(Larsson and Öhlund, 2015)
Blade noise

- Mainly CFD models, some amount of wind tunnel measurements and field measurement campaigns
- Ice on the leading edge
- Rime ice, thickness some mm
- Ice causes boundary layer flow separation
- Result is increased noise at the trailing edge
- Field measurements point to increase in sound pressure levels during icing events
Blade noise

- Noise levels increase with ice thickness
  - Wind speed
  - Angle of attack
- Icing at the outer part of the blade has higher impact
  - Higher speed
- Up to 10 dB increase in noise levels in the iced case

Fig. 8. Averaged OASPL difference between airfoil with ice model and baseline airfoil for different ice thickness \((U = 40 - 80 \text{ m/s, } \alpha = 0^\circ)\). (Xiao and Tong, 2021)

Figure 10: TE noise \((R_{\text{noise}})\) for the blade tip. (Hann et al., 2013)
A simplified model for influence of blade icing on rotor trailing edge noise
Wind turbine aerodynamic noise mechanisms

2 main mechanisms:

- **Turbulent Inflow (TI) noise** → Interaction of blades with atmospheric turbulence
- **Trailing Edge (TE) noise** → Scattering of boundary layer turbulence at TE
Icing modeled as roughness – Increase BL turbulence

TE noise mechanism is considered:
- Trailing Edge (TE) noise ➔ Scattering of boundary layer turbulence at TE

Here: Ice model by roughness \( r=1\text{mm} \) and \( r=20\text{mm} \)
\( r=1\text{mm} \) ~ Very coarse sandpaper (P20)
Over 50% of airfoil chord
A modern 2.5MW-sized wind turbine
TI and TE noise spectra – Clean / Iced – TI 4% / 8%
TI + TE SPL(A) noise spectra – Clean / Iced – TI 4% / 8%
TI + TE SPL(A) time-series – Clean / Iced – TI 4% / 8%
Conclusions on present modeling approach

- Crude approximation of icing effects through surface roughness (relatively *light icing*: \( r=1\text{mm and 2cm} \))

- Only trailing edge induced noise is considered as noise source mechanism

- These **VERY preliminary** results show that for low atmospheric turbulence conditions (e.g. at night), noise emission differences should be noticeable

- More **severe conditions** need to be investigated – As well as other possible noise generation mechanisms...
Conclusions

- Ice on blades has noticeable effect
  - Noise created on the trailing edge
  - Noise levels correlate with
    - Ice thickness
    - Tip speed

- Sound propagation different in winter
  - Snow
  - Atmospheric conditions

- Evidence points to increase in noise levels in icing conditions

- Questions remain
  - Magnitude?
  - Sensitivity to icing?

- Impacts
  - Siting
  - Acceptance

- Applications
  - Ice detection
  - Active curtailment
Bibliography

Arbinge, P., 2012. The effect on noise emission from wind turbines due to ice accretion on rotor blades.


Bibliography


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