Developing Solutions to Tonal Noise from Wind Turbines using COMSOL Multiphysics

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Introduction:

- Tonal noise emission by onshore wind turbines can lead to health issues (1) for nearby residential communities.
- Tonal noise incurs strict regulatory penalties including curtailment and closure of wind farms.
- Wind turbine towers can become modal if matched in frequency with the excitation of the rotating components in the drive train, such as gearboxes and generators.
- When frequency matching occurs modal response is greatly amplified due to the very low structural damping of the steel structure resulting in audible tones. (2)
- The authors present a model of a new broadband damping approach where containers filled with EniDamp™, an Advance Particle Damping material. The containers, so-called APD pods, (3, 4) are magnetically fixed to wind turbine towers.

Computational Methods:

- A structural-acoustic interaction model was developed to determine the sound pressure level (SPL) at an observer position at a distance of tip height.
- A 3D model of the wind turbine was constructed with
  - blades as beam elements,
  - tower and nacelle walls as shell elements, and
  - drive train components and the foundation as solid elements.
- The model was excited using forces representing the gear meshing and calibrated with experimental data.
- To overcome the scaling problem of placing APD pods on a tower wall, APD pods were modelled to be part of the tower wall. Their material properties reflected material properties of the combined tower with APD pods, determined from lab-based experiments.
- SPL at observer positions were computed using perfectly matched layers (PML) on the acoustic domain and 2D axisymmetric models of the acoustic domain through the COMSOL-Matlab LiveLink.

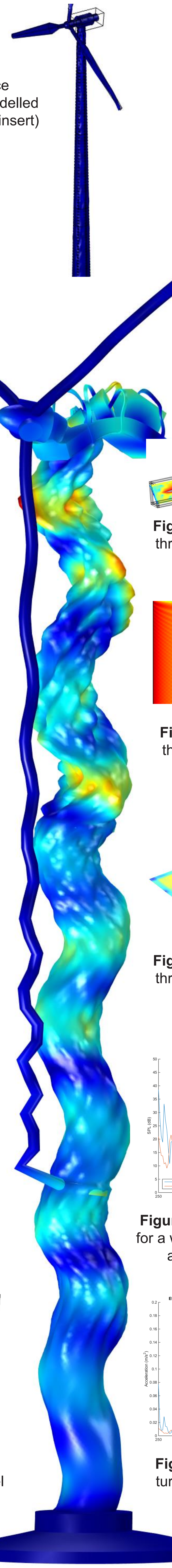

Figure 1. Normal surface acceleration of the tower modelled without and with APD pods (insert)

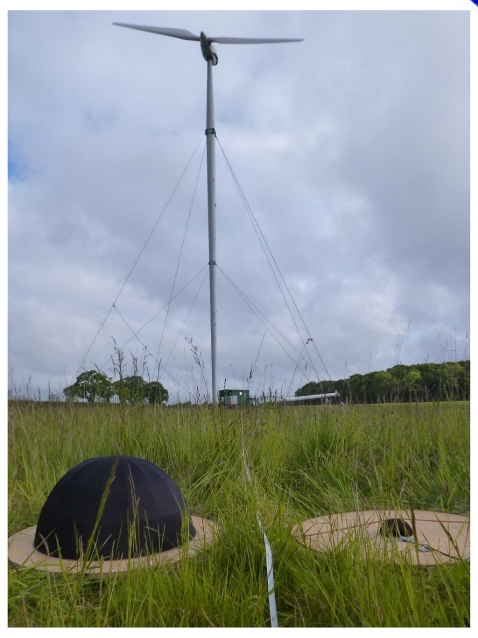

Figure 2. Acoustic measurement of a wind turbine

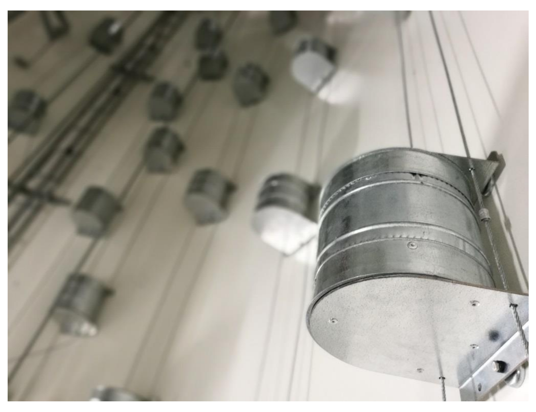

Figure 3. APD pods placed on the inside of the tower wall

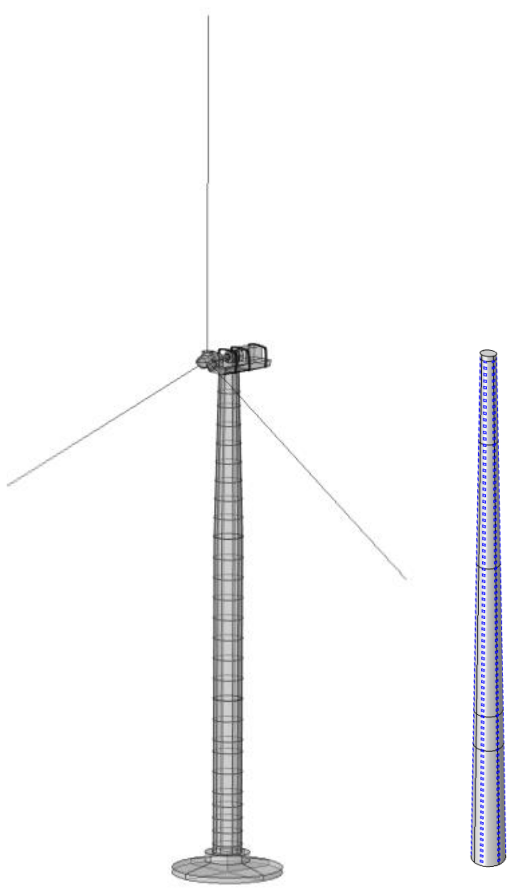

Figure 4. Geometry of the turbine (left) and the geometric simplification of APD pods (right).

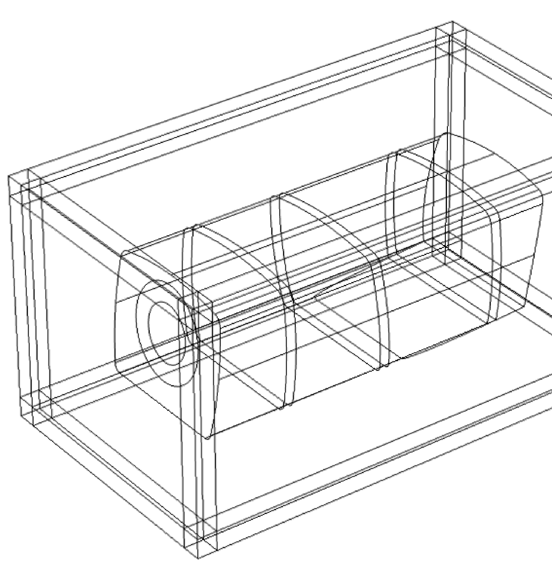

Figure 5. Geometry of the nacelle walls coupled to the full tower model with the acoustic domain and perfectly matched layer

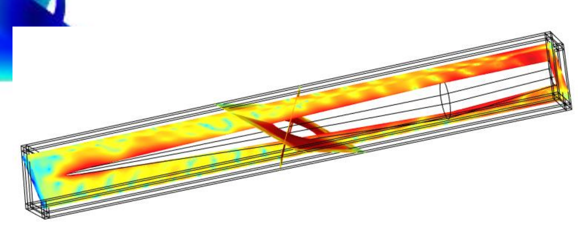

Figure 6. Sound propagating through the acoustic domain from a blade

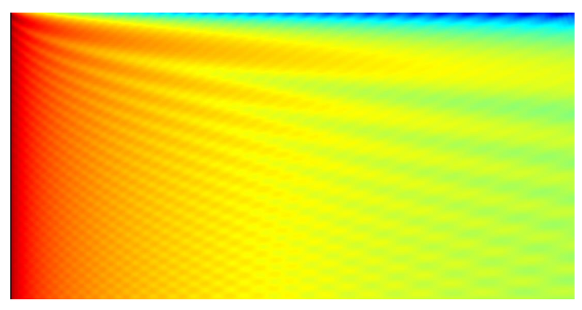

Figure 7. Sound propagating through the acoustic domain from the tower

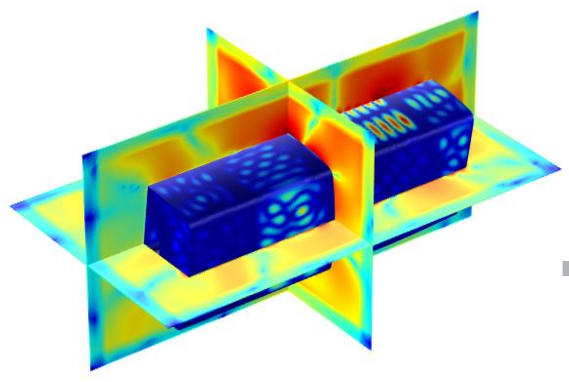

Figure 8. Sound propagating through the acoustic domain from the nacelle

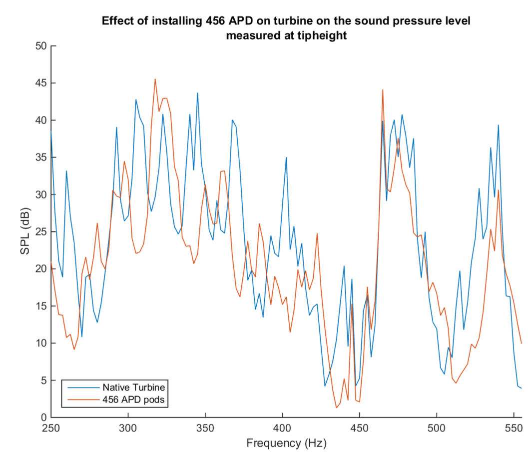

Figure 9. Surface acceleration for a wind turbine modelled with and without APD pods

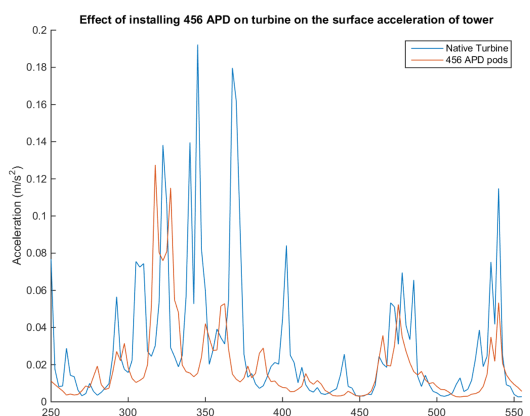

Figure 10. SPL for a wind turbine modelled with and without APD pods

Results:

- The present FE model of a wind turbine can predict noise contributions from the blades, the tower, and the nacelle.
- The placement of APD pods on the tower of a wind turbine increases its damping characteristics leading to significant reductions in the vibration and the tonal noise emissions.
- The APD pods greatly reduce the surface acceleration over the whole modelled frequency range. In particular, the reduction in surface acceleration leads to a significant reduction in tonal noise levels in the far-field, particularly between 340 and 440 Hz.
- Further dB reductions can be achieved by optimising the APD pod placement using the COMSOL model and/or increasing the number of APD pods.

Conclusions:

- The present model predicts that the placement of APD pods on the tower of a wind turbine leads to significant reductions in the vibration and the tonal noise emissions from the tower.
- The present models can also be used to determine the optimal positioning of the APD pods.

References:

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