ENHANCED TRAILING EDGE NOISE PREDICTION METHODS OF WIND TURBINES

zEPHYR Marie Skłodowska-Curie project: towards a more efficient exploitation of on-shore and urban wind energy resources

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CONTEXT

Wind parks installed at the vicinity of **urban areas** are a component of future environmentally-friendly smart cities. The exploitation of urban wind resources involves specific challenges to the prediction of the wind park performance (see Fig. 1). Human factors (visual impact and **noise emissions)** must play an important role in urban wind parks.

Free stream turbulence [1]:
- 20% in rural areas
- 40% in urban areas

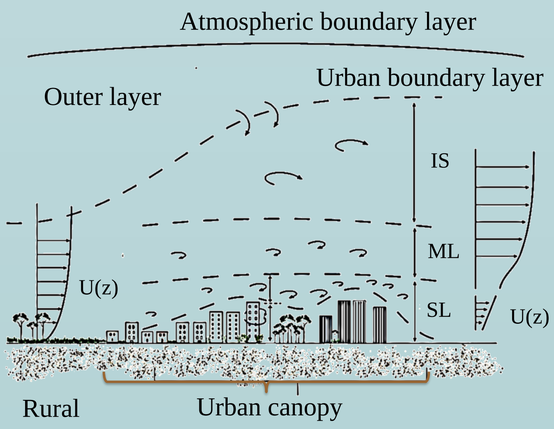

Fig 1. Atmospheric boundary layer in urban environments [1]

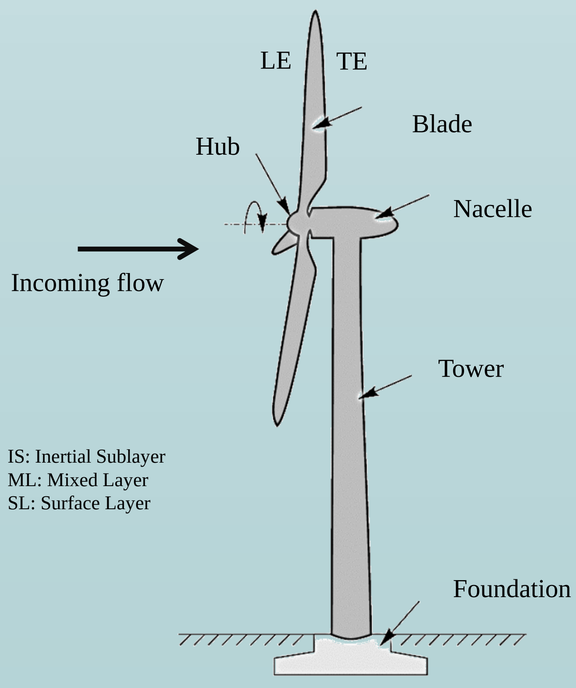

Fig 2. Wind turbine components

PROBLEM DEFINITION

The main wind turbine noise source is the **trailing edge noise**, caused by turbulent structures within the turbulent boundary layer interacting with the trailing edge. **The influence of high incoming turbulence in the trailing edge noise has not been studied.**

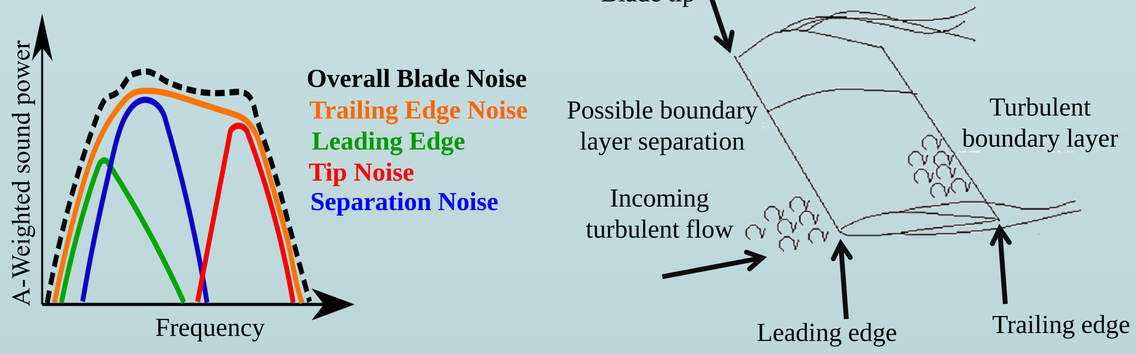

Fig 3. Wind turbine noise mechanisms

Boundary layer turbulence → surface pressure fluctuations → Far-field noise

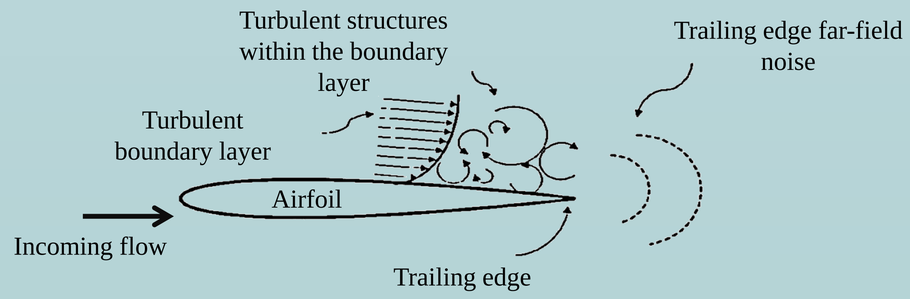

Fig 4. Trailing edge noise mechanism

TRAILING EDGE NOISE MODELING

Stalnov, O. [2] proposed a model to **predict the trailing edge noise.** The model uses the **Amiet theory** [3] for a flat finite-chord plate for modeling the **airfoil response function** and **an extension of TNO-Blake model** for modeling the **turbulent beneath the boundary layer** and use them to calculate the **surface pressure fluctuations near the trailing edge**.

$$S_{pp}(x_1, x_2, x_3 = 0, \omega) = \left(\frac{\omega x_2 c}{4\sigma^2 \pi c_0}\right) \pi \frac{L_3}{2} \int_{-\infty}^{\infty} |L|^2 \quad \widehat{P_w}(k_1, k_3 = 0, \omega) dk_1$$

Far-field predicted noise — **Observer/airfoil position** — **Airfoil response function (Amiet theory)** — **Surface pressure fluctuation (TNO-Blake model)**

OBJECTIVES

- Develop an enhanced/novel trailing edge noise prediction method, which will consider real conditions for urban environments (effect of high free stream turbulence in trailing edge noise production).
- Extrapolate the 2D airfoil noise prediction method to a 3D scale wind turbine.
- Couple the novel prediction method to optimization techniques.

METHODOLOGY

Experiments in a wind tunnel – free stream turbulence generated by grids:

- Boundary layer turbulence
- Surface pressure fluctuations
- Far-field noise

Fig 5. Experimental set-up. Grid to generate turbulence of 20% upstream the airfoil

[1] Carpman, N. (2011). "Turbulence intensity in complex environments and its influence on small wind turbines."
[2] Stalnov, O., Chaitanya, P., & Joseph, P. F. (2016). "Towards a non-empirical trailing edge noise prediction model." *Journal of Sound and Vibration*, *372*, 50-68.
[3] Amiet, Roy K. (1976). "Noise due to turbulent flow past a trailing edge." *Journal of Sound and vibration*, 47, 387-393.

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