Vertical Axis Wind Turbine Noise

Developing prediction tools to determine noise generated by rotating turbine blades coming into contact with clean air

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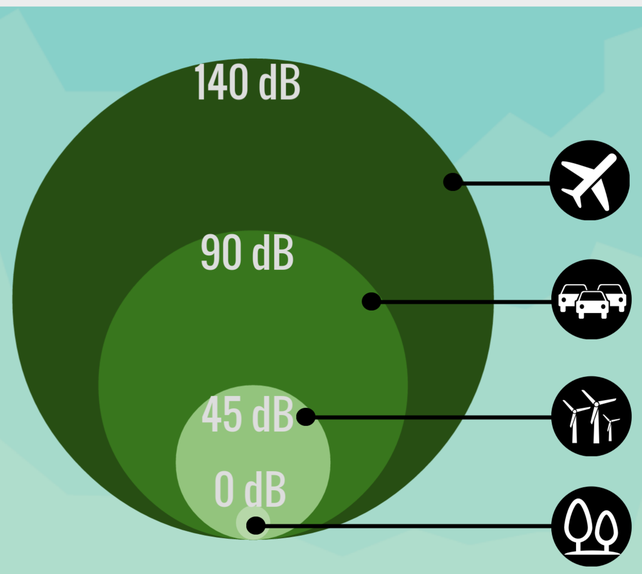
Introduction

Vertical Axis Wind Turbines (VAWT's) are a type of wind turbine used to convert kinetic energy from moving air into electrical power by means of LIFT PRODUCING BLADES. A by-product of this lift production is that aerodynamically generated (AEROACOUSTIC NOISE) is also produced. [1]



TYPICAL NOISE LEVELS

20%

The European Commission aims to achieve 20% Competitive wind power penetration compared to total energy production by 2020.

The FP7 project, SWIP, aims to deal with, and overcome, the main barriers that slow down the large scale deployment of small and medium size wind turbines.

Specifications

rotor radius	1.0 m
span	4.5 m
chord	0.3 m
blade offset	90 º
rated power	2 kW
wind speed	8.4 m/s
rotational speed	17.2 rad/s

SWIP V2

SEE MODEL

As part of the SWIP project, a new Vertical Axis Wind Turbine (the SWIP V2) will be produced.

TCD's Department of Mechanical and Manufacturing Engineering has been tasked with performing acoustic source modelling.

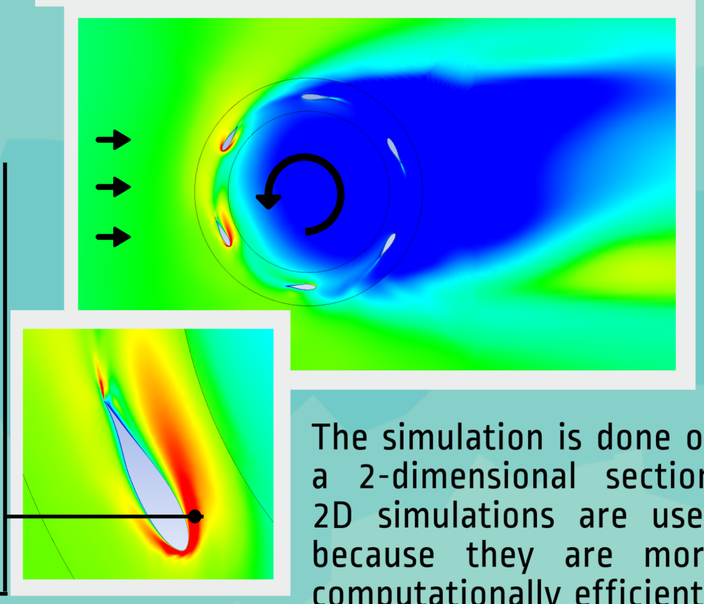
To date there has been NO SUCH CODE DEVELOPED to determine noise from a Vertical Axis Wind Turbine. This research develops a code to do just that!

The SWIP V2 turbine is designed to be installed on the roof of an office building. It will be able to run up to 20 fluorescent office light tubes.

CFD

A Computational Fluid Dynamics (CFD) simulation was run to determine the input parameters to the acoustic solver. The numerical results were exported into a format that the code could read.

Turbulent Kinetic Energy



Turbulence is a measure of the chaotic motion of flowing air. Turbulent Kinetic Energy (TKE) is the energy contained in this flow.

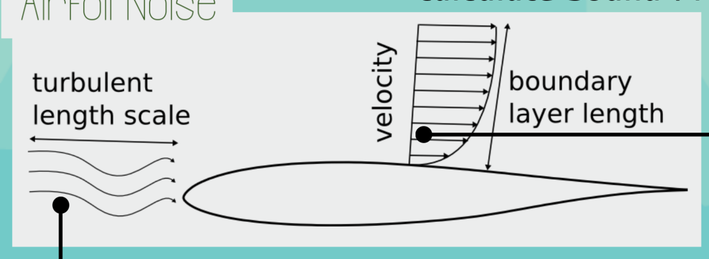
The motion of upstream blades increases the TKE downstream. (red is higher)

The simulation is done on a 2-dimensional section. 2D simulations are used because they are more computationally efficient.

AIRFOIL SELF-NOISE

is due to the INTERACTION between an airfoil blade and the turbulence produced in its own boundary layer and near wake. Two noise generation mechanisms are considered dominant. The models (shown below) use input data derived from the CFD simulation to calculate Sound Pressure Level (SPL)

Airfoil Noise



TURBULENT BOUNDARY LAYER TRAILING-EDGE NOISE [2]
Produced as turbulence passes over the trailing edge.

SPL TBL-TE = f(δ, δ*, u, M, ρ, c, r)
FROM CFD:
δ: boundary layer thickness
δ*: boundary displacement thickness

INFLOW NOISE [3]
Produced by turbulent air contacting the leading edge of the blade.

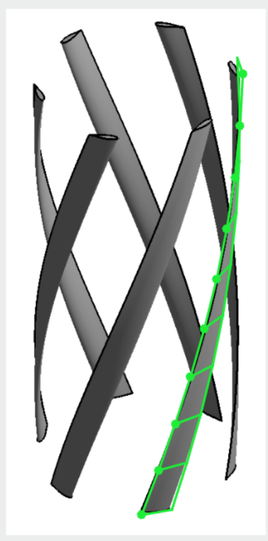
SPL inflow = f(k, l, u, M, ρ, c, r)
FROM CFD:
k: turbulent kinetic energy
l: length scale

CONSTANTS:

u:	inflow velocity	[m/s]
M:	Mach number	[~]
ρ:	air density	[kg/m^3]
c:	speed of sound	[m/s]
r:	distance to receiver	[m]

CODE

Computational Model



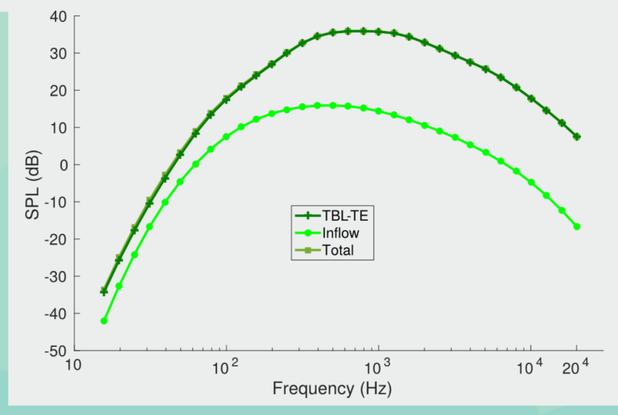
A quasi-steady approach is used to model the noise generated by the wind turbine. A computational model of the blade is produced by the code and 2D CFD data is interpolated onto the correct position in time and space. The airfoil self noise models are then solved and total noise of the blade is summed.

SPL 47 dB

Overall sound prediction for a receiver 10 m away. This is comparable to data from VAWT manufacturers but will be compared to experimental data once the design is produced.

It is of interest that TBL noise dominates noise production for the turbine - as literature for conventional wind turbines states otherwise. It is assumed that due to the rotation of the device, the self induced TKE inflow noise becomes less dominant. Future work will investigate this further.

Noise Prediction



References

[1] R K Amiet. Acoustic radiation from an airfoil in a turbulent stream. Journal of Sound and vibration, 41(4):407–420, 1975.
[2] Thomas F Brooks, Stuart D Pope, and Michael A Marcolini. Airfoil self-noise and prediction, volume 1218. National Aeronautics and Space Administration, Office of Management, Scientific and Technical Information Division, 1989.
[3] Martin V Lowson. Assessment and prediction of windturbine noise. Technical report, Flow Solutions Ltd., Bristol (United Kingdom), 1993.

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