Aeroacoustic study of a side-by-side propellers

Aeroacoustics

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Outline

eVTOL Aircraft

- New Urban Air Mobility Vehicles
- Unconventional VTOL aircraft based on electric distributed propulsion (eVTOLs)
- 2 types of rotor-rotor aerodynamic interaction:
  - Side-by-side propellers
  - Tandem propellers

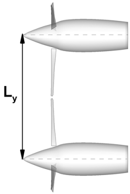
(a) Archer Aircraft

(b) Vahana by A^3 by Airbus LLC

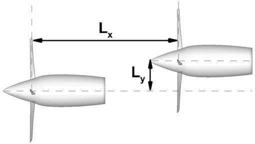
Outline

Problem Geometry

Three-bladed propeller equipped with a left-handed Varioprop 12C 3-blades (diameter = 300 mm) [1] [2].



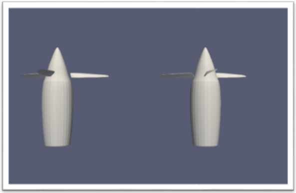
(a) Side-by-side



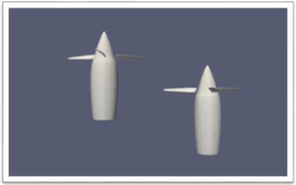
(b) Tandem

	L_x [m]	L_y [m]
Side-by-Side Props	0	[0.31 0.40]
Tandem Props	0.1	[0.25 0.31]

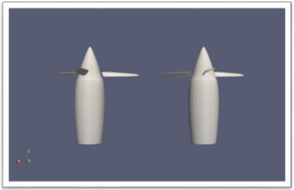
Problem Geometry



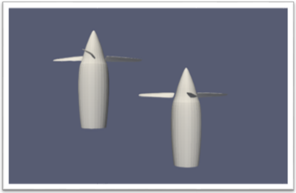
(a) 040.000



(b) 031.010



(c) 031.000



(d) 025.010

Setup

- $V_{\text{inf}} = 28$ m/s & $M_a = 0.082$
- $\omega = 738$ rad/s
- Tip Mach Number $\rightarrow \mathrm{M}_t = 0.32$
- Propellers aligned to the freestream velocity vector

Outline

Dust

- Novel mid-fidelity aerodynamic solver based on:
  - Vortex Particle Method (VPM) → Wake modeling
  - Lifting Line Elements → Solid Boundaries

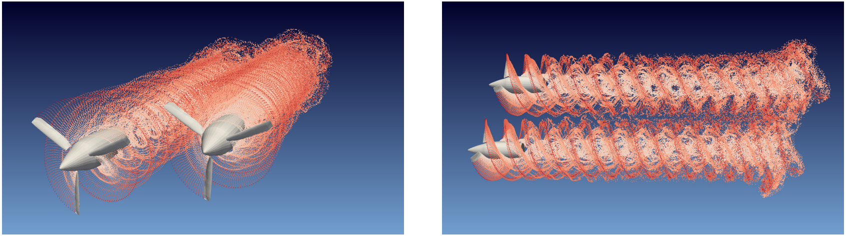
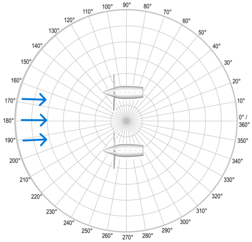


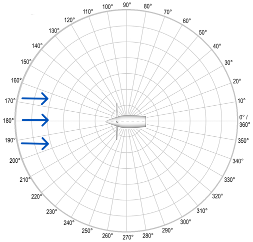
Figure: DUST's wake visualization (L_x=0.1m, L_y=0.31m)

SU2 (CAA)

- FWH numeric approach
- Surface flow files (DUST outputs)
- Dummy mesh
- Acoustic Configuration
- 36 Observers, located at R = 2m:



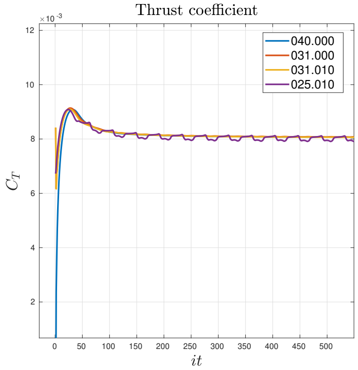
(a) 2 rotors

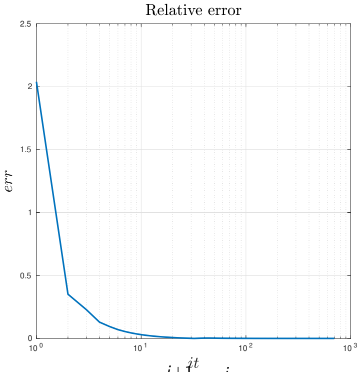


(b) 1 rotor

Outline

Transitory Regime



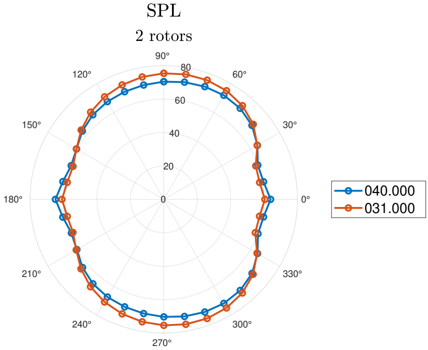


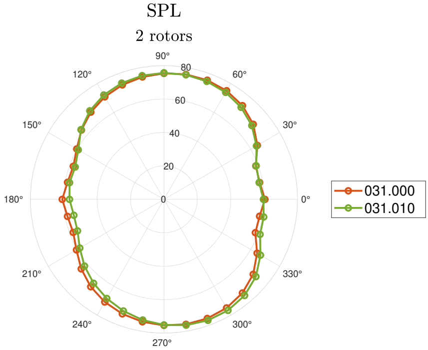
$$c_T = \frac{T}{\rho n^2 D^4}$$

$$err = \frac{c_T^{i+1} - c_T^{i}}{c_T^{i+1}}$$

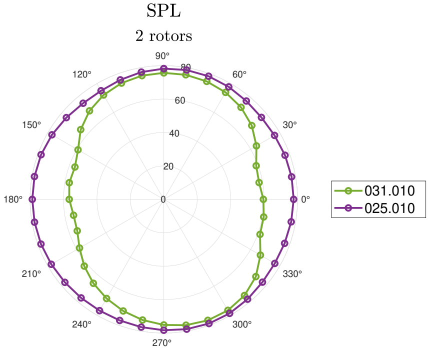
1 rev = 128 iter → Stationary regime after 3 revs = 384 iter

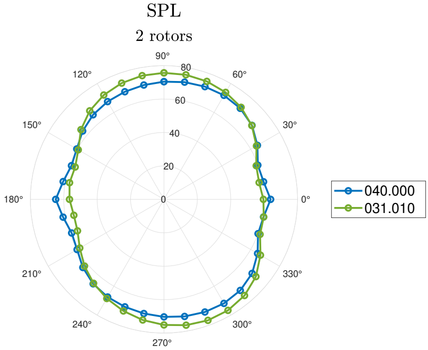
SPL: Two rotors



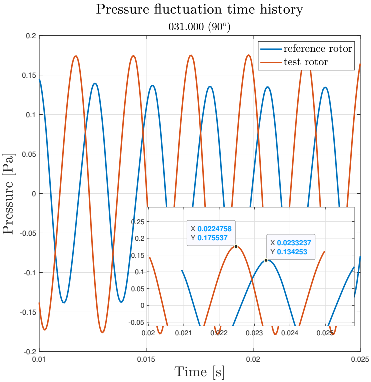


SPL: Two rotors

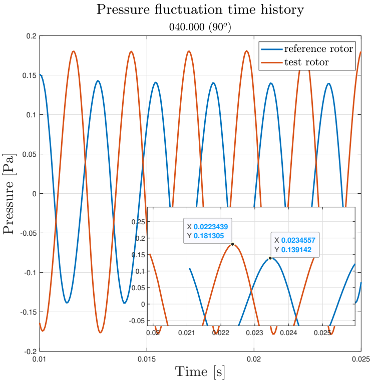




Pressure Fluctuation

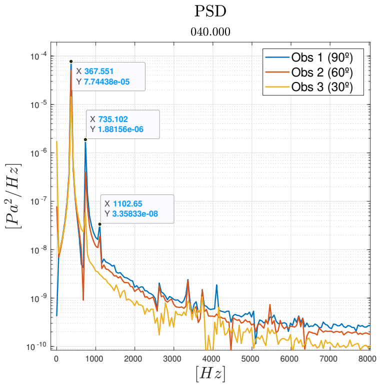


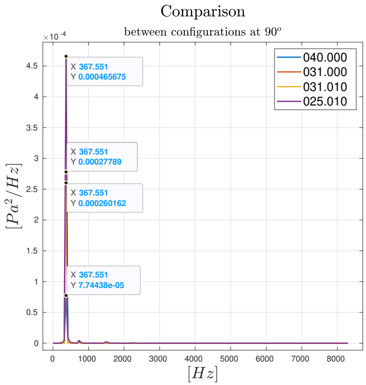
(a) $\Delta t = 9.09\text{x}10^{-4}$ s



(b) $\Delta t = 1.12\text{x}10^{-3}$ s

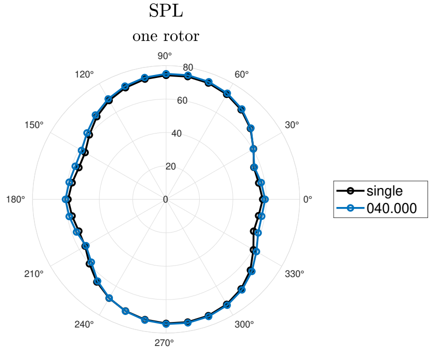
PSD

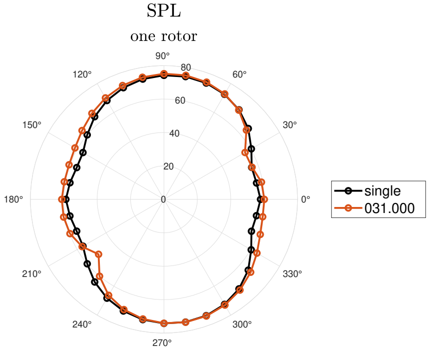




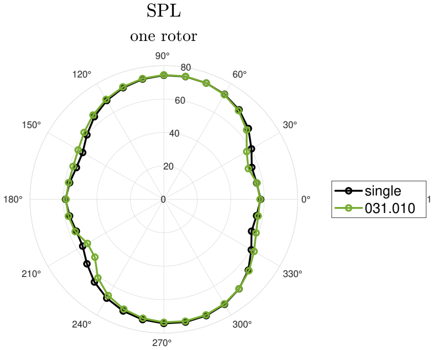
Sampling frequency $[Hz]$	Time Step $[s]$	Signal duration $[s]$
1.6726x10^4	6.6514x10^{-5}	0.08514 (10 rev)

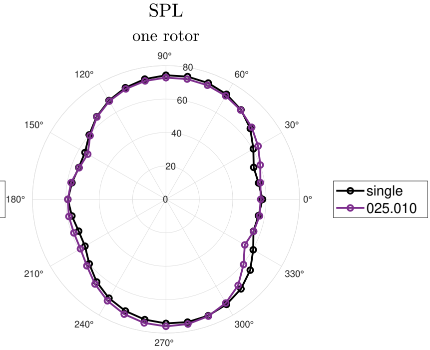
SPL: One rotor



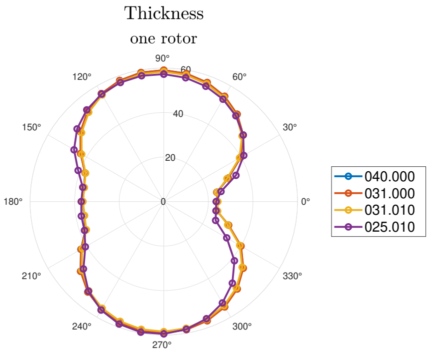


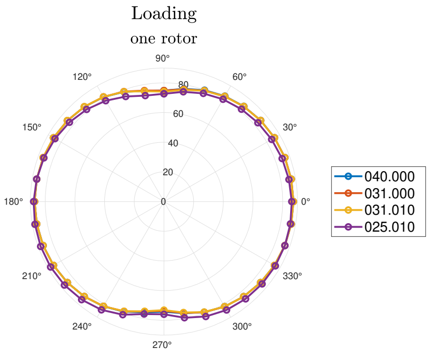
SPL: One rotor





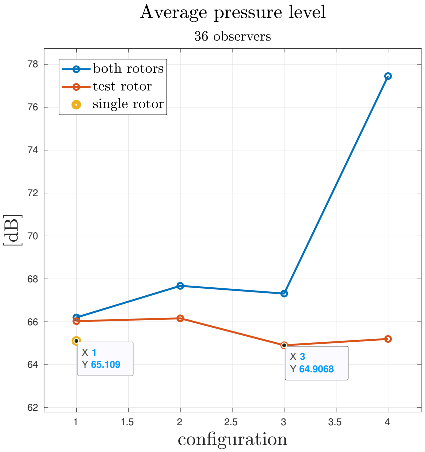
Tonal Noise: One rotor





Outline

Configurations Comparison



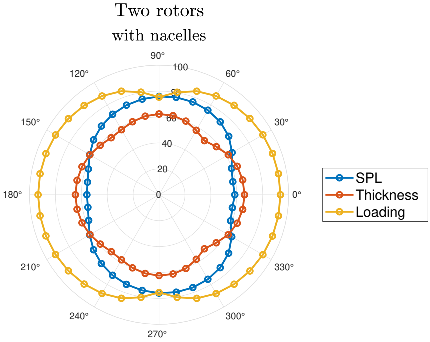
Config	1 rotor [dB]	2 rotors [dB]
1 (040.000)	66.03	66.20
2 (031.000)	66.16	67.68
3 (030.010)	64.91	67.32
4 (025.010)	65.20	77.45
Single Rotor	65.11	

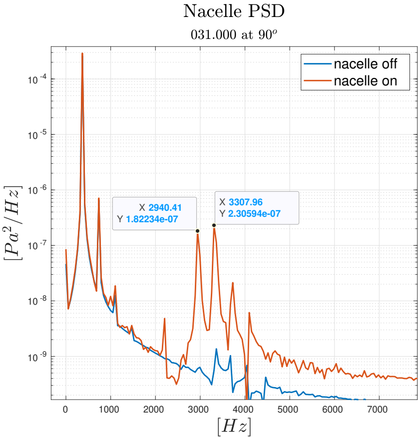
- Sound gets **reduced** with:
  - Increasing rotor axis distance
  - Adding a stagger
- Sound gets **amplified** when Blade Vortex Interaction occurs
- **Aerodynamic performance**:
  - Similar behavior for non-wake interference configurations
  - The more the wake interaction, the more reduction in performance
- **Tonal Noise** is attributed to the Blade Passing Frequency

Further Investigation

- Observers located in the vertical plane
- Changing the stagger distance → Find the optimal configuration
- Validation with numerical or experimental data
- Aeroacoustic study of the nacelles' influence

Preliminary nacelle results





[1] Algarotti, D. **Experimental-Numerical Investigation of the Aerodynamic Interaction between Tandem Propellers in eVTOL Airplane Mode**. Scuola di Ingegneria Industriale e dell'Informazione

[2] Piccinini, R.; Tugnoli, M.; Zanotti, A. **Numerical Investigation of the Rotor-Rotor Aerodynamic Interaction for eVTOL Aircraft Configurations**. Energies 2020, 13, 5995.

Reference Papers