Acoustic Interference Between Three Distributed Propellers

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Background

The EU-funded ENODISE project is investigating the noise emitted by three low Reynolds number propellers installed at the leading edge of a wing. This research aims to deepen our understanding of noise emission from distributed propulsion systems. The insights gained hold potential for optimising such configurations, with relevance to the development of quieter and more efficient aerial vehicles, especially in the context of Regional and Urban Air Mobility.

Methodology

A method using an analytical model able to quantify the acoustic emission associated with such a configuration has been developed. Initially, the pressure distribution around blade profiles is computed using XFOIL by Mark Drela. The resulting polar diagrams are used by the Blade Element Momentum Theory to determine the propeller aerodynamic performance, neglecting the mutual interaction between propellers. The accuracy of this approach has been validated with the experimental data collected at TU Delft as can be seen in Fig. 1.

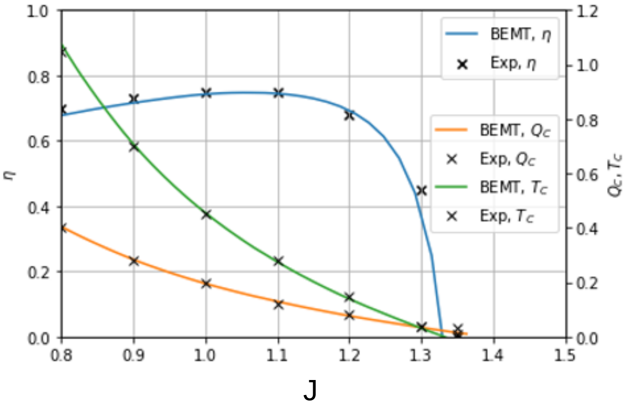

Fig. 1 Propeller performance (thrust and torque coefficients, efficiency) as a function of the advance ratio J.

Building upon the aerodynamic results, the acoustic emission is calculated using the acoustic analogy, as described in Ref. [1]. This approach enables to calculate the rotor self-tones due to steady lift, drag, and thickness, as well as the interaction noise arising through the interaction of the rotor wakes with the wing. Interference effects between individual noise sources are obtained using an extension of the method described in Ref. [2]. Our initial prediction efforts were devoted to the acoustic emission from the reference configuration. Far from the simple case, the results (reproduced in Figure 2) reveal the complexity of the directivity patterns. They also show that the interaction between the rotor wakes and the wing can be the dominant noise mechanism, especially in the axis of the flow ($\varphi_{xy} = 0°/180°$).

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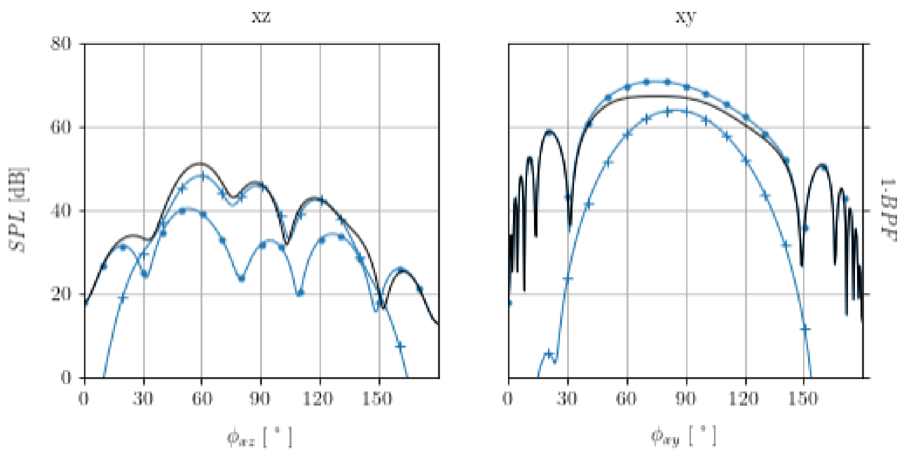

Fig. 2 For the 3 propeller—wing configuration, SPL directivity obtained at the blade passing frequency in the (left) propeller plane and (right) perpendicular to the wing; (+) self-tones, (dots) interaction tones, (black line) summation.

Parametric Study on Acoustic Interference

In fact, the acoustic emission of such a configuration highly depends on several key parameters, among which:

1. the spatial arrangement of the propellers, including tip gaps and axial distances relative to the wing,
2. the phase shift and the rotation direction.

A comparison of the pressure field from the reference configuration and two modified configurations with a different tip gap and arbitrary values of phase shift is shown in Figure 3. In the workshop, we will further develop this aspect. The results of a comprehensive parametric study regarding the impact on acoustic power and directivity will be presented.

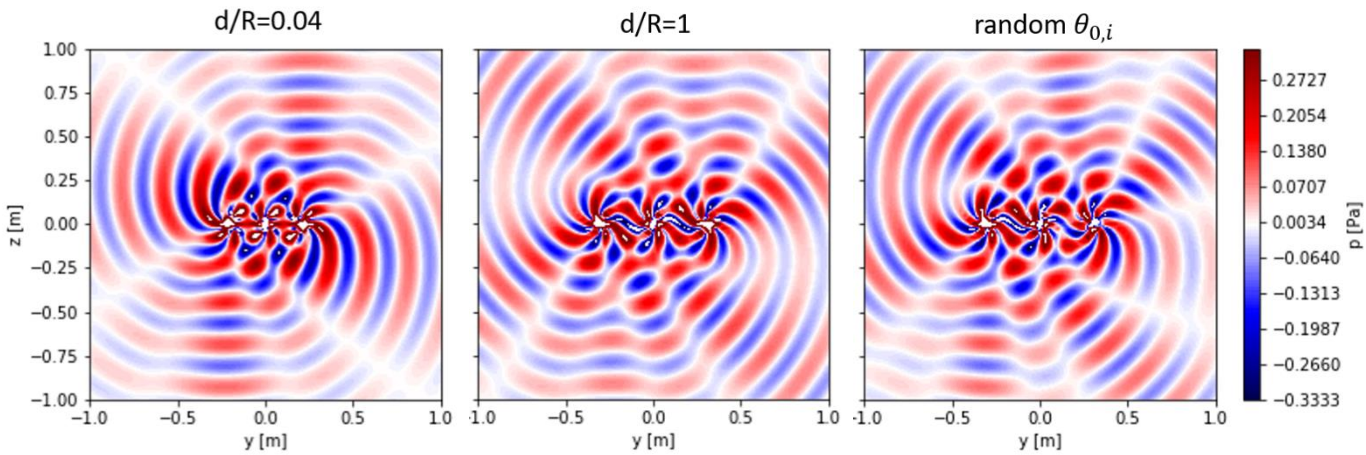

Fig. 3 Sound field at BPF of three different configurations (left: baseline, middle: altered tip gap, left: random phase shift)

References

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