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Resolvent-based Trailing Edge Noise Analysis Using a Wavepacket Source Model

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In our current investigation, we employed the methodology outlined by [3]. This method involves constructing the resolvent operator numerically to address an aeroacoustic problem associated with a specific geometry and source distribution, as outlined in an acoustic analogy framework. The process entails solving an inhomogeneous Helmholtz equation using a boundary element method to determine the tailored Green's function for the given problem, enabling the numerical construction of the resolvent operator. We focus on the scattering phenomenon at the trailing edge by a wavepacket source model applied to a NACA0012 airfoil.

The results obtained by [1, 2] demonstrated that the primary turbulent patterns consist of a wavepacket traveling along the surface of the airfoil, exhibiting stronger intensities towards the trailing edge zone. We consider a wavepacket source model proposed by [4], given by

$$T_{ij} = \exp(ik_h z_1)\exp(-\frac{z_1^2}{L_1^2} - \frac{z_2^2}{L_2^2}), \tag{1}$$

with $k_h = k_0/M$ is the hydrodynamic wavenumber, $\mathbf{z} = (z_1, z_2)$, L_1 and L_2 the length scales of the wavepacket amplitude envelope in the streamwise and wall-normal directions, respectively.

The wavepackets modeled by eq. 1 are shown in Figure 1 for the NACA0012 airfoil and $k_0 = 0.1$, 2 and 5. The number of spatial oscillations that arise between the beginning of perturbation growth and the end of its decay depends on the value of $k_h L_1$. When this parameter is small, the source is compact, as we can see in Figure 1 (a); when it is large, on the other hand, the source is an extended wavepacket, as Figures 1 (b,c).

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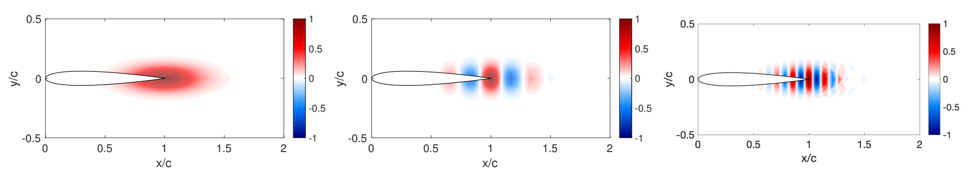

(a) $k_0 = 0.1$ (b) $k_0 = 2$ (c) $k_0 = 5$

Figura 1: Source as a wavepacket located in the airfoil surface near the trailing edge for three different acoustic wavenumbers $k_0 = 0.1$, 2 and 5, for the NACA 0012 airfoil. Source: by the authors

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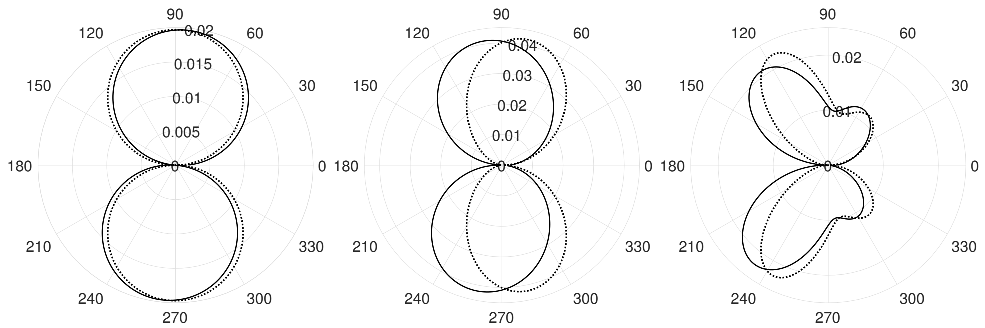

(a) $k_0 = 0.1$ (b) $k_0 = 2$ (c) $k_0 = 5$

Figura 2: Pressure field due to a wavepacket located in the surface near the trailing edge (solid black line) compared with the optimal response from resolvent analysis U_1 (dashed black line) for three different acoustic wavenumbers $k_0 = 0.1$, 2 and 5. Source: by the authors

The pressure distributions depicted here for the NACA0012 airfoil are presented in 2 (a), (b) and (c) for $k_0 = 0.1$, 2, and 5, respectively. It is evident that the resolvent analysis's optimal response (represented by dashed black lines) closely captures the primary characteristics of the pressure field (solid black lines) generated by a wavepacket near the trailing edge of the airfoil.

Consequently, the resolvent analysis demonstrates that while the primary features of the pressure field induced by a wavepacket on the airfoil surface can be effectively captured using optimal, linearized flow responses, considering suboptimal modes is essential for accurately assessing the directional characteristics.

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