FREQUENCY RESPONSE AS A TOOL FOR OPTIMIZING ACTIVE CONTROL OF TRAILING VORTICES

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Abstract A Frequency Response analysis of a Lamb-Oseen vortex with different axial Single Point Injections to determine the optimal location for experimental active control is performed. (wingtip vortex, frequency response, active flow control).

A primary concern in aeronautics revolves around the formation of wingtip vortices, an undesired consequence of finite-span lifting wings. These persistent and highly rotating axial flows remain for a long time over airport runways during landing and takeoff operations, constituting a potential hazard on flight safety and dictating operational restrictions in air traffic management. Efficient control of the wake behind the wing is crucial, not only to minimize the time interval between operations at airports but also to enhance the safe maneuvering of trailing UAVs in flight formation. A potential approach to mitigate trailing vortices involves employing an effective vorticity reduction method utilizing an active control device based on pulsating spanwise blowing of a jet [1].

This study investigates the effect of the variation of the active control application distance, d_f, on the frequency response of a Lamb-Oseen vortex [2]. The theoretical base flow pertains to the experimental configuration of a wing model with a NACA0012 airfoil at an angle of attack of α=9° and a chord-based Reynolds number of $Re_c = 1.7 \times 10^5$ [3]. The harmonic injection was implemented numerically using a Single Point Injection (SPI) jet configuration in the streamwise direction. A parameter analysis has been carried out on the axial wavenumber k, the forcing frequency ω_f and the radial distance, d_f, of the SPI axial forcing. As it is shown in Figure 1, the impact of the active control application distance is evident not only in terms of the energy gain but also in the alteration of the main vortex structure [4]. This analysis is crucial to maximize the effect of the injection for flow control in future applications.

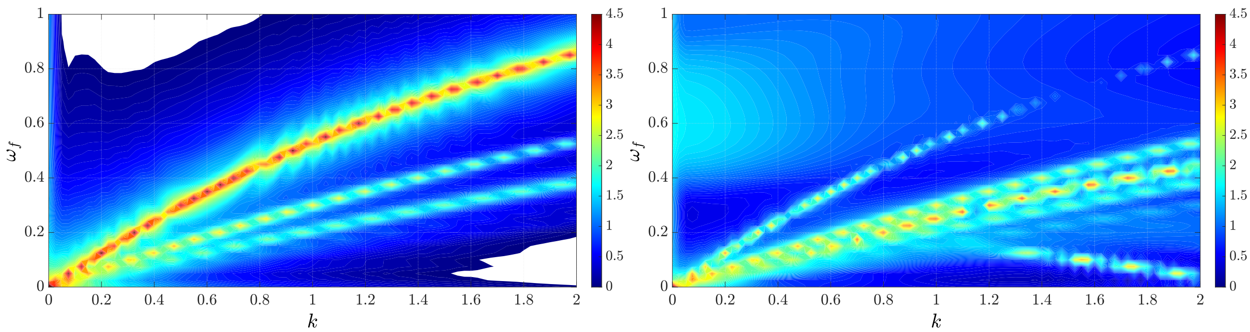

Figure 1. Frequency Response energy gain maps (in logarithmic scale) for the Lamb-Oseen vortex model with $Re = 7940$, considering a SPI forcing located at (a) $d_f = 0$ (vortex center) and (b) $d_f = 1$ (vortex core radius). The blank regions in (a) correspond with energy gain lower than unity.

References

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