SOUND GENERATED BY A WING WITH A FLAP INTERACTING WITH A PASSING VORTEX

A. Manela
Faculty of Aerospace Engineering, Technion - Israel Institute of Technology
Haifa 32000 , Israel

L. Huang
Department of Mechanical Engineering, The University of Hong Kong
Pokfulam Road, Hong Kong

Airframe noise, and in particular sound generated by high-lift devices, is known to be a major cause for acoustic radiation, particularly during airplanes approach for landing[1]. Significant efforts have therefore been made to analyse the sound generated by such devices, in various setups and flight conditions. Common to almost all of these works is a *static* configuration of a *detached* lift device, where the acoustic field is affected mainly by vortex shedding and flow separation phenomena occurring at the gap between the airfoil and the flap. Motivated by recent investigations of continuous "mold-line link" flap configurations[2], the objective of the present study is to consider an *attached-flap* configuration and examine the effect of flap *motion* on its acoustic radiation.

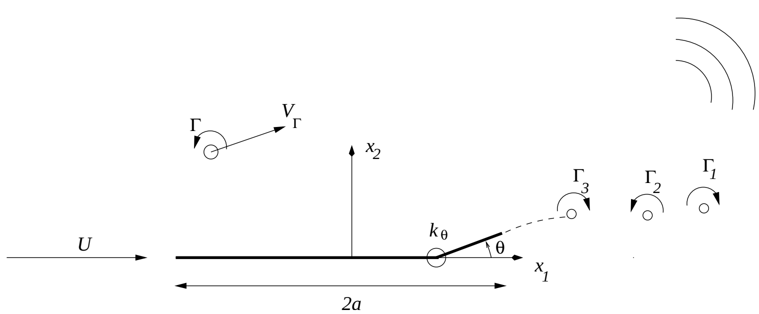

Figure 1: Schematic of the problem.

Schematic of the problem is given in Fig. 1. We consider a two-dimensional airfoil consisting of a stationary upstream part, aligned with the x_1-axis, attached to a flap at $x_1 = \bar{\eta}a$ (with $0 < \bar{\eta} < 1$). The flap is hinged to the airfoil through a torsion spring of constant k_θ, and the system is subject to low-Mach high-Reynolds number flow of speed U in the x_1-direction. An incident line vortex of strength Γ is released into the flow at a given location, and moves past the airfoil-flap system. Fluid vorticity is assumed to be concentrated at the incident vortex location and along a trailing

[1]M.J.T. Smith, *Aircraft Noise*, (Cambridge University Press, Cambridge,1989).

[2]F.V. Hutcheson, T.F. Brooks and W.M. Humphreys, *Int. J. Aero.* **10**, 565-588 (2011).

edge wake, with the latter modeled using the Brown and Michael equation. The near-flow field is treated by means of potential thin-airfoil methodology, while the far-field sound is analysed using Powell-Howe acoustic analogy.

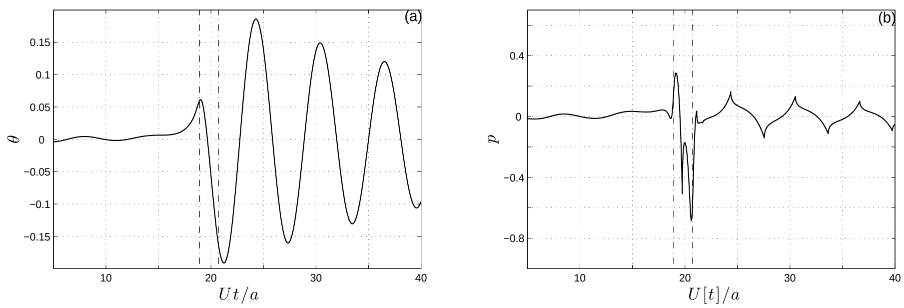

Figure 2: Flap angular motion $\theta(t)$ (Fig. 2a) and far-field acoustic pressure $p([t])$ in the x_2-direction (Fig. 2b) generated by passage of the incident vortex above the airfoil. The dash-dotted lines confine the time interval during which the vortex passes above the airfoil.

A typical example of our results is presented in Figure 2. Here, at time $t = 0$ the flap is aligned with the x_1-axis, and the incident vortex is set into the flow at $x_1/a = -20 + 0.2$ (far upstream of the airfoil). Examining Fig. 2a, we observe that at early times the incident vortex induces only vanishingly small flap oscillations. Yet, shortly after the incident vortex passes above the airfoil leading edge significant flap oscillations are initiated, characterized by the system natural frequency, $\bar{\omega} = \sqrt{k_\theta a^2/I_f U^2}$ (= 1 in the present example, where I_f marks flap moment of inertia about its hinge). Remarkably, this frequency is amplified by the fluid-flap system above all other frequencies contained in the spectrum of the forcing vortex. At late times, and as the vortex propagates away from the airfoil, flap oscillations decay.

The corresponding dipole-type radiation of the system along the x_2-axis is presented in Fig. 2b. The acoustic field can be viewed as a combination of relatively strong leading and trailing edge interactions of the airfoil with the incident vortex, together with late-time sound reflecting the motion of the flap. Interestingly, while flap motion is the indirect cause for late-time radiation, direct flap sound is negligible, and the acoustic radiation is dominated by incident and trailing edge wake sound at all times. In particular, late-time radiation is generated by "vortex-street" vortices, released into the trailing-edge wake due to flap oscillations. Following flap motion, the system acoustic signature is strongly affected by the fluid-flap natural frequency. The talk will examine the effects of system natural frequency and fluid-flap coupling on the radiated sound, and suggest means for monitoring it.