Noise Radiation of an Aircraft Wing Next to an Engine Jet Using the Curle Integral and Results of a Scale-Resolving Simulation

Ulf Michel[1], Daniel Lindblad, Maximilian Höchel

CFD Software Entwicklungs- und Forschungsgesellschaft mbH, Berlin

Florian Renard

Airbus Operations S.A.S, Toulouse

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Abstract

The sound emission of aircraft with underwing engines is increased substantially due to jet-wing interaction noise. It is shown that this noise radiation can be computed with the Curle integral over the pressure fluctuations on the wing surface. The surface pressures required for the integration are obtained from high-fidelity, scale-resolving simulations performed by Airbus. In order to assess the influence of the different wing elements, the far-field noise contributions from the slat, main wing, and flap are computed separately. The sum of all the contributions is also computed.

Curle integral over wing surface

The radiation of jet-wing interaction noise is primarily caused by the scattering of the jet near field at the trailing edge of the wing. The scattered field results in pressure fluctuations on the wing surface including the surfaces of the flaps. The associated sound radiation can be computed by solving the Curle integral [1] if the pressure fluctuations are known on the wing surface as function of time. It was shown in a previous study based on a simulation with DES in the framework of the European project JERONIMO that this is possible [2].

We use the Curle integral based on the convective wave equation to account for the influence of a uniform flight stream with Mach number M_0 on the sound propagation. The integral is given for the pressure fluctuations p' in the acoustic far field by neglecting the viscous stress tensor on the surface.

$$p'(x,t) = \frac{1}{4\pi c_0}\int_S \frac{1}{r_e D_f}\frac{\partial r_e}{\partial n}\frac{\partial p(y,t_r)}{\partial t} dy \tag{1}$$

x is the observer position and y the point on the hard surface S. $t_r = t - r_e/c_0$ is the retarded time with the sound speed c_0 in the ambience and

$$D_f = 1 - M_0 cos\, \theta_e \tag{2}$$

is the Doppler factor with the emission angle $\theta_e$relative to the flight direction. The simplicity of solution (1) is a result of using emission coordinates (r_e, θ_e) [3]. In this work, we solve Eq. (1) in the frequency domain. This makes it possible to directly add up the contributions from the different surfaces in the far-field.

Unsteady flow about an aircraft wing

One objective of DJINN was to use high-fidelity CFD methods to simulate the unsteady flow around an aircraft wing with a realistic dual-stream jet nozzle installed under the wing. Such simulation provides the unsteady pressure on the wing surface required to solve the Curle integral. The simulation was performed by Airbus using the finite volume Navier-Stokes solver Flusepa [1].

Outlook on talk at conference

The directivity of the sound radiation as function of polar angle θ relative to the aircraft axis is evaluated for various azimuthal angles including the flyover and the sideline plane. A comparison will be performed between

[1] Registered trademark in France with number 0103733880.

the noise radiation of a standard co-annular nozzle and a nozzle with serrations on the secondary nozzle as a noise reduction device. The serrations are restricted to top half of the nozzle, adjacent to the wing. Noise will also be computed for a set of observers located on the fuselage.

References[2]

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