# Prediction of Far-Field-Sound from Turbulence near Plate in Flow Using Wall Pressure Fluctuations as the Source Model

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In this work, a method is developed for prediction of noise produced by turbulent flow near trailing edge of a streamlined plate. It is based on the Green's function technique and the methods of spectral and correlation analysis [1-3]. The cases of inhomogeneous and homogeneous turbulence are considered, and the corresponding expressions for the characteristics of the acoustic field are developed. For example, the acoustic pressure $p$ is given by the surface integral over the control surface $S_c$ (the details can be found in [4]), viz.

$$\breve{p}(\vec{r},\omega) = -\frac{1}{2\pi}\iint_{S_c} \breve{p}_t(\vec{r}_0,\omega)\frac{\partial G(\vec{r},\vec{r}_0,\omega)}{\partial y_0} dS(\vec{r}_0)$$

where the integrand includes the turbulent pressure fluctuations, $p_t$, and the normal derivative of the Green's function $G$ [4,5]:

$$\left.\frac{\partial G}{\partial y_0}\right|_{y_0=0,x_0>0} = \frac{e^{i\pi/4}}{\sqrt{\pi}}\frac{e^{-ik_0R_0}}{R_0}\sqrt{2k_0\sin\Phi}\,\frac{\cos\frac{\theta}{2}}{\sqrt{x_0}} + O(k_0r_0)\,.$$

The sound pressure spectrum, $P(\vec{r},\omega)$, produced by *inhomogeneous* turbulence is expressed in terms of the cross-spectrum of the turbulent pressure, $S_p(x_0,z_0,x_0^{/},z_0^{/},\omega)$, as [4]

$$P(\vec{r},\omega) = \frac{1}{4\pi^2}\iint_{S_c} dx_0 dz_0 \iint_{S_c} S_p(x_0,z_0,x_0^{/},z_0^{/},\omega)\left(\frac{\partial G(\vec{r},\vec{r}_0,\omega)}{\partial y_0}\right)^{*}\frac{\partial G(\vec{r},\vec{r}_0^{/},\omega)}{\partial y_0^{/}} dx_0^{/}dz_0^{/},$$

whereas in case of *homogeneous* turbulence it is rewritten via the wavenumber-frequency spectrum of the pressure fluctuations, $\Phi_p(k_x,k_z,\omega)$, viz.

$$P(\vec{r},\omega) = (2\pi)^2\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\left|\breve{T}(\vec{r},k_x,k_z,\omega)\right|^2\Phi_p(k_x,k_z,\omega)dk_x dk_z$$

with $\left|\breve{T}\right|^2$ the transfer function:

$$\left|\breve{T}(\vec{r},k_x,k_z,\omega)\right|^2 = \frac{2}{(2\pi)^4}\cos^2\frac{\theta}{2}\sin\Phi_0\frac{k_0}{q_x}\frac{L_z^2}{|\vec{r}|^2}\frac{\sin^2(q_zL_z/2)}{(q_zL_z/2)^2}$$

The main advantage of the method developed in this study over those developed by other researchers (see, for example, [6,7]) is that, firstly, it uses the wall pressure fluctuations (rather than the Lighthill's stresses) as the noise sources and, secondly, it allows the use of the available wall pressure models [1,2]. Furthermore, the method allows principally the use of the wall pressure data obtained from the numerical techniques (such as LES and LEE with SNGR techniques), as well as findings from the scientific literature in which necessary information about the turbulent pressure is already reflected.

Also, the method suggested (with the appropriate modifications made) can, in principle, be used for noise prediction in many practical situations. These include trailing edge noise (both finite and semi-infinite airfoil), tip vortex noise, flap side edge noise, noise of separated flow behind blunt bodies. In other words, it can give a helpful and useful way for solving the problems of *urgent* practical interest.

For the case of homogeneous turbulence, predictions of noise are made for the typical aircraft parameters, the wall pressure models of Corcos, Chase, Ffowcs Williams and Smol'yakov & Tkachenko being used. The estimates agree reasonably well with those found in periodicals and obtained experimentally.

## References


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