LECTURE 2
NOISE FROM MOVING SURFACES

This part is devoted to the noise generated by rigid moving surfaces interacting with flows, according to Ffowcs Williams & Hawkings' formulation. The method applies essentially to airfoils and wings, structures embedded in a flow, and to rotating blade technology, not accounting for the effect of surrounding passive surfaces acting as diffracting screens, such as casings or ducts. Connections are made with numerical techniques, detailed in other lectures.

I THE FFOWCS WILLIAMS -HAWKINGS EQUATION

I-1 Solution of the Wave Equation

As stated in the preceding lecture, the active surfaces generating sound in any aeroacoustic problem can be replaced by equivalent sources, so that a wave equation is solved in an unbounded medium at rest by means of the Green's function technique. The solution is described below for the standard application with integration on the solid surfaces. In a formal way, the density fluctuation at point $\vec{x}$ and time t is expressed as:

$$c_0^2\,\rho'(\vec{x},t) = \frac{\partial^2}{\partial x_i \partial x_j} \int_{-\infty}^{\infty}\int_{\vartheta_\infty} \frac{\delta(t'-t+R/c_0)}{4\pi R} T_{ij}(\vec{y},t')\; d\vec{y}\; dt' \tag{1}$$

$$+\frac{\partial}{\partial x_i} \int_{-\infty}^{\infty}\int_{\vartheta_\infty} \frac{\delta(t'-t+R/c_0)}{4\pi R} \left(\sigma'_{ij}\,\delta(f)\frac{\partial f}{\partial x_j}\right)(\vec{y},t')\; d\vec{y}\; dt'$$

$$+\frac{\partial}{\partial t} \int_{-\infty}^{\infty}\int_{\vartheta_\infty} \frac{\delta(t'-t+R/c_0)}{4\pi R} \left(\rho_0 V_{S_i}\,\delta(f)\frac{\partial f}{\partial x_i}\right)(\vec{y},t')\; d\vec{y}\; dt'$$

with $R = |\vec{x}-\vec{y}|$. Because generalised functions are used, this equation holds anywhere in the unbounded space ϑ_∞. The sources are described in a frame of reference of variables $(\vec{y},t')$, stationary with respect to the ambient fluid, assumed at rest outside the source domain. So the sound is thought of as produced by stationary sources. This is not well suited to the case of aeroacoustic sources in circular or helical motion, which is a probable configuration if the sound from fans, propellers or aeronautical engines is investigated. For this reason, it is more convenient to express the equation in a frame of reference fixed to the moving surfaces (fig.1).

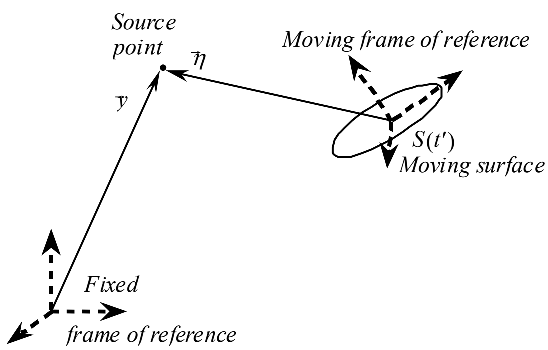

Fig. 1 Source coordinates